Faick, Katherine@Waterboards

From:	Melton, Jessica <JE11@pge.com> on behalf of Krausse, Mark <MCKd@pge.com>
Sent:	Thursday, December 01, 2016 3:38 PM
To:	Larsen, Karen@Waterboards
Cc:	Jauregui, Renan@Waterboards; Faick, Katherine@Waterboards; Jones, Kathleen (Law); Strickland, Jearl; Cunningham, Bryan K
Subject:	OTC Interim Mitigation Fee Submittal
Attachments:	Attachment 1 - Diablo Canyon Cooling Water Entrainment Study 2008-09.pdf; Attachment 2 - Tenera Technical memo - Diablo Canyon OTC Interim Mitigat....pdf; Attachment 3 - Diablo Canyon Intake Flow (October 2015 - September 2016)....pdf
Follow Up Flag:	Follow up
Flag Status:	Flagged
Categories:	OTC - IMF, OTC - Nuclear

Dear Ms. Larsen:

In response to your September 26, 2016 letter regarding the OTC interim mitigation fee requirements for Diablo Canyon Power Plant, Pacific Gas and Electric Company would like to establish a site-specific interim mitigation fee for Diablo Canyon. The information requested to calculate the fee is attached and further background on the information is provided below.

<u>Valid Entrainment Data</u>
Data previously submitted for Diablo Canyon was used by the SWRCB's consultant to calculate a site-specific fee for the plant which was then used along with entrainment data from other OTC plants to calculate an average interim mitigation fee for facilities without site-specific data. This Diablo Canyon fee of $3.12 MGD should be the starting point for determining the plant's fee.

We have also provided additional data collected in 2008-09 as an update to the earlier study (Attachment 1). The update was developed in coordination with the plant's technical work group and the results have been shared at a workshop. As with the earlier study, entrainment data was collected, ETM estimates were developed, and these results were used to determine an area of Habitat Production Foregone (HPF). The attached draft report includes a description of the study method, detailed results by species, and an impact assessment, as well as an executive summary.

Finally, we have also provided a technical memorandum prepared by our consultant, Tenera (Attachment 2). The memo provides a recommended approach, using the equation provided in the Board's Resolution 2015-0057. The memo's approach addresses an error in the Diablo Canyon HPF number used in the equation included in the Resolution, recalculates the fee using the correct number, calculates a fee based on the 2008-09 data, and averages the results of the two studies to determine a proposed interim mitigation fee.

<u>Monthly and Total Intake Volume</u>
Attachment 3 includes Diablo Canyon's monthly intake volume for October 2015 – September 2016.

<u>Intake Flow Measuring Device for Future Intakes</u>
Diablo Canyon plans to cease power production at the end of its current NRC licenses and does not plan to install any future intakes or additional flow measuring devices. The plant has operations logs which track the start and stop times of the individual intake circulating pumps to the nearest minute. Intake flow volume is

calculated by using the minutes each circulating pump operates and the pumping capacity in gallons per minute for each pump.

Actual Impingement Data

Diablo Canyon does not collect impingement data. It has long been recognized by the plant's technical work group and the Central Coast Regional Board that impingement is not an issue at Diablo Canyon. For the impingement portion of the interim mitigation fee, it is recommended that the Diablo Canyon impingement data included in the OTC policy SED be used, an average of 710 pounds per year.

We would be happy to meet with your team to discuss this information in more detail. If you have any questions, please give me a call.

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Pacific Gas and Electric Company
Diablo Canyon Power Plant

Cooling Water Entrainment Study: July 2008 – June 2009

November 29, 2016

ESLO2015-016.3

Prepared for:
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Executive Summary

This report presents the results from entrainment sampling of marine plankton at the Diablo Canyon Power Plant (DCPP) cooling water intakes and similar sampling of source water plankton populations in adjacent nearshore areas. The sampling design was similar to the 1996-1999 Section 316(b) Demonstration Study (Tenera 2000). The primary purpose of this study was to update the facility administrative record in preparation for renewal of the DCPP National Pollutant Discharge Elimination System (NPDES) permit. Section 316(b) of the Federal Clean Water Act which regulates power plant cooling water systems is implemented through NPDES permits issued by the Regional Water Boards in California. The DCPP NPDES permit is issued by the Central Coast Regional Water Quality Control Board (CCRWQCB).

This report includes an overview of the field sampling, laboratory, and analytical methods, larval concentrations for the entrainment and source water samples, estimates of power plant entrainment, abundance plots by survey for the most abundant taxa, a description of water current flows measured along the Diablo Canyon coastline during the study period, and summaries of all data by survey, included as appendices. The primary analytical approach, the empirical transport model (*ETM*), is used in determining entrainment effects for the most abundant taxa using entrainment and source water data to calculate an estimate of the mortality due to entrainment on the populations of larvae in the source water. The results of this modeling approach are used to estimate the area of habitat necessary to fully compensate for the entrainment losses to that group of organisms. An additional modeling approach that estimates the number of adult females whose reproductive capacity was removed due to entrainment was also used on two taxonomic groups of rockfish larvae.

The sampling design for the DCPP entrainment study was consistent with entrainment studies conducted at several other power plants in California over the past 15 years. Similar to the 1996–1999 Study, a technical advisory group was convened to review the study design and provide comments on the sampling and analysis methods. This Technical Workgroup (TWG) was composed of staff from PG&E and their consultants, Tenera Environmental Inc, Dr. Peter von Langen from the CCRWQCB and Drs. Gregor Cailliet, Michael Foster, John Largier, and Peter Raimondi, who were consultants to the CCRWQCB. The study plan was submitted to the TWG for review, and was approved following a meeting in May 2008. The final methodology used in the ETM calculations, including the derivation of the source water estimates, was presented, discussed, and approved by the TWG in May 2010.

Entrainment

Estimates of the composition and abundance of larval fish and selected shellfish larvae entrained by DCPP were determined by sampling directly in front of the cooling water intake system (CWIS) intake structure twice per month from July 2008 through June 2009. The sampling design was consistent with entrainment studies conducted at other power plants in California, but was not as extensive as the previous study conducted at DCPP during the 1996–1999 period. The main differences included sampling a significantly reduced source water area, sampling at only two of the four original entrainment stations at the cooling water intake, and sampling using a six-hour sampling interval at the intake per 24-hr period instead of the three-hour interval used previously. Also, the overall time period of the study covered one year instead of 2.5 years. As a result, there was a reduced list of larval taxa enumerated.

A total of 16,961 entrainable fish larvae from 80 separate taxonomic categories (not including fragments but including unidentified larval fish) was collected from 383 samples in the 24 entrainment surveys. Eighteen taxa comprised the top 90% of specimens collected. The most abundant taxa were sculpins (Cottidae, *Artedius* spp., and *Orthonopias triacis*), rockfishes (*Sebastes* spp. V_ and V [two unique groups based on pigmentation patterns]), monkeyface eel (*Cebidichthys violaceus*), kelp blennies (*Gibbonsia* spp.), blennies/zoarcoids (Blennioidei/Zoarcoidei; largely comprised of unidentified pricklebacks), and blackeye goby (*Rhinogobiops nicholsi*). Most of the common taxa were from species in which the adults are distributed in shallow nearshore waters, but larvae from some deepwater species (e.g., northern lampfish [*Stenobrachius leucopsarus*]) were also collected in smaller numbers. The total annual entrainment based on actual cooling water flow during the study was estimated to be 2.86 billion fish larvae.

Target invertebrate larvae included rock crab megalops and market squid paralarvae. Totals of 7,822 cancer crabs megalops and two market squid paralarvae were identified from the entrainment samples. Total annual entrainment of target shellfish larvae was estimated to be 1.82 billion cancer crabs megalops and 360,000 squid paralarvae.

Source Water

Ichthyoplankton concentrations in the source water were estimated in order to calculate the fractional mortality due to entrainment using the *ETM*. The source water sampling area was divided into six areas designated S1–S6 (**Figure ES-1**). The area designated as Station EA (Entrainment Abundance) was also considered as part of the source water. The width of the sampling area was approximately 1 km (0.6 miles) alongshore with the total offshore extent being approximately 2.9 km (1.8 miles). The average depth was approximately 61 m (200 ft) at the offshore boundary of Station S6.

A total of 18,995 entrainable fish larvae from 93 separate taxonomic categories (not including fragments but including unidentified larval fish) was collected from 732 samples in the 12 source water surveys. The most abundant taxa were sculpins, northern lampfish (*Stenobrachius leucopsarus*), rockfishes, ronquils (Bathymasteridae), blennies/zoarcoids (probably species of unidentified pricklebacks), white croaker (*Genyonemus lineatus*), and monkeyface eel (*Cebidichthys violaceus*). Several of the common source water taxa such as sanddabs, other flatfishes, croakers and northern anchovy are species whose adults have broad habitat and depth range distributions. The greatest concentrations of larvae in the source water occurred in April 2009 with sculpins, blennies/zoarcoids, gobies, ronquils, white croaker, monkeyface eel and rockfishes comprising a high proportion of the larvae. Lowest larval concentrations occurred in early September 2008 and mainly blackeye goby, unidentified yolksac larvae, sculpins, and speckled sanddab larvae were collected.

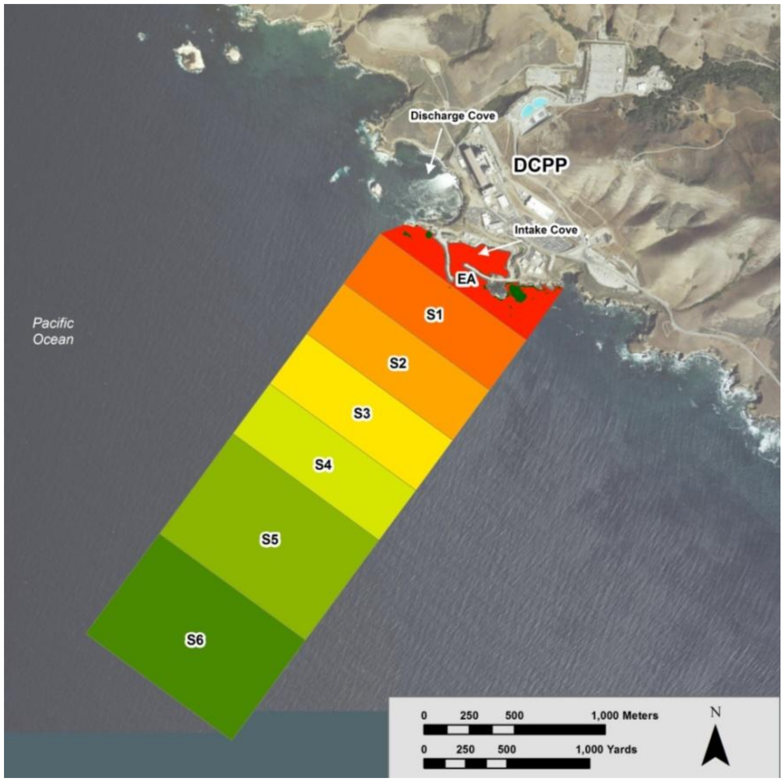


Figure ES-1. Location of source water plankton collection stations offshore from DCPP. Entrainment samples were collected within the Intake Cove at two locations in front of the intake structure.

Analysis Methods

Data from the entrainment and source water sampling were used to estimate the effects of entrainment on fish and target shellfish populations. Estimates were mostly limited to taxa that were relatively abundant in order to improve statistical confidence in the modeling results, but some species, such as cabezon, that were not among the most abundant species were also included because of their local fishery importance. The assessment was primarily done by calculating entrainment estimates based on CWIS actual flow volumes and individual taxa concentrations, and then using these estimates to model the losses to adult and larval source populations using one or two general approaches. One approach (fecundity hindcasting [*FH*]) used species life history information in a demographic model to estimate the equivalent number of adult females whose lifetime reproductive capacity was lost due to entrainment. For species that are broadcast spawners of pelagic eggs, *FH* uses the number of larvae entrained to hindcast the number of eggs required to produce those larvae considering daily mortality rates, and the number of eggs is then used to estimate the number of adult females that would have produced them. The life history information necessary for using this modeling approach was not available for most species, so the demographic assessments were limited to rockfishes (*Sebastes* spp.), which have internal egg development and extrude larvae directly into the plankton.

The other approach, the *ETM* (Entrainment Transport Modeling), estimates the average annual larval mortality due to entrainment (P_M) per individual taxon, using estimates of proportional entrainment (*PE*) that compare the number of larvae entrained in one day to the number of larvae potentially at risk of entrainment in the source water body during the same day. The total estimated annual mortality due to entrainment was calculated after the *PE* estimates were weighted by the estimated fraction of the total population affected and compounded by the time larvae are susceptible to entrainment.

The two approaches combined demographic information with environmental data to model entrainment effects and then, where possible, the results were compared to corollary data. The corollary data used in this report included fisheries information and fishery-independent data consisting of subtidal surveys of juvenile and adult fishes in the vicinity of DCPP. The integration of growth, reproduction, and mortality parameters in the models used in obtaining estimates of adult loss and entrainment mortality is similar to the modeling done by fisheries scientists in conducting stock assessments. Similar to the corollary data used in this report, recent stock assessments for fishes included in this study such as gopher rockfish (Key et al. 2005), blue rockfish (Key et al. 2008), and cabezon (Cope and Key 2009) also use corollary data to improve assessments of fished populations.

The results of the *ETM* were also used in calculating estimates of the "habitat of production foregone" (*HPF*). The State of California has authority to implement §316(b) in the state and the California State Water Quality Control Board (SWRCB) adopted a statewide "Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling" (OTC Policy) on May 4, 2010, which became fully effective on October 1, 2010. Prior to full compliance, the OTC Policy requires mitigation for interim entrainment and impingement impacts. If a plant chooses to mitigate by funding projects through the California Coastal Conservancy, the HPF approach or a similar approach approved by the SWRCB must be used to determine the appropriate habitat scale for project funding. The Board's 2015-0057 Resolution further documented an interim mitigation fee approach.

Comparison with Previous 316(b)

The total entrainment estimates from the 2008–09 sampling were approximately twice those of the previous comparable one-year periods from the 1997–99 study (**Table ES-1**). The most notable differences among taxa were that sculpins and blennies/zoarcoids (mainly unidentified pricklebacks) were an order of magnitude greater in 2008–09 than either of the previous study periods, and northern anchovies and sardines, which were very abundant in 1997–98 (over 106 million anchovy and 103 million sardine larvae entrained), were in low abundance in both 1998–99 and 2008–09. The KGB rockfish group abundance was somewhat lower in the 1998–99 period than in the other two periods, but the blue rockfish group was significantly lower (7 million compared to 123 million). California halibut was lower in 2008–09, but species such as California halibut that occurred in generally low numbers throughout the year could not be confidently compared among periods because of the large amount of variation in the estimates.

El Niño oceanographic conditions can delay or suppress the annual spring phytoplankton bloom, affect the distribution and abundance of planktonic invertebrates, improve recruitment of southern fish species, cause recruitment failures of rockfish, and cause poor growth and condition of adult rockfish (Lenarz et al. 1995). The low abundances of blue rockfish larvae in 1997–98 may have been caused by the poor reproductive condition of females in the previous fall/winter months of 1997 during a strong El Niño period. Although northern anchovy and Pacific sardine are coastal pelagic species, and their abundances are usually considered to be closely tied to broad oceanographic conditions such as sea surface temperatures, surface currents, mixed layer depths, and plankton biomass levels, their abundances were highest during the warmer 1997–98 El Niño period. Data from the coastwide CalCOFI plankton surveys for the spring periods of 1998 and 1999 showed much higher abundances during 1999, which would be expected due to the high levels of upwelling that year. Strong upwelling in 1999 displaced nearshore surface waters offshore, and as a result, northern anchovy and Pacific sardine larvae were located further offshore than in 1998 when peak abundances occurred closer to shore. These observations point out the challenges in trying to compare differences between years that occur on a small spatial scale when larger scale coastal processes are acting simultaneously.

The difference between sampling periods in **Table ES-1** would not have resulted from any differences in plant operations since the entrainment estimates were all calculated using the maximum daily volume of 9.41 million m^3/d (2,486 mgd) used in NPDES reporting.

Impact Assessment

Data collected from the entrainment and source water sampling were used to assess the potential effects to fish and target shellfish populations. The assessment was limited to the taxa that were sufficiently abundant to provide reasonable assessment of impacts, but also included some species, such as cabezon, that were not among the most abundant but had local fishery importance. The assessment was primarily done by calculating annual entrainment estimates based on CWIS actual flow volumes for individual taxa, and then using these results to model the losses to adult and larval source populations using the *FH* and *ETM* approaches referenced previously in the analysis methods.

Table ES-1. Comparison of estimated annual larval fish entrainment at DCPP among study periods based on fixed (maximum) flows. Only the most abundant taxa from the 2008–09 study are listed, in addition to selected species that were abundant during the other study periods. Bars depict approximate abundance relative to the greatest value in the table. Abundance of Blennioidei/Zoarcoidei and Stichaeidae were combined for this comparison to provide consistency between studies. Values for July 1997-June 2008 are higher than those presented in the 2000 report because actual cooling water flow was used in the earlier report calculations.

Taxon	CommonName	Jul '08 - Jun '09	Jul '98 - Jun '99	Jul '97 - Jun '98
Cottidae	sculpins	398,997,613	29,486,564	43,038,418
Blennioidei/Zoarcoidei/Stichaeidae	blennies/zoarcoids/pricklebacks	340,986,238	35,359,048	34,618,904
Sebastes spp. V_	KGB rockfish complex	289,113,661	294,214,870	208,013,064
Cebidichthys violaceus	monkeyface prickleback	246,235,382	132,041,503	118,013,273
Gibbonsia spp.	kelpfishes	222,069,865	94,418,006	121,584,994
Artedius spp.	sculpins	210,254,738	110,769,886	109,446,173
larval/post-larval fish	larval fishes	191,868,513	9,057,466	5,642,001
Orthonopias triacis	snubnose sculpin	154,474,150	55,185,666	75,253,148
Rhinogobiops nicholsi	blackeye goby	134,331,694	130,469,817	156,299,633
CIQ goby complex	gobies	126,496,301	22,464,407	76,290,848
Sebastes spp. V	blue rockfish complex	123,147,095	99,736,511	7,016,351
Stenobrachius leucopsarus	northern lampfish	67,431,908	36,850,992	32,273,776
Genyonemus lineatus	white croaker	66,630,820	20,935,413	65,660,099
Oligocottus/Clinocottus spp.	sculpins	54,726,305	68,322,304	38,786,809
Platichthys stellatus	starry flounder	49,490,717	2,951,452	363,651
Cyclopteridae	snailfishes	49,365,874	15,845,867	7,917,269
Bathymasteridae	ronquils	43,662,117	31,817,216	32,405,185
Oxylebius pictus	painted greenling	31,761,018	20,524,941	11,234,578
Scorpaenichthys marmoratus	cabezon	22,521,855	9,782,966	15,028,255
Blennioidei	blennies	19,438,626	2,152,777	467,833
Leptocottus armatus	Pacific staghorn sculpin	15,007,993	1,286,156	1,533,552
Sebastes spp.	other rockfishes	14,068,454	3,131,568	4,062,504
Brosmophycis marginata	red brotula	12,346,006	1,470,788	5,373,624
Pleuronectoidei	flatfishes	10,515,444	1,550,593	4,816,484
Radulinus spp.	sculpins	9,262,747	0	2,124,449
Gobiesocidae	clingfishes	8,703,341	479,965	961,728
Ruscarius creaseri	roughcheek sculpin	7,987,014	23,187,512	7,600,530
Lepidopsetta bilineata	rock sole	7,838,725	0	68,016
Osmeridae	smelts	7,442,639	2,567,789	182,306
Citharichthys spp.	sanddabs	6,669,908	2,585,270	6,233,295
Gobiesox spp.	clingfishes	6,349,896	4,824,812	6,736,611
Pleuronectidae	righteye flounders	6,060,652	707,716	5,771,052
Agonidae	poachers	5,424,722	711,507	87,802
Lepidogobius lepidus	bay goby	5,316,238	4,535,785	14,377,886
Aulorhynchus flavidus	tubesnout	5,184,751	264,780	123,516
Parophrys vetulus	English sole	4,315,304	1,065,718	11,316,611
Sardinops sagax	sardine	1,100,324	146,637	103,563,065
Hypsoblennius spp.	combtooth blennies	1,012,230	10,850,340	7,255,072
Engraulis mordax	Northern anchovy	353,214	3,229,835	106,443,470
Paralichthys californicus	California halibut	308,642	11,594,892	13,696,238
	Other taxa	39,422,521	56,979,513	60,225,665
	Total	**3,017,695,253**	**1,353,558,846**	**1,521,907,737**

The populations least affected by CWIS entrainment, as evidenced by the *ETM* modeling **(Table ES-2**), were those taxa that had a wide range of depth and onshore-offshore distributions such as white croaker, rock crabs, and blue rockfish complex. Intermediate effects were found in KGB rockfishes, blackeye goby, cabezon, and other species of sculpins. Although the greatest potential effects could occur for species that live in very shallow habitats directly adjacent to the DCPP intake, these taxa were not analyzed as the data was potentially biased by the source water sampling which focused on taxa that could be transported into the Intake Cove where they would be subject to entrainment. The large entrainment estimates for several taxa, such as the Blennioidei/Zoarcoidei/Stichaeidae taxa group and monkeyface prickleback, were likely due to production of larvae in the habitat provided by the breakwaters around the DCPP Intake Cove (**Table ES-1**).

The fish taxon with the highest estimated annual larval entrainment was the combined group Blennioidei/Zoarcoidei/Stichaeidae. The larvae for these taxa were only collected during four of the source water surveys resulting in very few replicate measures of *PE*, which are the basis for the *ETM* estimate of P_M. As with any sampling program, increasing the sample size usually decreases the variance in the estimate, and the small sample size for these taxa decreased the level of confidence in the *ETM* estimate of P_M. In addition, the sampling results for Stichaeidae showed that the larvae were most abundant in the Intake Cove and only occurred in two of the source water stations. Although the results likely reflect the actual distribution of larvae for this taxon, the sampling does not provide an accurate estimate of the source water population. This would affect both the use of the data for the *ETM* and in any scaling for mitigation done using the Habitat Production Foregone (*HPF*) approach adopted by the California State Water Quality Control Board in the “Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling” (OTC Policy) in May 2010.

Any comparison of the results of the ETM models among the study periods needs to account for the differences in the sampling, as well as the methods for calculating larval durations, the types of ocean current data used to measure larval transport, and differences in the currents among the study periods that affected the relative sizes of the source water area for each taxon. Although the plant typically operates at full capcity, the differences among the three periods may also reflect differences in the duration and timing of plant curtailments. In general, the P_M estimates were higher in the 2008–09 study than in the previous study years, especially for the estimates based on the CODAR backprojections. Despite these differences, a comparison of the results of the *ETM* from the two studies is still valid since estimates of entrainment, the source water population, and the source water volumes were common to both studies and were derived using methods approved by TWGs convened for the studies.

The estimates of P_M estimates between the 2008–09 study and previous study years can be directly compared for several of the taxa that were evaluated during both studies. The estimates for smoothead sculpin, snubnose sculpin, blackeye goby, cabezon, and KGB and blue rockfish complex larvae were all approximately equal or greater for the data collected during the 2008–09 study (**Table ES-2**) when compared with the estimates from the 1997–99 study (**Table ES-3**).

Table ES-2. Summary of DCPP entrainment sampling results and model output for fishes and shellfishes based on actual CWIS flows in 2008–2009. *ETM* model estimates provided for both ADCP and CODAR extrapolated estimates of source water areas.

Taxon	Common Name	Estimated Annual Entrainment (actual flows)	CODAR *ETM* P_M (%)	2●*FH*
Fishes				
Cottidae	unid. Sculpins	387,206,952	39.7*	
Artedius spp.	smoothhead sculpins	203,081,623	20.6	
Orthonopias triacis	snubnose sculpin	145,338,931	19.8	
Rhinogobiops nicholsi	blackeye goby	121,557,282	18.5	
Sebastes spp. V_	KGB rockfish complex	279,117,506	14.1*	1,310
Scorpaenichthys marmoratus	Cabezon	17,911,195	9.9*	
Sebastes spp. V	blue rockfish complex	104,394,654	6.3*	258
Genyonemus lineatus	white croaker	61,383,451	3.0*	
72 other taxa		1,536,263,685		
	Total larval fish	**2,856,255,279**		
Shellfishes				
Cancridae (megalops)	cancer crabs	1,822,947,583	2.7*	

* Average of 60 and 91 m depth backprojections . All others used only backprojections inside 60 m contour.

Table ES-3. ETM estimates of population mortality (PM) for fishes and crabs for 1997-1998 and 1998-1999 study periods calculated using larval durations based on maximum lengths at entrainment, and alongshore and offshore PS, and survey proportions of entrainment and source water populations for weights.

		ETM Estimate of P_M Alongshore		*ETM* Estimate of P_M Onshore+Alongshore	
Taxon	Common Name	1997-98	1998-99	1997-98	1998-99
Fishes					
Artedius spp.	smoothhead sculpin	11.4	22.6	–	–
Cebidichthys violaceus	monkeyface prickleback	13.8	11.8	–	–
Citharichthys spp.	Sanddabs	1.0	0.8	0.1	0.1
Engraulis mordax	northern anchovy	–	–	<0.1	<0.1
Genyonemus lineatus	white croaker	0.7	3.5	<0.1	0.4
Gibbonsia spp.	kelp blennies	18.9	25.0	–	–
Orthonopias triacis	snubnose sculpin	14.9	31.0	13.9	31.0
Oxylebius pictus	painted greenling	6.3	5.6	5.1	4.3
Paralichthys californicus	California halibut	0.5	7.1	0.1	0.6
Rhinogobiops nicholsi	blackeye goby	11.5	6.5	2.7	3.6
Sardinops sagax	Pacific sardine	–	–	<0.1	–
Scorpaenichthys marmoratus	Cabezon	1.1	1.5	0.9	0.8
Sebastes spp. V	blue rockfishes	0.4	2.8	<0.1	0.2
Sebastes spp. V_	KGB rockfishes	3.9	4.8	0.5	4.3
Shellfishes					
Romaleon antennarius	brown rock crab	0.3	1.0	<0.1	<0.1

Some commercially important fish with pelagic eggs and widespread populations that were not abundant in the entrainment samples in the present study (e.g., northern anchovy, Pacific sardine, sanddabs, and California halibut) were more abundant in the previous study. It was concluded that these species had low estimated larval mortalities or small numbers of adult losses to their populations based on results in the previous entrainment study in 1997–99. Five taxa (smoothhead sculpin, snubnose sculpin, monkeyface prickleback, clinid kelpfishes [common name subsequently changed to ‘kelp blennies’], and blackeye goby) had larval mortalities that exceeded 10% of the population living in an area 2–8 times the study grid area (Tenera 2000). For most of these (except kelp blennies), subtidal surveys of adults showed no consistent declining trends in numbers over recent years in the vicinity of DCPP outside the influence of the thermal plume. The results indicated that the effects on all these taxa were limited to a small portion of their total geographic distribution. The increase in the entrainment estimates in the current study from the estimates in 1997–1999 also provides evidence that the DCPP intake does not result in any substaintial impacts on adult populations that produce larvae subject to entrainment (**Table ES-1**).

The assessment of entrainment effects considered functions critical to the life history of the target taxa. The primary model used in the assessment considered the numbers of individuals entrained relative to the population in the adjacent nearshore areas that were then extrapolated to a larger population of inference based on the results of ADCP and CODAR current data. The population of inference was estimated for pelagic species and other widespread taxa differently from taxa that are distributed largely in nearshore areas shallower than approximately 61 m (200 ft) at the outer edge of the source water sampling area. The area around DCPP encompasses nursery and feeding areas for many of the target taxa. These areas also extend well beyond the zone of influence of the DCPP intake. Larval length measurements indicate that most of the target taxa are exposed to entrainment for a relatively short period of time during their early development and thus were produced locally, including within the Intake Cove. These results indicate that entrainment effects appear to be limited to localized effects on nearshore species. Therefore, the potential for damage due to entrainment on the biological value of the larger source water body is low.

Differences between the sampling approaches for the two studies need to be considered in the assessment of the results. The previous study included source water sampling of 64 stations along 17.4 km (10.8 mi) of coastline. As a result, the sampling included a wide range of depths and habitats that were not included in the source water sampling for this study (**Figure ES-1**). This is especially important in determining which taxa to include in the *HPF* estimates for the California OTC Policy. *ETM* estimates of P_M were not calculated for four of the taxa of fish larvae (Blennioidei/Zoarcoidei, Stichaeidae, monkeyface pricklebacks, and kelp blennies) that had some of the highest estimates of annual entrainment. The primary reason for excluding Blennioidei/Zoarcoidei and Stichaeidae from the *ETM* assessment was the limited number of source water surveys they were collected which would affect the levels of confidence associated with the *ETM* estimate of P_M. It was also clear from the data that the sampling did not provide an accurate estimate of the source water population for Stichaeidae, monkeyface pricklebacks (also a member of the family Stichaeidae), and kelp blennies, as the larvae for these taxa were most abundant inside the Intake Cove and only occurred in the source water stations closest to shore.

The results for other taxa analyzed using *ETM* show patterns of abundance that indicate the sampling provided a reasonable estimate of the source water as the larvae for other taxa were collected across all or most of the source water stations. In addition, these taxa occupy similar nearshore shallow rocky reef habitat as monkeyface pricklebacks and kelp blennies. The *HPF* estimates were calculated for each taxon as the product of the *ETM* estimate of P_M and the estimates of nearshore rocky reef habitat within the extrapolated source water areas. To maintain consistency with the approach used with the *ETM* estimates from the previous study, *HPF* estimates were not calculated for white croaker or Cancer crabs. Adult white croaker are not associated with nearshore rocky reef habitat and the Cancer crab group included numerous taxa that occupy a variety of habitats and were also not included in the *HPF* estimates from the 1997–1999 study. Averaging the estimates of *HPF* for the taxa associated with shallow rocky reef habitat helps compensate for some of the differences in the taxa used in the assessments from this study and the previous data from 1997–1999. The average *HPF* estimate of nearshore rocky reef habitat necessary to fully compensate for the losses of larvae due to entrainment at the DCPP was calculated to be 279 ha (690 acres). (**Table ES-4**).

Table ES-4. Estimates of Habitat Production Foregone (*HPF*) for nearshore rocky reef fish larvae based on nearshore *ETM* estimate of P_M based on extrapolated source water areas from CODAR data. For the taxa with depth limits deeper than 61 m (200 ft), the offshore extrapolated estimates of P_M were used in the *HPF* calculations.

Taxon	Common Name	Average alongshore distance (km) used in extrapolated source water	CODAR *ETM* P_M (%)	Depth (m) used in determining source water habitat	Estimate of subtidal rocky reef *HPF* (ha [acres])
Cottidae	unid. sculpins	30.7	38.6	91.4	1,331.1 (3,289)
Artedius spp.	smoothhead sculpins	24.9	20.6	15.0	125.1 (309)
Orthonopias triacis	snubnose sculpin	20.6	19.8	30.5	251.4 (621)
Scorpaenichthys marmoratus	cabezon	8.4	8.6	91.4	69.8 (172)
Sebastes spp. V_	KGB rockfish complex	9.1	12.6	86.0	103.9 (257)
Sebastes spp. V	blue rockfish complex	7.2	5.2	91.4	44.0 (109)
Rhinogobiops nicholsi	blackeye goby	4.8	18.5	76.2	29.9 (74)
				Average *HPF* =	**279.3 (690)**

Table of Contents

List of Tables

List of Figures

1.0 Introduction

The Diablo Canyon Power Plant (DCPP) is a nuclear-fueled steam-turbine power generating station that is owned and operated by the Pacific Gas and Electric Company (PG&E) and has a rated electric output of 2,200 megawatts. Commercial operation of Unit 1 began in May 1985, and Unit 2 in March 1986. The DCPP is located on a coastal terrace midway between the communities of Morro Bay and Avila Beach on the central California coast. The local coast is a steep and rugged rocky shoreline that is exposed to heavy wave activity. The study area supports a rich community of marine life that is a biogeographical extension of similar marine communities extending many hundreds of miles to the north. Except for the DCPP, the coast is largely uninhabited and undeveloped along the approximately 16 km (10 mi) between the cities of Morro Bay and Avila Beach.

The DCPP uses a once-through cooling water system for its two generating units with a maximum cooling water flow of 2,500 million gallons per day (mgd) (9.46 x10^6 m^3). Both units share a common shoreline intake structure protected from ocean waves by two constructed breakwaters. As the water passes through the plant's condensers, it causes the steam contained within the secondary reactor loop to recondense. After passing through the plant, the cooling water is discharged directly into Diablo Cove and the Pacific Ocean through a shoreline discharge structure. The discharged water is approximately 11°C (20°F) warmer than ambient ocean waters under normal operating conditions.

Cooling water intake systems (CWIS) are regulated under §316(b) of the federal Clean Water Act (CWA). In July 2004, the U.S. Environmental Protection Agency (EPA) published new regulations for §316(b) applicable to large existing power plants with daily cooling water volumes in excess of 50 mgd (Phase II Rule). The regulations required substantial reductions in flow or application of new screening systems to significantly reduce the entrainment and impingement of aquatic organisms in the cooling water intake flows. The new regulations were challenged by a coalition of environmental groups and six northeastern states, with the case eventually being heard by the Second U.S. Circuit Court of Appeals. The court rendered a decision in January 2007 that remanded several key components of the regulations back to the EPA. In March 2007, the EPA issued a memorandum suspending the rule and directing that all permits for Phase II facilities implement §316(b) on a case-by-case basis using "best professional judgment" (BPJ). The language of the memorandum was expanded and published in the Federal Register in July 2007 (Volume 72, 130:37107-37109). The Second U.S. Circuit Court of Appeals decision was appealed to the U.S. Supreme Court by several utility companies with EPA as one of the petitioners. The Court agreed to review only the aspect of the Phase II Rule related to allowing the use of cost-benefit in determining compliance. The case was heard on December 2, 2008 and a decision was issued by the Court on April 1, 2009 that reversed the Second Circuit Court ruling by agreeing with the EPA that cost-benefit can be considered, but would not be required to be included in any future rulemaking efforts.

The EPA published proposed revisions to Phase II in April 2011. The final regulations for §316(b) applicable to large existing power plants were published on August 15, 2014.[1]

While the federal regulations for §316(b) were being considered, the California State Water Resources Control Board (SWRCB), which has authority to implement §316(b) in the state, adopted the statewide "Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling" (OTC Policy) on May 4, 2010, which became fully effective on October 1, 2010. The OTC Policy established uniform, technology-based standards to implement federal Clean Water Act §316(b) and included a special process for consideration of compliance options for nuclear-fueled facilities such as the DCPP.

The primary purpose of this study was to update the facility administrative record in preparation for renewal of the DCPP NPDES permit. A previous intake assessment in response to the development of the §316(b) Phase II regulations was conducted from 1996–1999 (1996–1999 Study). A report from that study was submitted to the Central Coast Regional Water Quality Control Board (CCRWQCB) in 2000 (Tenera 2000), which was also intended to be used in the renewal process for the DCPP NPDES permit.

1.1 Study Approach

The sampling design for the DCPP entrainment study was consistent with entrainment studies conducted at several other power plants in California over the past 15 years. Similar to the 1996–1999 Study, a technical advisory group was convened to review the study design and provide comments on the sampling and analysis methods. This Technical Workgroup (TWG) was composed of staff from PG&E and their consultants, Tenera Environmental Inc, Dr. Peter von Langen from the CCRWQCB and Drs. Gregor Cailliet, Michael Foster, John Largier, and Peter Raimondi, who were consultants to the CCRWQCB. The study plan was submitted to the TWG for review, and was approved following a meeting in May 2008. The sampling for the study began in July 2008.

The source water sampling design for this study, which was approved by the TWG, was similar to other recent studies but was not as spatially extensive as the sampling grid design used in the 1996-1999 DCPP study. The entrainment sampling was done twice monthly at two entrainment stations in front of the intakes every six hours, instead of the weekly surveys that sampled at three hour intervals in the 1996-1999 DCPP study. The source water sampling was done monthly in both studies and included six of the original 64 source water stations from the 1996-1999 DCPP study. These six stations were positioned along a transect heading straight offshore from the entrainment sampling locations inside the DCPP Intake Cove. The source water stations were

[1] 40 CFR Parts 122 and 125 National Pollutant Discharge Elimination System—Final Regulations To Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities; Final Rule. Federal Register Vol. 79 Friday, No. 158 August 15, 2014.

sampled on the same six hour cycles as the entrainment stations. The source water sampling for the 1996-1999 study required a three-day period to sample all of the source water stations with entrainment sampling occurring on the second of the three days.

The estimation of the source water for the *ETM* analysis in the original study design was initially intended to be based on data from two acoustic Doppler current profiler (ADCP) instruments using an approach similar to the 1996–1999 Study. As the study progressed we became aware of the availability of data on surface currents from high frequency radar instruments (CODAR) over a large area of the central coast around the DCPP. The instruments were maintained by scientists and technicians at California Polytechnic State University, San Luis Obispo (Cal Poly). A decision was made to utilize the CODAR data in calculating the source water estimates for the *ETM*. Because the CODAR data provided much larger spatial coverage of ocean current data than the ADCPs, a more realistic estimates of the source water area could be obtained using a combination of ADCP and CODAR data, improving the estimate of mortality derived by the *ETM*. The final methodology was presented, discussed, and approved by the TWG during a meeting in May 2010.

The improvement due to the addition of CODAR data in the estimates of the source water for the *ETM* also affected the source water areas used in the calculation of *HPF*. Previous estimates of *HPF* provided in Raimondi et al. (2005) were calculated from the *ETM* results from the 1996–1999 Study that used ADCP data alone to estimate the source water area. As noted in Raimondi et al. (2005) there was a considerable degree of uncertainty associated with the source water estimates used in the *ETM* that was directly related to the resolution provided by the ADCP data on ocean currents used in the study. The other large source of uncertainty associated with the Raimondi et al. (2005) *HPF* estimates was the data used to estimate the areas of habitat in the source water. Data from aerial photographic surveys of kelp beds were used to estimate the area of nearshore rocky reef habitat. In addition to the greater resolution provided by the CODAR data, the habitat estimates in this study used more recent data on bottom habitats collected from GIS data from the Seafloor Mapping Lab at the California State University at Monterey Bay (CSUMB). These data were collected along much of the central California coast as part of the California Department of Fish and Wildlife initiative to develop a network of marine protected areas. The more precise estimates of coastal currents and habitat used in this study greatly improve on the estimates of *HPF* provided in Raimondi et al. (2005).

This study focused on the two groups of organisms also assessed in the 1996–1999 Study: larval fishes, and *Cancer* crab larvae. While some data on other planktonic organisms were collected during the 1996–1999 study, the assessment eventually focused on larval fishes, *Cancer* crabs, and market squid as representative groups because of their economic and ecological importance. This approach is consistent with established §316(b) guidelines that recognize that only a subset of the high diversity of entrained organisms can be practically quantified, and that inferences concerning potential impacts to other groups can be drawn from those studied in detail. Focusing on these groups of organisms also enabled a comparison with the results from the previous study. Due to the complications in accurately estimating the entrainment mortality of all the stages of cancrid crab larvae, the present study included processing only megalops stage larvae, which is consistent with other entrainment studies recently completed in California (MBC and Tenera 2007, MBC et. al. 2007). The entrainment mortality estimated for the megalops stage was applied to the entire larval duration covering all of the larval stages to estimate the effects of entrainment.

Larval fish and shellfish abundances can vary greatly through the year and, therefore, twice monthly sampling was used for characterizing entrainment. Models of the conditional mortality due to entrainment are based on proportional comparisons of entrainment and source water abundances and are theoretically less sensitive 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 other recently completed intake assessments in southern California.

1.2 Report Organization

The report is organized as follows: Section 2.0 includes a detailed description of the DCPP and CWIS. Data on circulating water pump flows from the study period are presented and discussed as these are the data used in calculating estimates of IM&E presented in other sections of the report. Section 3.0 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 for the entrainment and source water sampling and the analysis approach are presented in Section 4.0. Section 5.0 presents the sampling results, detailed life history and sampling information on the more abundant taxa entrained, and the results of the impact assessment methodology. The *HPF*-based impact assessment for the DCPP CWIS is presented in Section 6.0. The references used in the report are presented in Section 7.0. Appendices include detailed summaries of the physical studies, the entrainment analysis models, and the entrainment and source water data.

2.0 Power Plant Cooling Water System

2.1 Description of the CWIS

Diablo Canyon Power Plant (DCPP) Units 1 and 2 have independent cooling water intake systems (CWIS) for re-condensing freshwater steam for the turbine power cycle. Each unit has its own system of intake and discharge conduits, but they all share the same intake structure and discharge location (**Figures 2-1** and **2-2**). During normal operations, seawater is drawn from the Intake Cove through the Unit 1 and Unit 2 conduits and pumped approximately 26 m (85 ft) above mean sea level to the two condenser systems. The freshwater steam is condensed back to water by transferring heat to the seawater. The warmed seawater for each unit is then discharged back into the ocean at the shoreline of Diablo Cove. The discharge system consists of two parallel conduits (one for each unit) that converge immediately before discharging into Diablo Cove. Cutouts in the center wall that separate the two conduits allow mixing when flows from both units are unequal, but are of less importance when the flows from each unit are equivalent. The velocity of the effluent at the point of discharge into Diablo Cove is relatively high due to the momentum created by the water cascading down the discharge conduits, beginning from an elevation of about 26 m above mean sea level and ending at the shoreline. The first warm water discharges occurred intermittently in 1984 with start-up testing of Unit 1. Commercial operation of Unit 1 began in May 1985, and Unit 2 in March 1986.

The intake for the DCPP units is a shoreline structure that houses bar racks, vertical traveling screens, auxiliary cooling water systems, and main circulating water pumps. On the ocean side of the intake structure, a concrete curtain wall extends approximately 2.4 m (7.9 ft) below mean sea level to prevent floating debris from entering the structure (**Figure 2-2**). Seawater entering the intake structure passes through one of 16 sets of bar racks designed to exclude large debris from the forebays. The bar racks are either 1.5 or 3.1 m (5 ft or 10 ft) wide and consist of vertical rows of approximately 8 cm x 1 cm (3 in x ½ in.) steel bars spaced about 8 cm (3 in.) apart. There are seven vertical traveling screens per unit that are designed to remove debris that passes through the bar racks. The screens extend from the upper deck of the intake structure to the bottom at a depth of approximately 10 m (33 ft) below sea level. The six wider traveling screens filter seawater to each unit's two main circulating water pumps (CWP), and the one narrower traveling screen filters seawater to each unit's two auxiliary seawater (ASW) pumps. Each CWP traveling screen is composed of 57 baskets that are approximately 3.1 m (10 ft) wide by 61 cm (2 ft) tall. The ASW traveling screens also have 57 baskets that are 1.5 m (5 ft) wide by 61 cm (2 ft) tall. The interior of each basket is covered with 0.95 cm (3/8 in.) mesh designed to prevent material from entering the conduits and clogging the 2.5 cm (1 in.) diameter condenser tubes. Objects small enough to pass through the bar racks and larger than the 0.95 cm (3/8 in.) mesh of the traveling screens may be impinged.

Each CWP has a manufacturer's estimated maximum average flow rate of 1,641 m^3/min (433,506 gpm), equivalent to 624.25 mgd (PG&E 1998a). Actual average flow rates of the installed CWPs are slightly lower than the manufactures estimated maximum, and also differ between the operating units. The rated flow of each ASW pump is 60,000 m^3/d (15.97 mgd).

There are four ASW pumps (two per unit), during routine plant conditions only one ASW pump per unit is operated.

The nominal DCPP total daily intake volume when all four CWPs (two per unit) and two ASW pumps (one of two per unit) are operating is 9.41 million m^3/d (2,486 mgd). The total volume of cooling water circulated can vary daily due to a variety of factors that include changes in ocean tidal and swell height, as well as flow resistance caused by occlusion of steam condenser tubes resulting from fouling within the seawater system, or from debris which has bypassed the intake traveling screen systems. During planned or emergent power generation curtailments, and during unit refueling outages, one or multiple CWPs will be shut-down reducing total intake volume substantially during those periods.

The traveling screen assemblies are equipped with a high pressure seawater wash system, and screens are rotated either automatically or manually. When the screens rotate, impinged debris, fishes, and invertebrates are rinsed from the screens into a trough that slopes to a central refuse sump area. In Fall 1997, a grinder system was installed to decrease the size of all material before it entered the sump. All material in the sump is then pumped back to the ocean at the landward end of the west breakwater. Automatic operation of the screens occurs in one of two ways: by timed cycles or by hydrostatic pressure. Timers are typically set to initiate a 40-minute screen wash once every four hours. The screens also rotate automatically when a height differential of approximately 20 cm (8 in.) across the screen surface is detected. Manual operation of the traveling screens occurs whenever necessary, especially when heavy accumulations of kelp threaten the safe operation of the intake system. During these times continuous screen washing is usually necessary.

2.2 Circulating Water Pump Flows

Daily cooling water flow volumes at the DCPP during the July 2008 – June 2009 study period are depicted in **Figure 2-3**. Maximum daily reported flow rates of 9.41 million m^3/d (2,486 mgd) occurred for most of the study duration. There was one refueling outage (1R14) from 1/25/09 to 2/24/09 during which pump flows were reduced to approximately half of maximum. There were five other shorter periods of time when one or more of the DCPP CWPs were not in operation for periods of hours or a few days.

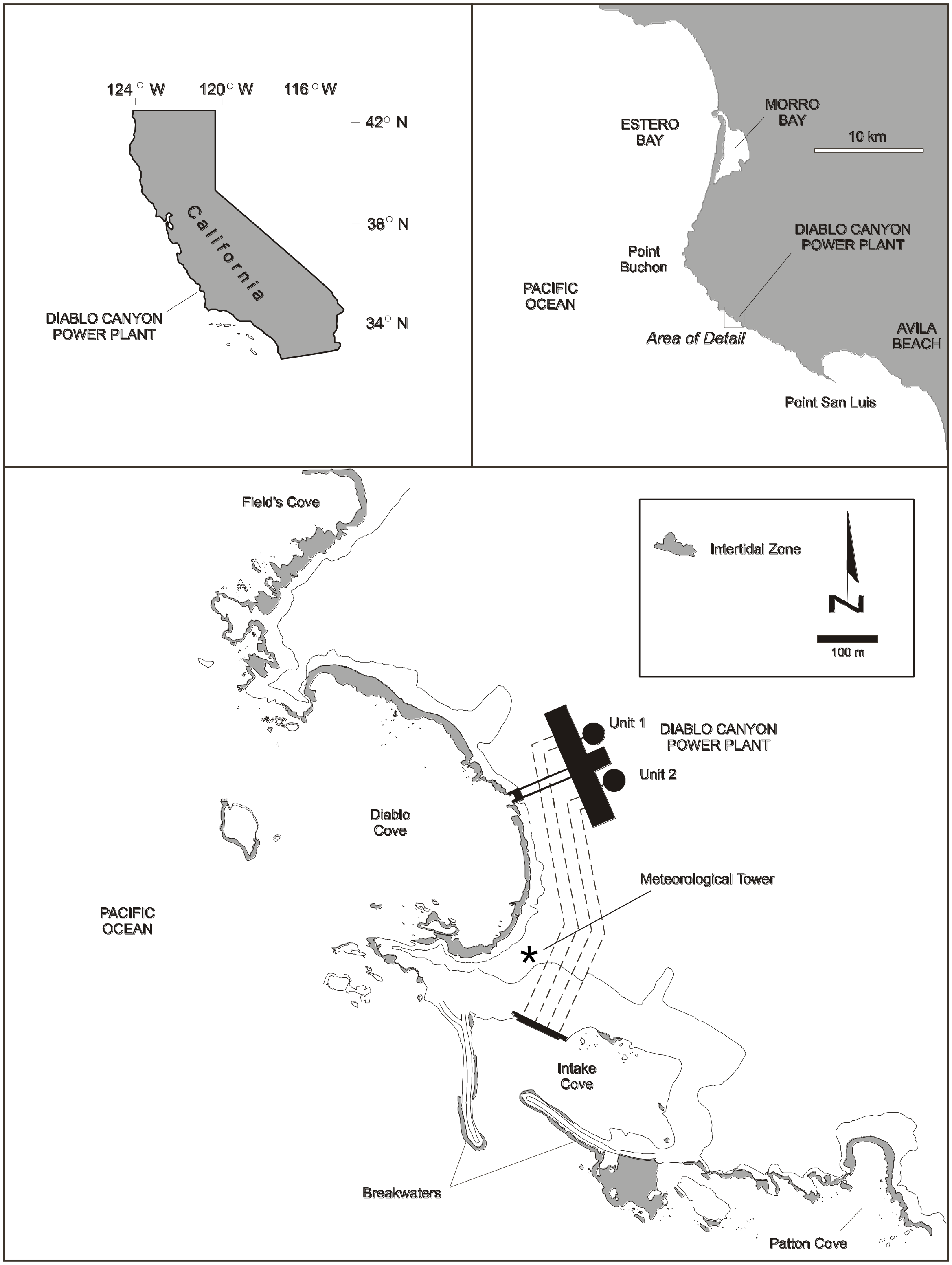


Figure 2-1. Location of Diablo Canyon Power Plant showing intake tunnel configuration (dashed lines).

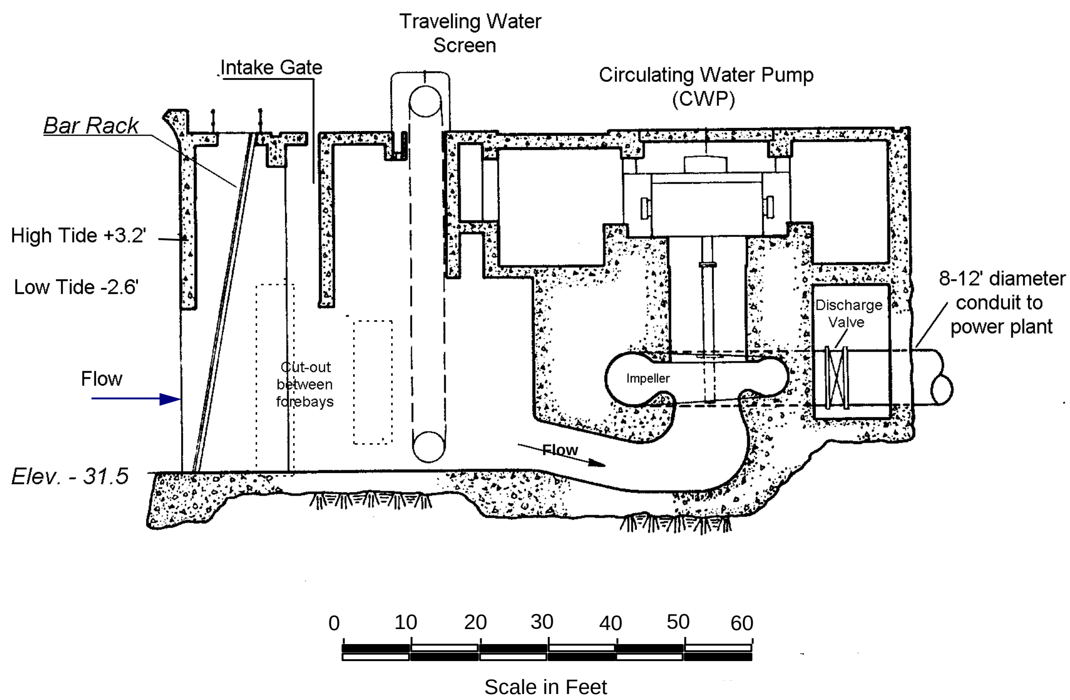


Figure 2-2. Cross-section diagram of DCPP intake structure showing water flow path. Elevations are based on mean sea level (modified from PG&E 1988a).

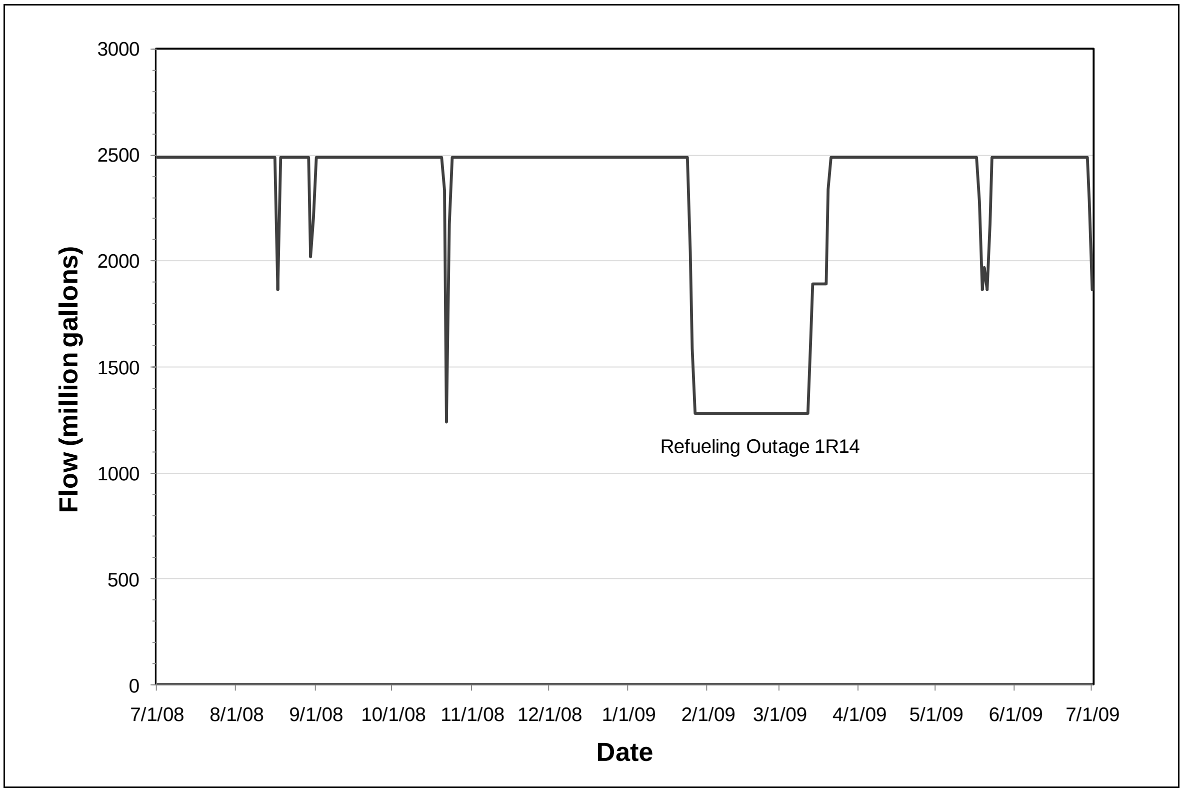


Figure 2-3. Daily cooling water flow volumes at DCPP from July 1, 2008 to July 1, 2009.

3.0 Environmental Setting

3.1 Bathymetry and Substrates

DCPP is situated on a coastal terrace located in central California midway between the coastal communities of Morro Bay and Avila Beach (**Figure 2-1**). The 20 km (12 mi) stretch of continuous rocky shoreline between these two communities consists of wave exposed headlands alternating with semi-protected coves. Diablo Cove has a surface area of approximately 15 hectares (38 acres). Field's Cove is directly north of Diablo Cove. South of Diablo Cove is the breakwater forming the DCPP Intake Cove, after which natural rocky shoreline extends to Avila Beach. The average depth of Diablo Cove is about 8 m (26 ft) with a maximum depth of approximately 18 m (59 ft). The intertidal and subtidal areas of the cove consist of bedrock, boulder, and cobble fields. Submerged and emergent offshore rock pinnacles are scattered throughout the cove and in areas north and south.

The bathymetry of the nearshore region between Point Buchon and Point San Luis is characterized by sloping bedrock and soft-bottom flats, with steeper relief generally increasing from the south to the north. The majority of the nearshore region near Pt. San Luis, from the shoreline to ~2 km offshore, is less than 40 m in depth, while the corresponding nearshore region off Point Buchon is 60–80 m in depth. Rocky pinnacles are relatively common out to the 40 m contour, in contrast to the relatively flat bottom typical of the 40–100 m region. Within the geographic area bounded by Point Buchon and Point San Luis, several prominent rocky ridges extend from the shoreline out to about the 20 m contour, especially noticeable at Point Buchon, Lion Rock, and Pecho Rock.

3.2 Water Temperatures

Ambient water temperatures during the study period, as measured at the DCPP shoreline intake structure, varied from a high of 15.9°C (60.6°F) in November 2008 to a low of 8.6°C (47.5°F) in April 2009 (**Figure 3-1**). An extended period of cool water indicative of spring upwelling occurred from mid-March 2009 through late-May 2009.

3.3 Tides

Tides in central California are classified as mixed, semi-diurnal, with two unequal high tides (i.e., high water and higher high water) and two unequal low tides (i.e., low water and lower low water) each lunar day (approximately 24.5 hours). From July 2008 through June 2009, the predicted extreme tides at Port San Luis ranged from +7.1 ft (+2.16 m) to -1.9 ft (-0.58 m) relative to MLLW.

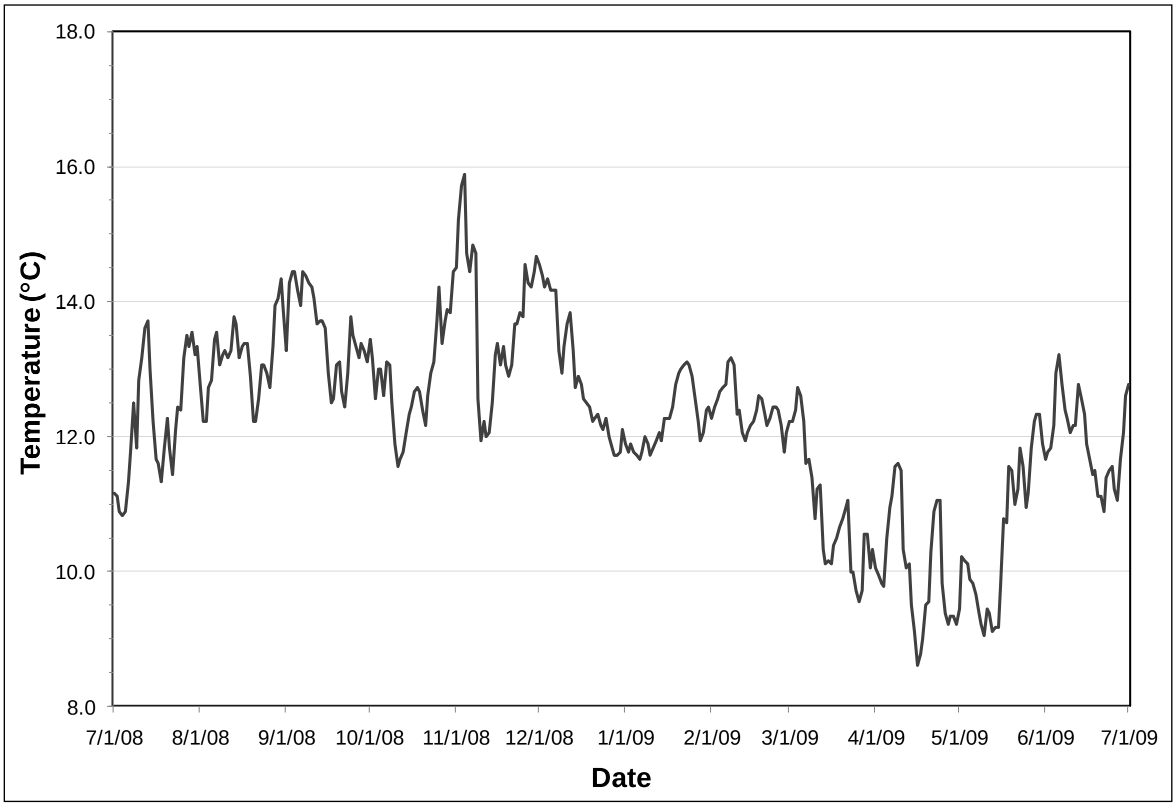


Figure 3-1. Daily average water temperatures at the DCPP intakes from July 1, 2008 to July 1, 2009.

3.4 Ocean Currents

The following sections include descriptions of nearshore currents in the vicinity of DCPP as well as results from current measurements made during the study period.

3.4.1 Regional Overview

The nature and origin of processes structuring the nearshore currents in the vicinity of Diablo Canyon are fairly complex, reflecting dynamics of seasonal currents, winds, and tidal cycles. The general current pattern near Diablo Canyon is composed of three currents: the constant current, the smoothed current, and the residual current (Safaie 1986). The constant current has a period of greater than 30 days and results from large-scale, southward and northward flows related to the California and Davidson currents, respectively. The smoothed current, with a period of 1-30 days, is primarily driven by wind; and the residual current, with a period of less than 1 day, is controlled largely by a combination of both the tide fluctuation and wind.

In general, two major types of currents exist off the coast of California: shore parallel and shore normal (perpendicular). The shore parallel currents include constant currents: the southward-flowing California Current and the northward-flowing Davidson Current. The California Current originates from the clockwise North Pacific Gyre, which creates a southward flow along the western coast of North America. This current is present year-round along the California coast, but is typically displaced offshore by the northward flowing Davidson Current in the fall and winter. The Davidson Current is formed by a deeper-water, counter-clockwise gyre in the California Current present between Cape Mendocino (Mendocino County) and Point Conception (Santa Barbara County). The Davidson Current is sometimes referred to as the California Undercurrent, particularly during the spring and summer when it is a deeper-water phenomenon. Of the two, the Davidson Current is weaker and more diffuse than the California Current. As such, current reversals can, and do, commonly occur during the winter.

Smoothed currents in the vicinity of Diablo Canyon (Safaie 1986) include both parallel, and shoreward and seaward currents. The shoreward and seaward currents originate from seasonal onshore and offshore winds, respectively. These seasonal, perpendicular currents are of minor magnitude relative to the shore-parallel currents, but their consequent downwelling and upwelling events are important to the nutrient cycling and productivity of the Diablo Canyon nearshore region.

The California Current ecosystem is characterized by seasonally high levels of primary production when northwesterly winds predominate and cause coastal upwelling to occur, typically in the spring and summer of each year. Upwelling occurs because the northwesterly winds generate Ekman transport of surface waters due to the Coriolis Force, resulting in a net movement of surface waters perpendicular to the wind direction: to the right in the northern hemisphere and offshore relative to the California coast. Regional water temperatures are also affected by the El Niño Southern Oscillation (ENSO) in the eastern Pacific Ocean that typically consists of a warm water El Niño phase followed by cooler water temperatures during a subsequent La Niña phase. Much of the interannual ocean variability on decadal and sub-decadal time scales can be attributed to El Niño events and these can significantly affect the coastal waters of Central California (Lenarz et al. 1995; Schwing et al. 1997).

3.4.2 Currents during the Study Period

Measuring the speed and direction of ocean waters offshore of the DCPP provided data for modeling the extent of the source water potentially entrained through the power plant. The data were coupled with estimates of larval growth and planktonic duration to estimate source water volumes used in *ETM* calculations for entrainment impact analysis. Current speed and direction were measured by a combination of three nearshore current meters deployed either on the bottom or in the water column, and by high-frequency (HF) radar SeaSondes® (CODAR) operated by the Center for Coastal Marine Sciences at California Polytechnic State University (Cal Poly) for surrounding surface waters (**Figures 3-2** and **3-3**). The three nearshore current meters at DCPP were a 600 kHz Nortek Aquadopp acoustic Doppler current profiler (ADCP), a 1 MHz Nortek Aquadopp ADCP, and an InterOcean Systems S4 point current meter that estimates velocity using electromagnetic induction (**Figure 3-2** and **Table 3-1**). The two ADCP current meters were installed June 14, 2008 on upward-looking bottom mounts at depths of approximately 21 m (68 ft) and 25 m (81 ft). The S4 was deployed June 30, 2008 at depth of 7 m (23 ft) from the surface over a 30 m (98 ft) deep mooring. Velocities were measured every half hour for each 1-m depth interval starting 0.4 m (1.3 ft) (South Station) or 0.5 m (1.6 ft) (North Station) above the ADCP instruments and every hour by the S4.

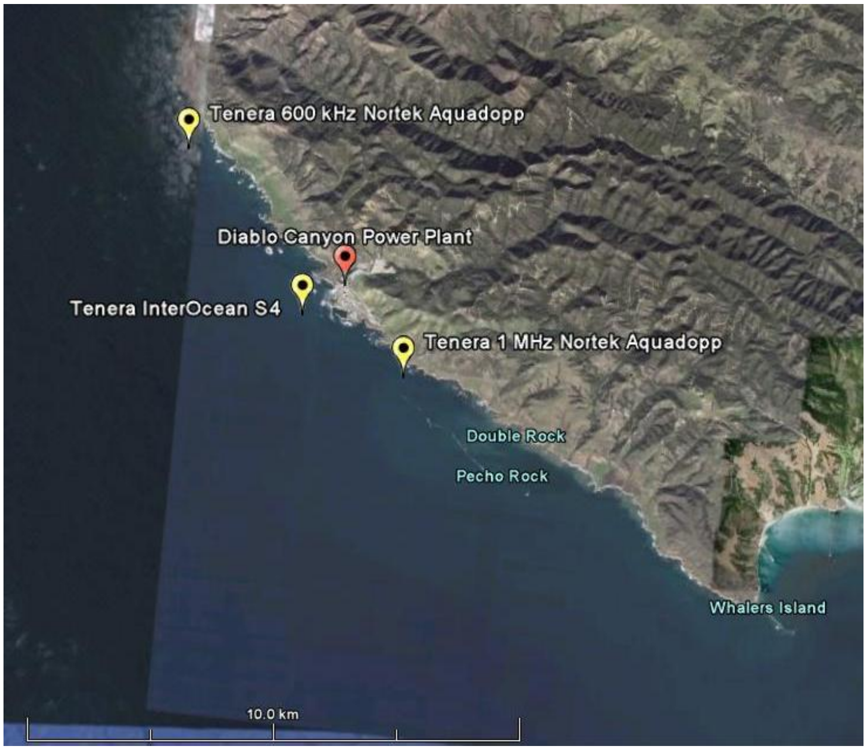


Figure 3-2. Locations of *in situ* current meters utilized during the study.

Table 3-1. Locations and specifications for *in situ* current meters near DCPP.

Current Meter	Latitude (°N)	Longitude (°W)	Distance from DCPP Intake	Mean Sensor Depth and Bottom Type	Averaging Interval and Period	Number of 1-m measurement intervals
North ADCP	35.23479	120.89298	4.7 km (2.9 mi)	24.7 m (81 ft) rock	320 s every 30 min	19-22
S4	35.20600	120.86383	0.85 km (0.5 mi)	30.0 m (98 ft) sand	300 s every 60 min	n/a
South ADCP	35.19599	120.83984	2.1 km (1.3 mi)	20.7 m (68 ft) sand	300 s every 30 min	16-18

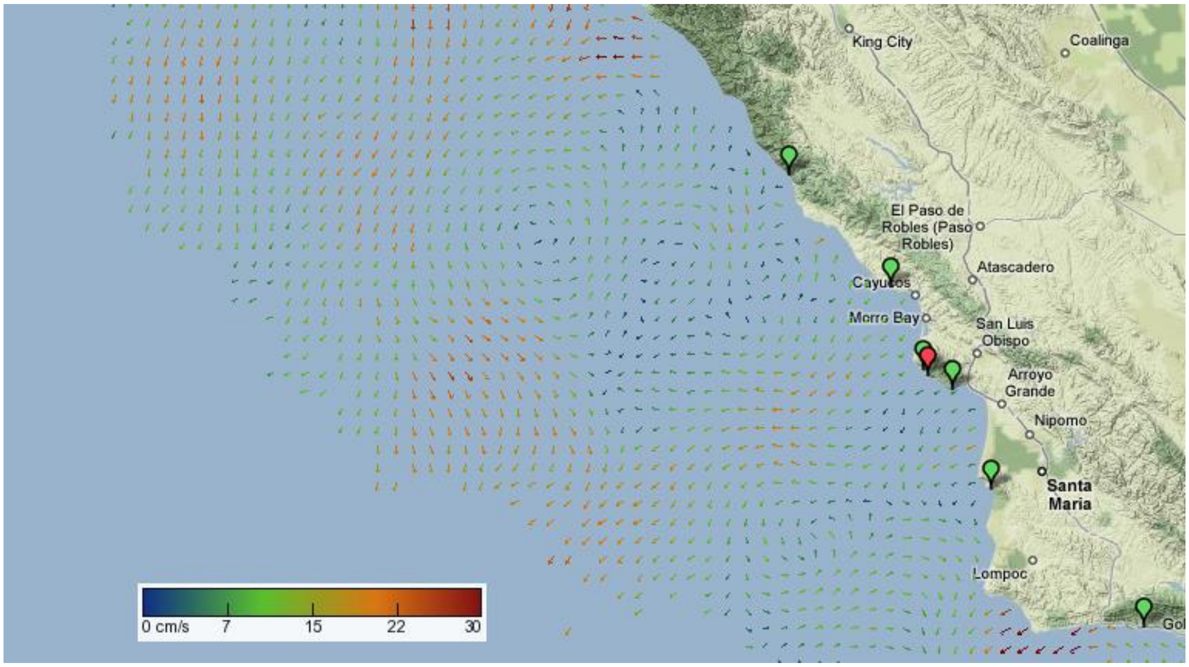


Figure 3-3. Example plot of ocean surface current vectors measured by Cal Poly's network of CODAR stations (green dots) offshore from DCPP (red dot) on October 21, 2008 at 2000 PDT. Shown are 6 km resolution vectors, shaded according to their velocity.

The two ADCPs were installed on June 14, 2008 and data were collected at the south station until July 10, 2009 and at the north station until July 21, 2009. The currents were measured at the S4 middle station from June 29, 2008 through December 31, 2008. While data were collected over the entire period at the ADCP South Station, measurements at the ADCP North Station were interrupted due to the loss of power for a week in September 2008, and two times when the mount was overturned by large swells from October through early December 2008, and later December 2008 through January 2, 2009. The mount was redesigned and there were no additional problems through the end of the study. As a result of the problems with the deployments of the S4 and North Station ADCP instruments, only the data from the South Station were used in adjusting the wide-area CODAR data on surface currents used for the source water extrapolations for the *ETM* analysis. In addition, as explained below, the data from the North Station showed a large degree of variation in direction and velocity due to its position just to the south of Point Buchon.

Progressive current vectors were computed in the alongshore and onshore directions for comparison with previous current measurements at DCPP that were collected at the location of the S4 meter using the same instrument (Tenera 2000). The coastline between Point Buchon and Point San Luis makes a slight bend (approximately 20°) northward at DCPP. Tangents along the coastline from the tip of the west breakwater at DCPP defined the inshore margins of the study grid used in the previous study (Tenera 2000) at 321° True (NW) and 121° True (ESE). These tangents were used for rotating between the North-East and Alongshore-Onshore reference planes by 39° for the north current meter station and by 59° for the South Station.

Currents measured by the ADCPs as the average over the entire water column at the North Station fluctuated among months between upcoast (northwest) and downcoast (southeast) directions, whereas currents at the South Station flowed predominantly in a downcoast direction (**Figure 3-4**). For purposes of the progressive current vectors in **Figure 3-4**, the South Station currents served as a proxy for the missing observations at the North Station. The coastline in the vicinity of DCPP trends in a northwest-southeast direction and currents at the South Station had only a very slight onshore-offshore component whereas the North Station's currents had a more offshore component. By way of comparison, **Figure 3-5** shows current measurements from 1997-1999 as reported in Tenera (2000) from the S4 location. The previous study showed south-moving alongshore currents similar to those from the ADCP South Station.

CODAR current displacements from interpolations to the ADCP locations were offshore over the study period (**Figure 3-6**) while only the current measured by the ADCP at the North Station had a net offshore displacement (**Figure 3-4**). The highest current speeds occurred at the surface at both locations (**Table 3-2**). Unadjusted CODAR current speeds were higher than ADCP surface speeds or the S4 current speeds. The data from the single location current instruments supplemented the data from the CODAR system which is not able to record current flow speeds close to shore as was done by the ADCP current meters.

An example of daily current vectors from the South Station ADCP (averaged over all depth ranges) are compared to surface current vectors in the same vicinity as measured by the CODAR system (**Figure 3-7**). The ADCP data showed fine-scale tidal components of the currents with generally slower velocities when compared to the CODAR-interpolated surface measurements. Furthermore, the CODAR measurements occasionally showed a strong daily signal of wind-generated surface currents, particularly evident during the June 15–20 period (**Figure 3-7b**). Modeling results using the CODAR data to describe the extent of the source water under various conditions are presented in **Appendix A**. Additional whisker plots of the data for the July 2008–July 2009 study periods from the ADCP and S4 data are presented in **Appendix B**. The average of current speeds measured near the surface was higher at the S4 location than at the ADCP locations (**Table 3-3**). The speed of unadjusted surface CODAR data interpolated to the locations of the current meters were about twice the magnitude of the ADCP water column averages.

The methodology used to integrate current vectors for each station with CODAR surface currents is explained in **Appendix A**. Because surface currents are stronger than those at depth, the CODAR-derived surface currents were scaled to approximate sub-surface magnitudes.[2] The proximity of the ADCPs to the HF-radar measurement field allowed the surface current values to be linearly interpolated to the ADCP locations. The U (east-west) and V (north-south) components of velocity were considered separately in their relationship with depth. Further, as there are seasonal variations in the currents, each month was assessed independently. The monthly mean of the absolute value of each component from the ADCPs, both average water-

[2] Technical memorandum from Mr. Brian Zelenke, Center for Coastal Marine Sciences, California Polytechnic State University, San Luis Obispo to Tenera Environmental dated December 14, 2009.

column and at 3 m (9.8 ft) depth, was divided by the monthly mean of the absolute value of each component from the interpolated CODAR values (**Table 3-4**, **Figure 3-8**). These ratios would provide a means to scale the CODAR data down through the water column. Application of the scaling factor to the CODAR data produces significantly tighter agreement with the speeds measured by the ADCP, while still preserving the similarity in the directional component of velocity as shown by the respective shapes of the lines.

Table 3-2. Monthly average current speeds (cm/s) at various depth strata as measured by three current meters near DCPP from July 1, 2008 to June 30, 2009.

	North Station ADCP		S4	South Station ADCP	
Survey Period	Near Surface Speed	Water Column Speed	Subsurface (ca -6 m) Speed	Near Surface Speed	Water Column Speed
July 2008	10.04	5.25	12.74	8.92	5.42
August 2008	8.42	4.51	6.65	7.57	4.81
September 2008	9.30	4.53	6.87	7.51	5.26
October 2008	11.25*	5.25*	9.33	7.56	5.34
November 2008	nd	nd	11.56	7.50	5.28
December 2008	10.38*	5.57*	10.03	7.07	4.98
January 2009	8.90	5.03	nd	5.95	4.43
February 2009	9.48	5.24	nd	7.29	4.51
March 2009	9.32	4.68	nd	8.03	5.20
April 2009	10.17	4.78	nd	8.80	6.01
May 2009	8.32	3.93	nd	10.10	7.04
June 2009	7.09	3.76	nd	8.70	5.38

*partial data collection; nd = no data collection

Table 3-3. Average speeds (cm/s) measured by two ADCP current meters near DCPP from July 1, 2008 to June 30, 2009 and from a S4 current meter July 1 to December 31, 2008. CODAR measurements are interpolations from offshore HF radar data to the current meter locations corresponding to the time periods sampled.

	Current Speed	CODAR Interpolated Speed
North Station ADCP Near Surface	9.10	19.06
North Station ADCP Water Column	4.69	
S4 (ca. 6 m below surface)	9.53	15.31
South Station ADCP Near Surface	7.91	16.22
South Station ADCP Water Column	5.31	

Table 3-4. Percentage of the surface currents measured by the CODAR radar to equal the ADCP measurements at 3 m and over the water column depths indicated by the mid-point. Values were omitted where the given ADCP was not operating. U = East velocity component, V= North velocity component.

	Jul 08		Aug 08		Sep 08		Oct 08		Nov 08		Dec 08	
	U	V	U	V	U	V	U	V	U	V	U	V
North ADCP 3.0 m	53	52	33	38	41	42	48	43	–	–	46	57
South ADCP 3.0 m	74	55	63	43	72	39	56	42	64	33	58	40
North ADCP 11.6 m	28	38	20	28	22	32	25	31	–	–	31	35
South ADCP 9.9 m	50	31	47	26	58	24	43	26	50	22	47	26
	Jan 09		**Feb 09**		**Mar 09**		**Apr 09**		**May 09**		**Jun 09**	
	U	**V**	**U**	**V**	**U**	**V**	**U**	**V**	**U**	**V**	**U**	**V**
North ADCP 3.0 m	41	67	51	47	43	31	52	31	54	34	50	37
South ADCP 3.0 m	64	43	66	38	57	39	68	33	77	46	71	41
North ADCP 11.6 m	30	40	34	25	24	17	28	15	30	18	25	25
South ADCP 9.9 m	50	29	48	22	45	22	58	20	62	27	49	24

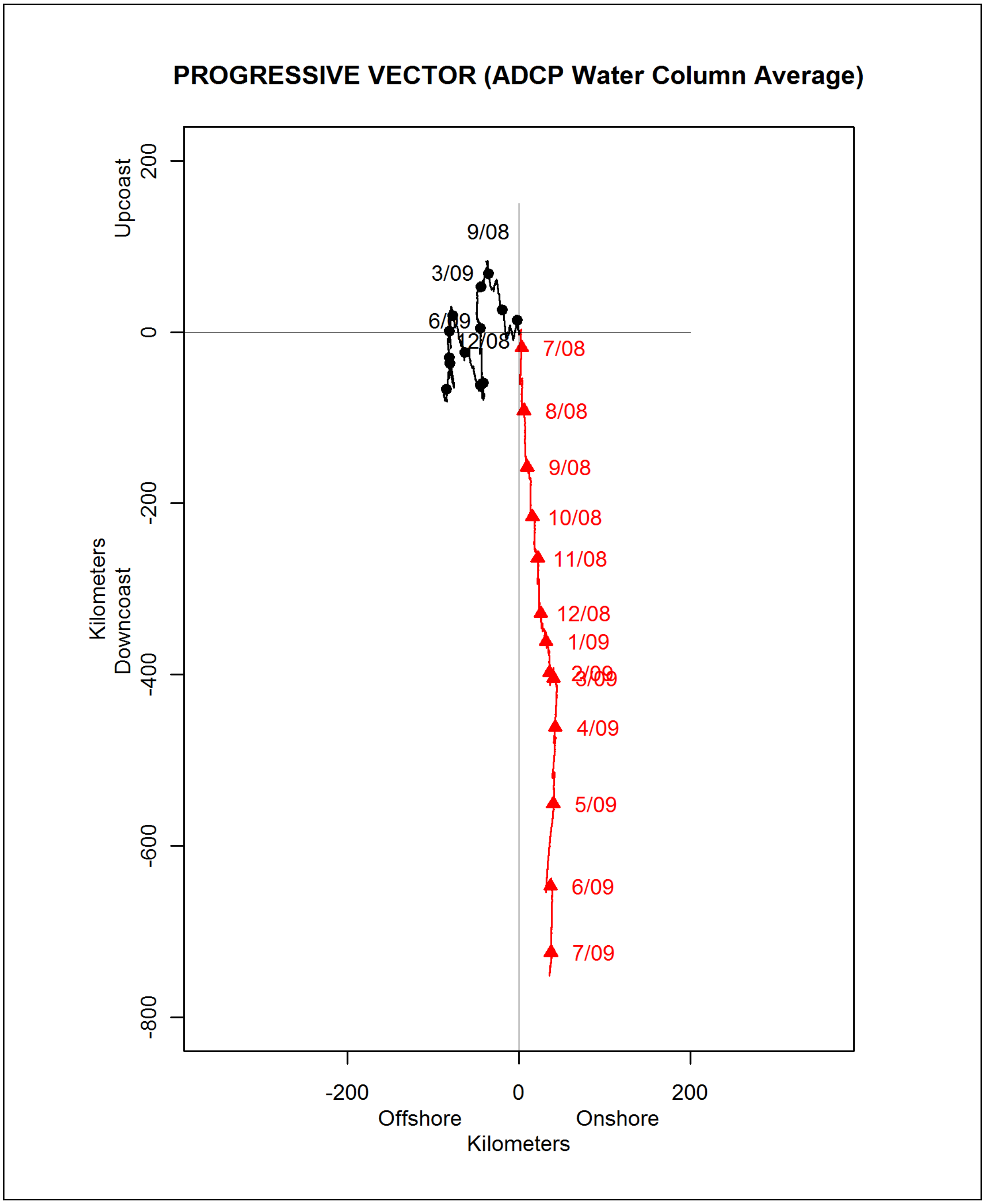


Figure 3-4. Coastwise current excursions measured from two locations near DCPP (current meter stations are located at the cross-hairs). Red triangles=South Station ADCP. Black circles=North Station ADCP. Progressive vectors are shown from late June 2008 to early July 2009.

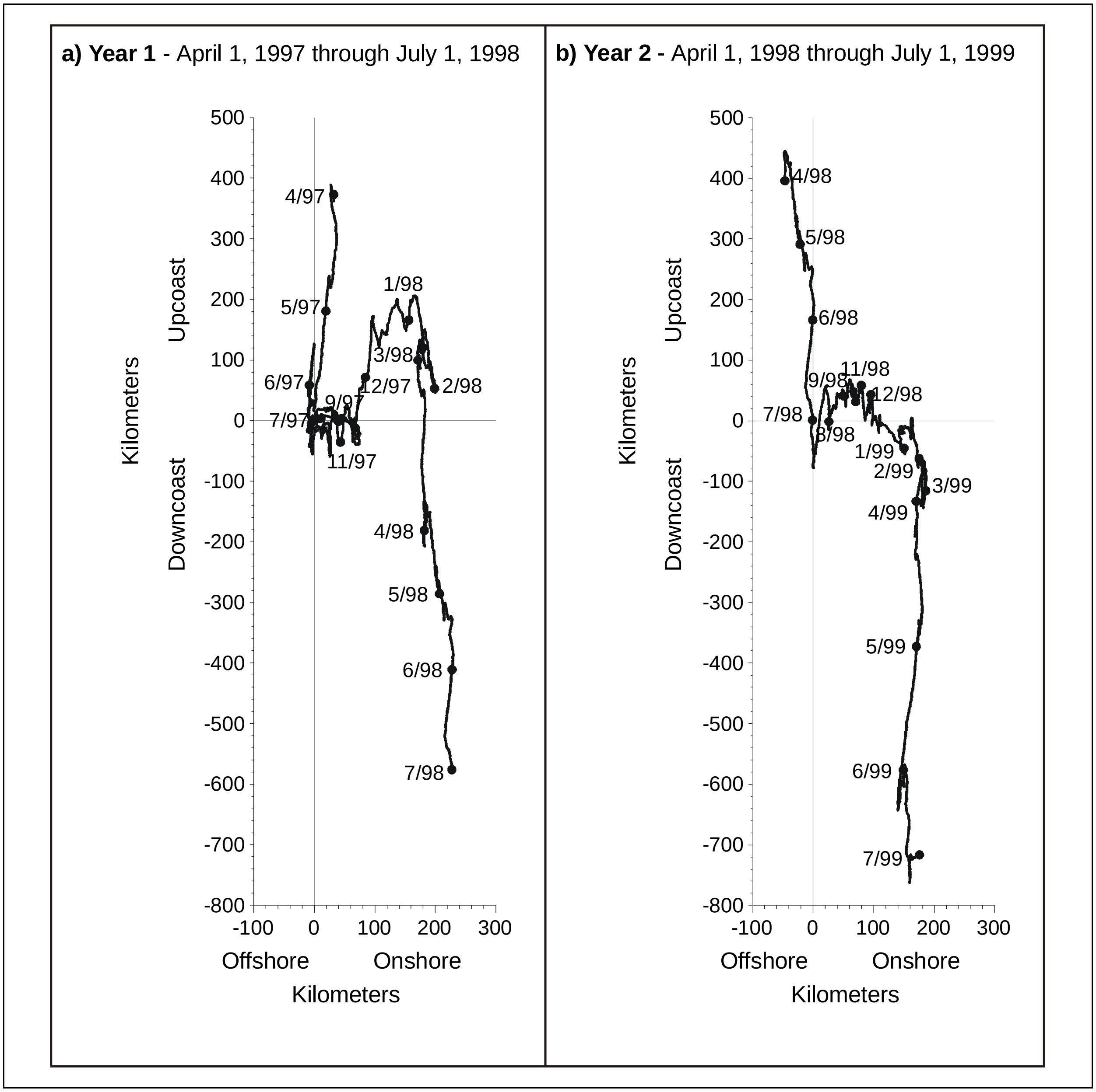


Figure 3-5. Cumulative upcoast/downcoast and onshore/offshore movement of water at the Diablo Canyon S4 current meter station (current meter station is located at the cross-hairs) from Tenera (2000). The cumulative vectors do not start at the origin (zero point) because data are included prior to the two periods used in the intake assessment (July 1997–June 1998 and July 1998–June 1999.

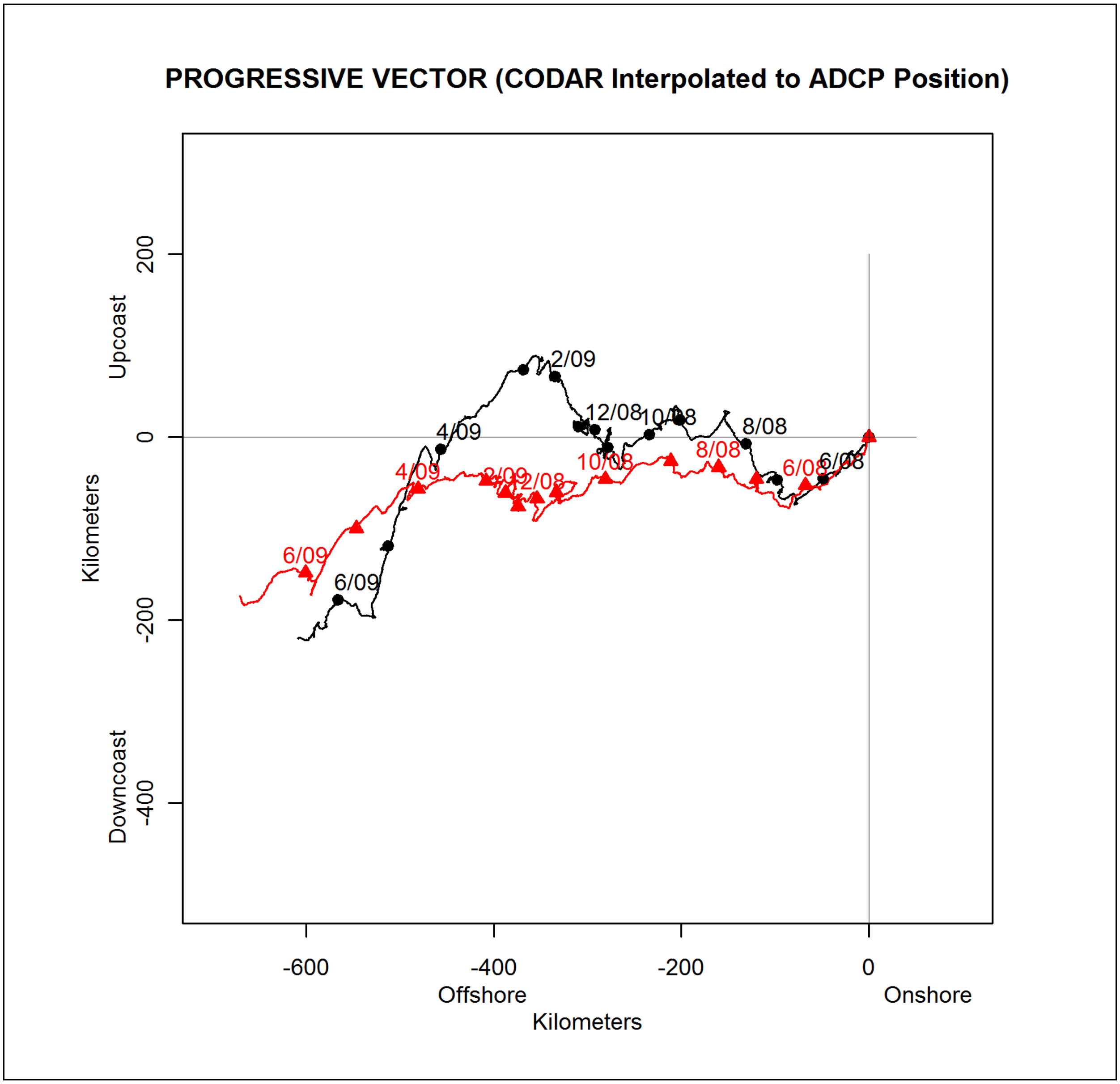


Figure 3-6. Coastwise surface current excursions interpolated to two locations near DCPP (current meter stations are located at the cross-hairs at position 0,0) from CODAR data. Red triangles= South Station ADCP. Black circles= North Station ADCP. Progressive vectors are shown from May 2008 through June 2009.

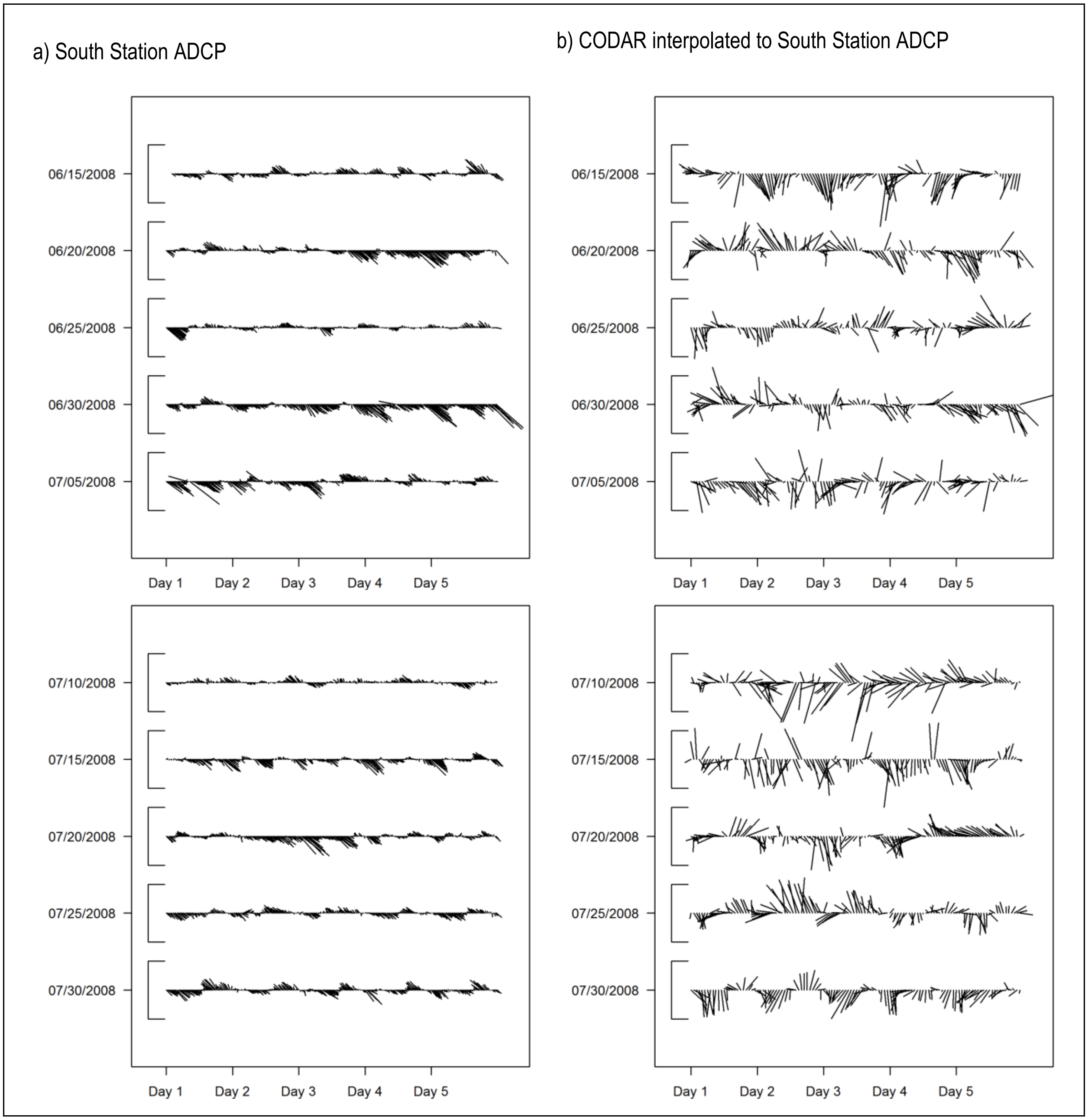


Figure 3-7. Comparison of South Station ADCP average water column velocities with CODAR surface estmates interpolated to the position of the ADCP. In each panel, north is up and east is to the right. Brackets at the beginning of each 5-day period have height ±25 cm/s. Dates are aligned with GMT times.

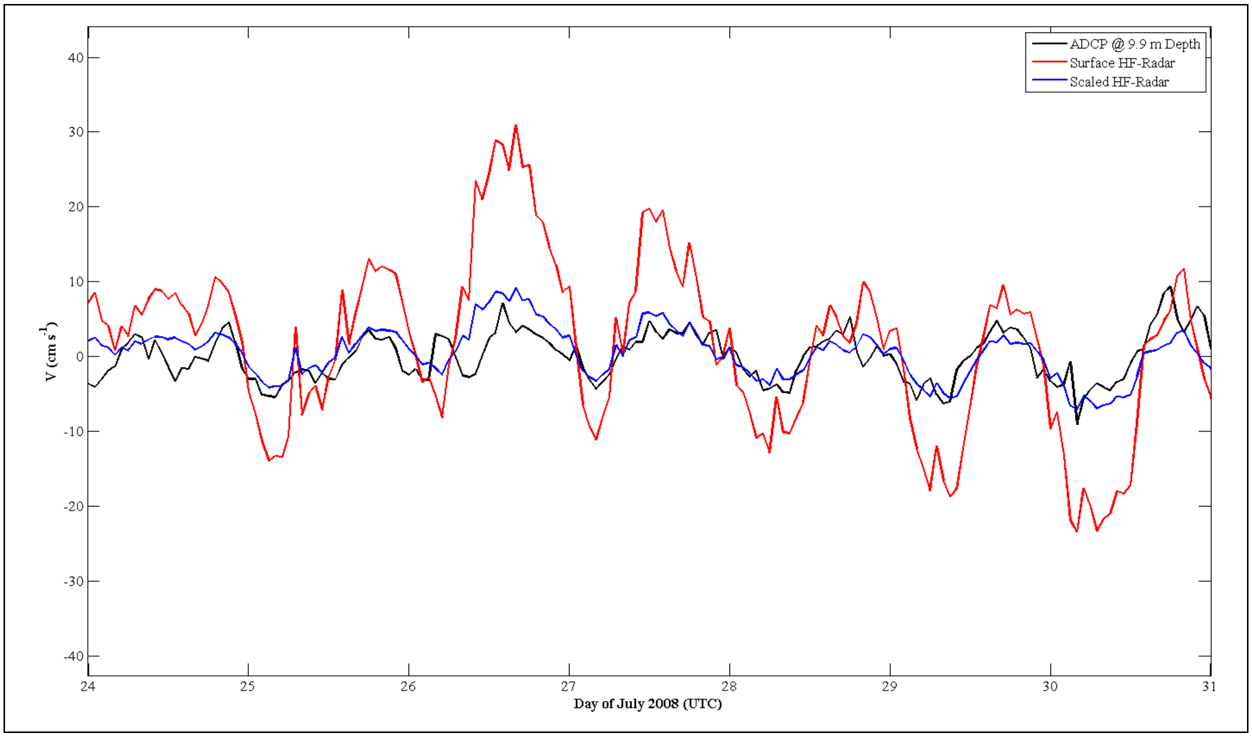


Figure 3-8. V component of velocity at the south ADCP for the last week of July 2008 as measured at the mid-point of the water column by the South Station ADCP (black line), HF-radar at the surface (red line), and with the surface HF-radar scaled to depth as per **Table 3-4** (blue line).

3.5 Biological Resources Overview

The pelagic habitat of the nearshore central California Coast includes the entire water column within which live a myriad of planktonic organisms (i.e., phytoplankton, zooplankton, and ichthyoplankton) that have little or no swimming ability to resist ocean currents, and nektonic organisms, such as fishes and sharks that are freely mobile in local and oceanic currents. The pelagic habitat also supports large numbers of pinnipeds (including Pacific harbor seal [*Phoca vitulina richardsi*] and California sea lion [*Zalophus californianus*]), cetaceans (such as gray whale [*Eschrichtius robustus*], bottlenose dolphin [*Tursiops truncatus*], and common dolphin [*Delphinus delphis*]), and birds, including California brown pelican (*Pelecanus occidentalis californicus*), terns, and gulls.

Rocky nearshore intertidal and subtidal areas are characterized by diverse assemblages of algae, invertebrates, and fishes (Allen et al. 2006; Carlton 2007; Foster and Schiel 1985). Over 300 species of algae, 700 species of invertebrates, and 120 species of fishes have been identified in the DCPP Receiving Water Monitoring Program that began in 1976 and was still ongoing in 2009 when this study was completed. The algae are of particular ecological importance as food and shelter for associated animals. The diversity of plants and animals is high, and natural variation in their abundance and distributions within the different nearshore zones results from variations in physical factors (temperature, elevation, wave exposure, open space, substrate type) and biological factors (grazing, predation, space competition, and recruitment episodes) (Dayton 1971; Connell 1972; Lubchenco and Menge 1978; Seapy and Littler 1978; Sousa 1979; Dayton and Tegner 1984; Dayton et al. 1984; Foster and Schiel 1985; McGuinness 1987; Menge et al. 1994).

The natural ecological setting and species composition in the nearshore area of DCPP area have been previously described by Sparling (1977), Gotshall et al. (1984), PG&E (1988a), and North et al. (1989). It is similar to other central California rocky nearshore habitats north of Point Conception (located 138 km (86 mi) south of DCPP), as described by McLean (1962). Murray and Littler (1981), and Foster and Schiel (1985). Point Conception is a biogeographic boundary between warm-temperate organisms to the south and cool-temperate organisms to the north (Murray and Littler 1981; Haury et al. 1986; Hobson 1994). The entire area from approximately Monterey Bay south to San Diego is recognized as a biogeographic transition zone between the Oregonian Province north of Point Conception and the Californian Province that extends south to Magdalena Bay in southern Baja California (Morris et al. 1980). Although the area around DCPP is dominated by cool-temperate organisms, the area also has some organisms with primarily warm-temperate distributions (Abbott and North 1971). Abundances of many organisms in central California nearshore communities fluctuate during the year (e.g., Foster et al. 1988; Horn et al. 1983; PG&E 1994), particularly in response to winter storm waves, whereas fewer seasonal storm-related changes are seen south of Point Conception (Devinny 1975). Threatened or endangered marine species that occur along the Diablo Canyon coastline include the southern sea otter (*Enhydra lutris nereis*), black abalone (*Haliotis cracherodii*), and humpback whale (*Megaptera novaeangliae*).

The area offshore from DCPP includes areas with essential fish habitat (EFH), a regulatory designation defined by the Magnusson-Stevenson Act as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” The coastal pelagic EFH includes habitats for five species: Pacific sardine, Pacific mackerel, northern anchovy, jack mackerel, and market squid. Technically, this habitat extends from the coast to the edge of the EEZ between the U.S. borders with Canada and Mexico. The Pacific Coast groundfish EFH includes habitats for 83 species of groundfish, including many species of rockfishes and flatfishes that produce planktonic larvae. EFH for Pacific Coast groundfish is defined as the aquatic habitat necessary to allow for groundfish production to support long-term sustainable fisheries for groundfish and for groundfish contributions to a healthy ecosystem. Habitat areas of particular concern (HAPCs) are described in the regulations as subsets of EFH that are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area. These include estuaries, canopy kelp, seagrass, and rocky reef habitats. Although designated HAPCs are not afforded additional protection under the Magnuson-Stevens Act, potential impacts on HAPCs are considered in consultation regarding federal projects that may affect designated HAPCs.

The coastline off of Diablo Canyon supports a wide variety of fishery species targeted by sport and commercial fishermen. At least 50 species of fishes and invertebrates are fished commercially, and recreational fisheries from commercial passenger fishing vessels (CPFV), private skiffs, piers and the shoreline catch many other species of finfish (PacFIN 2010, RecFIN 2010). Catches, seasons and size limits of individual species are regulated by the California Department of Fish and Wildlife within State waters. Targeted nearshore fisheries include several species of rockfishes, lingcod, cabezon, California halibut, greenlings, sheephead, surfperches, and salmon, among others.

The establishment of state marine reserves and state marine conservation areas along the central California coast in 2007 was the result of the Marine Life Protection Act which was enacted by the State legislature in 1999. Marine protected areas (MPAs) protect marine life and habitat, marine ecosystems, and allow the rebuilding of fishery stocks that have been depleted. The MPAs closest to Diablo Canyon are the Point Buchon State Marine Reserve (SMR) and the Point Buchon State Marine Conservation Area (SMCA). The Point Buchon SMR extends along approximately 5.6 linear km (3.5 miles) of shoreline from Lion Rock north to Point Buchon, and out to a distance of approximately 2.6 km (1.6 miles) and depths of 55 m (180 ft). The take of all living marine resources is prohibited with the SMR boundaries. The SMCA extends offshore beyond the SMR boundary to a distance of 5.6 km (3 nautical miles), and fishing is not allowed in this area except for the take of salmon and albacore.

4.0 Study Methods and Analysis Approach

4.1 Introduction

The entrainment study incorporates two design elements: 1) CWIS sampling, and 2) source water sampling. Sampling at the cooling water intake provided estimates of the total numbers of each larval species entrained through the CWIS on a twice per month basis depending on pumping capacity. The source water populations of fish and shellfish larvae were sampled to estimate proportional losses to those populations 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 twice a month, while source water sampling was conducted monthly.

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

- What are the species composition and abundance of the larval fishes, rock crab megalops, and market squid larvae entrained by DCPP?
- What are the local species composition and abundance of the entrainable larval fishes and target invertebrate larvae in nearshore waters off of DCPP?
- What are the potential impacts of entrainment losses on these populations due to operation of the DCPP 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 2008–2009.

4.2 Field Sampling Methods

The following sections describe the entrainment and source water sampling methods.

4.2.1 Entrainment Sampling

The entrainment sampling was conducted twice per month in front of the intake structure at two stations (**Figure 4-1**). The stations were sampled in random order every 6 hours (cycle) over a 24-hour period from a boat moored approximately 10 m (33 ft) from the intake structure (**Figure 4-2**) using a 0.71 m (2.33 ft) diameter bongo frame with two 1.8 m (5.2 ft) long, 335 µm (0.013 in.) white Nitex™ mesh nets similar to those used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). A calibrated flowmeter was suspended in the center of each net mouth. The frame with attached nets was lowered until it was approximately 25 cm (10 in) from the bottom. When the frame was retrieved and reached the surface, tension on the towline was reduced to allow the nets to be inverted and returned through the water column toward the bottom. The nets were inverted as close to the surface as possible without breaking the surface.

This procedure was repeated at least eight times or until each net on the frame had filtered a minimum of 40 m^3 (10,566 gal) of water.

The material from one of the nets on the bongo frame was preserved in 100% ethanol to allow potential DNA analysis to confirm the identity of some of the larval fishes. The material from the other net was preserved in a solution of 5% buffered formalin in seawater. Although the material from the two nets was kept separate during processing, the data from the two nets were combined to provide a total of eight samples per survey.

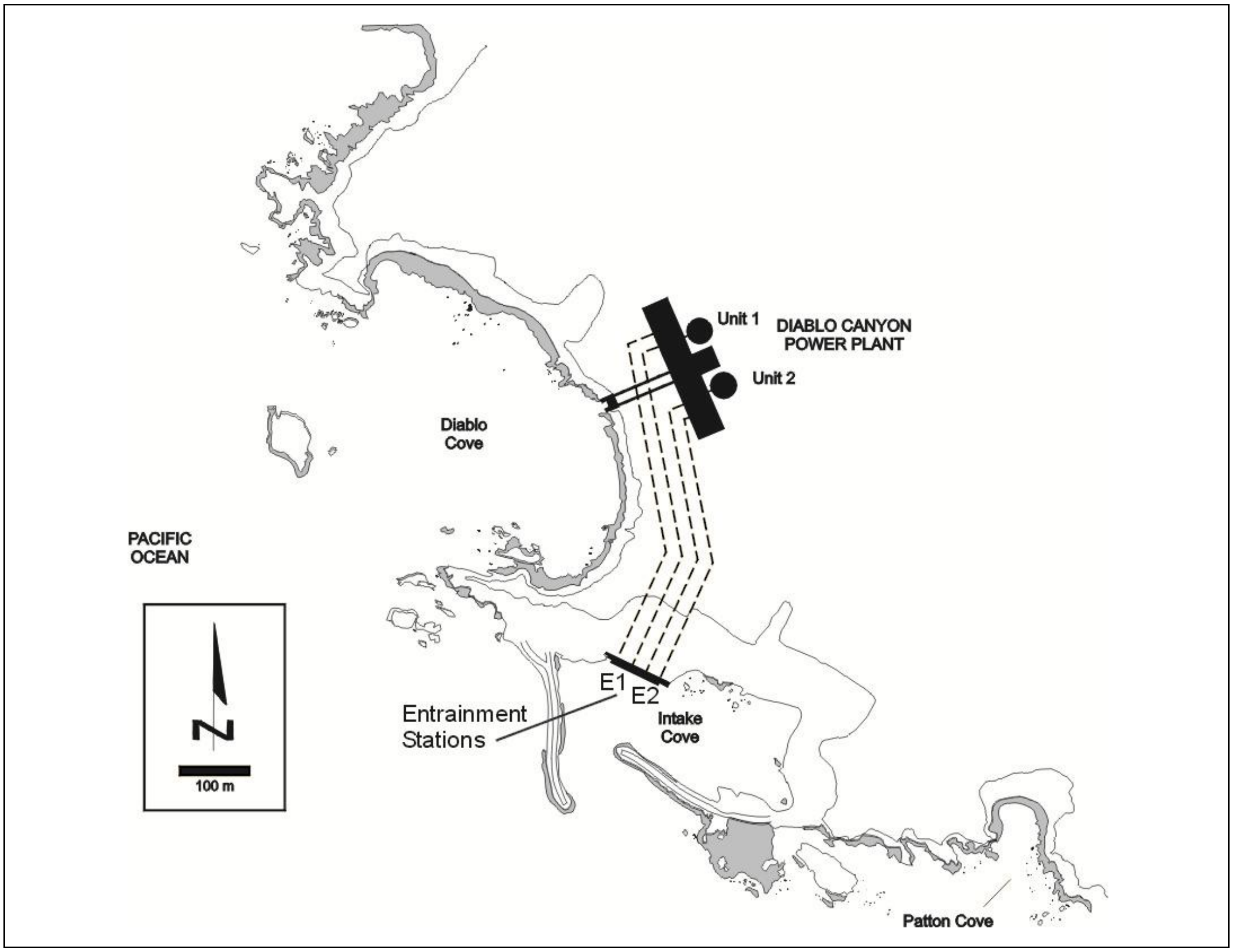


Figure 4-1. Location of entrainment stations (E1 & E2) in DCPP Intake Cove.

Figure 4-2. Sampling entrainment Station E1 in front of DCPP intake structure.

4.2.2 Source Water Sampling

The following sections characterize the source water sampling area and methods for sampling.

4.2.2.1 Source Water Definition

The source water area used for sampling was divided into six station areas designated S1–S6 (**Figure 4-3**). The width of the sampling area was approximately 1 km (0.6 miles) alongshore with the total offshore extent being approximately 2.9 km (1.8 miles). The average depth was approximately 61 m (200 ft) at the offshore boundary of Station S6.

The bathymetry used for calculating the volumes of the source water station areas was created in GIS (ESRI ArcGIS 10.2) using combined Digital Elevation Models (2 m [6.6 ft] resolution DEM's) from the Seafloor Mapping Lab at the California State University at Monterey Bay (CSUMB). The DEM was manually edited for the DCPP Intake Cove area for alignment with the cove's breakwaters and other features (and also used in previous tsunami impact modeling at DCPP). The resulting DEM was applied to the source water station areas using polygon shapefile analysis. All elevations were vertically corrected to mean lower low water (MLLW) in the NAD 83 datum for estimating the water volumes to the 0 MLLW level. For each source water area, volume was calculated as the sum of products of polygons' areas and depths (**Table 4-1**).
The calculated volumes of the source water station areas reflect the increasing depth with distance offshore and increased surface area of the two stations furthest offshore (S5 and S6)

(**Table 4-1**). The surface area of Station EA includes other shallow water areas outside of the Intake Cove and inshore of Station S1 (**Figure 4-3**).

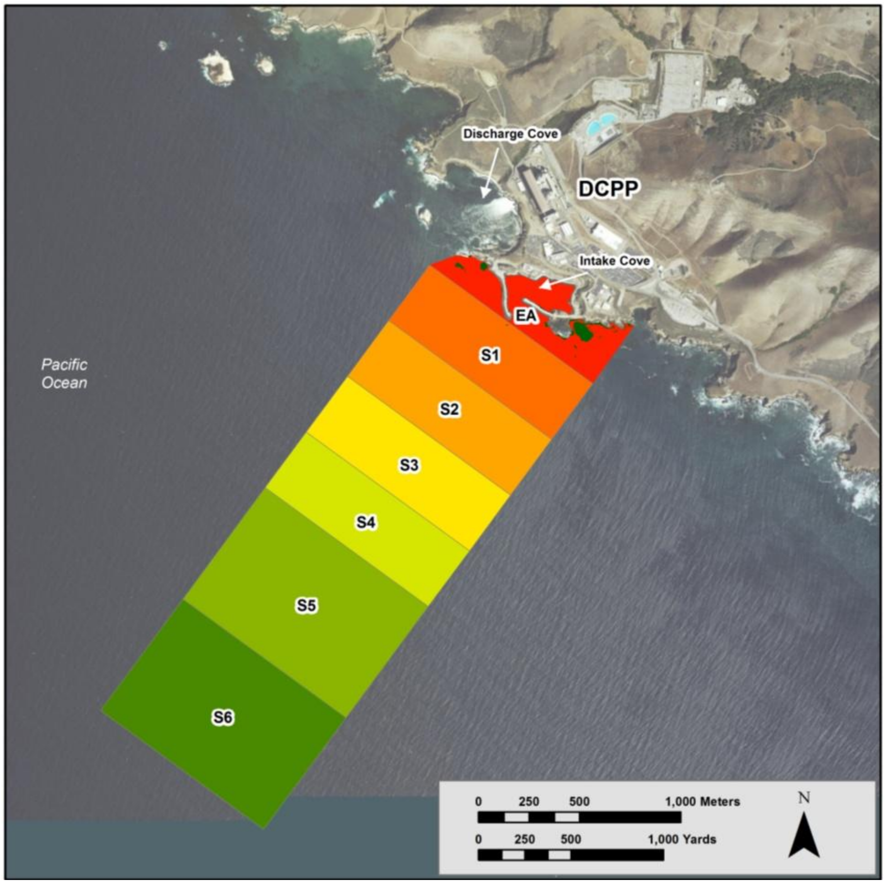


Figure 4-3. Location of source water plankton collection station areas offshore from DCPP.

Table 4-1. Physical descriptions of source water sampling areas.

Station	Area (m^2)	Maximum Depth (m)	Average Depth (m)	Volume (m^3)	Distance Offshore (m)
EA	184,592	24.7	9.9	1,888,031	0
S1	343,447	30.8	22.9	8,413,393	308
S2	343,841	36.7	31.6	10,911,393	650
S3	343,745	43.1	38.3	13,196,772	995
S4	343,447	48.5	44.2	15,175,065	1,339
S5	687,548	56.3	50.4	34,801,846	1,854
S6	686,925	64.3	56.5	38,667,851	2,541

4.2.2.2 Source Water Sampling Methods

The source water sampling was conducted once per month for an entire year along a transect running offshore from the Intake Cove (**Figure 4-3**). The transect extended approximately 3 km (1.9 mi) offshore (the same distance as the original 1996–1999 study grid) and was divided into six rectangular stations. This array of stations provided a gradient of distances offshore to compare larval abundance and species composition. It also allowed sampling closer to the entrance to the Intake Cove than in the previous study, an area that could not be safely sampled due to limited maneuverability of the larger boat that was used for the earlier sampling program.

Each 24-hr sampling period was divided into four 6-hr cycles with two samples (replicates) collected within each station during each of the four cycles. These two samples were collected at two randomly chosen locations within a station. Prior to each sampling cycle within each survey, the station that was sampled first was randomly pre-selected, with the other stations sampled sequentially beginning in the offshore direction. For example, if Station S3 was randomly chosen as the start location, the first samples were collected at Station S3, followed by Stations S4, S5, S6, E1, E2, S1 and S2. This ensured that the samples during each cycle did not have any potential bias from starting at the same location during each sampling event. The two actual sampling locations within each station area were also randomly chosen each survey.

Once the boat was on station, the nets and frame with center-mounted calibrated flowmeters were lowered through the water column until the frame was approximately 3 m (10 ft) from the bottom. The shallowest station depths were approximately 20 m (65 ft) and the deepest were approximately 55 m (180 ft). When the target depth was reached, the boat was motored forward and the cable was retrieved at a rate that maintained the same tow angle during the entire retrieval. When the frame reached the surface, it was secured to the side of the boat and the number of spins on the flowmeters was checked. If each net had not filtered at least 40 m^3 (10,566 gal) (based on a conversion chart equating the number of spins with filtered volume) the net was re-deployed to the bottom and retrieved until the target volume had been exceeded.

The samples from the two nets were preserved separately. The material from one of the nets in the first of the two replicates was preserved in 100% ethanol to allow for possible DNA analysis of the samples. The material from the other nets was preserved in a solution of 5% buffered formalin in seawater. During the first survey on July 31, 2008, one sample from each replicate was preserved in alcohol, but this procedure was amended in subsequent surveys to preserve a single sample per station in alcohol.

4.3 Laboratory Methods

The following sections describe how samples were processed.

4.3.1 Sorting and Identification

All collected entrainment samples were processed (16 per survey). Of the 96 source water samples that were collected during each survey, the number processed was dependent on the volume of water filtered for each sample. The filtered target volume for each net was 40 m^3 for a total combined sample volume of approximately 80 m^3. The volumes from the samples collected at the deepest source water stations typically exceeded this total target volume, and therefore only one of the two nets per replicate was processed. All samples preserved in alcohol were processed, regardless of the total volume in order to have larvae available for DNA analysis. However, the material collected by the second net was only processed when the volume for the first net was less than 60 m^3. These criteria resulted in fewer source water samples being processed than were collected.

Samples were initially preserved in either 5% buffered formalin seawater solution or in 95% alcohol. The samples preserved in formalin were transferred to 70–80 percent ethanol after approximately 72 hours and prior to removing the target organisms. All the samples were examined under dissecting microscopes and all fish larvae, cancer crab megalops larvae, and squid paralarvae were separated from debris and non-target zooplankton and placed in labeled vials. These taxa were identified to the lowest possible taxonomic level.

Larvae of many species of *Sebastes* (rockfishes) can have identical pigmentation patterns, especially when they are very early in their development, making visual identification problematic. *Sebastes* larvae were separated into three groups: *Sebastes* V_, *Sebastes* V, and *Sebastes* spp., based mainly on the length of the pigmentation pattern between the anus and the tail. A subsample of the larvae assigned to the rockfish pigment groups was sent to the National Marine Fisheries Laboratory (NMFS) laboratory in La Jolla, California for identification to the species level using DNA analysis. The identity of the larvae was established by comparing the sequencing results to DNA reference sequences for positively identified adult rockfishes.

4.3.2 Larval Length Measurements

The lengths (standard [notochord] length) of up to 50 fish larvae from each taxon collected from the entrainment stations during each survey were measured. The larvae were measured to the nearest 0.004 inch (0.1 mm) using a digital camera mounted on a microscope, and digital imaging analysis software. The system was recalibrated whenever it was necessary to adjust the microscope magnification to accommodate larvae of different sizes.

4.3.3 *Sebastes* spp. DNA Analysis

Larval *Sebastes* representing the two main pigment groups (plus *Sebastes* spp.) were identified to the species level by the NOAA/NMFS laboratory in La Jolla, California using DNA analysis. Between 450 and 500 larvae of each of the two groups, in addition to a smaller fraction of *Sebastes* spp., were randomly selected for analysis from the samples. For each pigment group, the number of larvae selected for detailed identification was determined by the overall percentage of larvae in that sample in relation to the total number in the group. Samples with more *Sebastes* larvae had a greater proportion analyzed. Larvae were analyzed from samples collected at the entrainment stations and from all six of the source water stations.

The DNA was extracted from each larva by placing either a portion of, or the entire larval specimen, into a lysis solution containing a chelating agent, which was then boiled. The extracted DNA was then subjected to Polymerase Chain Reaction (PCR) amplification of the mitochondrial cytochrome b gene. This gene was used because the sequence data for it has already been determined for every eastern Pacific species of *Sebastes*. The PCR products were purified by an enzymatic process and then subjected to a PCR-like protocol that labels the DNA for sequencing. The sequences were run on a laboratory sequencer instrument and the results edited and checked for quality. Once the sequences were completed, a phylogenetic analysis was preformed that clustered the unknown larva's sequence with the set of reference sequences, thereby determining the species identification of each larva. It should be noted that separation of two closely related nearshore rockfish (*S. carnatus* [gopher rockfish] and *S. chrysomelas* [black-and-yellow rockfish]) cannot be reliably done using this technique and when found they were left as a combined category of both species.

For each of the three *Sebastes* groups, the proportions of *Sebastes* species at a station (as determined by DNA analysis), were multiplied by the average concentrations of each group at that station. For example, if 85% of the *Sebastes* V larvae at station EA were determined to be *S. mystinus*, and the average concentration of *Sebastes* V at station EA was 100 per 1,000 m^3, then the average concentration of *S. mystinus* was calculated to be 85 per 1,000 m^3. Samples were pooled across all surveys to determine the species' proportions at a station because there was not a sufficient number of samples analyzed to accurately calculate proportions by survey. Only surveys from January through June (the main reproductive period) in which both the entrainment and source water stations were sampled together were used. Once the average concentration of a species by station was determined for each of the three groups, the individual species concentrations were summed across groups to get an estimate of the total concentration by species for each station. This resulted in a general description of the onshore-offshore distribution of each larval rockfish species during the 2009 recruitment period.

4.4 Quality Assurance/Quality Control

A quality assurance/quality control (QA/QC) program was implemented for the field and laboratory components of the study. The field survey procedures were reviewed with all personnel prior to the start of the study and all personnel were given copies of the procedures prior to their participation in either field collections or laboratory processing. Safety procedures were reviewed with the field sampling crews on a regular basis.

A more detailed QA/QC program was applied to all laboratory processing. The first 10 samples sorted by an individual were re-sorted by a designated QC sorter. A sorter was allowed to miss one target organism if the total number of target organisms in the sample was less than 10 (90% accuracy). After a sorter completed 10 consecutive samples with greater than 90% accuracy, the sorter had one of their next 10 samples randomly selected for a QC check. If the sorter failed to achieve an accuracy level of 90% then their next 10 samples were re-sorted by the QC sorter until they met the required level of accuracy. If the sorter maintained the required level of accuracy, then one sample check per 10 sorted by that sorter was randomly checked for accuracy.

A similar program was conducted for the taxonomists identifying the samples. The first 10 samples of fish or invertebrates identified by an individual taxonomist were completely re-identified by a designated QC taxonomist. A total of at least 50 individual fish or invertebrate larvae from at least five taxa must have been present in these first 10 samples; if not, additional samples were re-identified until this criterion was met. Taxonomists were required to maintain a 95% identification accuracy level in these first 10 samples. After the taxonomist identified 10 consecutive samples with greater than 95% accuracy, they had one of their next 10 samples checked by a QC taxonomist. If the taxonomist maintained an accuracy level of 95% then they continued to have one of each 10 samples checked by a QC taxonomist. If one of the checked samples fell below the minimum accuracy level then 10 more consecutive samples were identified by the QC taxonomist until 10 consecutive samples met the 95% criterion. Identifications were cross-checked against taxonomic voucher collections maintained by Tenera, and specialists were consulted for problem specimens.

4.5 Data Analysis

The following sections describe how the collected data were processed and analyzed.

4.5.1 Entrainment Estimates

Entrainment estimates were calculated using larval concentrations from field samples and the measured flow per day for the cooling water intake system. The precursor to assessing entrainment effects using demographic modeling approaches is an estimate of total annual larval entrainment (E_T). Estimates of larval entrainment were based on twice monthly sampling where E_T is the estimate of total entrainment for the study period and E_i is the entrainment estimate for each twice monthly survey period *i*.

$$E_T = \sum_i E_i$$

Estimates of entrainment for the study period (E_i) were based on a two-stage sampling design, with days within survey periods and cycles (four six-hour collection periods per day) within days. The within-day sampling was based on a stratified random sampling design with four temporal cycles and two replicates per cycle. The stratified variance calculated for the day was extrapolated across the days within each survey period and summed to compute the variance for the entire year-long study period.

4.5.2 Estimates from Source Water Stations

Estimates of the population of larvae at the source water stations were calculated using larval concentrations from field samples collected at the six source water stations (S1–S6) and the entrainment stations (EA) (**Figure 4-3**). Estimates of the average number of larvae in each of the source water areas during the day that sampling occurred were calculated from the monthly sampling based on a stratified random sampling design with four temporal cycles and two replicates per cycle. The estimates of the daily concentration for the stations were multiplied by the volume of each station area to calculate the source water population for the day. The estimates from the source water stations, including the extrapolated numbers from Station EA, were combined to provide an estimate of the source water population in the sampling area that was then extrapolated to estimate the entire source population at risk to entrainment Section 4.5.3.3).

4.5.3 Entrainment Impact Assessment

Entrainment effects were evaluated using two modeling approaches. The first used a demographic modeling approach that has been used extensively in evaluating the effects of losses due to power plant cooling water intake systems (Steinbeck et al. 2007). The demographic modeling approach used in this report, Fecundity Hindcasting (*FH*) and other related techniques use life history information to convert entrainment and impingement losses to their hypothetical adult equivalency. Horst (1975) provided an early example of this class of equivalent adult models. Goodyear (1978) extended the method to include the extrapolation of impinged juvenile losses to equivalent adults.

The primary method used in assessing the effects of the power plant cooling water intake system was a modeling approach that uses data on target taxa abundances from sampling of the entrained larvae and potential source populations of larvae to calculate estimates of proportional entrainment (*PE*) which is an estimate of the daily conditional mortality due to entrainment. The *PE* estimates and other information on the source population of larvae are used to estimate the total probability of mortality (P_M) due to entrainment using the *ETM* (Boreman et al. 1978, Boreman et al. 1981).

The assessment of entrainment effects was limited to the most abundant fish and invertebrate taxa (target taxa). An evaluation was also made of the quality of the estimates of entrainment and source water abundances based on the results of the sampling. Although the sampling results were presented for the most abundant groups of fishes, only taxa with results that would provide reasonable entrainment and source water estimates for the *ETM* were analyzed. There were several criteria used in screening the taxa to include in the intake assessment. The first criteria was based on the taxonomy of the taxa group. Larvae for several taxa groups can only be identified to the family level when the larvae are very small and likely recently hatched. Although this is may not be a problem when the family group is relatively distinct, several taxa could only be identified into taxa groups that likely included several families. The potential variation in the habitats for a large taxonomic group complicate the interpretation of the results, especially with the demographic and *ETM*/*HPF* assessments in this study.

Another important criteria in selecting taxa groups for analysis using the *ETM* is a review of the sampling results and estimates from the source water and entrainment sampling. The *PE* estimates that form the basis for the *ETM* calculations require unbiased, representative estimates of the source water and entrainment concentrations of larvae. The estimates from each survey provide the replicate estimates of *PE* used in the *ETM*. Therefore, there would be a high degree of uncertainty associated with *ETM* estimates for taxa that were only collected from a few surveys. An exception to using this criterion would be for species of concern such as listed species, or species representative of a unique habitat in the source water. In this study, only taxa with *PE* estimates for more than four surveys were analyzed.

Directly related to the above criterion that the data from the study provide unbiased, representative estimates of the source water and entrainment concentrations of larvae, is the confidence in the source water estimates for several of the taxa. Unlike the previous 1996–1999 Study which sampled a total of 64 source water stations over a wide range of habitats, the source water sampling for this study only sampled six stations aligned along a transect directly offshore of the DCPP Intake Cove. In addition, the habitat just offshore of the intake where the source water samples were collected is a mix of mostly soft bottom with some hard substrate, which is unlike many of the other nearshore areas north and south of the plant which have large areas of hard substrate that extend out into deeper water. The sampling of these areas in the 1996–1999 Study provided a more representative sample of nearshore larval populations, which would be expected with the large number of stations. As a result, the data show that the larvae for a few taxa were not collected in high abundance at any of the stations except inside the Intake Cove. Even though the data from the entrainment station inside the Intake Cove is included in the estimate of the source water, the high abundances at that station result in a biased estimate of the source water abundances for those taxa. This could be due to the fact that the Intake Cove provides artificial habitat for fishes that are not in high abundances along the coast around the DCPP, or the Intake Cove is the only station sampled that is located in shallow water where taxa such as pricklebacks (Family Stichaeidae) may be in high abundance. In both cases, the result will be source water estimates that are biased because of the high abundances inside the Intake Cove.

Detailed reasoning for excluding a taxon from analysis are provided in the results sections and summarized in Section 6.0.

4.5.3.1 Larval Lengths

To represent the distribution of the lengths of the entrained larvae, a random sample of 200 measurements was drawn with replacement from the measured larvae for each taxon and proportionally allocated among the surveys based on the abundances of larvae in those surveys. The samples of 200 measurements for each taxon were output as boxplots using SAS Graph® (SAS Institute). An explanation of the legend accompanying the histograms is shown in **Figure 4-4**, and may be referred to for interpreting the length frequency dispersion statistics for selected taxa that are presented in Section 5.4–*Analysis of Individual Taxa*. The tick marks below the histogram represent the individual measurements. The statistics accompanying each figure represent the values computed for the measurements presented in the figure, not the statistics used in calculating the average age at entrainment and period of exposure.

The average age at entrainment was calculated by dividing the difference between a computed size at hatching and the average length of the larvae by a larval growth rate obtained directly or derived from information available from scientific reports and journal articles. The period of time that the larvae were exposed to entrainment was calculated by dividing the difference between the estimated 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:

Estimated Hatch Length = (Median Length + 1st Percentile Length)/2.

This calculated value was used because of the large variation in size among larvae smaller than the average length, and approximates the value of the 25th percentile used in other studies as the hatch length. This calculation assumes that the length frequency distribution was skewed towards smaller-sized larvae. The methods usually resulted in a value close to the hatch size reported in the literature. The length frequency distributions for several of the fishes did not follow this pattern and the length of the 10th percentile of the distribution was used as the hatch length for these taxa to eliminate outlier values. All of the estimated hatch lengths were compared with estimates in Moser (1996) and adjusted accordingly as discussed in the sections for each taxon.

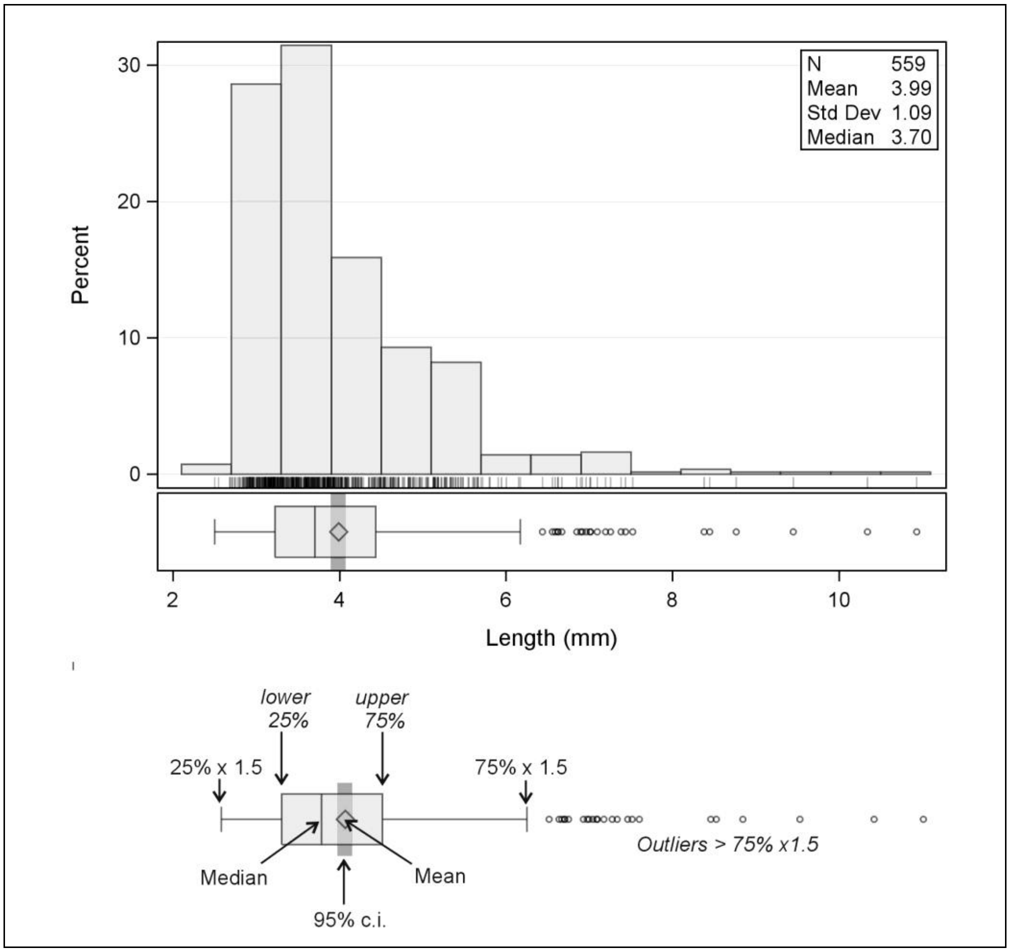


Figure 4-4. Explanation of dispersion statistics for length frequency histograms

The two modeling approaches each require an estimate of the age of the larvae being entrained. The *FH* model hindcasts 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. The number of larvae collected and measured from entrainment samples varied by species among surveys, so the statistics used in calculating the average age at entrainment and total larval duration were standardized by drawing

1,000 random samples of 100 measurements from the pool of measured larvae that were proportionally allocated among the surveys based on the abundances of larvae in those surveys. The samples were drawn with replacement because the number of larvae measured from each survey may have been less than the number needed to proportionally allocate the measurements among the surveys. The mean, median, and percentile values from each of the 100 samples were computed and the average of those values was used in calculating the average ages at entrainment and the period of time that the larvae were exposed to entrainment.

4.5.3.2 Demographic Models

Adult equivalent loss models evolved from impact assessments that compared power plant losses to commercial fisheries harvests and/or estimates of the abundance of adults. In the case of adult fishes impinged by intake screens, the comparison was relatively straightforward. To compare the numbers of impinged sub-adults and juveniles and entrained larval fishes to adults, it was necessary to convert all these losses to adult equivalents. Demographic approaches 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. There are two different but related demographic approaches to assess entrainment effects: adult equivalent loss (*AEL*), which expresses effects as absolute losses of numbers of adults, and *FH*, which estimates the number of adult females whose reproductive output has been removed by entrainment of larvae. Both approaches require an estimate of the age of the larvae at 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 to estimate the age at entrainment. The age at entrainment was calculated by dividing the difference between the size at hatching and the average size of the larvae from entrainment by the growth rate obtained from the literature.

Estimates of entrainment loss, in conjunction with life history data collected from the fisheries literature, were used in modeling entrainment effects using the *FH* model on target taxa with the necessary life history information (Steinbeck et al. 2007). The *FH* model is preferred over the more commonly used *AEL* model because it only requires larval survival data for the short period of time between when the larvae or eggs are released and the age at entrainment, usually less than 30 days. The *AEL* requires survival data for the period from entrainment through larval, juvenile, and adult stages. However, such detailed survival information is not available for most species in California, and the variation from year to year would be expected to be very large as oceanographic conditions and other physical and biological factors would be expected to cause large fluctuations in survival. It is also unnecessary to calculate both model estimates as *FH* and *AEL* should be related as $2FH \cong AEL$ for populations that have a 50:50 male:female ratio.

The *FH* requires egg and larval survivorship up to the age of entrainment plus estimates of fecundity. Species-specific survivorship information (e.g., age-specific mortality) for eggs and larvae is limited for many of the taxa considered in this assessment. These rates when available are 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 demographic modeling of entrainment effects. Since there were usually no estimates of variation available for the life history information, 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. As mentioned, the lack of demographic information for many species limited the use of this modeling approach. The modeling results provide estimates of adult fish losses, which ideally need to be compared to standing stock estimates of adult fishes. Details of the mathematical formulation of the model are presented in **Appendix C.**

4.5.3.3 *ETM* Model

As an alternative to the demographic models described above, the *ETM* was proposed by the United States Fish and Wildlife Service (USFWS) to estimate mortality rates resulting from circulating water withdrawals by power plants (Boreman et al. 1978, and subsequently in Boreman et al. 1981). The *ETM* provides an estimate of conditional mortality (an estimate of entrainment mortality in absence of other mortality, Ricker 1975) caused by DCPP entrainment on larval populations by using empirical data (plankton samples) rather than relying solely on hydrodynamic and demographic calculations. Consequently, the *ETM* requires an additional level of field sampling to characterize the abundance and composition of source water larval populations. The fractional loss to the source water population represented by entrainment is provided by estimates of *PE* for each survey that can then be expanded to predict regional effects on populations using *ETM*, as described below.

Variations of this model have been discussed in MacCall et al. (1983) and have been used to assess impacts in the previous DCPP study (Tenera 2000) and in several other studies at California power plants (MacCall et al. 1983, Parker and DeMartini 1989, Steinbeck et al. 2007). 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. It is important to note that presenting estimated mortality (P_M) from an *ETM* analysis and assessing the impact of entrainment on that basis does not include any consideration of controls on population levels such as density dependence. Density dependence is frequently encountered in the natural world, and can result in non-linear changes in both population and ecosystem level responses to change such as adverse impacts from entrainment of larvae. However, the complexity of natural systems makes forecasting population change with density dependent extremely difficult. Furthermore, presenting P_M allows for assessment of the effect of entrainment on the larval (and wider planktonic) population directly affected.

The estimate of the population-wide *PE* is the central feature of the *ETM* approach (Boreman et al. 1981, MacCall et al. 1983). Estimates of *PE* are calculated for each taxon as the ratio of the estimated numbers of larvae entrained per day to the larval population estimates within specific volumes of water as follows:

$$PE = \frac{N_{E_i}}{N_{S_i}} = \frac{\bar{\rho}_{E_i} V_{E_i}}{\bar{\rho}_{S_i} V_{S_i}}, \qquad (1)$$

where N_{E_i} and N_{S_i} are the estimated numbers of larvae in entrainment and sampled source water per day in survey period i, $\bar{\rho}_{E_i}$ and $\bar{\rho}_{S_i}$ are the average concentrations of larvae from entrainment and source water sampling, respectively, per day in survey period i, and V_{E_i} and V_{S_i} are the estimated volumes of the cooling water flow and sampled source water per day in each survey period i. While a reasonably accurate estimate of the volume of the cooling water intake flow can be obtained, estimating the extent of the source water is more difficult and will vary depending upon oceanographic conditions and the period of time that the taxon being analyzed is in the plankton and exposed to entrainment. Other studies and the previous study at DCPP calculated PE using Equation 1 and then adjusted the estimate of PE using the proportion of the sampled source water population to the total source population (P_S) (Steinbeck et al. 2007). In contrast to the previous study where PE estimates were first calculated on the sampled source water area, the large volume of the DCPP intake relative to the source water stations required that the estimates of PE were calculated directly from extrapolated source water populations.

The extrapolated source water areas used in the PE estimates were calculated using the data on surface currents from CODAR adjusted to mid-water column speeds using data from the South Station ADCP. The extrapolations were done for each survey period and were calculated over the period of time that the larvae were estimated to be exposed to entrainment. This period of time was estimated using length data from a representative number of larvae (100–200) from the entrainment samples for each taxon. The maximum age was calculated as the upper 95th percentile value of the lengths measured from the samples. The maximum age at entrainment was calculated by dividing the difference between the upper 95th percentile values of the lengths and the estimated hatch length by an estimated larval growth rate.

The CODAR data from the stations located along the central coast California (**Figure 3-3**) were used to extrapolate the source water populations along the coastline. As described in detail in **Appendix A**, a total of 30 back projections were calculated for each survey by randomly selecting an hour to start the back projection within the 72-hour period centered on the survey date. A period of 72 hours was used to provide a better estimate of the range of variation in currents during the survey period. The larval duration was used to determine the number of hour steps to include in the backprojections for each taxon. For example, the results of the 30 backprojections for one survey period are shown in **Figure 4-5**. The maximum extent upcoast and downcoast from DCPP for each of the 30 backprojections were indentified and used to calculate an average for each of the surveys. The depth distribution of the adults for the taxa analyzed was used in determining whether only the points from the back projections inside the 61 m (200 ft) depth contour were included in determining the alongshore extent of the source water extrapolations or whether the points out to the 91 m (300 ft) depth contour were included.

The extrapolated source water area for taxa that were generally distributed as adults inside the 61 m (200 ft) depth at the outer edge of Station S6 was calculated using only the alongshore extent of the CODAR backprojections. All of the fish taxa analyzed are generally distributed as adults in water shallower than 91 m (300 ft) which is approximately 4.8 km (3.0 mi) offshore directly offshore of DCPP. For species occurring at depths deeper than 61 m (200 ft) the concentrations at stations S1–S6 were converted to area densities and analyzed using linear regression. The extrapolation was not done when all of the backprojections were inside the outer edge of Station S6 (2.9 km [1.8 mi]), and when the slope of the regression was negative and the x-intercept occurred inside the outer edge of Station S6. Otherwise the extrapolation was done to the lesser of the 4.8 km (3.0 mi) offshore distance of the 91 m (300 ft) depth contour, or the distance indicated by the x-intercept. For these taxa, P_M based on both the alongshore extent of the backprojections and the alongshore+extrapolated offshore source water populations were calculated.

The source water was calculated as the ratio of the computed extent of the source water extrapolation to the alongshore distance of the sampled source water stations (1.0 km [0.6 mi]) and was used as a scalar to adjust the estimate of N_{S_i} in the calculation of the PE_i for each survey. Using the extrapolated estimate of the source water population in the calculation of PE, the proportional mortality (P_M) for each taxon was calculated as follows:

$$P_M = 1 - \sum_{i=1}^{12} f_i (1 - PE_i)^d , \qquad (2)$$

where f_i = the fraction of the source water population from the year present during survey i, and d = period of exposure in days that the larvae are exposed to entrainment mortality represented by the PE_i.

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;
- The conditional probability of entrainment, PE_i, is constant within each of the size classes of larvae present during each survey period;
- The concentrations of larvae in the sampled source water are representative of the concentrations in the extrapolated source water; and
- Lengths and applied growth rates of larvae accurately estimate larval duration.

A detailed mathematical formulation of the model is presented in **Appendix C.**

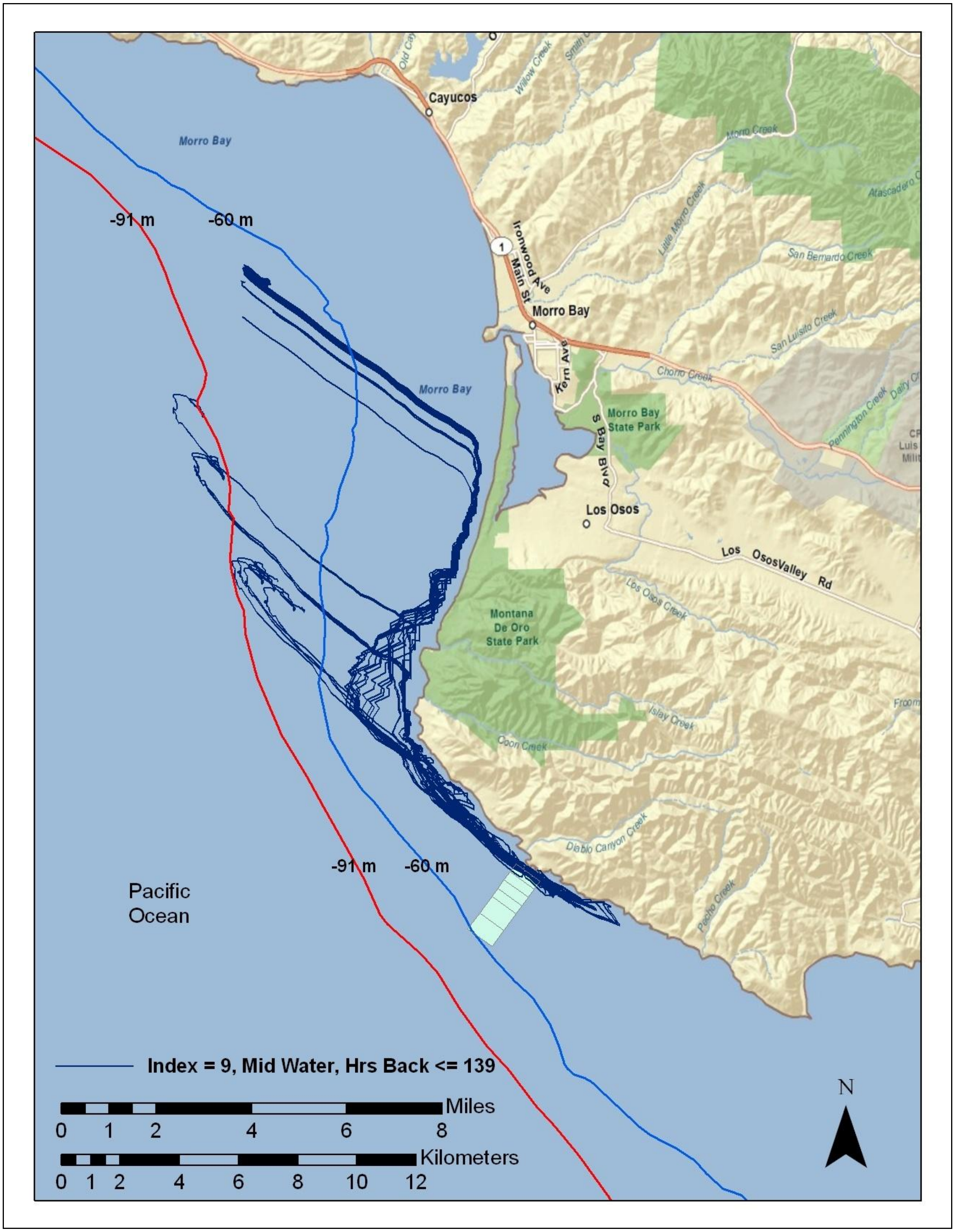


Figure 4-5. Example of 30 CODAR backprojections for one survey period.

4.5.3.4 *HPF* Estimates

The *HPF* approach adopted by the California State Water Quality Control Board in the "Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling" (OTC Policy) in May 2010 is being used by state agencies to determine appropriate mitigation for the effects of entrainment by power plant and ocean desalination plant intakes. The *HPF* is an estimate of the area of habitat required to fully compensate for the entrainment losses to an organism and is calculated using the *ETM* estimate P_M and an estimate of the area that corresponded to the habitat of the adult fishes. These taxa-specific areas were estimated as follows:

- A set of two backprojected positions, the averages of 30 backprojections' alongshore maximum and minimum positions, were calculated for each survey.
- The average positions were used to form radii of arcs with centers at Government Point near Point Conception (upcoast radius; 120.451667 W, 34.443429 N) and Cape San Martin (downcoast radius; 121.464874 W, 35.889290 N).
- Each arc, intersected with the coastline, at 1-m resolution, was used to form an upcoast or downcoast limit of the source water area for each survey (**Figure 4-6**).

Habitat areas for source water extrapolations

The area of hard substrate within the extrapolated source water areas was estimated to determine the potential adult spawning habitat for the fishes collected during this study that are primarily associated with nearshore subtidal rocky reef habitat. The extents of these areas were estimated using ADCP adjusted surface currents from CODAR data collected in 2008 and 2009 as described above (**Figure 4-6**).

The habitat within each source water area was estimated using GIS data on hard habitat obtained from the Seafloor Mapping Lab at CSUMB. The Seafloor Mapping Lab provided rough or smooth labeled points in a 2-m (6.6 ft) resolution grid. The identification of rough habitat was the best way to label rocky, hard substrate (P. Iampietro, Projects Manager and Chief Hydrographer at the Seafloor Mapping Lab at CSUMB, personal communication, 25 Sept 2015). Data on surface canopy kelp cover were also incorporated as a GIS layer to provide data on potential hard substrate for areas very close to shore that may not have been adequately surveyed by CSUMB. The data were obtained from California Department of Fish and Wildlife from aerial surveys in the following years: 1989, 1999, 2002-2006, and 2008-2009[3].

[3] http://www.dfg.ca.gov/biogeodata/bios/citing_bios.asp

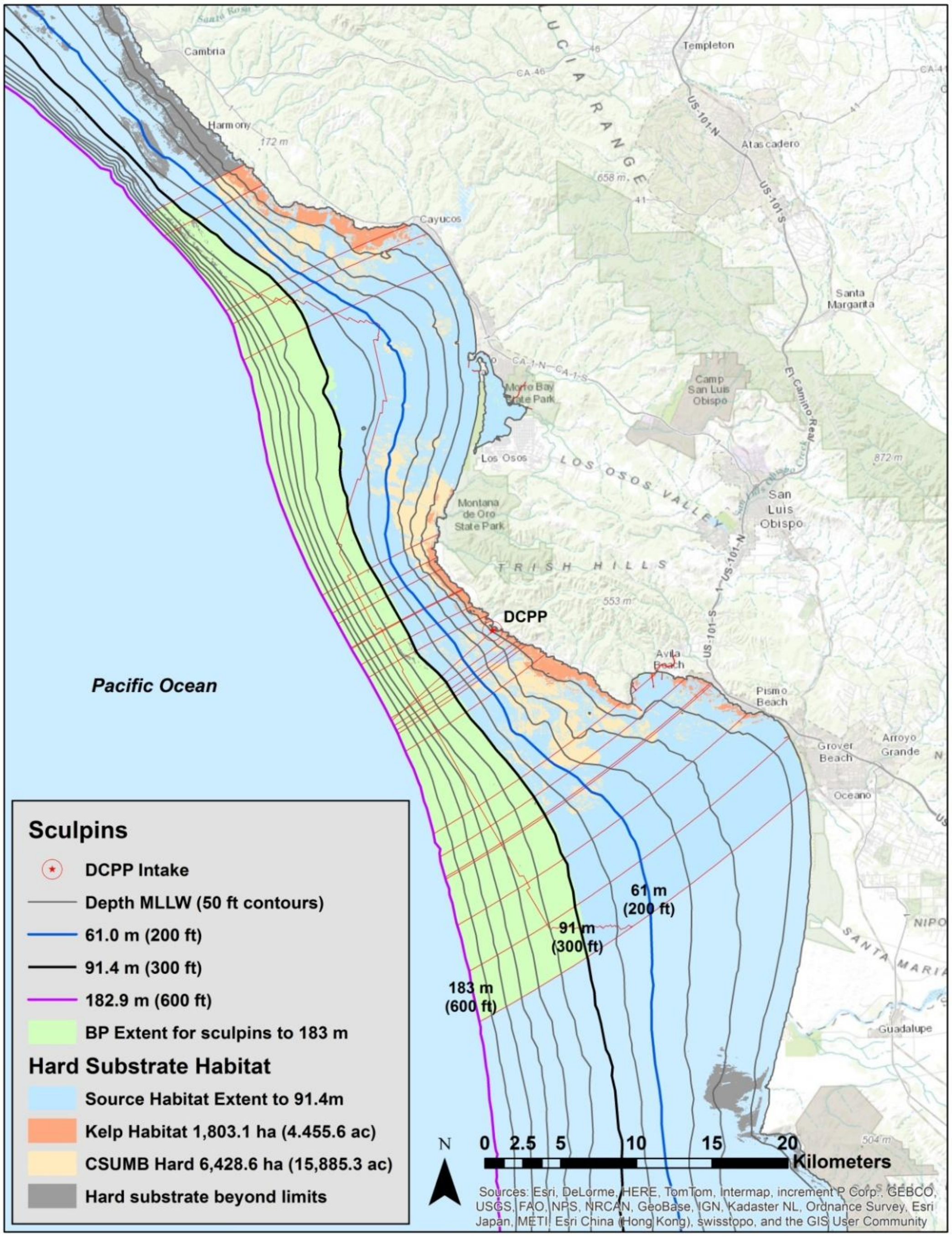


Figure 4-6. Extent of extrapolated source water areas for twelve surveys for a larval duration of 45 days for unidentified sculpins (Cottidae). The red lines represent the extent of the extrapolated source water areas along the coast for each survey. The habitat areas within each of the source water areas were used in calculating the estimates of *HPF*.

The habitat areas for each survey were estimated from the CODAR backprojections as described above (**Figure 4-6)**. The habitat areas included in the habitat estimates were limited by the depths of the adults for each taxa defined as the lesser of the 91 m (300 ft) isobath or the maximum depth occurrence values for fishes of the West Coast as presented in Love et al. (2005).

HPF Calculations

The estimates of *HPF* were calculated as habitat area multiplied by mortality (P_M). The calculation used the weighted average of habitat areas estimated for each survey (A_i) using the same proportions of the source water population using in the calculation of P_M, f_i. *HPF* was calculated as:

$$HPF = P_M \sum_{i=1}^{12} f_i A_i.$$

The variance of the weighted average *HPF* was estimated using the delta method approximation (Seber 1982) as follows:

$$var(HPF) = var(P_M)\left[\frac{\partial HPF}{\partial P_M}\right] + var(A)\left[\frac{\partial PP_M m}{\partial HPF}\right]$$

$$= var(P_M)[A^2] + var(A)\left[{P_M}^2\right]$$

The variance of the area was estimated as the variance of a sum as follows:

$$var(\bar{A}) = var(\textstyle\sum_{i=1}^{12} f_i A_i) = \sum_{i=1}^{12} {f_i}^2 \, CV^2 \, A_i,$$

where the coefficient of variation (CV) of the survey areas was estimated as the standard error divided by the average area. The standard error was estimated as the standard deviation of the areas over surveys divided by the square root of twelve, the number of surveys.

5.0 Sampling Results

Twenty-four surveys were conducted from July 2008 through June 2008 with a combined total of 1,484 samples collected (**Table 5-1**). All but one of the 384 entrainment samples were processed in the laboratory (sorting and identification), and 732 of the 1,100 source water samples were processed. Fewer samples were processed than collected due to the variation in sample volumes and the laboratory criteria used for selecting the samples for processing. Specifically, for source water surveys, one of the two bongo net samples was randomly chosen to be processed, so 96 samples were collected and a minimum of 48 were processed. Extra samples were processed when the average volume of water filtered by the nets was less than 60 m^3 (15,850 gal).

Some source water samples were not collected during Surveys 2 & 6 (July and September 2008) due to very high densities of gelatinous zooplankton that obstructed the nets and caused extensive delays in the field efforts. Rough sea conditions also prevented the safe collection of some samples during Survey 6. Surveys 20, 21, and 22 (April and May 2009) occurred during spring upwelling periods when plankton densities were very high. Some of these samples contained large volumes of porcellanid crab zoea, copepods, and other invertebrate specimens that necessitated splitting the samples in the lab using a Folsom plankton splitter. This allowed more manageable fractions of the original sample to be sorted and processed. The concentration of the larvae in the split samples was adjusted based on the volume sorted.

5.1 Entrainment Sampling

A total of 80 larval fish taxa (not including fragments but including unidentified larval fish) and 3 target invertebrate taxa were collected at entrainment Stations E1 & E2 from July 2008 through June 2009 (**Table 5-2**). The assemblage was diverse, with 18 taxa comprising the top 90% of specimens collected. The most abundant taxa were sculpins (Cottidae, *Artedius* spp., and *Orthonopias triacis*), rockfishes (species pigment groups *Sebastes* spp. V_ and V), monkeyface eel (*Cebidichthys violaceus*), kelp blennies (*Gibbonsia* spp.), blennies/zoarcoids (Blennioidei/Zoarcoidei; largely comprised of unidentified pricklebacks), and blackeye goby (*Rhinogobiops nicholsi*). Most of the commonly collected taxa were from species with adults that live in the shallow nearshore distributions, but larvae from some deepwater species (e.g., northern lampfish [*Stenobrachius leucopsarus*]) were also collected in smaller numbers.

Rockfish larvae collected during the study were separated into pigment groupings. Rockfish larvae with an elongated ventral pigment pattern (designated "V_") are composed mainly of the "KGB" complex of nearshore rockfishes that include kelp (*S. atrovirens*), gopher (*S. carnatus*), and black-and-yellow rockfishes (*S. chrysomelas*) among others. The short pigment series (designated "V") was comprised largely of blue rockfish (*S. mystinus*). DNA analysis on selected individuals of the two groups was used to identify the proportions of species within each of the groups. The results of this DNA analysis of the *Sebastes* larvae are discussed in the Section 5.4.2.

Table 5-1. Dates of entrainment and source water surveys in 2008 and 2009, and numbers of samples collected and processed.

		Entrainment Samples		Source Water Samples	
Survey	Start Date	Number Collected	Number Processed	Number Collected	Number Processed
DCPPEA001	7/17/08	16	16	–	–
DCPPEA002	7/31/08	16	16	52 [a]	52
DCPPEA003	8/18/08	16	16	–	–
DCPPEA004	9/4/08	16	16	96	67
DCPPEA005	9/15/08	16	16	–	–
DCPPEA006	9/29/08	16	15 [c]	88 [b,c]	69
DCPPEA007	10/20/08	16	16	–	–
DCPPEA008	11/7/08	16	16	96	74
DCPPEA009	11/17/08	16	16	–	–
DCPPEA010	12/9/08	16	16	96	65
DCPPEA011	12/18/08	16	16	–	–
DCPPEA012	1/12/09	16	16	96	61
DCPPEA013	1/22/09	16	16	–	–
DCPPEA014	1/29/09	16	16	96	69
DCPPEA015	2/12/09	16	16	–	–
DCPPEA016	2/26/09	16	16	96	66
DCPPEA017	3/12/09	16	16	–	–
DCPPEA018	3/27/09	16	16	96	65
DCPPEA019	4/13/09	16	16	–	–
DCPPEA020	4/22/09	16	16	96	48
DCPPEA021	5/18/09	16	16	–	–
DCPPEA022	5/28/09	16	16	96	48
DCPPEA023	6/15/09	16	16	–	–
DCPPEA024	6/30/09	16	16	96	48
	Totals:	384	383	1,100	732

a Only one replicate collected per station due to very dense plankton concentrations. [Exception: Two stations sampled in Cycle 1 had both replicates collected].

b Replicates not collected at three stations due to high jellyfish concentrations and rough seas

c One sample not processed due to incomplete preservation

Table 5-3 presents the estimated annual entrainment of each taxon. The total annual entrainment was estimated at 2.86 billion fish larvae and 1.82 billion crab megalops larvae. In general, the taxa with the highest average concentrations had the highest entrainment estimates, although the timing of some of the surveys during periods when the plant was not operating at full capacity changed the entrainment estimates for a few of the taxa that were in the highest concentrations in those samples (**Tables 5.2** and **5.3**).

The overall average concentration of larval fish was 850 per 1,000 m^3 (**Table 5-2**). The greatest concentrations of larvae during the study occurred in late April 2009 (ca. 5,800 larvae per 1,000 m^3) during spring upwelling conditions (**Figure 5-1**). Sculpins, pricklebacks and rockfishes comprised a high proportion of the fish larvae sampled in this survey (**Appendix D**). The lowest larval concentrations occurred in mid-November with a sampled abundance of approximately 20 larvae per 1,000 m^3. Kelp blennies and sculpins, including cabezon, were the most abundant taxa in that survey.

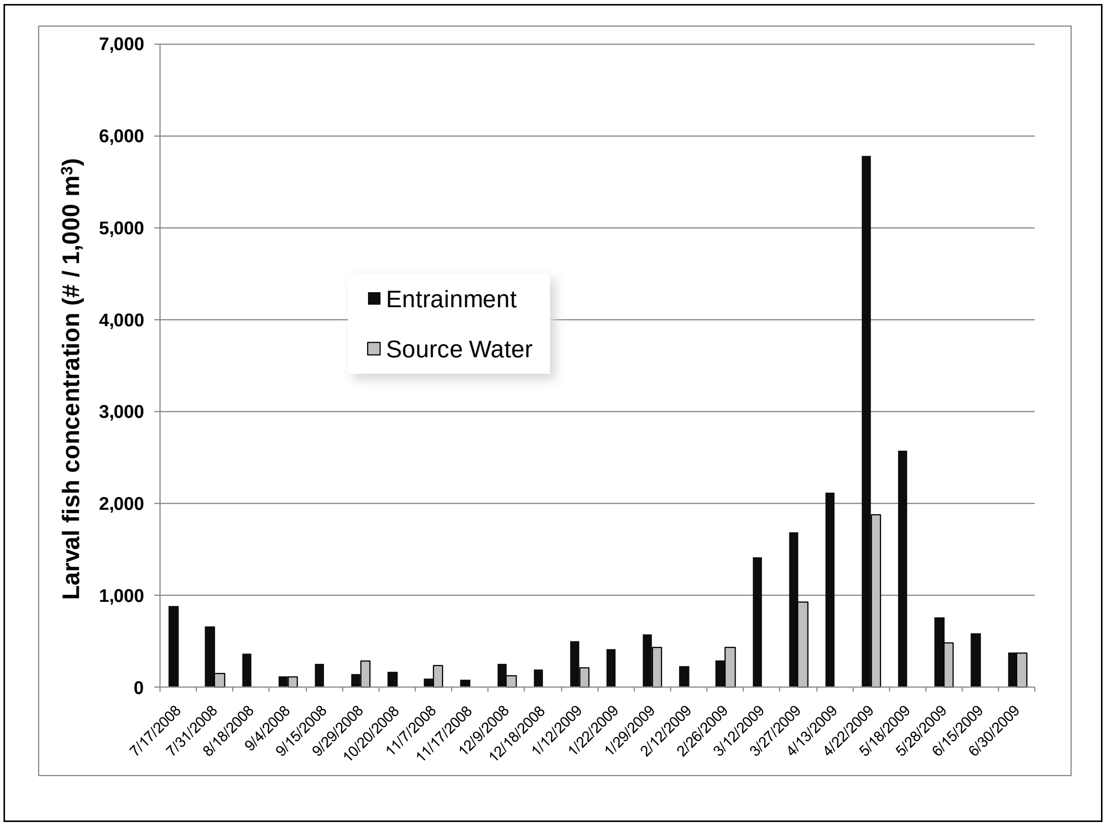


Figure 5-1. Total concentrations of larval fishes by survey for entrainment and source water samples. The source water stations were only sampled once per month.

Table 5-2. Average concentration of entrainable larval fishes and target shellfish larvae in entrainment samples collected at the DCPP intakes (Stations E1 & E2 combined), July 2008 – June 2009.

Rank	Taxon	Common Name	Total Count	Average Concentration (per 1,000 m³)	Percentage of Total	Cumulative Percentage
1	Cottidae	sculpins	2,202	108.64	12.78	12.78
2	*Sebastes* spp. V_	rockfishes	1,367	80.50	9.47	22.25
3	*Cebidichthys violaceus*	monkeyface prickleback	1,319	66.41	7.81	30.06
4	*Gibbonsia* spp.	kelp blennies	1,251	63.06	7.42	37.48
5	*Artedius* spp.	sculpins	1,186	57.70	6.79	44.26
6	Blennioidei/Zoarcoidei	blennies/zoarcoids	1,085	54.56	6.42	50.68
7	larval/post-larval fish	larval fishes	1,062	51.94	6.11	56.79
8	*Sebastes* spp. V	rockfishes	904	41.63	4.90	61.69
9	*Orthonopias triacis*	snubnose sculpin	882	44.04	5.18	66.87
10	*Rhinogobiops nicholsi*	blackeye goby	761	38.92	4.58	71.45
11	Stichaeidae	pricklebacks	744	36.23	4.26	75.71
12	CIQ goby complex	gobies	718	35.94	4.23	79.94
13	*Stenobrachius leucopsarus*	northern lampfish	435	21.09	2.48	82.42
14	*Genyonemus lineatus*	white croaker	398	19.53	2.30	84.72
15	*Oligocottus/Clinocottus* spp.	sculpins	329	15.67	1.84	86.56
16	*Platichthys stellatus*	starry flounder	315	15.16	1.78	88.34
17	*Bathymasteridae*	ronquils	257	12.40	1.46	89.80
18	*Liparis* spp.	snailfishes	251	12.65	1.49	91.29
19	*Oxylebius pictus*	painted greenling	195	9.48	1.12	92.40
20	*Scorpaenichthys marmoratus*	cabezon	161	7.83	0.92	93.32
21	Blennioidei	blennies	111	5.43	0.64	93.96
22	*Leptocottus armatus*	Pacific staghorn sculpin	93	4.49	0.53	94.49
23	*Sebastes* spp.	rockfishes	78	4.18	0.49	94.98
24	*Pleuronectoidei*	flatfishes	73	3.48	0.41	95.39
25	*Brosmophycis marginata*	red brotula	67	3.54	0.42	95.81
26	*Radulinus* spp.	sculpins	54	2.62	0.31	96.12
27	Gobiesocidae	clingfishes	48	2.37	0.28	96.40
28	*Lepidopsetta bilineata*	rock sole	43	2.18	0.26	96.65
29	*Ruscarius creaseri*	roughcheek sculpin	39	2.21	0.26	96.91
30	Osmeridae	smelts	39	1.93	0.23	97.14
31	*Citharichthys spp.*	sanddabs	37	1.90	0.22	97.36
32	*Gobiesox* spp.	clingfishes	36	1.78	0.21	97.57
33	*Pleuronectidae*	righteye flounders	35	1.63	0.19	97.76
34	*Lepidogobius lepidus*	bay goby	31	1.49	0.18	97.94
35	*Cyclopteridae*	snailfishes	31	1.41	0.17	98.10
36	Agonidae	poachers	30	1.46	0.17	98.28
37	*Parophrys vetulus*	English sole	28	1.39	0.16	98.44

(continued)

Table 5-2 (continued). Average concentration of entrainable larval fishes and target shellfish larvae in entrainment samples collected at the DCPP intakes (Stations E1 & E2 combined), July 2008 – June 2009.

Rank	Taxon	Common Name	Total Count	Average Concentration (per 1,000 m³)	Percentage of Total	Cumulative Percentage
38	*Aulorhynchus flavidus*	tubesnout	27	1.33	0.16	98.60
39	Chaenopsidae	tube blennies	22	1.00	0.12	98.71
40	Sciaenidae	croakers	16	0.86	0.10	98.82
41	Bathylagidae	blacksmelts	15	0.73	0.09	98.90
42	Pholidae	gunnels	14	0.68	0.08	98.98
43	Pholidae/Stichaeidae	gunnels/pricklebacks	14	0.66	0.08	99.06
44	Hexagrammidae	greenlings	12	0.71	0.08	99.14
45	Clinidae	kelp blennies	11	0.57	0.07	99.21
46	*Typhlogobius californiensis*	blind goby	11	0.59	0.07	99.28
47	*Synchirus gilli*	manacled sculpin	10	0.54	0.06	99.34
48	*Ammodytes hexapterus*	Pacific sand lance	10	0.50	0.06	99.40
49	*Tarletonbeania crenularis*	blue lanternfish	9	0.40	0.05	99.45
50	*Bathylagus* spp.	blacksmelts	8	0.33	0.04	99.49
51	*Merluccius productus*	Pacific hake	8	0.33	0.04	99.53
52	Myctophidae	lanternfishes	8	0.39	0.05	99.57
53	Ophidiidae	cusk-eels	7	0.38	0.04	99.62
54	*Chitonotus/Icelinus* spp.	sculpins	7	0.33	0.04	99.66
55	Zoarcoidei	zoarcoids	7	0.40	0.05	99.70
56	*Sardinops sagax*	Pacific sardine	7	0.32	0.04	99.74
57	*Hypsoblennius* spp.	combtooth blennies	6	0.29	0.03	99.77
58	*Pleuronichthys* spp.	turbots	6	0.31	0.04	99.81
59	*Nannobrachium* spp.	lanternfishes	4	0.19	0.02	99.83
60	Blenniidae	blennies	2	0.13	0.02	99.85
61	*Engraulis mordax*	northern anchovy	2	0.10	0.01	99.86
62	*Hexagrammos* spp.	greenlings	2	0.09	0.01	99.87
63	*Hexagrammos spp. /Ophiodon elongatus*	greenlings	2	0.09	0.01	99.88
64	*Lythrypnus* spp.	gobies	2	0.09	0.01	99.89
65	*Paralichthys californicus*	California halibut	2	0.09	0.01	99.90
66	*Zaniolepis* spp.	combfishes	1	0.12	0.01	99.92
67	*Acanthogobius flavimanus*	yellowfin goby	1	0.06	0.01	99.92
68	*Heterostichus rostratus*	giant kelpfish	1	0.06	0.01	99.93
69	Pomacentridae	damselfishes	1	0.06	0.01	99.94
70	*Triphoturus mexicanus*	Mexican lampfish	1	0.06	0.01	99.94
71	*Cataetyx rubrirostris*	rubynose brotula	1	0.05	0.01	99.95
72	Clupeiformes	herrings and anchovies	1	0.05	0.01	99.96
73	*Gonostomatidae*	bristlemouths	1	0.05	0.01	99.96

(continued)

Table 5-2 (continued). Average concentration of entrainable larval fishes and target shellfish larvae in entrainment samples collected at the DCPP intakes (Stations E1 & E2 combined), July 2008 – June 2009.

Rank	Taxon	Common Name	Total Count	Average Concentration (per 1,000 m³)	Percentage of Total	Cumulative Percentage
74	*Ophiodon elongatus*	lingcod	1	0.05	0.01	99.97
75	*Ruscarius meanyi*	Puget Sound sculpin	1	0.05	0.01	99.97
76	*Sebastolobus* spp.	thornyheads	1	0.05	0.01	99.98
77	*Syngnathus* spp.	pipefishes	1	0.05	0.01	99.99
78	*Atherinopsis californiensis*	jacksmelt	1	0.04	0.00	99.99
79	Clupeidae	herrings	1	0.04	0.00	100.00
80	*Hemilepidotus spinosus*	brown Irish lord	1	0.04	0.00	100.00
		Total larval fish	16,961	850.13	100.00	
1	Cancridae (megalops)	cancer crabs megalops	7,807	477.64	99.76	99.76
2	*Cancer productus/ Romaleon* spp. (megalops)	rock crab megalops	13	1.03	0.22	99.98
3	*Doryteuthis opalescens*	market squid	2	0.11	0.02	100.00
		Total target shellfish	7,822	478.78	100.00	

Table 5-3. Estimated annual entrainment of larval fishes and target shellfish larvae based on entrainment samples collected at the DCPP intakes and actual plant flows during the sampling period (Stations E1 & E2 combined), July 2008 – June 2009.

Rank	Taxon	Common Name	Estimated Annual Entrainment	Percentage of Total	Cumulative Percentage
1	Cottidae	sculpins	387,206,952	13.56	13.56
2	*Sebastes* spp. V_	rockfishes	279,117,506	9.77	23.33
3	*Cebidichthys violaceus*	monkeyface prickleback	236,852,269	8.29	31.62
4	*Gibbonsia* spp.	kelp blennies	213,716,434	7.48	39.10
5	*Artedius spp.*	sculpins	203,081,623	7.11	46.21
6	Blennioidei/Zoarcoidei	blennies/zoarcoids	200,901,994	7.03	53.25
7	larval/post-larval fish	larval fishes	184,556,914	6.46	59.71
8	*Orthonopias triacis*	snubnose sculpin	145,338,931	5.09	64.80
9	Stichaeidae	pricklebacks	127,060,764	4.45	69.25
10	CIQ goby complex	gobies	122,893,258	4.30	73.55
11	*Rhinogobiops nicholsi*	blackeye goby	121,557,282	4.26	77.80
12	*Sebastes* spp. V	rockfishes	104,394,654	3.65	81.46
13	*Genyonemus lineatus*	white croaker	61,383,451	2.15	83.61
14	*Oligocottus/Clinocottus* spp.	sculpins	50,258,626	1.76	85.37
15	*Platichthys stellatus*	starry flounder	49,295,886	1.73	87.09
16	*Stenobrachius leucopsarus*	northern lampfish	48,432,692	1.70	88.79

(*continued*)

Table 5-3 (continued). Estimated annual entrainment of larval fishes and target shellfish larvae based on entrainment samples collected at the DCPP intakes and actual plant flows during the sampling period (Stations E1 & E2 combined), July 2008 – June 2009.

Rank	Taxon	Common Name	Estimated Annual Entrainment	Percentage of Total	Cumulative Percentage
17	*Liparis* spp.	snailfishes	43,747,471	1.53	90.32
18	Bathymasteridae	ronquils	41,714,797	1.46	91.78
19	*Oxylebius pictus*	painted greenling	28,533,976	1.00	92.78
20	*Scorpaenichthys marmoratus*	cabezon	17,911,195	0.63	93.41
21	Blennioidei	blennies	17,716,220	0.62	94.03
22	*Leptocottus armatus*	Pacific staghorn sculpin	14,461,955	0.51	94.53
23	*Sebastes spp.*	rockfishes	13,065,506	0.46	94.99
24	*Brosmophycis marginata*	red brotula	12,336,586	0.43	95.42
25	Pleuronectoidei	flatfishes	9,923,436	0.35	95.77
26	*Radulinus* spp.	sculpins	9,099,959	0.32	96.09
27	Gobiesocidae	clingfishes	8,435,774	0.30	96.38
28	*Lepidopsetta bilineata*	rock sole	7,652,523	0.27	96.65
29	Osmeridae	smelts	7,273,051	0.25	96.91
30	*Ruscarius creaseri*	roughcheek sculpin	6,838,333	0.24	97.15
31	*Citharichthys* spp.	sanddabs	6,523,621	0.23	97.38
32	*Gobiesox* spp.	clingfishes	6,219,322	0.22	97.59
33	Pleuronectidae	righteye flounders	5,838,981	0.20	97.80
34	Agonidae	poachers	5,380,787	0.19	97.99
35	*Lepidogobius lepidus*	bay goby	5,230,130	0.18	98.17
36	*Aulorhynchus flavidus*	tubesnout	4,959,594	0.17	98.34
37	Cyclopteridae	snailfishes	4,530,360	0.16	98.50
38	*Parophrys vetulus*	English sole	3,950,478	0.14	98.64
39	Sciaenidae	croakers	3,244,699	0.11	98.75
40	Chaenopsidae	tube blennies	2,847,917	0.10	98.85
41	Bathylagidae	blacksmelts	2,718,957	0.10	98.95
42	Pholidae/Stichaeidae	gunnels/pricklebacks	2,540,310	0.09	99.04
43	Hexagrammidae	greenlings	2,524,223	0.09	99.13
44	*Typhlogobius californiensis*	blind goby	2,126,112	0.07	99.20
45	Pholidae	gunnels	2,061,680	0.07	99.27
46	*Synchirus gilli*	manacled sculpin	2,048,572	0.07	99.34
47	Clinidae	kelp blennies	1,967,390	0.07	99.41
48	Myctophidae	lanternfishes	1,406,525	0.05	99.46
49	Zoarcoidei	zoarcoids	1,223,096	0.04	99.50
50	*Bathylagus* spp.	blacksmelts	1,198,059	0.04	99.55
51	Ophidiidae	cusk-eels	1,178,331	0.04	99.59
52	*Chitonotus/Icelinus spp.*	sculpins	1,081,629	0.04	99.63
53	*Tarletonbeania crenularis*	blue lanternfish	1,027,084	0.04	99.66

(continued)

Table 5-3 (continued). Estimated annual entrainment of larval fishes and target shellfish larvae based on entrainment samples collected at the DCPP intakes and actual plant flows during the sampling period (Stations E1 & E2 combined), July 2008 – June 2009.

Rank	Taxon	Common Name	Estimated Annual Entrainment	Percentage of Total	Cumulative Percentage
54	*Hypsoblennius* spp.	combtooth blennies	1,009,058	0.04	99.70
55	*Merluccius productus*	Pacific hake	975,304	0.03	99.73
56	*Ammodytes hexapterus*	Pacific sand lance	933,053	0.03	99.76
57	*Pleuronichthys* spp.	turbots	857,717	0.03	99.79
58	*Sardinops sagax*	Pacific sardine	684,980	0.02	99.82
59	*Nannobrachium spp.*	lanternfishes	646,926	0.02	99.84
60	*Zaniolepis* spp.	combfishes	455,599	0.02	99.86
61	Blenniidae	blennies	412,193	0.01	99.87
62	*Engraulis mordax*	northern anchovy	353,214	0.01	99.88
63	*Hexagrammos* spp. /*Ophiodon elongatus*	greenlings	331,373	0.01	99.89
64	*Paralichthys californicus*	California halibut	305,002	0.01	99.91
65	*Lythrypnus* spp.	gobies	293,706	0.01	99.92
66	*Cataetyx rubrirostris*	rubynose brotula	209,647	0.01	99.92
67	*Ophiodon elongatus*	lingcod	200,901	0.01	99.93
68	*Syngnathus* spp.	pipefishes	181,536	0.01	99.94
69	*Acanthogobius flavimanus*	yellowfin goby	177,018	0.01	99.94
70	*Triphoturus mexicanus*	Mexican lampfish	177,018	0.01	99.95
71	Pomacentridae	damselfishes	177,018	0.01	99.95
72	*Heterostichus rostratus*	giant kelpfish	171,663	0.01	99.96
73	Gonostomatidae	bristlemouths	170,758	0.01	99.97
74	*Hexagrammos* spp.	greenlings	161,138	0.01	99.97
75	Clupeiformes	herrings and anchovies	160,327	0.01	99.98
76	*Ruscarius meanyi*	Puget Sound sculpin	150,584	0.01	99.98
77	*Hemilepidotus spinosus*	brown Irish lord	139,265	0.00	99.99
78	*Atherinopsis californiensis*	jacksmelt	136,802	0.00	99.99
79	*Sebastolobus spp.*	thornyheads	102,228	0.00	100.00
80	Clupeidae	herrings	93,378	0.00	100.00
		Total larval fish	2,856,255,279	100.00	
1	Cancridae (megalops)	cancer crabs megalops	1,819,054,688	99.77	99.77
2	*Cancer productus/ Romaleon* spp. (megalops)	rock crab megalops	3,892,895	0.21	99.98
3	*Doryteuthis opalescens*	market squid	360,417	0.02	100.00
		Total target shellfish	1,823,307,999	100.00	

5.2 Source Water Summary

A total of 93 larval fish taxa (not including fragments but including unidentified larval fish) and 5 target invertebrate taxa were collected at the six source water station areas from July 2008 through June 2009 (**Table 5-4**). The average concentration across all samples was 465 fish larvae per 1,000 m^3. Twenty-three taxa comprised 90% of the total number collected. The most abundant taxa were sculpins, northern lampfish (*Stenobrachius leucopsarus*), rockfishes, ronquils (Bathymasteridae), blennies/zoarcoids (probably species of unidentified stichaeids), white croaker (*Genyonemus lineatus*), and monkeyface eel (*Cebidichthys violaceus*). Several of the common source water taxa such as sanddabs, other flatfishes, croakers and northern anchovy are species whose adults have broad habitat and depth range distributions.

The greatest concentrations of larvae in the source water occurred in April 2009, peaking in April 2009 at 1,870 larvae per 1,000 m^3 (**Figure 5-1**). Sculpins, blennies/zoarcoids, gobies, ronquils, white croaker, monkeyface eel and rockfishes comprised a high proportion of the larvae in these surveys. Lowest larval concentrations occurred in the early September 2008 survey at 110 larvae per 1,000 m^3. Blackeye goby, unidentified yolksac larvae, sculpins, and speckled sanddab, comprised most of the larvae in that survey. Larval fish and target shellfish concentrations in the source water are summarized by survey in **Appendix E**.

A total of 22,314 target shellfish larvae composed almost entirely of rock crab megalops (22,142 individuals) was identified from the monthly source water samples. In addition to the megalops, 172 market squid paralarvae were also collected.

Table 5-4. Average concentration of larval fishes and target shellfish larvae at the nearshore source water stations off DCPP, July 2008 – June 2009.

Rank	Taxon	Common Name	Total Count	Average Concentration (per 1,000 m³)	Percentage of Total	Cumulative Percentage
1	Cottidae	sculpins	1,702	46.27	9.96	9.96
2	*Artedius* spp.	sculpins	1,668	41.08	8.84	18.80
3	*Stenobrachius leucopsarus*	northern lampfish	1,773	37.58	8.09	26.89
4	*Sebastes* spp. V	rockfishes	1,696	37.22	8.01	34.90
5	larval/post-larval fish	larval fishes	1,313	32.05	6.90	41.80
6	Bathymasteridae	ronquils	1,121	30.11	6.48	48.28
7	Blennioidei/Zoarcoidei	blennies/zoarcoids	1,012	29.27	6.30	54.58
8	*Sebastes* spp. V_	rockfishes	1,004	27.59	5.94	60.52
9	*Genyonemus lineatus*	white croaker	949	20.00	4.30	64.82
10	*Cebidichthys violaceus*	monkeyface prickleback	691	18.44	3.97	68.79
11	*Orthonopias triacis*	snubnose sculpin	772	16.58	3.57	72.36
12	*Liparis* spp.	snailfishes	536	14.66	3.16	75.51
13	CIQ goby complex	gobies	488	11.53	2.48	77.99

(continued)

Table 5-4 (continued). Average concentration of larval fishes and target shellfish larvae at the nearshore source water stations off DCPP, July 2008 – June 2009.

Rank	Taxon	Common Name	Total Count	Average Concentration (per 1,000 m^3)	Percentage of Total	Cumulative Percentage
14	*Rhinogobiops nicholsi*	blackeye goby	380	9.50	2.04	80.04
15	*Citharichthys* spp.	Sanddabs	412	8.62	1.86	81.89
16	*Platichthys stellatus*	starry flounder	263	8.00	1.72	83.62
17	*Sebastes* spp.	Rockfishes	235	5.51	1.19	84.80
18	Stichaeidae	Pricklebacks	201	4.90	1.05	85.86
19	Pleuronectidae	righteye flounders	182	4.65	1.00	86.86
20	*Parophrys vetulus*	English sole	156	4.17	0.90	87.76
21	*Lepidopsetta bilineata*	rock sole	154	4.13	0.89	88.64
22	Bathylagidae	Blacksmelts	152	3.94	0.85	89.49
23	*Gibbonsia* spp.	kelp blennies	178	3.78	0.81	90.31
24	*Chitonotus/Icelinus* spp.	sculpins	137	3.35	0.72	91.03
25	*Oxylebius pictus*	painted greenling	134	3.22	0.69	91.72
26	*Merluccius productus*	Pacific hake	151	3.01	0.65	92.37
27	*Tarletonbeania crenularis*	blue lanternfish	137	2.95	0.63	93.00
28	*Scorpaenichthys marmoratus*	cabezon	131	2.68	0.58	93.58
29	*Engraulis mordax*	northern anchovy	121	2.65	0.57	94.15
30	*Pleuronichthys* spp.	turbots	86	2.06	0.44	94.59
31	*Oligocottus/Clinocottus* spp.	sculpins	77	2.05	0.44	95.03
32	*Leptocottus armatus*	Pacific staghorn sculpin	81	1.95	0.42	95.45
33	Ophidiidae	cusk-eels	68	1.45	0.31	95.77
34	Pleuronectoidei	flatfishes	74	1.43	0.31	96.07
35	*Ruscarius creaseri*	roughcheek sculpin	56	1.37	0.29	96.37
36	*Radulinus* spp.	sculpins	50	1.26	0.27	96.64
37	*Zaniolepis* spp.	combfishes	42	1.19	0.26	96.90
38	*Lyopsetta exilis*	slender sole	42	1.10	0.24	97.13
39	Myctophidae	lanternfishes	49	1.07	0.23	97.36
40	*Pleuronichthys verticalis*	hornyhead turbot	44	1.07	0.23	97.59
41	*Typhlogobius californiensis*	blind goby	34	0.97	0.21	97.80
42	Agonidae	poachers	31	0.83	0.18	97.98
43	Sciaenidae	croakers	31	0.79	0.17	98.15
44	*Ammodytes hexapterus*	Pacific sand lance	39	0.77	0.17	98.32
45	Cyclopteridae	snailfishes	30	0.71	0.15	98.47
46	*Paralichthys californicus*	California halibut	26	0.63	0.14	98.61
47	*Brosmophycis marginata*	red brotula	19	0.62	0.13	98.74
48	*Microstomus pacificus*	Dover sole	25	0.50	0.11	98.85
49	*Lepidogobius lepidus*	bay goby	21	0.44	0.09	98.94
50	Pholidae/Stichaeidae	gunnels/pricklebacks	15	0.38	0.08	99.02

(continued)

Table 5-4 (continued). Average concentration of larval fishes and target shellfish larvae at the nearshore source water stations off DCPP, July 2008 – June 2009.

Rank	Taxon	Common Name	Total Count	Average Concentration (per 1,000 m^3)	Percentage of Total	Cumulative Percentage
51	Hexagrammidae	greenlings	14	0.37	0.08	99.10
52	*Ophiodon elongatus*	lingcod	17	0.37	0.08	99.18
53	Chaenopsidae	tube blennies	16	0.36	0.08	99.26
54	*Hexagrammos* spp. /*Ophiodon elongatus*	greenlings	17	0.34	0.07	99.33
55	Pholidae	gunnels	18	0.33	0.07	99.40
56	Blennioidei	blennies	13	0.31	0.07	99.47
57	*Nannobrachium spp.*	lanternfishes	15	0.30	0.06	99.54
58	*Ruscarius meanyi*	Puget Sound sculpin	9	0.22	0.05	99.58
59	*Triphoturus mexicanus*	Mexican lampfish	10	0.19	0.04	99.62
60	*Odontopyxis trispinosa*	pygmy poacher	6	0.17	0.04	99.66
61	*Sebastolobus* spp.	thornyheads	8	0.17	0.04	99.70
62	*Hypsoblennius* spp.	combtooth blennies	7	0.15	0.03	99.73
63	*Psettichthys melanostictus*	sand sole	3	0.10	0.02	99.75
64	*Lipolagus ochotensis*	popeye blacksmelt	4	0.09	0.02	99.77
65	*Leuroglossus stilbius*	California smoothtongue	4	0.08	0.02	99.79
66	*Syngnathus* spp.	pipefishes	4	0.08	0.02	99.80
67	Clupeiformes	herrings and anchovies	3	0.07	0.02	99.82
68	*Diaphus theta*	California headlight fish	2	0.07	0.02	99.83
69	*Sphyraena argentea*	Pacific barracuda	2	0.06	0.01	99.85
70	*Gobiesox* spp.	clingfishes	2	0.05	0.01	99.86
71	*Hemilepidotus spinosus*	brown Irish lord	2	0.05	0.01	99.87
72	*Hexagrammos* spp.	greenlings	2	0.05	0.01	99.88
73	Osmeridae	smelts	2	0.05	0.01	99.89
74	*Lythrypnus* spp.	gobies	2	0.04	0.01	99.90
75	*Oxyjulis californica*	senorita	2	0.04	0.01	99.91
76	*Sebastes diploproa*	splitnose rockfish	2	0.04	0.01	99.92
77	*Enophrys* spp.	buffalo sculpins	2	0.03	0.01	99.92
78	Gobiesocidae	clingfishes	1	0.03	0.01	99.93
79	*Symphurus atricaudus*	California tonguefish	2	0.03	0.01	99.94
80	*Synodus lucioceps*	California lizardfish	2	0.03	0.01	99.94
81	Zoarcoidei	zoarcoids	1	0.03	0.01	99.95
82	Atherinopsidae	silversides	1	0.02	<0.01	99.95
83	*Atherinopsis californiensis*	jacksmelt	1	0.02	<0.01	99.96
84	*Gillichthys mirabilis*	longjaw mudsucker	1	0.02	<0.01	99.96
85	*Isopsetta isolepis*	butter sole	1	0.02	<0.01	99.97
86	Melamphaidae	bigscale fishes	1	0.02	<0.01	99.97
87	Paralichthyidae	sand flounders	1	0.02	<0.01	99.97

(continued)

Table 5-4 (continued). Average concentration of larval fishes and target shellfish larvae at the nearshore source water stations off DCPP, July 2008 – June 2009.

Rank	Taxon	Common Name	Total Count	Average Concentration (per 1,000 m^3)	Percentage of Total	Cumulative Percentage
88	*Pleuronichthys decurrens*	curlfin turbot	1	0.02	<0.01	99.98
89	Pomacentridae	damselfishes	1	0.02	<0.01	99.98
90	*Protomyctophum crockeri*	California flashlightfish	1	0.02	<0.01	99.99
91	Scorpaenidae	scorpion fishes	1	0.02	<0.01	99.99
92	*Sebastes levis*	cow cod	1	0.02	<0.01	100.00
93	*Synchirus gilli*	manacled sculpin	1	0.02	<0.01	100.00
		Total larval fish	18,995	464.62	100.00	
1	Cancridae (megalops)	cancer crabs megalops	22,109	659.71	99.10	99.10
2	*Doryteuthis opalescens*	market squid	172	5.05	0.76	99.86
3	*Cancer productus/Romaleon* spp. (megalops)	rock crab megalops	33	0.92	0.14	100.00
		Total target shellfish	22,314	665.68	100.00	

5.3 Entrainment and Source Water Comparison

Average concentrations of larval fishes were generally greater at the entrainment station than for all source water stations combined when comparing the paired monthly samples (**Figure 5-1**). The source water stations had higher averages in fall 2008 and February 2009, but the entrainment station had higher averages in all other seasons, especially during the upwelling period in spring. The monthly averages were similar between the entrainment and source water stations during June 2009. Average concentrations of all taxa combined declined with distance from shore (**Figure 5-2**).

The inshore fish assemblage represented by the entrainment samples differed from the offshore (source water) stations as shown by a comparison of the most abundantly entrained taxa (**Table 5-5**). The greatest percentage difference was in kelp blennies and pricklebacks with an approximately 90% reduction between inshore and offshore stations. Many of the differences in species composition and relative abundance can be attributed to the location of the intake structure in an area surrounded by shallow rocky reef habitat. This habitat, comprised of the concrete tri-bars used to construct the breakwaters that protect the Intake Cove, supports robust populations of adult fishes such as KGB rockfishes, , sculpins, and blackeye gobies. The adults of these fishes tend to be more abundant in shallow nearshore areas than offshore.

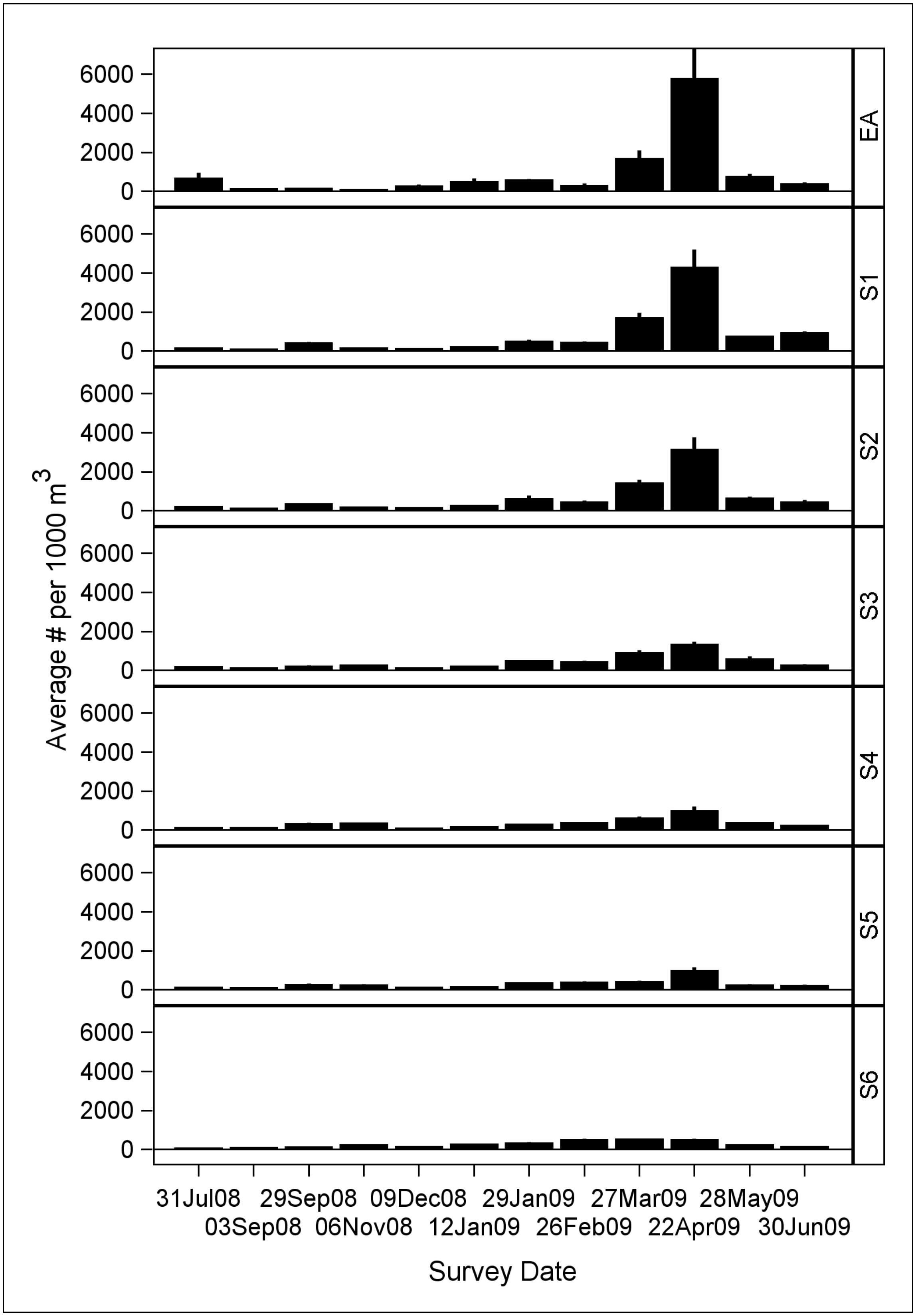


Figure 5-2. Average concentrations of larval fishes by station from July 2008 through June 2009.

A comparison between abundances of major taxonomic groups at the level of family and order showed that herrings/anchovies, blacksmelts/lanternfishes, and flatfishes were more abundant at the offshore stations than inshore (**Figure 5-3** and **Table 5-6**). The larvae of fishes that normally occur much farther offshore and in deeper water as adults, such as northern lampfish (a member of the family Myctophidae), can be transported into nearshore areas, especially during periods when winds and upwelling subside resulting in increased onshore transport. The average concentration of northern lampfish was 38 per 1,000 m^3 at the source water stations and 21 per 1,000 m^3 at the entrainment stations, demonstrating its predominantly offshore distribution. The average concentration for croakers (primarily white croaker) was approximately equal between entrainment and source stations. It is a species that occurs out to depths of approximately 100 m (330 ft) and is usually associated with sand bottom habitats. The larvae were widely distributed in nearshore waters, even in very shallow areas in close proximity to rocky reefs.

Table 5-5. Comparison of larval fish concentrations (average per survey) between entrainment and source water stations for the ten most abundant taxa from the entrainment sampling (excluding unidentified larval/post-larval fishes). The negative values indicate a greater abundance at the entrainment station.

Taxon	Common Name	Entrainment Average Concentration (per 1,000 m^3)	Source Water Average Concentration (per 1,000 m^3)	Source Water Percent Difference
Cottidae	unidentified sculpins	108.64	46.27	-57
Sebastes spp. V_	rockfishes	80.50	27.59	-66
Cebidichthys violaceus	monkeyface eel	66.41	18.44	-72
Gibbonsia spp.	kelp blennies	63.06	3.78	-94
Artedius spp.	sculpins	57.70	41.08	-29
Blennioidei/Zoarcoidei	blennies/zoarcoids	54.56	29.27	-46
Orthonopias triacis	snubnose sculpin	44.04	16.58	-62
Sebastes spp. V	rockfishes	41.63	37.22	-11
Rhinogobiops nicholsi	blackeye goby	38.92	9.50	-76
Stichaeidae	unidentified pricklebacks	36.23	4.90	-86

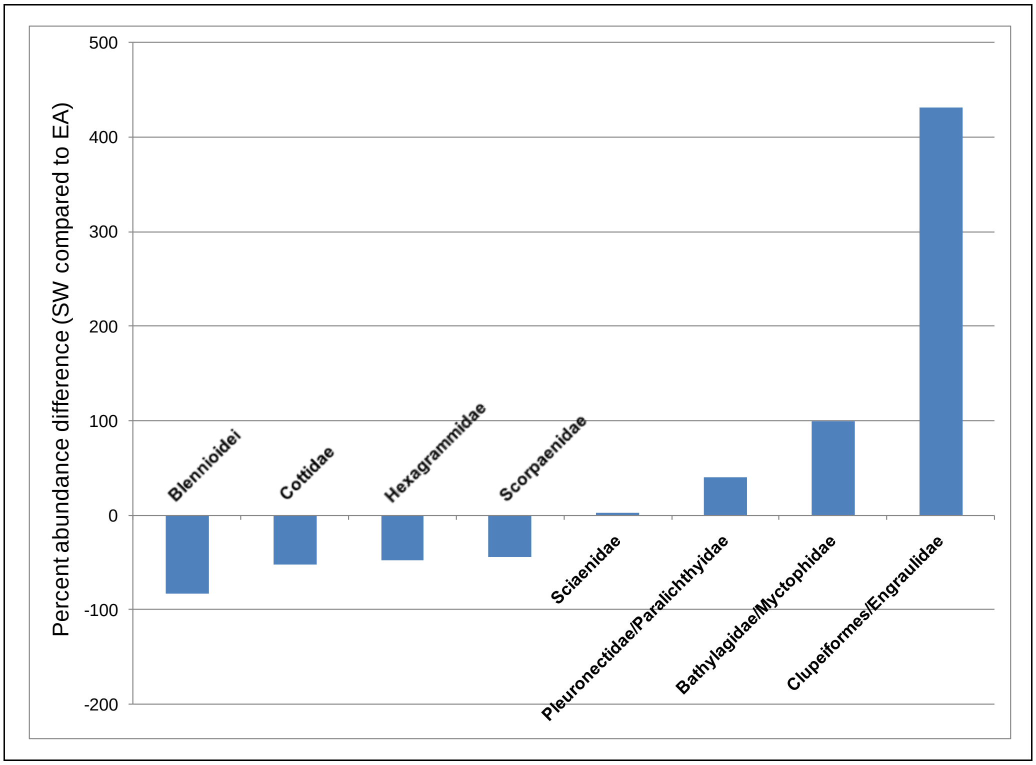


Figure 5-3. Percent difference in larval fish concentrations (average per survey) between entrainment and source water stations for eight taxa groups, with all species within a group being combined. Positive values indicate greater abundance at source water stations.

Table 5-6. Comparison of larval fish concentrations (average per survey) between entrainment and source water stations for eight taxa groups, with all species within a group being combined. A positive value indicates a greater abundance at the source water stations, while a negative value indicates a greater abundance at the entrainment stations.

Taxon	Common Name	Entrainment Combined Concentration (per 1,000 m^3)	Source Water Combined Concentration (per 1,000 m^3)	Percent difference
Cottidae	sculpins	244.16	116.99	-52
Blennioidei	pricklebacks, gunnels, blennies	174.52	28.61	-84
Scorpaenidae	rockfishes	126.36	70.55	-44
Pleuronectidae/Paralichthyidae	flatfishes	26.14	36.59	+40
Bathylagidae/Myctophidae	blacksmelts and lanternfishes	23.23	46.29	+99
Sciaenidae	croakers	20.39	20.91	+3
Hexagrammidae	greenlings	10.54	5.53	-48
Clupeiformes/Engraulidae	herrings and anchovies	0.51	2.71	+431

5.4 Analysis of Individual Taxa

5.4.1 Sculpins (Cottidae)

The family Cottidae comprises about 70 genera and 300 species worldwide (Nelson 1994). Forty-two species of sculpin occur along the California coast (Miller and Lea 1972), primarily in intertidal or shallow subtidal habitats. Based on their overall abundance in the entrainment samples, a taxonomic group of unidentified sculpins (Cottidae) and three separate species were selected for detailed assessment: smoothhead sculpin (*Artedius lateralis*), snubnose sculpin (*Orthonopias triacis*), and cabezon (*Scorpaenichthys marmoratus*).

Intertidal and shallow subtidal fishes, including the sculpins, display a wide range of life histories that defy broad demographic generalization. They range from relatively short-lived to longer-lived species (Gibson 1969, 1982; Miller 1979). Staghorn sculpin (*Leptocottus armatus*), common in Pacific coast bays and estuaries, is known to live to 3 yr and reach sexual maturity after 1 yr (Jones 1962; Tasto 1975), while the fluffy sculpin (*Oligocottus snyderi*) and tidepool sculpin (*O. maculosus*) have even shorter lifespans (deVlaming et al. 1982). Cabezon, the largest of the North American sculpins, may live to 13 yr but only inhabits tidepools during its first or second year of life (O'Connell 1953). The detailed life history information necessary to apply demographic population models is available for only a few sculpin species.

There were eleven species or combination taxa of sculpins, in addition to unidentified sculpins (Cottidae), collected in the entrainment samples (**Table 5-1**). The estimated number of sculpin larvae of all species entrained annually was 837.6 million, which comprised 29.3% of all fish larvae entrained (**Table 5-3**).

5.4.1.1 Unidentified Sculpins (Cottidae)

Sculpin specimens that could not be identified to the genus or species level with certainty were combined at the family level into the unidentified sculpin group. These also included damaged specimens that had myomere counts or pigmentation patterns that were diagnostic of sculpins. Because the group includes many species with varying reproductive, age, and growth characteristics, specific information is presented only for smoothhead sculpins (*Artedius* spp.), snubnose sculpin (*Orthonopias triacis*), and cabezon (*Scorpaenichthys marmoratus).*

Sampling Results

Unidentified sculpins (Cottidae) were the most abundant taxon collected at the entrainment stations (12.8% of all larvae) and the source water stations (10.0%) (**Tables 5-2** and **5-4**). The mean concentration per survey at the entrainment stations ranged from zero to approximately 1,200 larvae per 1,000 m^3, peaking in abundance during late April 2009 (**Figure 5-4**). Larvae were most abundant at the inshore stations with a trend toward declining abundance offshore (**Figure 5-5**).

The mean length of 200 specimens proportionally sampled from the 488 larvae measured was 4.93 mm (0.19 in.) (**Figure 5-6**). The smallest larva measured was 2.05 mm (0.08 in.) and the largest was 22.50 mm (0.89 in.). The averages from the all the measured cottid larvae were 5.05 mm (0.20 in.) for the mean and 4.56 mm (0.18 in.) for the median. The computed hatch length from the average values was slightly higher than the average lower quartile value, so that value of 3.51 mm (0.14 in.) was used as the estimated hatch length.

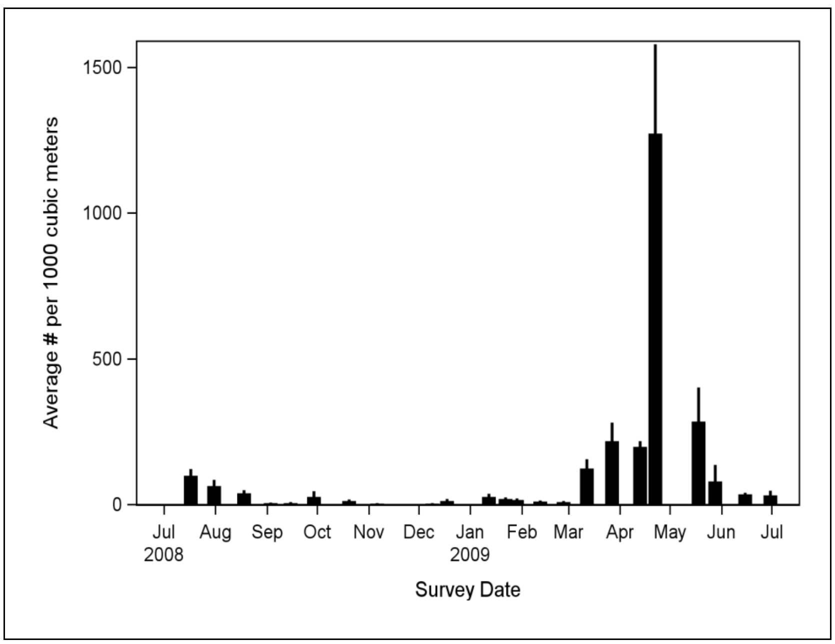


Figure 5-4. Survey mean concentration (#/1,000 m^3) of unidentified sculpin (Cottidae) larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

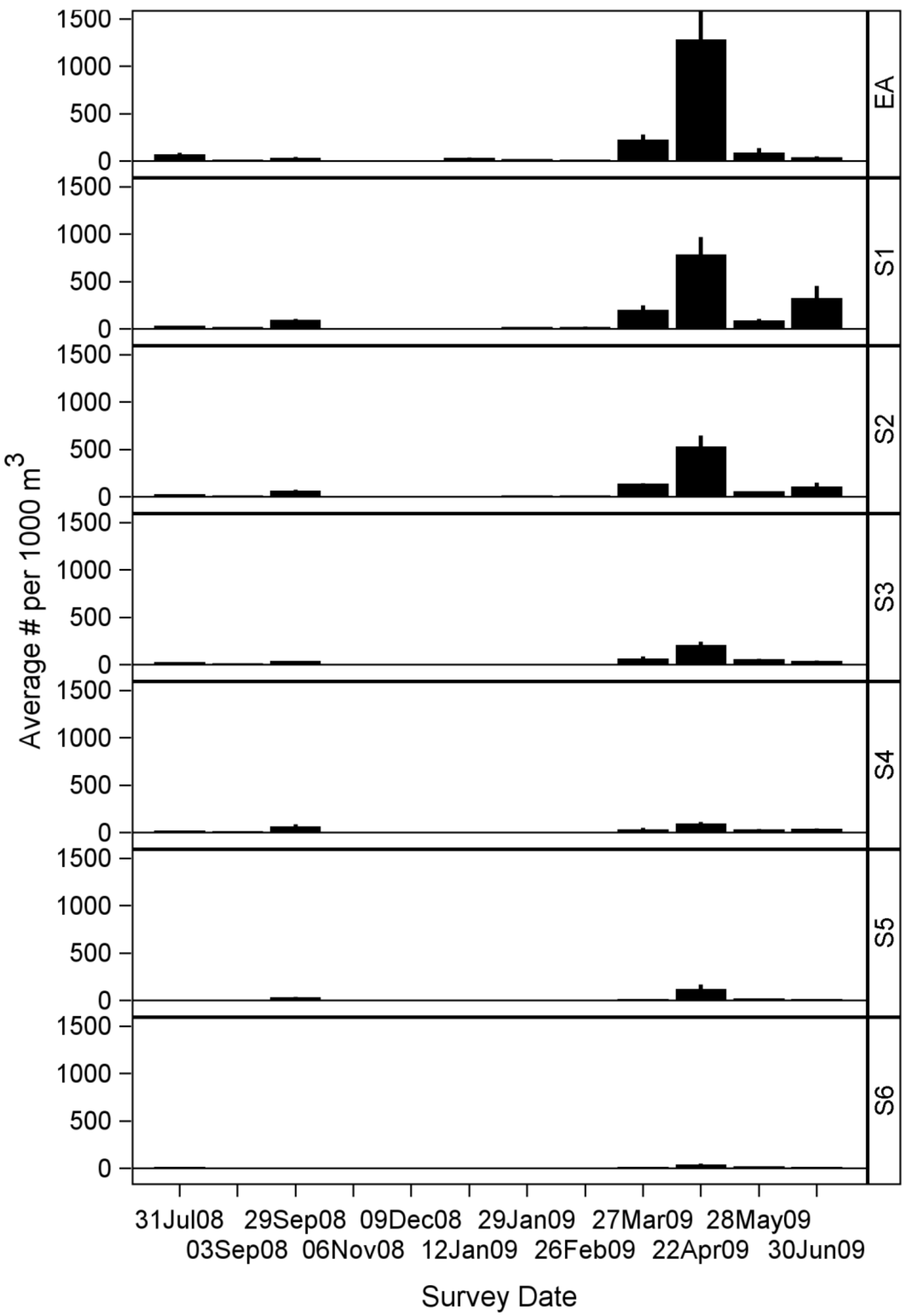


Figure 5-5. Survey mean concentration (#/1,000 m^3) of unidentified sculpin larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

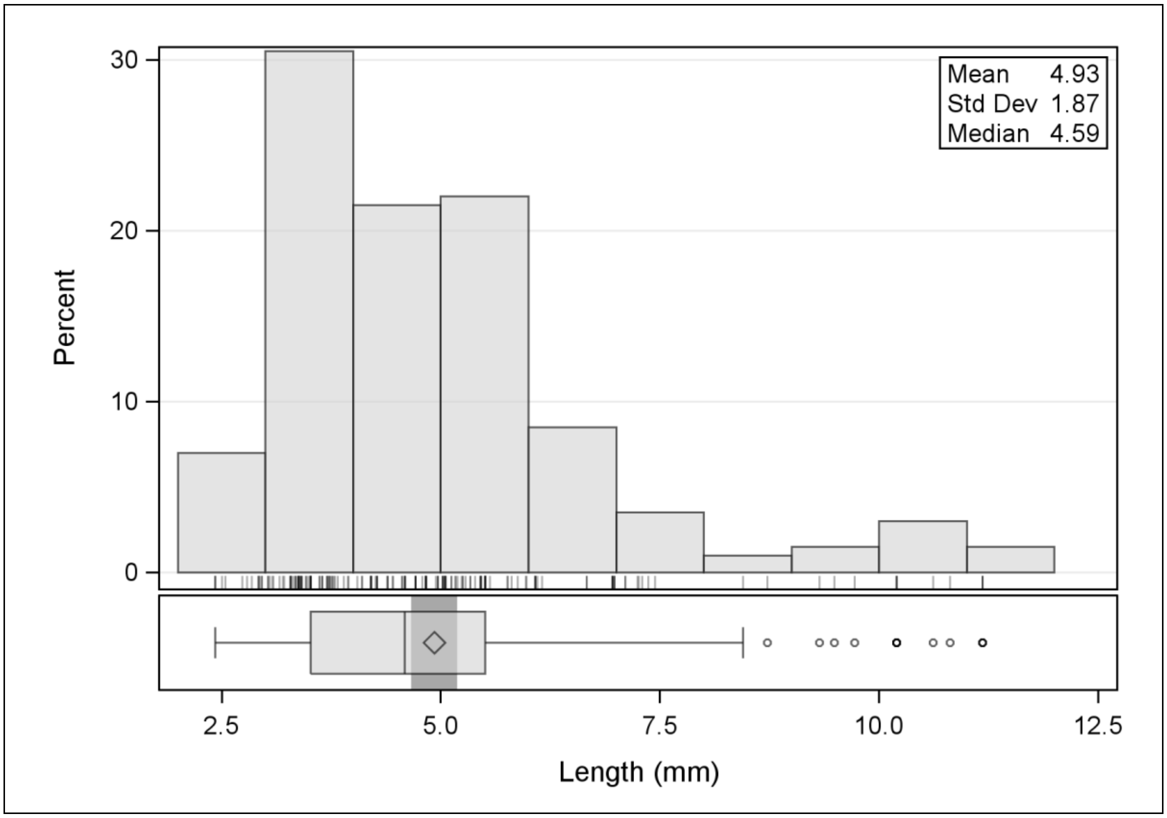


Figure 5-6. Length frequency histogram and statistics for unidentified sculpins (Cottidae) based on a sample of 200 larvae proportionally sampled with replacement from the 488 sculpin larvae measured.

Entrainment Effects

An estimated 387.2 million unidentified sculpin larvae (Cottidae) were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary life history demographic information was not available for this multi-species group.

An *ETM* estimate of P_M was calculated for this taxa group because the results show that the source water sampling likely provided a reasonable estimate of nearshore abundance as the larvae were collected across all of the stations, even though the highest abundances were usually collected inside the Intake Cove (**Figure 5-5**). The pattern of abundance across the stations is not unexpected as many sculpins are associated with shallow, rocky reef habitats; the type of habitat created with the construction of the Intake Cove. The distribution across all of the source water stations may be due to the range of habitats and depths occupied by the numerous species in this group. Although this taxonomic group likely includes numerous species, the larvae for the other sculpins identified during the study are fairly distinct and can be identified to those species groups even at small sizes. The larvae for this taxon were also collected during all of the surveys providing a robust estimate of P_M. The results of the *ETM* for this taxon will be used in the *HPF* assessment presented in Section 6.0.

Empirical Transport Model *(ETM)*

The larval growth rate for unidentified sculpins was estimated from data on the hatch sizes in this study, transformation lengths (Moser 1996), and average planktonic larval durations of five species in the genera Artedius, Clinocottus, and Oligocottus (Shanks and Eckert 2005). These data from Shanks and Eckert (2005) were used to estimate a planktonic duration of 48 d with an average size at transformation of 10.2 mm (0.40 in.). Using these values with the hatch length from this study, the average growth rate was calculated as 0.14 mm/d (10.2–3.51 mm / 48 d [0.40–0.14 in / 48 d]). The estimated period of entrainment exposure of 45.5 d was calculated by dividing the difference between the estimated hatch length of 3.51 mm (0.14 in.) and the 95th percentile value of 9.85 mm (0.39 in.) by the estimated larval growth rate. The entrainment exposure duration was calculated from size and growth values with greater decimal precision than those shown, and differs slightly from the duration calculated using these rounded values.

The data used to calculate the *ETM* estimates (f_i values) for unidentified sculpins showed that almost 85% of the larvae were collected from the source water stations from March through June 2009 (**Table 5-7**). Some species of sculpins can occur in deeper water so both alongshore and offshore extrapolations of the source water populations were calculated. The x-intercept was calculated at 2,598 m (8,524 ft) for the regression based on the concentrations at the source water stations, which was inside the outer edge of the sampled source water (2,890 m [9,482 ft]).

Table 5-7. *ETM* data for unidentified sculpin larvae using alongshore and offshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from all surveys with *PE* > 0.

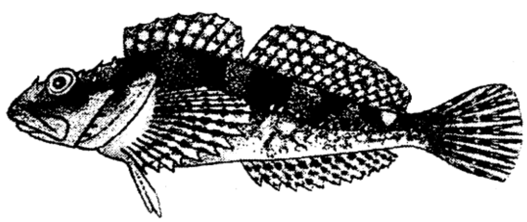
	Alongshore		Offshore Extrapolated			
Survey Date	*PE* Estimate	*PE* Std. Err.	*PE* Estimate	*PE* Std. Err.	f_i	Alongshore Displacement (km)
31-Jul-08	0.01638	0.00201	0.01638	0.00201	0.0369	28.14
3-Sep-08	0.00578	0.00094	0.00578	0.00094	0.0076	23.89
29-Sep-08	0.00178	0.00048	0.00164	0.00044	0.0867	38.74
6-Nov-08	0.00700	0.00195	0.00700	0.00195	0.0045	26.83
9-Dec-08	0.00820	0.00246	0.00811	0.00243	0.0031	34.06
12-Jan-09	0.07001	0.01306	0.07001	0.01306	0.0038	18.09
29-Jan-09	0.01204	0.00213	0.01203	0.00213	0.0059	18.41
26-Feb-09	0.00336	0.00054	0.00336	0.00054	0.0075	41.23
27-Mar-09	0.01621	0.00184	0.00905	0.00103	0.1064	24.00
22-Apr-09	0.01550	0.00149	0.01540	0.00148	0.5512	32.50
28-May-09	0.00738	0.00184	0.00738	0.00184	0.0886	30.20
30-Jun-09	0.00197	0.00038	0.00197	0.00038	0.0977	29.45
Average =	0.01380		0.01318			28.80

Although the offshore areas may not contribute many larvae based on the abundance data, the alongshore extent of the backprojections differed depending on whether or not excursions in water depths beyond the edge of the grid (60 m [200 ft]) were included. The excursions calculated from the CODAR data, in just the alongshore area inside the 60 m (200 ft) depth contour, extended an average of 28.79 km (17.89 mi) alongshore, while the excursions including depths to 91 m (300 ft) extended an average of 30.71 km (19.08 mi) alongshore. The difference in some of the *PE* estimates using the two alongshore and offshore extrapolated estimates of the source water populations (**Table 5-7**). The larger source water area extrapolated by the excursions that include deeper depths resulted in slightly lower *PE* estimates. These differences are also reflected in the P_M estimates for the 45.5-day period of exposure of 0.4076 (40.76%) and 0.3861 (38.61%) from the CODAR backprojections using the shallow and deeper depth limits, respectively, for the excursions (**Table 5-8**).

Table 5-8. Estimates for *ETM* models for unidentified sculpin larvae calculated using alongshore and offshore extrapolations based on current data from CODAR backprojected from the survey data with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	28.80	0.40759	0.02348	0.43107	0.38411
Offshore Extrapolated P_M	30.71	0.38605	0.02344	0.40949	0.36261

5.4.1.2 Smoothhead sculpins (*Artedius* spp.)



Artedius lateralis (Girard 1854); smoothhead sculpin; length to 14 cm (5.5 in.); Kodiak Island, Alaska to Cabo San Quintin, northern Baja California; intertidal to 13 m (43 ft); greenish to brown on top, cream to light brown below (Miller and Lea 1972; Eschmeyer et al. 1983).

As many as seven species in the genus *Artedius* may occur in the vicinity of Diablo Canyon, but positive identification of preflexion larvae to the species level is not always possible due to variation in numbers of post-anal ventral melanophores between and within species. Therefore, collected specimens were only identified to the generic level and are referred to collectively as “smoothhead sculpins”, the common name for *Artedius lateralis*, one of the more abundant adult cottid species that occurs in the study area.

Reproduction, Age, and Growth

Spawning in *Artedius lateralis* varies between locations: winter–spring in British Columbia (Marliave 1977) and June in Puget Sound (Matarese et al. 1989). Their eggs hatch into pelagic larvae in about 16 d at 15.5°C (60°F) (Budd 1940; Matarese et al. 1989). Love (1996) indicates that these sculpins likely mature within their first year of life and probably live as long as 3 yr.

The life history information available for smoothhead sculpin and its close relatives do not provide sufficient data to compute demographic model estimates using *FH*. Estimates of fecundity and spawning periodicity are available for closely related species that likely compare favorably with *A. lateralis* based on their similar ecological roles, adult habitats, and close phylogenetic relationships. However, in the absence of any estimates of egg or larval survivorship, demographic model estimates cannot be computed for this species.

Population Trends and Fishery

Smoothhead sculpins have neither commercial nor recreational fishery value, and there is little information on their ecological role in the community. Trends in adult populations were examined using data from the DCPP Receiving Water Monitoring Program studies on subtidal fishes. Mean abundance from three 50 m (164 ft) transects, in an area approximately 1 km (0.6 mi) south of Diablo Cove that was not contacted by the plant's thermal discharge, combine data for *A. lateralis* with data for other cottids in the genus *Artedius* because of the difficulties in field identification to the species level. The data varied considerably among years and showed no clearly defined trends, partly because the visual count method is not an accurate method for enumerating small, cryptic fishes like smoothhead sculpins (**Figure 5-7**).

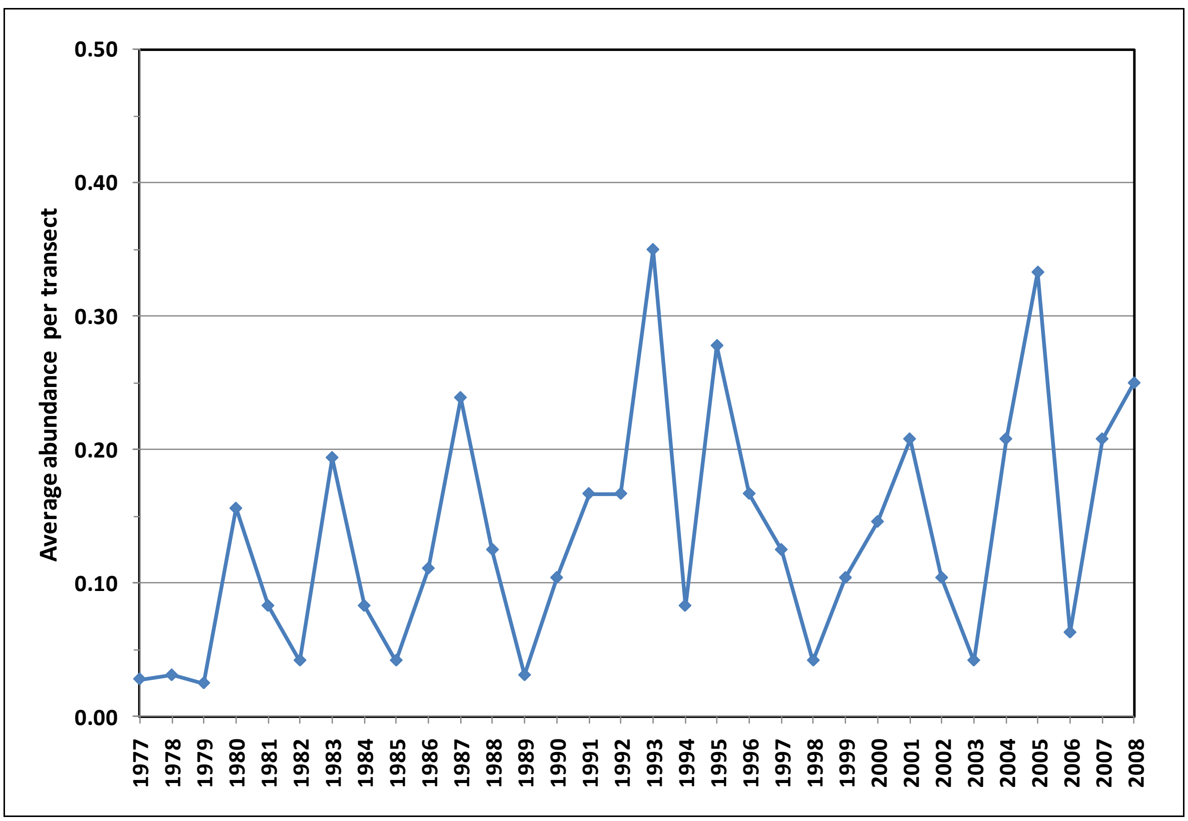


Figure 5-7. Average abundance per 50x4 m transect for *Artedius* at the DCPP control site.

Sampling Results

Larval smoothhead sculpins was the fifth most abundant taxon collected from the entrainment stations and second most abundant from the source water stations, comprising 9.5% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The mean concentration per survey ranged from zero to over 700 larvae per 1,000 m^3 peaking in abundance during late April 2009 (**Figure 5-8**). Larvae were most abundant at the inshore stations with only a small fraction of the total occurring at offshore station S6 (**Figure 5-9**).

The mean length of 200 specimens proportionally sampled from the 443 larvae measured was 4.16 mm (0.16 in.) (**Figure 5-10**). The smallest larva measured was 2.18 mm (0.09 in.) and the largest was 10.68 mm (0.42 in.). Reported hatch size for *Artedius lateralis* ranges from 3.9–4.5 mm (0.15-0.18 in.) (Moser 1996). The fact that some of the measured larvae were smaller than the minimum reported hatching lengths of *A. lateralis* can be explained partly by natural variation of hatch lengths and the probable occurrence of other species within the group. The averages from the random samples proportionally drawn from all the measurements resulted in averages of 4.19 mm (0.16 in.) for the mean with a median of 3.62 mm (0.14 in.). The average 25% percentile length of 2.96 mm (0.12 in.) from the bootstrap samples was used as the estimated hatch length.

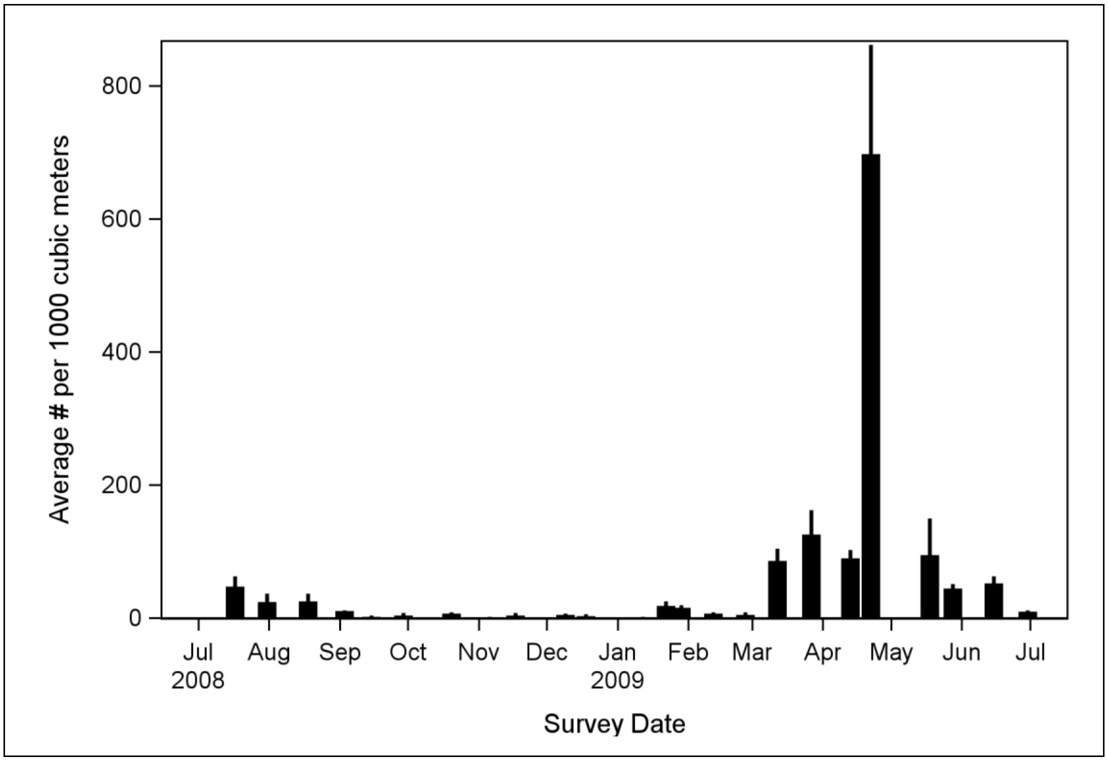


Figure 5-8. Survey mean concentration (#/1,000 m^3) of sculpin (*Artedius* spp.) larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

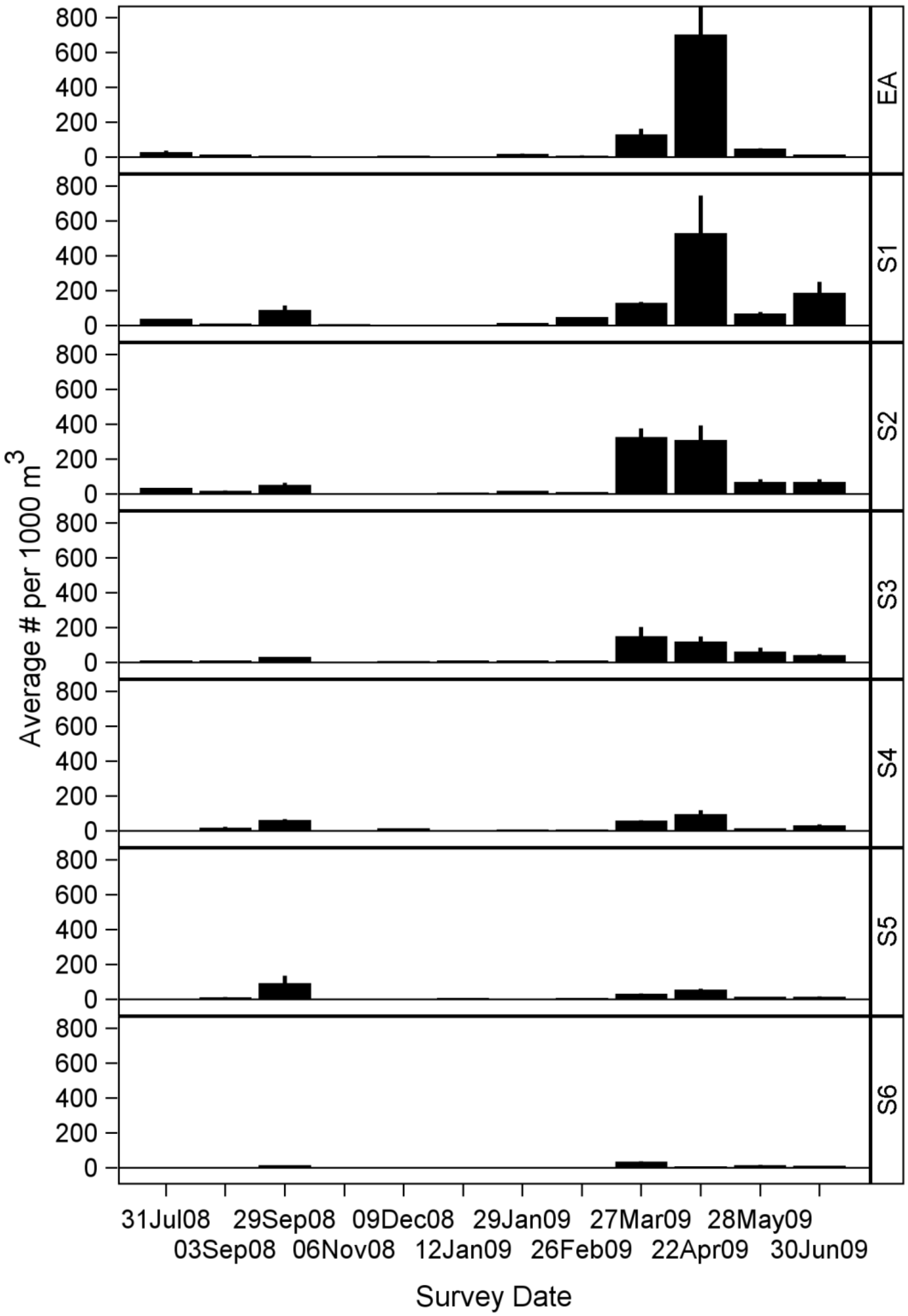


Figure 5-9. Survey mean concentration (#/1,000 m^3) of sculpin larvae (*Artedius* spp.) collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

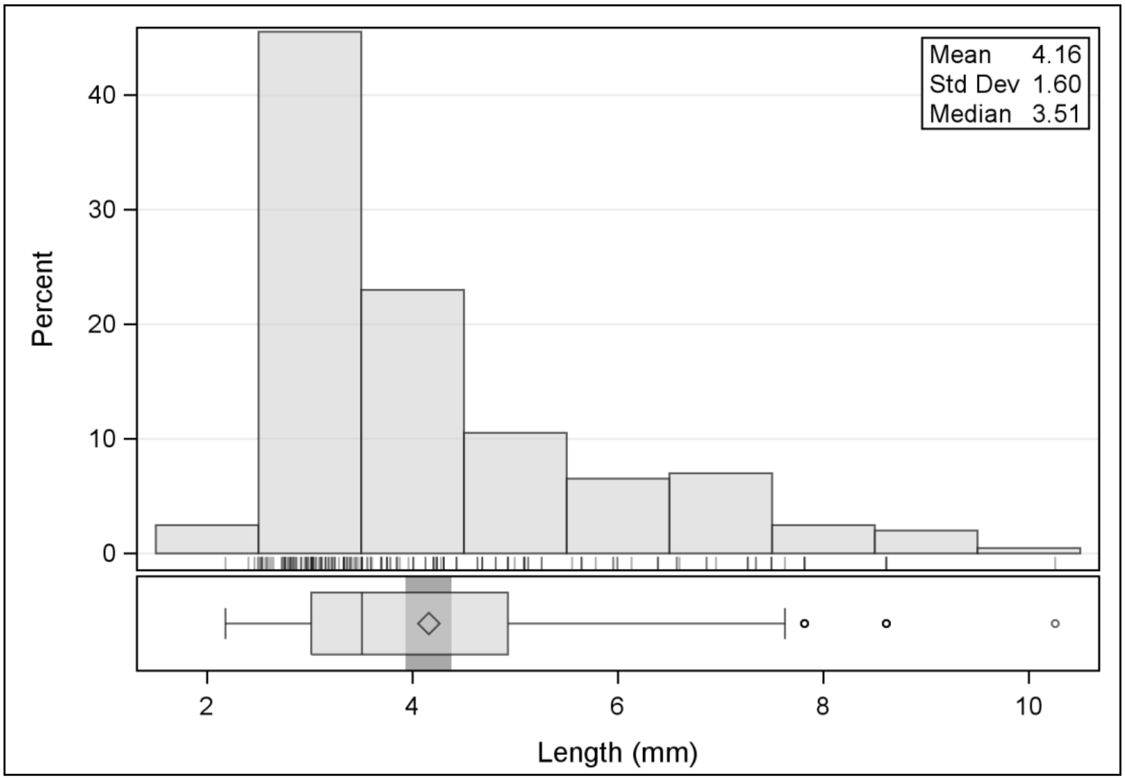


Figure 5-10. Length frequency histogram and statistics for sculpins (*Artedius* spp.) based on a sample of 200 larvae proportionally sampled with replacement from the 443 sculpin larvae measured.

Entrainment Effects

An estimated 203.1 million smoothhead sculpin larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary life history demographic information was not available for this species.

An *ETM* estimate of P_M was calculated for this species group because the results show that the source water sampling likely provided a reasonable estimate of nearshore abundance, even though the highest abundances were usually collected inside the Intake Cove (**Figure 5-9**). The pattern of abundance at the stations is not unexpected as smoothhead sculpin are associated with shallow, rocky reef habitats; the type of habitat created with the construction of the Intake Cove. The larvae for this taxon were also collected during all of the surveys providing a robust estimate of P_M. The results of the *ETM* for this taxon will be used in the *HPF* assessment presented in Section 6.0.

Empirical Transport Model (*ETM*)

An estimate of the larval growth rate was calculated from data presented in Shanks and Eckert (2005) and Moser (1996) on the hatch sizes, transformation lengths, and planktonic larval durations of species in the genera *Artedius*. The reported planktonic duration of 48 d and transformation size of 9.5 mm (0.37 in.) was used with the computed hatch size from this study to compute a larval growth rate of 0.14 mm/d (9.5 mm–2.96 mm/48 d [0.37-0.11 in/48 d]). The estimated period of entrainment exposure of 33.1 d was calculated by dividing the difference between the estimated hatch length of 2.96 mm (0.12 in.) and the size of the 95th percentile value of 7.68 mm (0.30 in.) by the estimated larval growth rate. The entrainment exposure duration was calculated from size and growth values with greater decimal precision than those shown, and differs slightly from the duration calculated using these rounded values.

The data used to calculate the *ETM* estimates for *Artedius* spp. show that approximately 75% of the larvae were collected from the source water stations from the March–June 2009 surveys (**Table 5-9**). Only alongshore extrapolations of the source water populations were calculated since smoothhead sculpins adults occur at depths less than 60 m (200 ft) at the edge of the sampling areas. The average alongshore displacement for the source water population was 24.91 km (15.48 mi) based on the backprojections calculated from the CODAR data. The P_M estimate for the 33.1-day period of exposure was 0.2059 (20.6%) based on the source water area from the CODAR backprojections (**Table 5-10**).

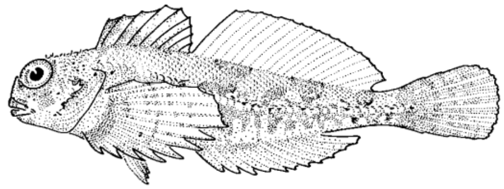
Table 5-9. *ETM* data for sculpin larvae (*Artedius* spp.) using alongshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i	Alongshore Displacement (km)
31-Jul-08	0.01076	0.00185	0.0244	28.14
3-Sep-08	0.00801	0.00096	0.0207	14.32
29-Sep-08	0.00024	0.00009	0.1616	24.72
6-Nov-08	0.00295	0.00125	0.0036	26.83
9-Dec-08	0.00465	0.00078	0.0097	29.94
12-Jan-09	0.00162	0.00061	0.0071	17.80
29-Jan-09	0.00954	0.00119	0.0085	17.19
26-Feb-09	0.00117	0.00029	0.0199	26.81
27-Mar-09	0.00518	0.00058	0.2173	23.43
22-Apr-09	0.01461	0.00147	0.3583	32.31
28-May-09	0.00475	0.00038	0.0856	30.20
30-Jun-09	0.00081	0.00008	0.0834	27.21
Average =	0.00536			24.91

Table 5-10. Estimates for *ETM* models for sculpins (*Artedius* spp.) calculated using alongshore extrapolations based on current data from CODAR backprojected from the survey date with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP.

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	24.91	0.20587	0.02263	0.22851	0.18324

5.4.1.3 Snubnose sculpin (Orthonopias triacis)



Orthonopias triacis (Starks and Mann 1911); snubnose sculpin; length to 10 cm (3.9 in.). Farallon Islands, northern California to Isla San Geronimo, northern Baja California; intertidal to 30 m (100 ft); green to reddish brown or orange above, with dark and light mottling; white below (Miller and Lea 1972; Eschmeyer et al. 1983; Long 1992).

Reproduction, Age, and Growth

Despite the common occurrence of snubnose sculpin in nearshore rocky subtidal and intertidal habitats, their life history remains relatively undescribed. Females are oviparous and spawn year round with peaks between February and October. The eggs are demersal and adhesive and hatch into planktonic larvae (Feeney 1992; Moser 1996). Bolin (1941) conducted studies of the embryology and development of early larval stages of *O. triacis* in laboratory rearing experiments. Egg incubation took 16–19 d at about 13°C, after which the larvae hatched at sizes ranging from 2.9–3.8 mm (0.11-0.15 in.). All larvae increasing by about 0.2 mm (0.08 in.) in length over that time (i.e., growth rate of 0.02 mm/d [0.0008 in/d]), but died within 10 d of hatching despite several regimes of aeration and nutrition. The larval yolk sacs were exhausted by about 5 days of age. The growth described above, representing the first 5–6 d of life until the yolk stores were exhausted, probably underestimates the growth rate in the wild where they can feed successfully.

There were no estimates in the scientific literature on the age at sexual maturity and life-span for snubnose sculpin, though they are likely to be similar to other small, nearshore cottids: 1–3 yr for sexual maturity and 2–7 yr for longevity (Gibson 1969; Miller 1979; deVlaming et al. 1982; Grossman and deVlaming 1984; Freeman et al. 1985; Wells 1986; Pierce and Pierson 1990).

The life history demographic data available for *O. triacis* do not provide sufficient information for computation of estimates using the *FH* model. Phylogenetic analyses indicate that the relationship of *O. triacis* to other sculpins found in similar habitats remains unresolved (Begle 1989). In the absence of egg or larval survivorship estimates, the impact of entrainment on the smoothhead sculpin population will be assessed using only the *ETM*.

Population Trends and Fishery

Snubnose sculpin has neither commercial nor recreational fishery value and there is little information on its ecological role in the community. Adult abundance of snubnose sculpin observed in the DCPP Receiving Water Monitoring Program (RWMP) studies on subtidal fishes showed peaks in abundance in 1985 and 2008 with minimum abundances in 1996 and 1998 (**Figure 5-11**). These data were collected along three 50 m (164 ft) transects in an area approximately 1 km south of Diablo Cove which is not contacted by the plant's thermal discharge. The method is not considered an accurate method for enumerating this species because their small size and cryptic nature, but the data may reflect general trends in the species' abundance over time.

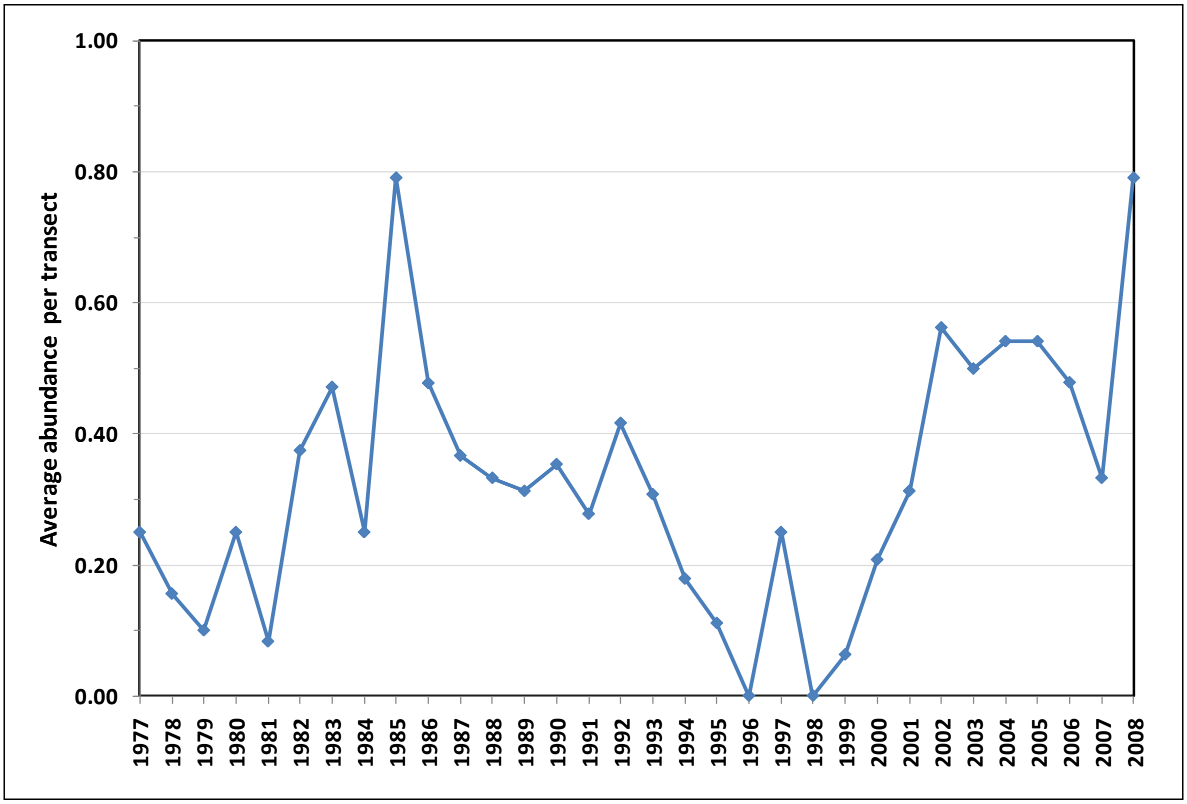


Figure 5-11. Average abundance per 50x4 m transect for snubnose sculpin at the DCPP control site

Sampling Results

Snubnose sculpin was the ninth most abundant taxon collected from the entrainment stations and eleventh most abundant from the source water stations, comprising 5.2% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The mean concentration per survey ranged from approximately 10 to over 150 larvae per 1,000 m^3 peaking in abundance during March and April 2009 but also with high concentrations recorded in July 2008 (**Figure 5-12**). Larvae were most abundant at the inshore stations with only a small fraction of the total occurring at offshore Station S6 (**Figure 5-13**).

The mean length of 200 specimens proportionally sampled from the 559 larvae measured was 4.27 mm (0.17 in.) (**Figure 5-14**). The smallest of the larva measured was 2.50 mm (0.10 in.) and the largest was 10.93 mm (0.43 in.). Reported hatch size for snubnose sculpin ranges from 2.6–3.8 mm (0.10-0.15 in.) (Moser 1996). The fact that some of the measured larvae were smaller than the minimum reported hatching lengths can be explained partly by natural variation of hatch lengths. The averages from the random samples proportionally drawn from all the measurements resulted in a length of 4.09 mm (0.16 in.) for the mean and 3.78 mm (0.15 in.) for the median. The computed hatch length was 3.25 mm (0.13 in.), which is within the range reported by Moser (1996).

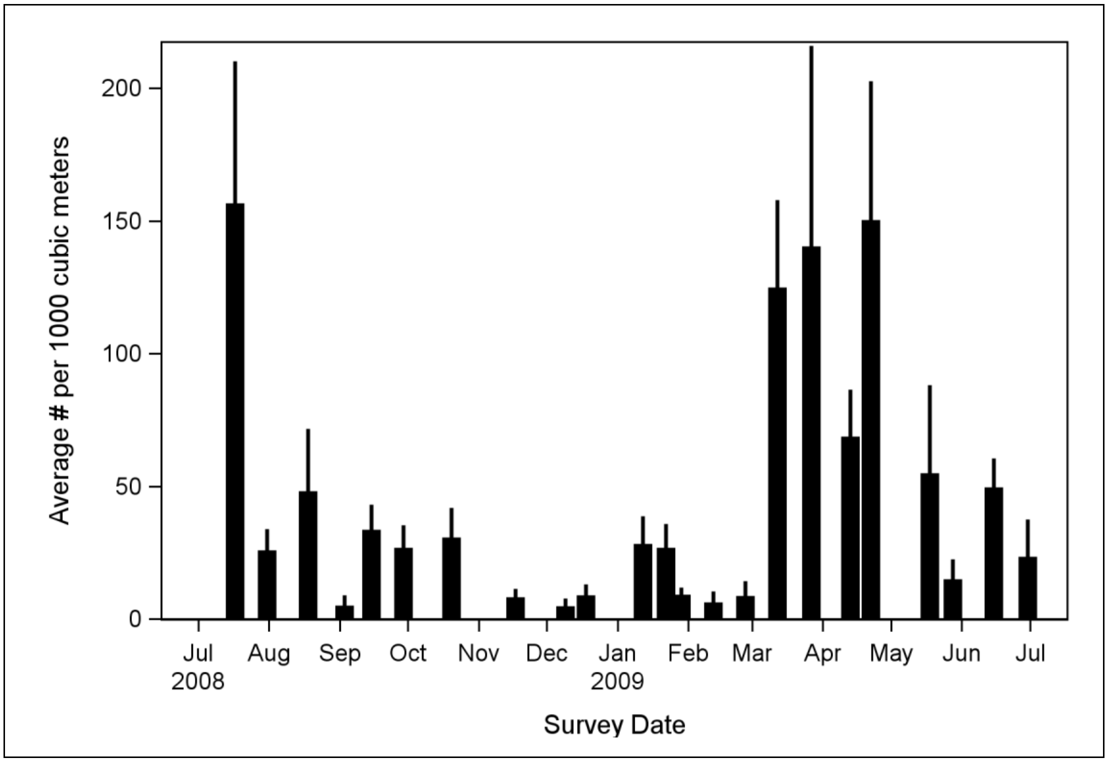


Figure 5-12. Survey mean concentration (#/1,000 m^3) of snubnose sculpin larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

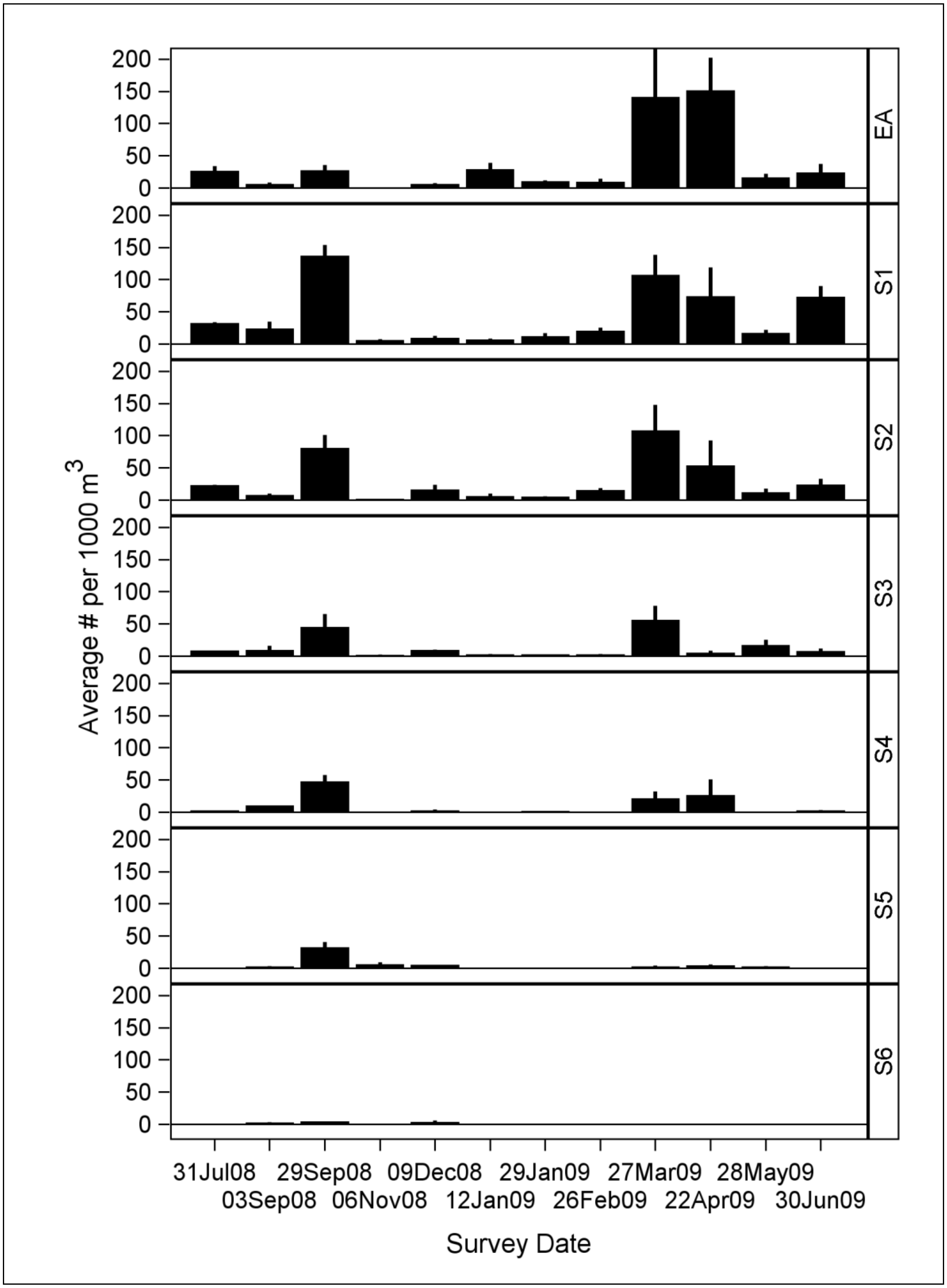


Figure 5-13. Survey mean concentration (#/1,000 m^3) of snubnose sculpin larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

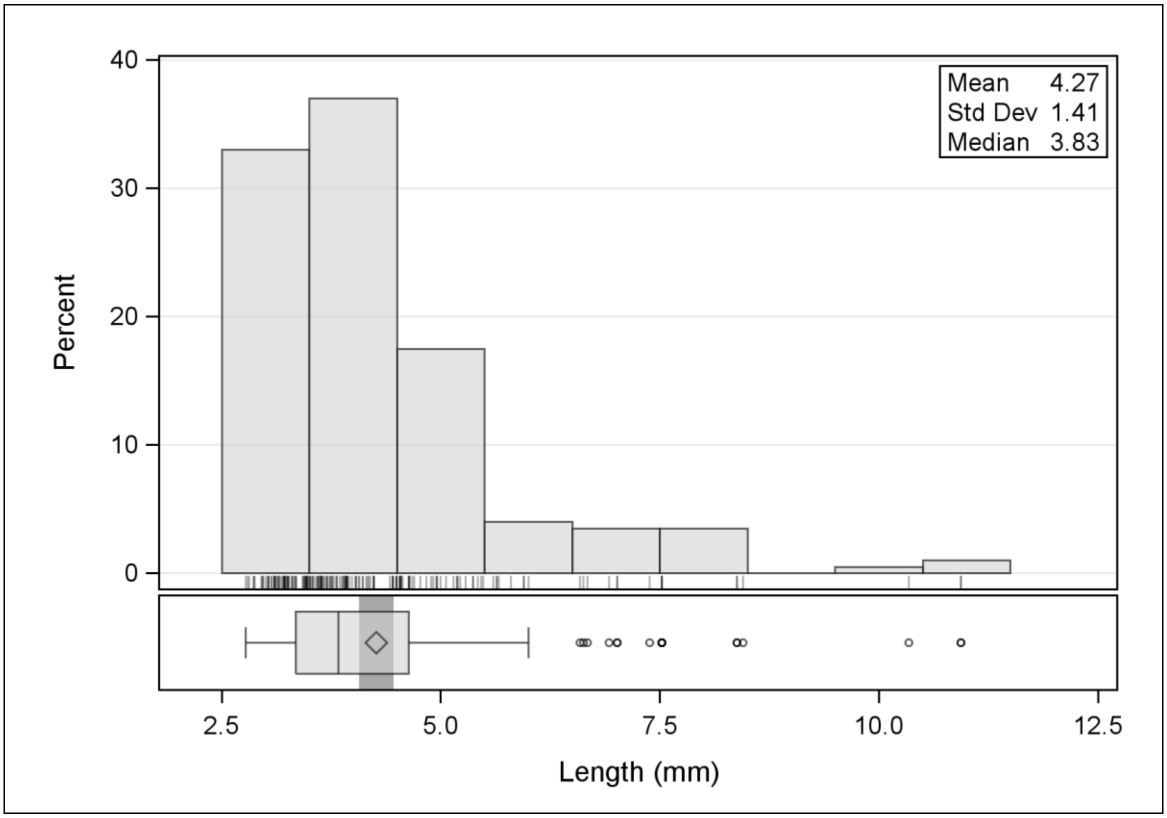


Figure 5-14. Length frequency histogram and statistics for snubnose sculpin based on a sample of 200 larvae proportionally sampled with replacement from the 559 snubnose sculpin larvae measured.

Entrainment Effects

An estimated 145.3 million snubnose sculpin larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary demographic information was not available for this species.

An *ETM* estimate of P_M was calculated for species because the results indicate that the sampling provided a reasonable estimate of nearshore larval abundances because the larvae were collected across the entire source water sampling stations, even though the highest abundances tended to occur inside the Intake Cove (**Figure 5-13**). The pattern of abundances across the stations is not unexpected as snubnose sculpin are associated with shallow, rocky reef habitats; the type of habitat created with the construction of the Intake Cove. The larvae for this species were also collected during all, but one, of the surveys providing a robust estimate of P_M. The results of the *ETM* for this species will be used in the *HPF* assessment presented in Section 6.0.

Empirical Transport Model (*ETM*)

The larval growth rate for this species was calculated from data presented in Shanks and Eckert (2005) and Moser (1996) on the hatch sizes, transformation lengths, and planktonic larval durations of snubnose sculpin and other similar species. The reported planktonic duration of 48 d and transformation size of 9.5 mm (0.37 in.) were used with the computed hatch size from the data collected from this study to compute a larval growth rate of 0.14 mm/d (10.2 mm–3.25

mm/48 d [0.40-0.13 in/48 d]). The estimated period of entrainment exposure of 21.6 d was calculated by dividing the difference between the estimated hatch length of 3.25 mm (0.13 in.) and the size of the 95th percentile value of 6.37 mm (0.25 in.) by the estimated larval growth rate. The entrainment exposure duration was calculated from size and growth values with greater decimal precision than those shown, and differs slightly from the duration calculated using these rounded values.

The data used to calculate the *ETM* estimates for snubnose sculpin show that approximately 70% of the larvae were collected from the source water stations in three surveys: September 2008, March 2009, and April 2009 (**Table 5-11**). Only alongshore extrapolations of the source water populations were calculated since adult snubnose sculpin occurs at depths less than the 60 m (200 ft) at the outer edge of the sampling area. The average alongshore displacement was estimated at 20.63 km (12.82 mi) from the backprojections calculated from the CODAR data **Table 5-11**). The P_M estimate for the 21.6-day period of exposure was 0.1979 (19.8%) (**Table 5-12**).

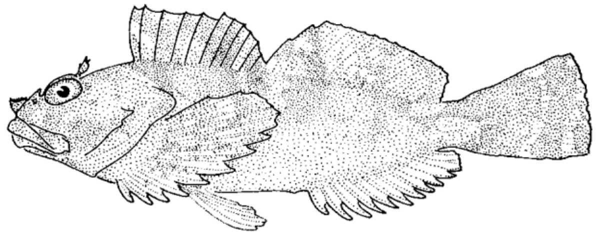
Table 5-11. *ETM* data for snubnose sculpin larvae using alongshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from surveys with *PE* > 0.

	Alongshore			
Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	Alongshore Displacement (km)
31-Jul-08	0.01362	0.00151	0.0585	26.20
3-Sep-08	0.00540	0.00143	0.0447	13.44
29-Sep-08	0.00296	0.00035	0.3321	18.45
6-Nov-08	0	0	0.0193	26.07
9-Dec-08	0.00650	0.00147	0.0477	10.94
12-Jan-09	0.08775	0.01571	0.0110	16.18
29-Jan-09	0.02399	0.00350	0.0096	9.85
26-Feb-09	0.00451	0.00106	0.0233	26.57
27-Mar-09	0.01643	0.00330	0.2085	23.31
22-Apr-09	0.02189	0.00382	0.1410	31.87
28-May-09	0.00821	0.00167	0.0448	30.20
30-Jun-09	0.01041	0.00236	0.0595	19.87
Average =	0.018334			20.63

Table 5-12. Estimates for *ETM* models for snubnose sculpin larvae calculated using alongshore extrapolations based on current data from CODAR backprojected from the survey date with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP.

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	20.63	0.19791	0.02309	0.22100	0.17482

5.4.1.4 Cabezon (Scorpaenichthys marmoratus)



Scorpaenichthys marmoratus (Ayres 1854); cabezon; length to 99 cm (39 in.); Sitka, Alaska to Punta Abreojos, central Baja California; intertidal to approx. 85 m (280 ft); brown, reddish, or greenish above whitish or greenish below (Miller and Lea 1972; Eschmeyer et al. 1983).

Reproduction, Age, and Growth

The cabezon (*Scorpaenichthys marmoratus*) is the largest North American species of marine cottid and occurs over the nearshore continental shelf from depths of 85 m (280 ft) up to the intertidal zone (O'Connell 1953; Matarese et al. 1989). Cabezon are a popular sport fish and are also landed commercially (Fitch and Lavenberg 1971; Lamb and Edgell 1986). Females are oviparous and lay demersal, adhesive eggs in rocky crevices or on algae; males guard the egg nest until the pelagic larvae hatch (Burge and Schultz 1973; Feder et al. 1974; Matarese et al. 1989).

Moser (1996) indicates that cabezon larvae hatch at 3–6 mm (0.1-0.2 in.). They first appear in the water column around November or December and recruit to tidepools at around 40 mm (1.6 in.) SL in March off Moss Beach, California (R. R. Harry unpubl. data cited in O'Connell 1953), implying a 3–4 month planktonic duration. Females grow larger than males and begin to mature in their third year between 25–48 cm [9.8-19 in.] SL (Fitch and Lavenberg 1971), and all are mature by year five (Starr et al. 1998). Fecundity for this species has been reported in several sources: 45,000 eggs for a 43 cm (17 in.) SL specimen and 95,000 eggs for a 65 cm (26 in.) SL specimen (Hart 1973); mean fecundity of 48,700 eggs for a 1.4 kg (3.1 lb) female and 97,600 eggs for a 4.6 kg (10 lb) female (O'Connell 1953; Bane and Bane 1971); and up to 152,000 eggs from a 76 cm (30 in.) SL female (Starr et al. 1998). O'Connell (1953) stated that females spawn more than a single batch of eggs per year. In California, females live to 14 yr and males to around 13 yr (Grebel 2003, Cope and Key 2009; **Figure 5-15**).

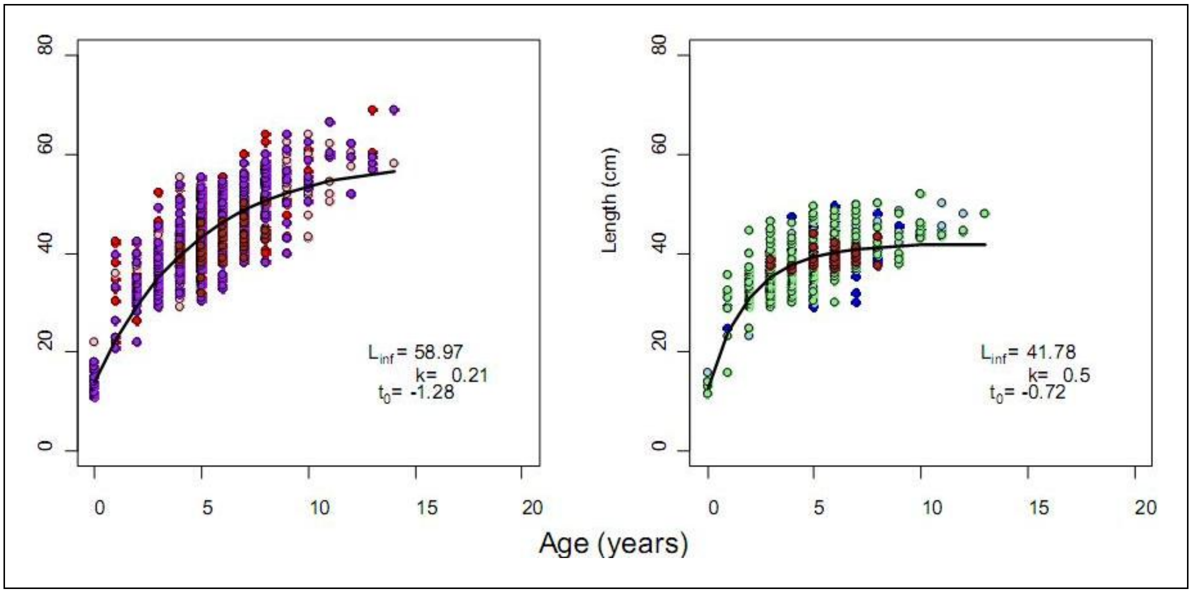


Figure 5-15. Age and growth fits and parameter estimates for the von Bertalanffy growth function incorporating multiple age reads (differing colored circles) for females (left) and males (right). From Cope and Key (2009).

Population Trends and Fishery

Cabezon has a long history of utilization in both the sport and commercial fisheries in California. As a primarily recreational fishery for many years, catches from the commercial passenger fishing vessel (CPFV) fishery from 1947 to 1980 indicate that catches of cabezon were declining (Leet et al. 2001). Increases in commercial fishing of cabezon intensified significantly in the early 1990s as a new market for live fish was established. No management regulations existed for cabezon before 1982 when a size limit (30 cm, 12 in.) was set for recreationally caught cabezon off California. In 2000 this limit was raised to 36 cm (14 in.), and extended to include commercially retained fish. In 2001 it was increased further to 38 cm (15 in.). Recreational bag limits have been 10 fish/day in California since 2000. Cabezon are included in the California recreational regulatory complex of rockfish, cabezon, and greenlings (the RCG complex) and subject to seasonal closures for recreational fishers.

Cabezon is managed on a regional basis using the California Department of Fish and Wildlife northern/central (NCS) and southern California (SCS) management areas. The NCS, the major fished substock off California, was described as “healthy” in 2005, and was just above its target level (Cope and Key 2009). As of 2005, the reproductive output of the cabezon resource off California was estimated to be about 40.1% and 28.3% of unfished levels for the NCS and SCS, respectively.

Cabezon abundance trends based on data from the DCPP Receiving Water Monitoring Program (RWMP) studies on subtidal fishes showed a declining trend from 1986 through 1994 (**Figure 5 16**). Average abundance on control transects, though variable, was approximately 0.8 per 50 m transect prior to 1992. This dropped to approximately 0.3 per transect after 1992 and has stayed at this level through 2008. Prior to September 2001, the study area surrounding DCPP was open to nearshore commercial and sport fishing, but entry into the area was restricted after that time resulting in a permanent no-fishing reserve.

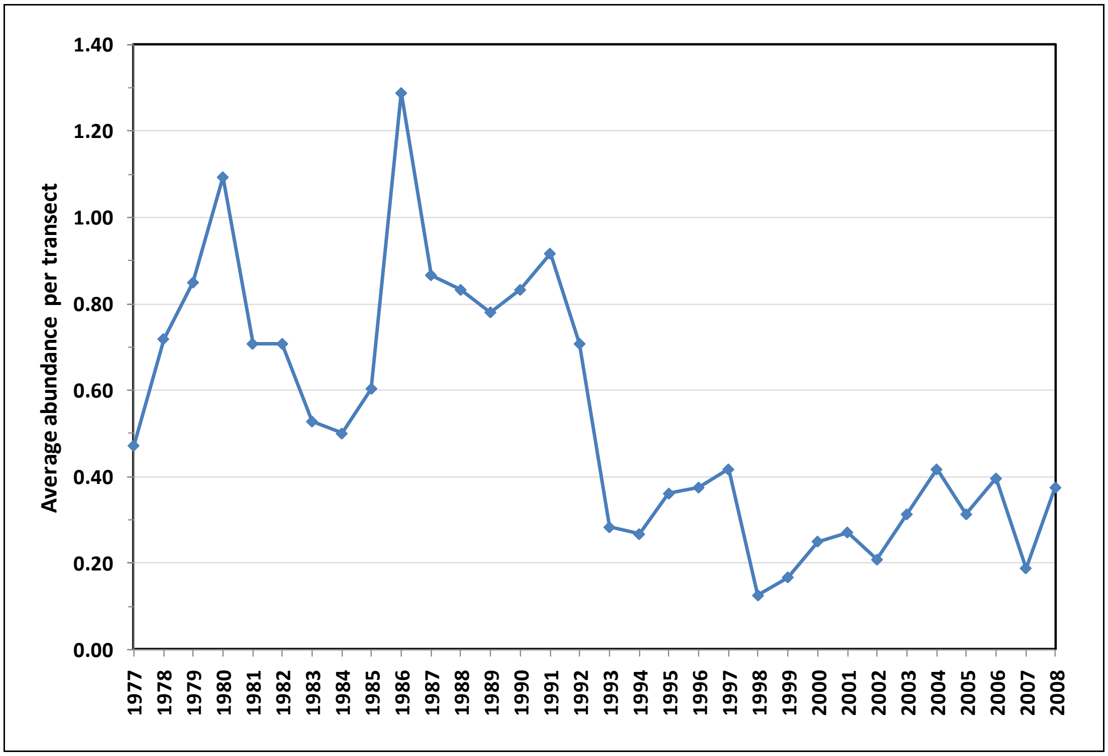


Figure 5-16. Average abundance of cabezon per 50x4 m transect at the DCPP control site.

Recreational fishery landings of cabezon have increased in central California in the five-year period since 2005 whereas commercial landings have decreased (**Table 5-13**). The average annual commercial landing weight was approximately three times greater than the estimated weight of recreational landings over the same time period. Over 163 MT (359,000 lbs) of cabezon was landed by the commercial fleet in the NCS in 1998, and this had declined to less than 20 MT (44,000 lbs) by 2008 (Cope and Key 2009). Recreational catches over the same period declined from 76 MT (167,551 lbs) to 19.7 MT (43,431 lbs).

Sampling Results

Larval cabezon was the twentieth most abundant taxon collected from the entrainment stations and twenty-eighth most abundant from the source water stations, comprising 0.9% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). Larvae were only present at the entrainment station from November through April. The mean concentration per survey ranged from zero to over 40 larvae per 1,000 m^3 peaking in abundance during January and February 2009 (**Figure 5-17**). Larvae occurred at all stations but were most abundant at the inshore stations EA and S1 (**Figure 5-18**).

Table 5-13. Cabezon recreational fishing catch in central California, and commercial fishing landings and ex-vessel value in San Luis Obispo County, 2005–2009. Data from RecFIN (2010) and PacFIN (2010).

Year	Recreational Fishery Estimated Catch (No.)	Recreational Fishery Estimated Weight (lbs)	Commercial Fishery Landings (lbs)	Commercial Fishery Ex-vessel Value ($)
2005	2,638	7,329	33,086	$182,771
2006	2,357	7,938	31,014	$183,120
2007	3,326	9,530	27,891	$175,987
2008	3,307	4,110	24,044	$153,454
2009	5,823	16,998	14,853	$85,945
Average	3,490	9,181	26,178	$156,255

The mean length of 200 specimens proportionally sampled with replacement from the 157 larvae measured was 5.32 mm (0.21 in.) (**Figure 5-19**). The smallest larva measured was 3.63 mm (0.14 in.) and the largest was 6.49 mm (0.26 in.). The reported hatch size for cabezon ranges from 3–6 mm (0.1-0.2 in.) (Moser 1996).The averages from the random samples proportionally drawn from all the measurements resulted in mean length of 5.35 mm (0.21 in.) for the mean and 5.31 mm (0.21 in.) for the median. The computed hatch length was 4.64 mm (0.18 in.), which is within the range reported by Moser (1996).

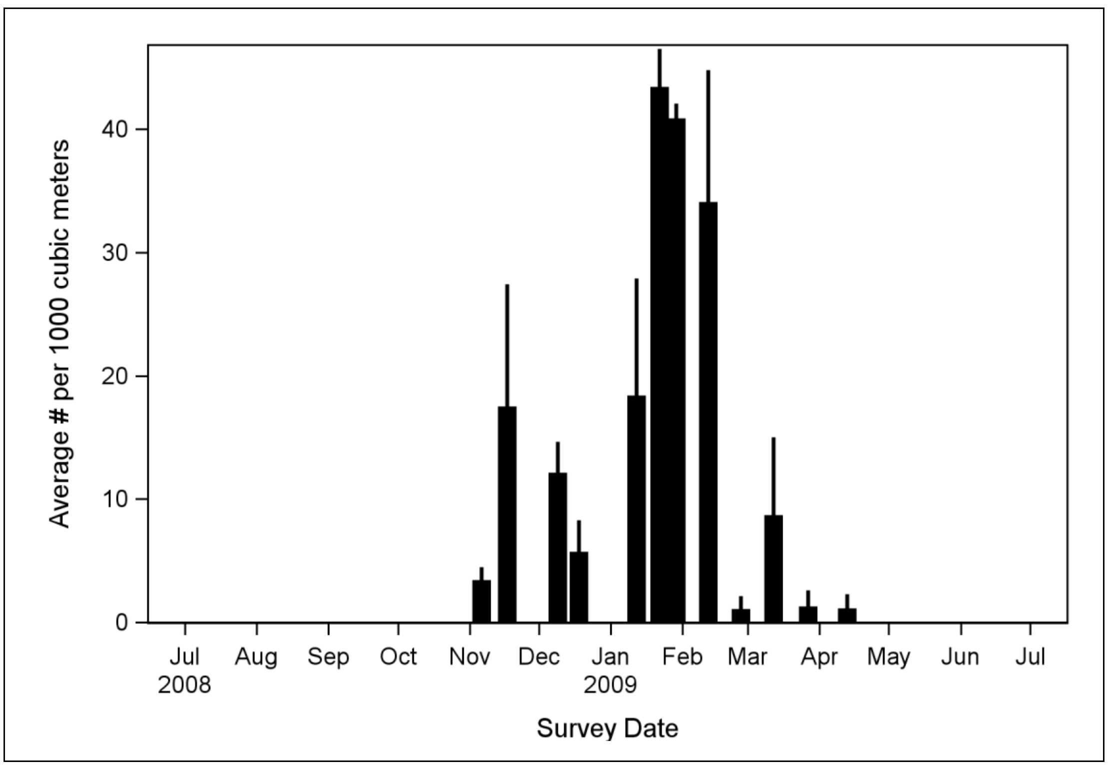


Figure 5-17. Survey mean concentration (#/1,000 m^3) of cabezon larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

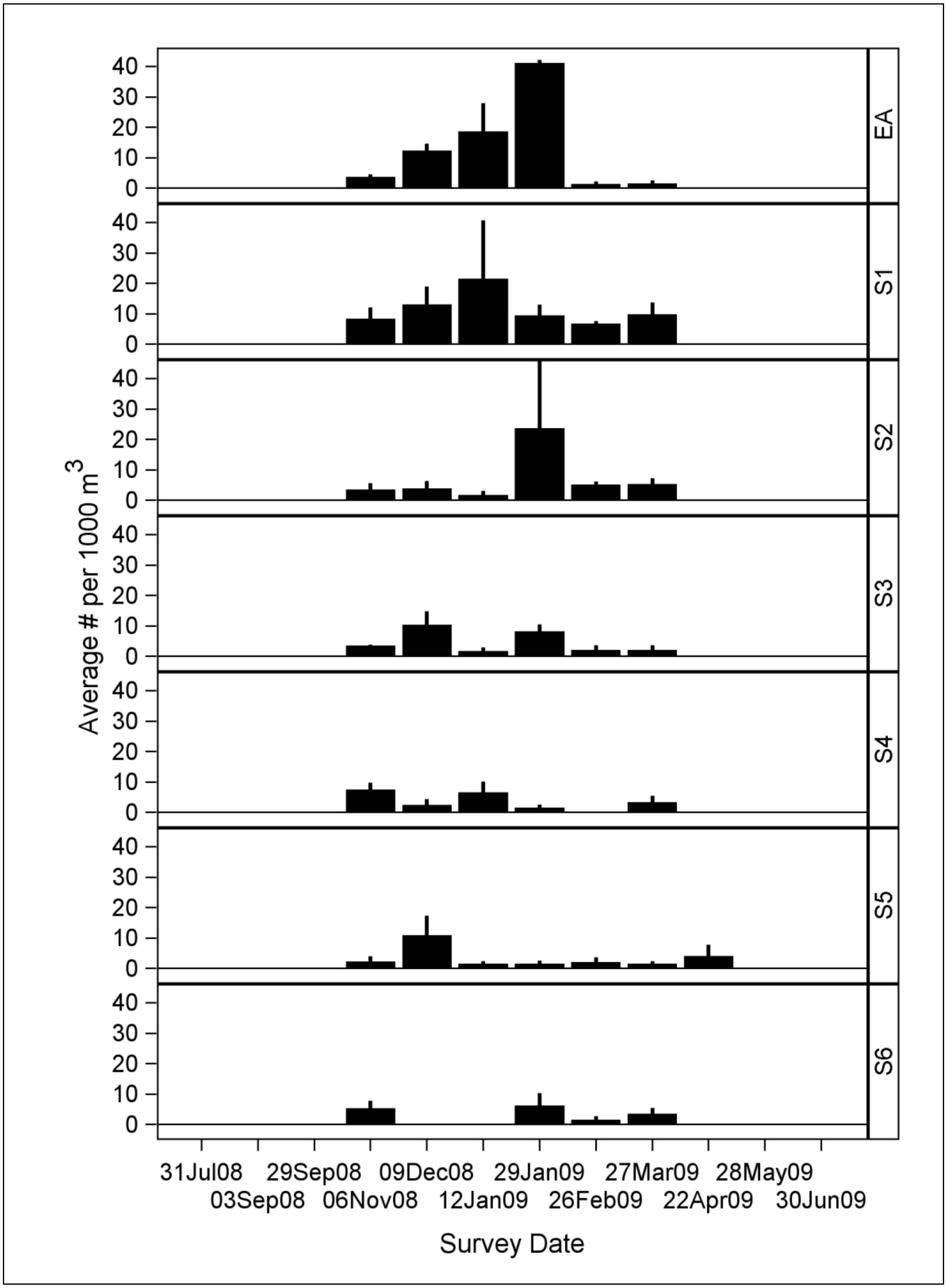


Figure 5-18. Survey mean concentration (#/1,000 m^3) of cabezon larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

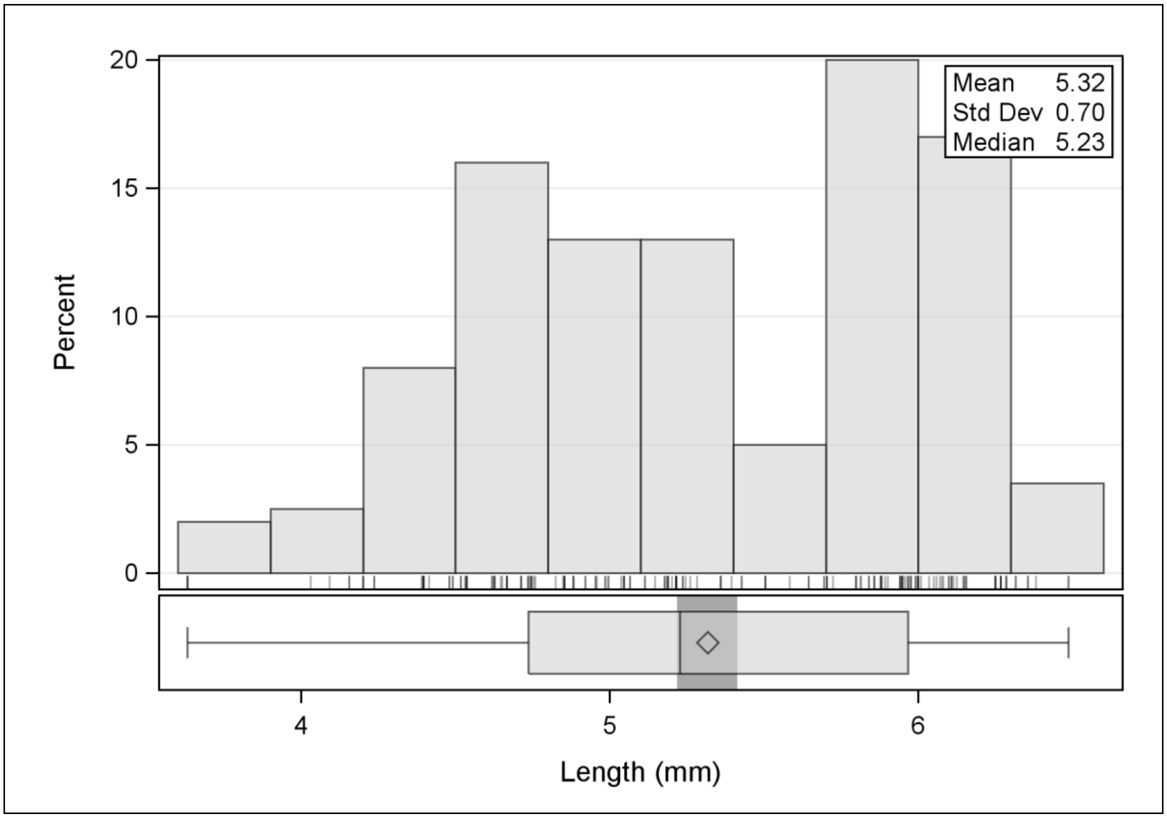


Figure 5-19. Length frequency histogram and statistics for cabezon based on a sample of 200 larvae proportionally sampled with replacement from the 157 cabezon larvae measured.

Entrainment Effects

An estimated 17.9 million cabezon larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary demographic information was not available for cabezon.

An *ETM* estimate of P_M was calculated for this species because the results indicate that the sampling provided a reasonable estimate of nearshore larval abundances because the larvae were collected across the entire source water sampling stations, even though the highest abundances tended to occur inside the Intake Cove (**Figure 5-18**). Even though only six estimates of *PE* were available from the sampling, those estimates do correspond to the spawning period for this species and likely represent the best available estimate of P_M. This species is also an important component of the sport and commercial fisheries and it is important to confirm that entrainment is not adding a large source of additional mortality which already occurs on adult stages of this species as a result of fishing. The results of the *ETM* for this species will be used in the *HPF* assessment presented in Section 6.0.

Empirical Transport Model *(ETM)*

The estimated larval growth rate for cabezon was calculated from information presented in Cope and Key (2009) who stated that the larvae spend 3–4 months as pelagic larvae and juveniles with settlement occurring after the young fish have reached 3–5 cm (1-2 in.) in length. Using this information and the computed hatch length from this study, a growth rate of 0.332 mm/d (0.013 in/d) was computed ((40 mm-4.64 mm) / (3.5 mo*(365.25 d/12 d)). The estimated period of entrainment exposure of 4.8 d was calculated by dividing the difference between the estimated hatch length of 4.64 mm (0.18 in.) and the size of the 95th percentile value of 6.24 mm (0.25 in.) by the estimated larval growth rate.

The data used to calculate the *ETM* estimates for cabezon show that they were most abundant during the November 2008 through January 2009 surveys (**Table 5-14**). Although both alongshore and offshore extrapolations of the source water populations were calculated, since cabezon are distributed to depths of 76 m (250 ft) (Miller and Lea 1972), the short larval duration resulted in onshore current vectors that were almost all within the outer edge of the sampled source water at 2,890 m (9,481 ft) offshore and identical to the alongshore displacement estimates (**Table 5-14**). An exception was the March 2009 survey were the alongshore displacement for the offshore extrapolation was 17.13 km (10.6 mi). This contributed to the difference in the two *ETM* estimates based on the CODAR backprojections and the differences in the alongshore and offshore areas included in the source water extrapolations, 7.88 and 8.41 km (4.89 and 5.23 mi) respectively (Table 5-15). The difference in the *PE* estimates using the two methods reflect the differences due to the offshore extrapolation of the source water populations. These differences are also reflected in the P_M estimates for the 4.8-day period of exposure which were 0.1123 (11.2%) and 0.0860 (8.6%) based on two source water area estimates from the CODAR backprojections (**Table 5-15**).

Table 5-14. *ETM* data for cabezon larvae using alongshore and offshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from all surveys with *PE* > 0.

Survey Date	Alongshore		Offshore Extrapolated		f_i	Alongshore Displacement (km)
	PE Estimate	*PE* Std. Err.	*PE* Estimate	*PE* Std. Err.		
31-Jul-08	0	0	0	0	0	6.88
3-Sep-08	0	0	0	0	0	3.74
29-Sep-08	0	0	0	0	0	3.97
6-Nov-08	0.00832	0.00118	0.00605	0.00085	0.2056	7.48
9-Dec-08	0.02546	0.00366	0.02005	0.00288	0.2550	6.34
12-Jan-09	0.08105	0.01989	0.05488	0.01347	0.1105	5.49
29-Jan-09	0.04021	0.00530	0.03255	0.00429	0.1945	6.22
26-Feb-09	0.00274	0.00102	0.00152	0.00057	0.0783	7.78
27-Mar-09	0.00832	0.00086	0.00121	0.00045	0.1105	13.94
22-Apr-09	0	0	0	0	0.0455	4.70
28-May-09	0	0	0	0	0	5.28
30-Jun-09	0	0	0	0	0	6.17
Average =	0.02768		0.01938			7.88

Table 5-15. Estimates for *ETM* models for cabezon larvae calculated using alongshore and offshore extrapolations based on current data from CODAR backprojected from the survey date with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP.

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	7.88	0.11277	0.04045	0.15272	0.07182
Offshore Extrapolated P_M	8.41	0.08601	0.04128	0.12729	0.04473

5.4.2 Rockfishes (Scorpaenidae)

Rockfishes (*Sebastes* spp.) belong to the family Scorpaenidae that contains two other genera: the scorpionfishes (*Scorpaena* spp.) and the thornyheads (*Sebastolobus* spp.). The rockfishes (*Sebastes* spp.) are the most diverse genus in the Scorpaenidae with some 62 species reported from California coastal waters (Starr et al. 1998), approximately 85% of which are harvested in California commercial or sport fisheries. They are also abundant in nearshore California habitats and play important trophic and ecological roles in these communities (Love et al. 2002). They comprise a large component of the shallow subtidal fish community, ranging from nearshore coastal habitats (e.g., kelp forests) to the continental shelf. Adult California scorpionfish (*Scorpaena guttata*) are reported as far north as Santa Cruz, California, but adults are most common in waters south of Point Conception where they are an important component of the sport and commercial catch between Santa Monica Bay and San Diego, California (Leet et al. 1992; Love 1996). No California scorpionfish larvae were entrained at DCPP during the study. Commercial landings of rockfishes (*Sebastes* spp.) have historically included fishes in the genus *Sebastolobus* (thornyheads) represented by two species common in deepwater shelf habitats: the shortspine thornyhead (*Sebastolobus alascanus*) and the longspine thornyhead (*S. altivelis).*

Reproductive capacity of rockfishes is directly related to size, with larger females carrying significantly more eggs than smaller females. Rockfishes are viviparous with internal fertilization (Yoklavich et al. 1996), and the female retains the eggs until she extrudes thousands of eyed, live larvae (Bloeser 1999). The larvae and juveniles can remain in the plankton from one month to as long as one year before settling into primarily benthic habitats as juveniles (Matarese et al. 1989; Moser 1996; Starr et al. 1998; Love et al. 2002). This extended planktonic period makes environmental variation an important determinant of the population abundance of many rockfish species since their vulnerable life stages are exposed to potentially adverse conditions for greater periods of time. Once on the bottom, individuals of many species migrate to deeper water as they mature.

Many rockfish species are closely related, and the larvae share many morphological and meristic characteristics, making it difficult to visually identify the individual larvae to species (Moser et al. 1977; Moser and Ahlstrom 1978; Baruskov 1981; Kendall and Lenarz 1987; Moreno 1993). To standardize the identification of *Sebastes* spp. larvae, rockfish larvae were grouped by pigment characteristics and representative samples from these groups were identified to the species level using genetic analysis (see Section 5.4.2.1 – *Sebastes* spp. Identification).

5.4.2.1 *Sebastes* spp. Identification

A representative sample of 987 *Sebastes* larvae was selected from the three taxonomic categories (*Sebastes* V [Blue rockfish complex], *Sebastes* V_ [KGB complex], and *Sebastes* spp.) and identified to the species level using DNA analysis. The *Sebastes* V complex was found to be comprised of fifteen species, 78.0% of which were blue rockfish (**Table 5-16**). The next most abundant species in the *Sebastes* V complex was squarespot (6.4%) followed by olive rockfish (6.0%) and treefish (2.4%). The *Sebastes* V_ complex was comprised of nine species, 80.0% of which were in the gopher/black-and-yellow complex. (These two species could not be unambiguously separated based on the DNA analysis protocol used in this study). The next most abundant species was kelp rockfish (13.2%) followed by grass rockfish (2.0%). The *Sebastes* spp. complex included larvae with irregular pigmentation that could not be confidently classified visually as either *Sebastes* V or *Sebastes* V_. It was comprised of eleven species, all of which were also found in at least one of the other two groups. The *Sebastes* spp. complex included halfbanded (24.4%), gopher/black-and-yellow (17.8%), and brown rockfishes (11.1%).

Blue, gopher/black-and-yellow, and kelp rockfishes had a predominantly inshore distribution whereas squarespot, halfbanded, rosy and chilipepper rockfishes were more abundant at the offshore stations (**Table 5-17)**. Species richness increased with distance from shore with as few as 8 species identified from station S1 and as many as 18 from station S5. Detailed descriptions of the temporal and spatial distributions of the blue rockfish complex and KGB complex are presented in the following sections.

Table 5-16. Percent species composition of Sebastes larval taxa categories based on DNA analysis.

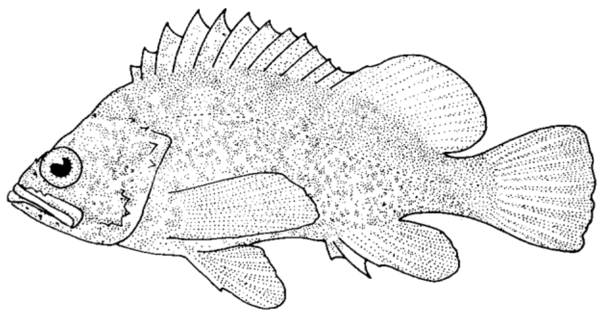
Sebastes species	Rockfish common name	Number identified	*Sebastes* V "Blue rockfish complex"	*Sebastes* V_ "KGB rockfish complex"	Sebastes spp.
S. atrovirens	kelp	60	-	13.15	4.44
S. auriculatus	brown	12	-	1.59	11.11
S. carnatus/chrysomelas	gopher/black-and-yellow	361	-	80.05	17.78
S. caurinus	copper	6	-	1.36	-
S. constellatus	starry	7	0.80	-	6.67
S. crocotulus	sunset	1	0.20	-	-
S. dalli	calico	6	-	0.45	8.89
S. entomelas	widow	3	0.60	-	-
S. flavidus	yellowtail	1	0.20	-	-
S. gilli	bronzespotted	1	0.20	-	-
S. goodei	chilipepper	4	0.80	-	-
S. hopkinsi	squarespot	35	6.39	-	6.67
S. jordani	shortbelly	8	1.60	-	-
S. levis	cowcod	1	0.20	-	-
S. mystinus	blue	397	78.04	0.91	4.44
S. nebulosus	china	1	-	0.23	-
S. paucispinis	bocaccio	1	0.20	-	-
S. rastrelliger	grass	12	-	2.04	6.67
S. rosaceus	rosy	12	2.00	-	4.44
S. semicinctus	halfbanded	14	0.40	0.23	24.44
S. serranoides	olive	30	5.99	-	-
S. serriceps	treefish	14	2.40	-	4.44
	Percent		100.00	100.00	100.00
Total number identified		987	501	441	45

Table 5-17. Average concentration (abundance per 1,000 m^3) of larval Sebastes species by station from the period January through June 2009.

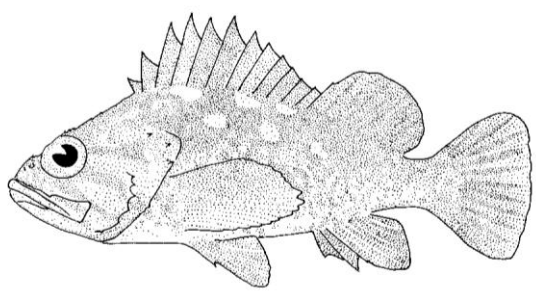
Rockfish Species Names	Common Names	Stations						
		EA	S1	S2	S3	S4	S5	S6
S. atrovirens	kelp	19.87	12.81	2.43	9.47	3.21	-	-
S. auriculatus	brown	1.33	1.16	-	4.90	1.07	2.99	3.09
S. carnatus/chrysomelas	gopher/black-and-yellow	84.05	47.75	50.75	53.09	28.92	29.52	24.68
S. caurinus	copper	1.74	-	-	-	-	-	3.09
S. constellatus	starry	-	-	-	-	-	3.01	7.20
S. crocotulus	sunset	-	-	-	-	-	1.25	-
S. dalli	calico	0.75	-	2.16	-	2.34	2.99	-
S. entomelas	widow	-	-	0.96	-	1.20	1.25	-
S. flavidus	yellowtail	-	-	-	-	-	-	1.35
S. gilli	bronzespotted	-	-	-	-	-	1.25	-
S. goodei	chilipepper	-	-	-	-	-	2.49	2.71
S. hopkinsi	squarespot	0.53	2.38	0.96	1.12	9.75	8.73	20.52
S. jordani	shortbelly	-	-	-	2.24	-	2.49	5.41
S. levis	cowcod	-	-	-	-	-	1.25	-
S. mystinus	blue	103.74	60.68	51.85	52.61	27.62	17.44	17.59
S. nebulosus	china	-	-	-	-	1.07	-	-
S. paucispinis	bocaccio	-	-	-	-	-	1.25	-
S. rastrelliger	grass	-	-	2.16	2.50	5.36	1.76	3.09
S. rosaceus	rosy	-	-	-	1.12	4.87	4.25	5.41
S. semicinctus	halfbanded	-	3.36	-	-	1.27	7.75	10.77
S. serranoides	olive	4.76	8.33	7.68	-	3.60	3.74	-
S. serriceps	treefish	0.75	3.57	1.92	2.24	3.67	2.49	1.35
	Total	217.53	140.05	120.88	129.29	93.96	95.90	106.26
Number of species		9	8	9	9	13	18	13

5.4.2.2 KGB Complex (*Sebastes* spp. V_)

The rockfishes that comprise the KGB complex can be considered a guild of nearshore, benthic, or epi-benthic rockfishes sharing similar morphology and ecological roles. The three species (kelp, gopher, and black-and-yellow rockfishes) are common to Diablo Canyon nearshore habitats are described in the following section.



Sebastes atrovirens (Jordan and Gilbert 1880); kelp rockfish; length to 42 cm (17 in.); Timber Cove, northern California to Punta San Pablo, central Baja California; inshore to 46 m (150 ft); olive-brown to gray brown, with darker brown mottling, sometimes pinkish below (Miller and Lea 1972; Eschmeyer et al. 1983)



Sebastes carnatus (Jordan and Gilbert 1880); gopher rockfish; length to 30 cm (12 in.); Eureka, northern California to San Roque, central Baja California; inshore to 80 m (262 ft); brownish to olive, mottled with pale areas, flesh-colored to slightly whitish areas on back (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2002).

Sebastes chrysomelas (Jordan and Gilbert 1881); black-and-yellow rockfish; length to 39 cm (15 in.); Eureka, northern California to Isla Natividad, central Baja California; intertidal to 37 m (120 ft); mostly blackish or olive-brown, with large irregular yellow areas on back, paler below (Miller and Lea 1972; Eschmeyer et al. 1983).

Reproduction, Age, and Growth

Kelp rockfish fecundity ranges from 344 to 403 eggs/g (female body weight), and spawning occurs once during late winter to spring (MacGregor 1970; Love et al. 1990; Moser 1996). The reproductive period lasts about 7 months (Lea et al. 1999) and parturition occurs in April and

May (Moreno 1993). Larval kelp rockfish are extruded at around 4.0 mm (0.16 in.) (Moser 1996). Young-of-the-year (YOY) first appear under nearshore kelp canopies from July through August and then as schooling fish in the water column from August through October. Lengths of YOY ranged from 20 to 40 mm TL (0.8–1.6 in.) (Lea et al. 1999).

Longevity for the kelp rockfish is estimated at 25 yr but few are older than 20 yr (Love et al. 2002). The smallest sexually mature male was 246 mm (9.69 in.) TL at 4 yr, and the largest immature male was 338 mm (13.3 in.) TL (not aged; Lea et al. 1999). The smallest sexually mature female was 160 mm (6.3 in.) TL at 3 yr, and the largest immature female was 320 mm (13 in.) TL at 7 yr (Lea et al. 1999). Females attain 50% maturity at 3.5 yr and 100% maturity at 6 yr (Bloeser 1999).

Gopher rockfish fecundity ranges from 176–307 eggs/g female weight, and spawning occurs once per season in spring (MacGregor 1970; Wyllie Echeverria 1987; Moser 1996). Fecundity has been measured at about 425,000 eggs in a 260 mm (10 in.) fish from central California and 175,000 eggs from a similar sized fish in southern California (Love et al. 2002). The reproductive period lasts 10 months (Lea et al. 1999), and parturition occurs in March–May (Moreno 1993). Planktonic duration is approximately 2–3 months (Larson 1980). Metamorphosing juveniles first appear in nearshore habitats in mid- to late-June (Larson 1980). YOY first appear associated with nearshore reefs in July and August at 20 to 40 mm (0.8 to 1.6 in.) TL (Lea et al. 1999).

Longevity for the gopher rockfish was estimated at 30 yr, but few live longer than 20 yr (Love et al. 2002). A 24 yr old (316 mm TL) tagged fish reported by Lea et al. (1999) grew only 4 mm (0.2 in.) in nearly 11 years between capture dates. A 15 yr old tagged fish (282 mm TL) grew 10 mm (0.4 in.) TL in 6.7 yr between capture dates (Lea et al. 1999). The smallest sexually mature male in their study was 237 mm (9.33 in.) TL at 10 yr, and the largest immature male was 237 mm TL at 10 yr (Lea et al. 1999). The smallest sexually mature female was 207 mm (8.15 in.) TL (not aged), and the largest immature female was 306 mm (12 in.) TL at 9 yr (Lea et al. 1999). Females are estimated to attain 50% maturity at 4 yr (Wyllie Echeverria 1987; Bloeser 1999).

Parturition timing and early development of black-and-yellow rockfish is similar to that of other species in the KGB complex. Black-and-yellow rockfish spawn between February and May (Larson 1980; Wyllie Echeverria 1987), and larvae are released annually (Lea et al. 1999). YOY have been observed in kelp beds in July and August at ca. 20 to 30 mm (0.8 to 1.2 in.) TL (Lea et al. 1999).

Longevity for the black-and-yellow rockfish was estimated at 21 yr (Lea et al. 1999). Age estimates were validated for fish up to about 5 yr and assumed to be accurate for older fish (Lea et al. 1999). The smallest sexually mature male was 239 mm (9.41 in.) TL at 4 yr, while the largest immature male was 301 mm (11.9 in.) TL at 9 yr (Lea et al. 1999). The smallest sexually mature female was 243 mm (9.57 in.) TL at 6 yr and the largest immature female was 270 mm (10.6 in.) TL at 7 yr (Lea et al. 1999). Females are estimated to attain 50% maturity at 3 yr and 100% maturity at 4 yr (Wyllie Echeverria 1987; Bloeser 1999).

Most adults of species in the KGB complex live on or near the bottom of nearshore kelp beds and rocky reefs with peak abundance found at less than 50 to 100 m (160 to 330 ft) depth (Love

1996). The notable exception to this distribution is the halfbanded rockfish (*Sebastes semicinctus*), which is commonly observed on hard and soft, flat bottom habitat in waters up to 402 m (1,320 ft) deep (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996). The southern end of the geographic ranges for all members of this group begins off central Baja California, Mexico, with the exception of quillback and China rockfishes (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996). These latter two species begin their distribution near San Miguel Island off southern California (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996). The northern distribution of this group ranges from Monterey Bay and San Francisco, California for halfbanded and calico, and to the northern Gulf of Alaska for brown, copper, and China rockfishes (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996). Fishes with the most northerly distributions in this group typically attain the greatest total lengths and ages for the complex. Brown, copper, quillback, and grass rockfishes can attain maximum lengths of >50 cm (20 in.) (Miller and Lea 1972; Eschmeyer et al. 1983). This is also true for estimated longevity. Copper and quillback rockfishes may reach 41 yr and 76 yr, respectively, in the Canadian fishery (Yamanaka and Kronlund 1997). The smallest and shortest living rockfish of this group is the calico rockfish that attains a total length of 25 cm (9.8 in.) and has an estimated longevity of about 12 yr (Chen 1971; Miller and Lea 1972; Eschmeyer et al. 1983). The calico rockfish also has the lowest fecundity recorded in the KGB complex at about 2,000 eggs per female at 50% maturity but ranging to as high as 113,000 eggs per female (Haldorson and Love 1991). The most fecund rockfish from this group is the grass rockfish with about 760,000 eggs for a 26 cm (10 in.) female (Love and Johnson 1999). The highest age range at 50% maturity is 6–11 yr for quillback rockfish (Wyllie Echeverria 1987; Yamanaka and Kronlund 1997).

Population Trends and Fishery

Subtidal fish abundance estimates at the DCPP South Control station from 1978 to 2008 have shown differing long-term trends for KGB complex fishes. Black and yellow rockfish (*S. chrysomelas*) has shown a long-term decline from a peak of approximately 4.0 per 50 m transect in the early 1980s to approximately 1.5 per transect in the 1997–2008 period (**Figure 5-20**). In contrast, kelp rockfish (*S. atrovirens*) has increased steadily over time from an average of approximately 0.3 per transect to 0.6 per transect. Grass rockfish (*S. rastrelliger*) was targeted for the live-fish fishery in the early 1990s and declined substantially during that period, after which the species showed a variable but steady increase. No fishing has been allowed in the nearshore area around DCPP since 2001.

Rockfishes in the KGB complex have both commercial and recreational fishery value (Starr et al. 1998; Bloeser 1999; Lea et al. 1999). Commercial groundfish landings from all gear types reported by Pacific States Marine Fishery Council (PSMFC) in the PacFIN database for the years 2005–2009 show combined landings of black-and-yellow, gopher, kelp, and grass rockfishes in central California averaging 56,787 lbs (25,758 kg) per year with an annual ex-vessel value of $450,580 (**Table 5-18**). Starr et al. (1998) note that while catches were stable or increasing between in the 1980s and 1990s, the abundance of these species was much higher before 1980. Recreational landings in San Luis Obispo County during the 2005–2009 time period averaged nearly 75,000 fish per year.

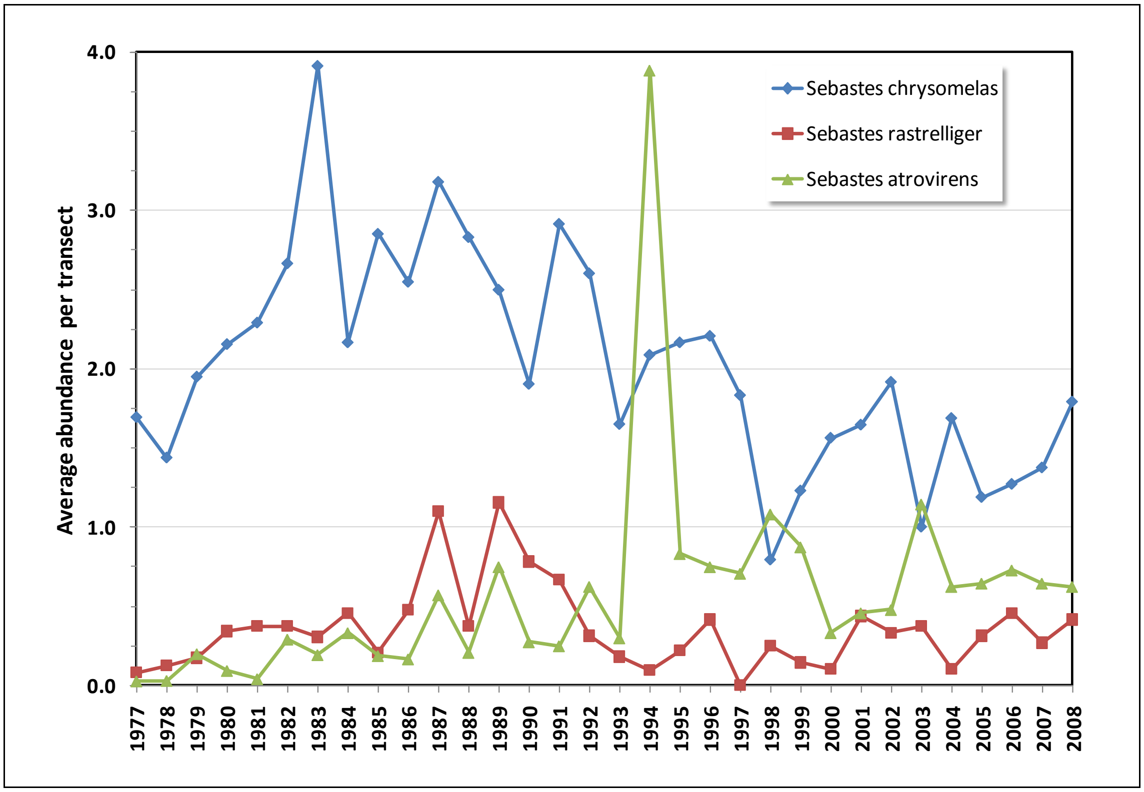


Figure 5-20. Average abundance per 50 x 4 m transect for three species of rockfishes (YOY not included) at the DCPP control site.

Table 5-18. KGB complex* recreational fishing catch in central California, and commercial fishing landings and ex-vessel value in San Luis Obispo County, 2005-2009. Data from RecFIN (2010) and PacFIN (2010).

Year	Recreational Fishery		Commercial Fishery	
	Estimated Catch (No.)	Estimated Weight (lbs)	Landings (lbs)	Ex-vessel Value ($)
2005	68,082	57,383	50,529	$389,802
2006	66,210	59,411	48,285	$403,477
2007	63,330	55,803	62,463	$516,058
2008	74,578	54,715	67,800	$547,909
2009	100,370	88,296	54,859	$395,656
Average	74,514	63,122	56,787	$450,580

* includes data for kelp, gopher, black and yellow, and grass rockfish species.

Sampling Results

Rockfish larvae from the KGB complex (*Sebastes* spp. V_) were the second most abundant taxon collected from the entrainment stations and eight most abundant from the source water stations, comprising 9.5% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). Larvae were present at the entrainment station from February through July (**Figure 5-21**).

The mean concentration per survey ranged from zero to over 500 larvae per 1,000 m^3 peaking in abundance during May 2009 (**Figure 5-21**). Larvae occurred at all stations and had a gradient of decreasing abundance with distance offshore (**Figure 5-22**).

The mean length of 200 specimens proportionally sampled with replacement from the 403 larvae measured was 4.18 mm (0.16 in.) (**Figure 5-23**). The smallest larva of the 403 measured was 2.74 mm (0.11 in.) and the largest was 7.25 mm (0.29 in.). Reported length at birth for gopher rockfish, *Sebastes carnatus*, is approximately 4.15 mm (0.16 in.) (Moser 1996), indicating that most of the larvae were recently extruded. The random samples proportionally drawn from all the measurements resulted in averages of 4.16 mm (0.16 in.) for the mean length and 4.13 mm (0.16 in.) for the median. The computed hatch length was 3.74 mm (0.15 in.) which is less than the value reported by Moser (1996). Therefore, the average 25th percentile length of 3.83 mm (0.15 in.) was used as the hatch length for the *ETM* calculations.

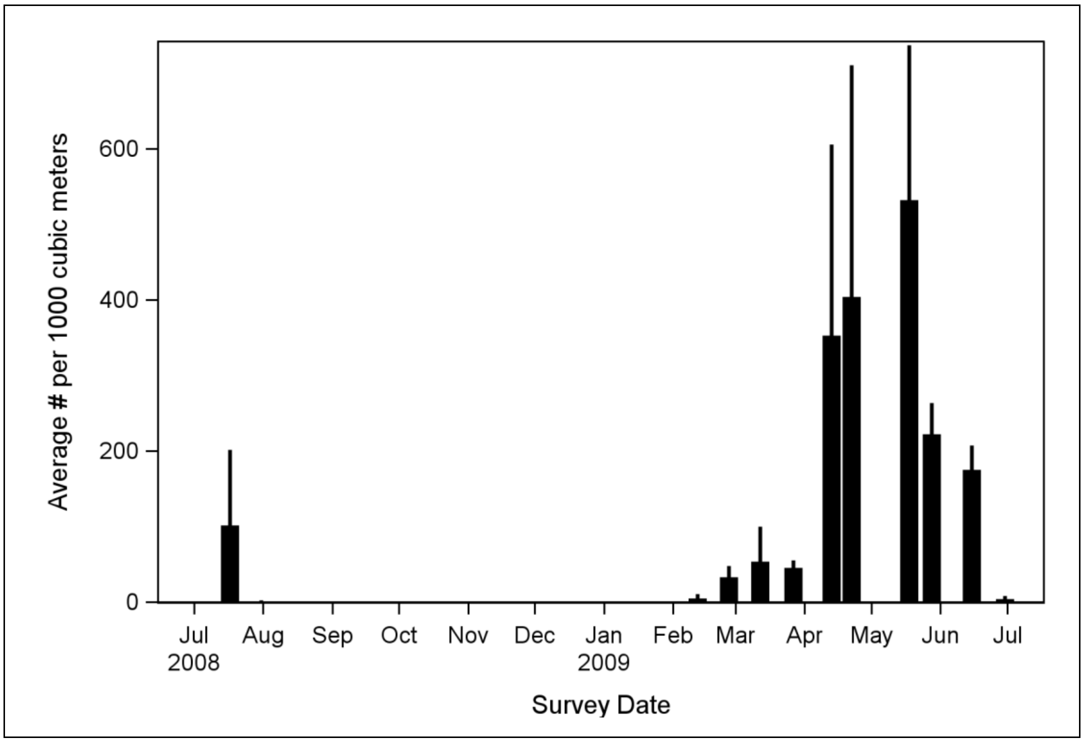


Figure 5-21. Survey mean concentration (#/1,000 m^3) of KGB complex rockfish larvae (*Sebastes* spp. V_) collected at the DCPP entrainment stations with standard error indicated (+1 SE).

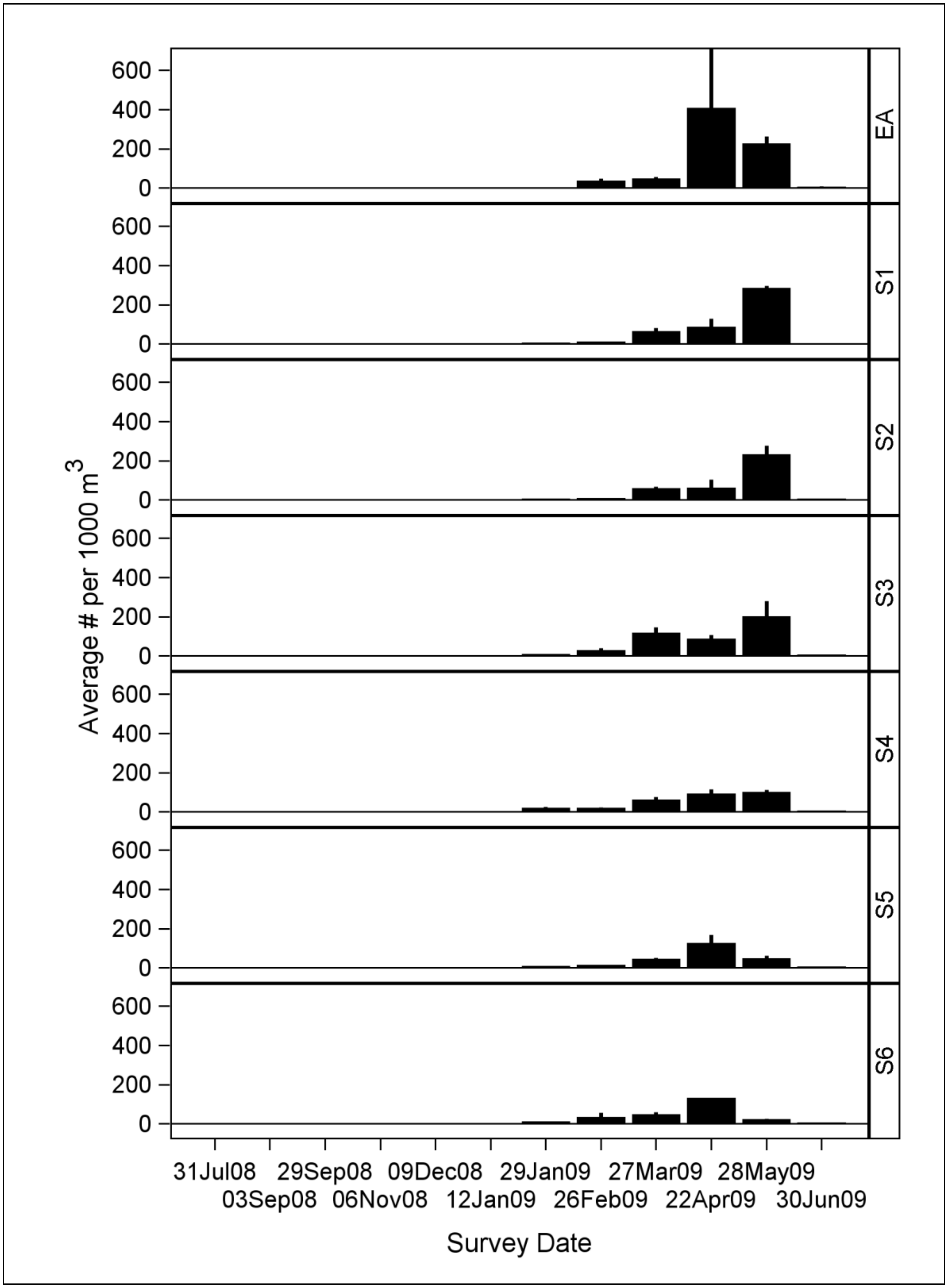


Figure 5-22. Survey mean concentration (#/1,000 m^3) of KGB complex rockfish larvae (*Sebastes* spp. V_) collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

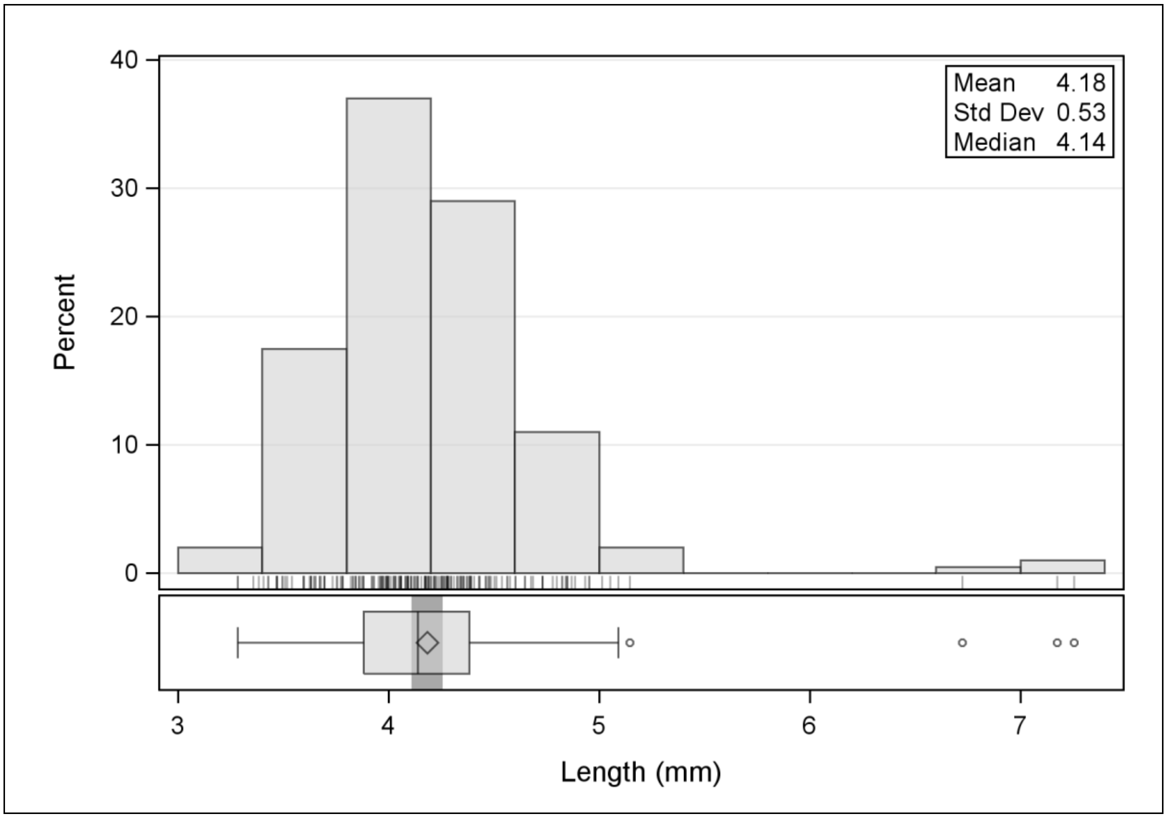


Figure 5-23. Length frequency histogram and statistics for KGB complex rockfish larvae (*Sebastes* spp. V_) based on a sample of 200 larvae proportionally sampled with replacement from the 403 rockfish larvae measured.

Entrainment Effects

An estimated 279.1 million KGB rockfish larvae were entrained during the one-year study period (**Table 5-3**). The assessment of effects on KGB rockfish included hindcasting the estimate of entrained larvae to reproductive adult female production using *FH* and proportional losses to the population using *ETM.*

An *ETM* estimate of P_M was calculated for this species complex because the results indicate that the sampling provided a reasonable estimate of nearshore abundances as the larvae were collected across all of the entire source water sampling stations (**Figure 5-22**). Although estimates for *PE* are derived from six survey periods, these periods correspond to the spawning season for this species and therefore represent an accurate estimate of P_M. Many rockfish species in this complex are an important component of the sport and commercial fisheries, therefore it is important to confirm that entrainment is not adding a large source of man-made mortality to adult stages in addition to fishing mortality. The results of the *ETM* for this taxon will be used in the *HPF* assessment presented in Section 6.0.

The estimated growth rate for KGB rockfish larvae used in both the *FH* and *ETM* modeling was calculated from information on larval growth presented in Yoklavich et al. (1996) for blue rockfish (*Sebastes mystinus*). The data on hatch size, age and growth were used to calculate an average larval growth rate of 0.22 mm/d (0.01 in/d).

Fecundity Hindcasting *(FH)*

The parameters required for the formulation of *FH* estimates for the KGB rockfish complex were compiled from several sources including a recent stock assessment for gopher rockfish (Key et al. 2005). The calculation of *FH* requires estimates of the survival of the larvae from the age of release to the age at entrainment as well as the lifetime fecundity of adult females. Survival of larvae from the time of release to entrainment was estimated using a daily mortality rate for blue rockfish larvae up to 15 days of 0.1165 in Yoklavich et al. (1996) which was modified from data presented in Ralston and Howard (1995). The mortality rate was converted to a daily survival rate as $0.8900 = e^{(-0.1165)}$. Survival to the average age at entrainment was calculated by subtracting the computed hatch length of 3.83 mm (0.15 in.) from the mean length of 4.16 mm (0.16 in.) and dividing by the larval growth rate of 0.22 mm/d (0.01 in/d) to calculate that the average number of days the larvae were exposed to entrainment was 1.5 and using this duration with the daily survival to calculate the total survival over the period.

The total lifetime fecundity was calculated over the period from age four years when 50% of the females in the population reach sexual maturity (Love et al. 2002; Key et al. 2005) to the maximum age, which is reported to vary from 24 to 30 years (Love et al. 2002; Key et al. 2005). The age of 27 years, which is half way between the two estimates, was used in determining the total lifetime fecundity. Love et al. (2002) provide von Bertalanffy growth parameters for female black and yellow rockfish (*S. chrysomelas*) that were used to estimate length (standard length [SL]) at age for females through age 27 years. Cailliet et al (2000) reports an equation for calculating fecundity at length (SL) for black and yellow rockfish from Zaitlin (1986). Finally, Key et al. (2005) assign natural mortality (M) at 0.20 for their stock assessment model. The fishing mortality from the model for $M = 0.20$ was $F = 0.104$. More recent stock assessment data for the period of 2007–09 was obtained from Alec MacCall one of the authors of the Key et al. (2005) stock assessment. The average Z for gopher, and black and yellow rockfishes for this period was 0.2703. These estimates were combined to estimate that the total lifetime fecundity for a female reaching the age of four years was 509,254 (**Table 5-19**).

The estimated number of four-year old adult KGB rockfish females whose reproductive output was equivalent to the number of larvae entrained per year at DCPP was 687 (**Table 5-20**). This value could be converted to 1,310 equivalent adults by assuming a 50:50 sex ratio for the population. The sensitivity analysis indicates that the largest degree of uncertainty in the estimate was associated with the life history parameters.

Table 5-19. Calculation of the total lifetime fecundity for KGB rockfish complex larvae. Using von Bertalanffy growth for female *S. chrysomelas* (Love et al. 2002), to calculate SL at age and size-based fecundity for *S. chrysomelas* from Cailliet et al (2000) and *Z*=0.2703 from MacCall (pers. comm.).

Age (years)	Computed Standard Length (SL [cm]) at Age from von Bertalanffy Growth Curve	Fecundity = $0.0000464(SL)^{4.09}$	Female Mortality Curve for 10^6 Age 4 Females (Z=0.2703)	Fecundity Curve (larvae per 10^6 age 4 females)
3	13.40	23,269		
4	15.73	44,817	1,000,000	44,817,029,129
5	17.60	70,941	763,189	54,141,467,900
6	19.10	99,128	582,457	57,737,839,359
7	20.31	127,284	444,525	56,580,723,447
8	21.27	153,939	339,256	52,224,659,053
9	22.05	178,216	258,916	46,143,086,409
10	22.67	199,705	197,602	39,462,135,052
11	23.17	218,321	150,808	32,924,464,342
12	23.57	234,185	115,095	26,953,451,080
13	23.89	247,534	87,839	21,743,110,588
14	24.15	258,656	67,038	17,339,687,302
15	24.36	267,851	51,162	13,703,907,138
16	24.52	275,407	39,047	10,753,714,157
17	24.66	281,587	29,800	8,391,265,782
18	24.76	286,622	22,743	6,518,620,307
19	24.85	290,711	17,357	5,045,915,712
20	24.92	294,024	13,247	3,894,878,820
21	24.98	296,704	10,110	2,999,618,729
22	25.02	298,868	7,716	2,305,970,463
23	25.06	300,613	5,889	1,770,166,713
24	25.08	302,019	4,494	1,357,290,051
25	25.11	303,151	3,430	1,039,750,839
26	25.13	304,062	2,618	795,910,020
27	25.14	304,794	1,998	608,892,606
			Sum for 10^6 females =	509,253,554,999
			Total Lifetime Fecundity =	509,254

Table 5-20. Results of *FH* modeling for KGB rockfish complex larvae based on entrainment estimates calculated using actual CWIS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH Estimate	655	567	157	2,722	2,564
Total Entrainment	279,117,506	6,052,952	631	678	47

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

Empirical Transport Model *(ETM)*

The estimated period of entrainment exposure of 5.14 d used in the *ETM* calculations was calculated by dividing the difference between the estimated hatch length of 3.83 mm (0.15 in.) and the average 95th percentile value of 4.96 mm (0.20 in.) from the bootstrap samples by the estimated larval growth rate of 0.22 mm/d (0.01 in/d). The entrainment exposure duration was calculated from size and growth values with greater decimal precision than those shown, and differs slightly from the duration calculated using these rounded values.

The data used to calculate the *ETM* estimates for KGB rockfish show that they were most abundant during the April and May 2008 surveys (**Figure 5-21** and **Table 5-21**). Although both alongshore and offshore extrapolations of the source water populations were calculated, since gopher rockfish can occur to depths of 80 m (262 ft) (Love et al. 2002), the short larval duration resulted in onshore current vectors that were within the outer edge of the sampled source water at 2,890 m (9,481 ft) offshore, except for the April 2009 survey. The two *ETM* estimates based on the CODAR backprojections are different because the average alongshore and offshore areas included in the source water extrapolations were slightly different, 8.11 and 9.11 km (5.04 and 5.66 mi) respectively, and the offshore extrapolation included the numbers extrapolated from the regression based on abundances at the source water stations (**Table 5-22)**. The differences in the *PE* estimates using the two methods reflect the differences due to the offshore extrapolation of the source water populations. These differences are also reflected in the P_M estimates for the 5.14-day period of exposure which were 0.1559 (15.6%) and 0.1262 (12.6%) based on two source water area estimates from the CODAR backprojections (**Table 5-22**).

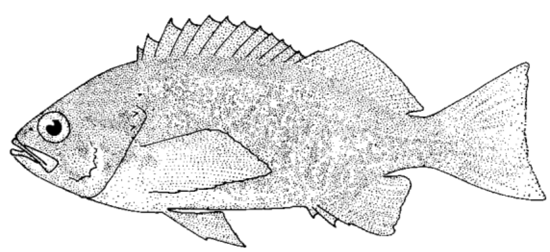
Table 5-21. *ETM* data for KGB rockfish larvae using alongshore and offshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from all surveys with *PE* > 0.

	Alongshore		Offshore Extrapolated			
Survey Date	*PE* Estimate	*PE* Std. Err.	*PE* Estimate	*PE* Std. Err.	f_i	Alongshore Displacement (km)
31-Jul-08	0.60777	0.22791	0.00041	0.00015	0.0001	8.20
3-Sep-08	0	0	0	0	0	3.87
29-Sep-08	0	0	0	0	0	4.25
6-Nov-08	0	0	0	0	0.0006	8.36
9-Dec-08	0	0	0	0	0	6.34
12-Jan-09	0	0	0	0	0.0014	5.94
29-Jan-09	0	0	0	0	0.0183	6.44
26-Feb-09	0.00766	0.00166	0.00328	0.00071	0.0623	8.55
27-Mar-09	0.00430	0.00038	0.00201	0.00018	0.1632	14.51
22-Apr-09	0.05127	0.01391	0.04218	0.01144	0.3806	5.35
28-May-09	0.03360	0.00257	0.02684	0.00205	0.3660	5.28
30-Jun-09	0.01651	0.00617	0.00158	0.00059	0.0076	6.78
Average =	0.12019		0.01272			8.11

Table 5-22. Estimates for *ETM* models for KGB rockfish larvae calculated using alongshore and offshore extrapolations based on current data from CODAR backprojected from the survey date with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP.

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (PM)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	8.11	0.15587	0.02841	0.18429	0.12746
Offshore Extrapolated P_M	9.11	0.12618	0.02636	0.15254	0.09981

5.4.2.3 Blue Rockfish (*Sebastes mystinus*) Complex



Sebastes mystinus (Jordan and Gilbert 1880); blue rockfish; length to 53 cm (21 in.); northern limit uncertain, at least Vancouver I. (possibly Aleutian Is.) to Pt. Santo Tomas, northern Baja California; surface to 549 m (1800 ft); dark blue with light blue mottling (Miller and Lea 1972; Eschmeyer et al. 1983).

The species that comprise the blue rockfish complex are those rockfish larvae that have a short ventral pigment series and no dorsal series or pectoral pigmentation; designates as *Sebastes* spp. V larvae. The pigment characteristics of young blue rockfish place them in this complex because they cannot be distinguished from other species in the group until they develop pectoral and dorsal pigmentation. Nearly 80% of the larvae classified in this group by DNA analysis were determined to be blue rockfish, followed by squarespot and olive rockfishes at approximately 6% (**Table 5-7**). Fifteen species comprised this group based on DNA analysis of 501 larval specimens.

Reproduction, Age, and Growth

Blue rockfish are viviparous with planktonic larvae and juveniles (Moser 1996; Love et al. 2002). Miller and Geibel (1973) estimated that their fecundity ranges from 50,000–300,000 eggs per female per year. However, a female that measured 405 mm (15.9 in.) TL had 525,000 young (Wales 1952). Spawning (extrusion of larvae) occurs November through March with a peak in January through February (Miller and Geibel 1973; Wyllie Echeverria 1987; Moser 1996; Love et al. 2002), making this one of the earliest species of rockfish larvae to be released seasonally. Individual females generally spawn once annually (Lea et al. 1999), but Moreno (1993) found evidence that this species may produce multiple spawns. Larvae are about 3.5 mm (0.14 in.) at parturition (Miller and Geibel 1973), with an average planktonic duration of 129 d, as calculated from observations of nine larvae (Dave Woodbury, NOAA/NMFS, Tiburon Laboratories, CA, pers. comm.). Pelagic juveniles were 3–5 months when they were observed to settle to the nearshore benthos (Adams and Howard 1996). Young-of-the-year (YOY) were first observed in nearshore kelp beds in May and June at 40–60 mm (1.6-2.4 in.) TL (Lea et al. 1999). In April, juveniles of about 45–50 mm (1.8-2.0 in.) TL concentrate in shallow rocky areas and in kelp canopies. By October these fish range from 65–90 mm (1.8-2.0 in.) TL (Miller and Geibel 1973). Estimated instantaneous mortality for juveniles in their first year of life ranged from 0.001 to 0.008 (Adams and Howard 1996).

Longevity for the blue rockfish, which was previously estimated at 17 yr for males and 24 yr for females using unvalidated readings using scales (Miller and Geibel 1973), has recently been estimated to be 44 years for male blue rockfish and 41 years for females (Laidig et al. 2003). Growth of 0.23 to 0.35 mm/d (0.009 to 0.014 in/d) was observed for 85 mm (3.4 in.) juveniles (Miller and Geibel 1973), and mean monthly growth from tag returns on adults was 2.46 mm (0.1 in.) (Wales 1952). The smallest sexually mature male Lea et al. (1999) collected was 219 mm (8.62 in.) TL, and the largest immature male was 332 mm (13.07 in.) TL. The smallest sexually mature female was 196 mm (8.62 in.) TL, and the largest immature female was 293 mm (11.54 in.) TL. Females were estimated to attain 50% maturity at 5 yr, and 100% maturity at 11 yr (Key et al. 2008).

Population Trends and Fishery

Subtidal fish abundance estimates at the DCPP South Control station from 1978 to 2008 showed a peak in blue rockfish of over 40.0 per 50 m (164 ft) transect in 1979 followed by a sharp decline from 1979–1982 after which the species increased slowly over the next 10 years. After a second peak in 1991, numbers again declined and remained at very low levels except for small peaks in 1999 and 2002 (**Figure 5-24**). Blue rockfish were not a highly sought species historically, but an increase in catches in the 1970s resulted in a continuous decline in spawning biomass through the early 1990s (Key et al. 2008). Spawning biomass reached a minimum (10% of unexploited) in 1994 and 1995; however, there has been a constant increase since then.

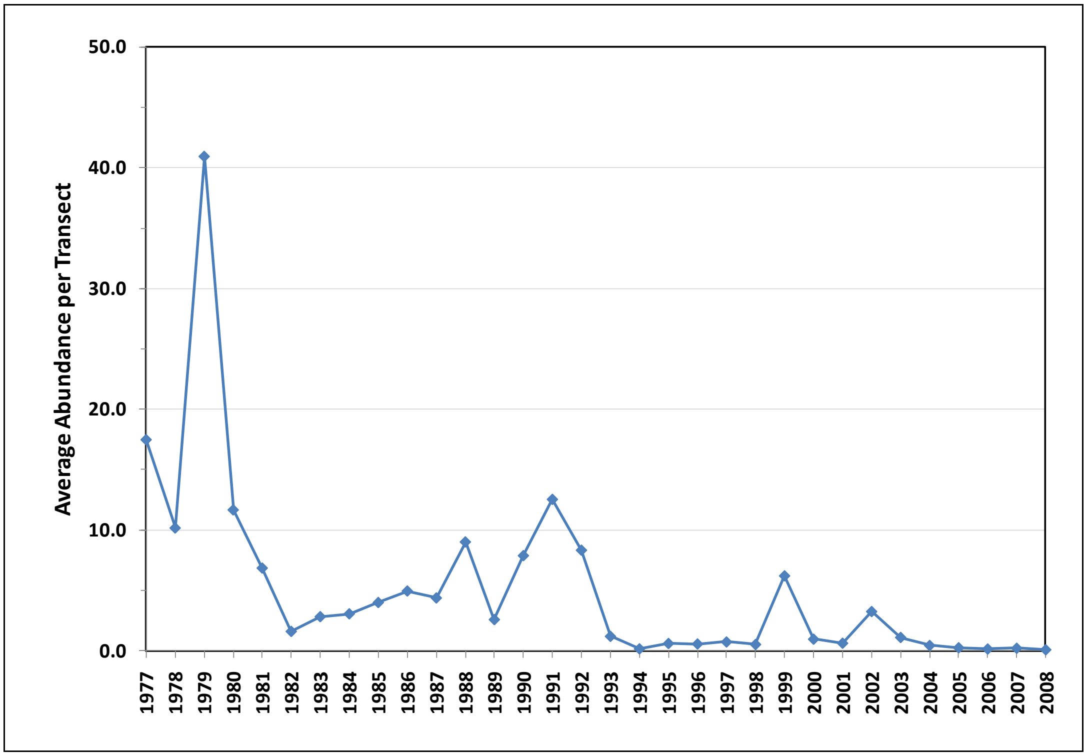


Figure 5-24. Average abundance per 50x4 m transect for blue rockfish (all ages) at DCPP control site.

Blue rockfish are one of the most important rockfish in recreational sport fishery along the California coast. In some years, at some locations, up to 31% of all fishes taken in the marine recreational fishery were blue rockfish (Love 1996). Blue rockfish are taken on hook-and-line or while diving (Love 1996). The commercial fishery is typically small with a few exceptions (Starr et al. 1998). Recreational landings in central California during the 2005–2009 time period averaged 136,971 fish per year with a high of nearly 225,000 fish in 2005 and a low of 57,526 in 2009 (**Table 5-23**).

Table 5-23. Blue rockfish recreational fishing catch in central California, and commercial fishing landings and ex-vessel value in San Luis Obispo County, 2005-2009. Data from RecFIN (2010) and PacFIN (2010).

	Recreational Fishery		Commercial Fishery	
Year	Estimated Catch (No.)	Estimated Weight (lbs)	Landings (lbs)	Ex-vessel Value ($)
2005	224,976	229,971	990	$1,347
2006	182,864	195,361	966	$1,416
2007	107,954	112,485	2,190	$3,111
2008	111,533	102,063	895	$1,601
2009	57,526	48,897	1,479	$2,069
Average	136,971	137,755	1,304	$1,909

Sampling Results

Rockfishes of the blue rockfish group (*Sebastes* spp. V) were the eighth most abundant taxon collected from the entrainment stations and fourth most abundant from the source water stations, comprising 4.9% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The larvae were present at the entrainment station during almost all months of the year, but were most abundant in January. This was about three months earlier than the peak for the KGB group. The mean concentration per survey ranged from zero to over 300 larvae per 1,000 m^3 peaking in abundance during January 2009 (**Figure 5-25**). Larvae occurred at all stations and had a gradient of decreasing abundance with distance offshore (**Figure 5-26**).

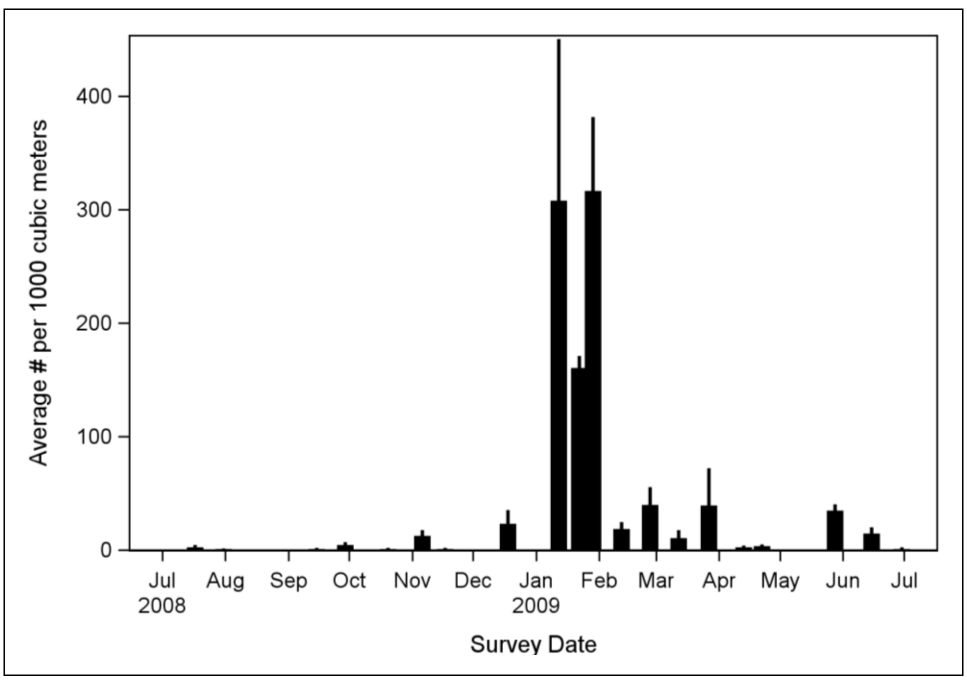


Figure 5-25. Survey mean concentration (#/1,000 m^3) of blue rockfish complex larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

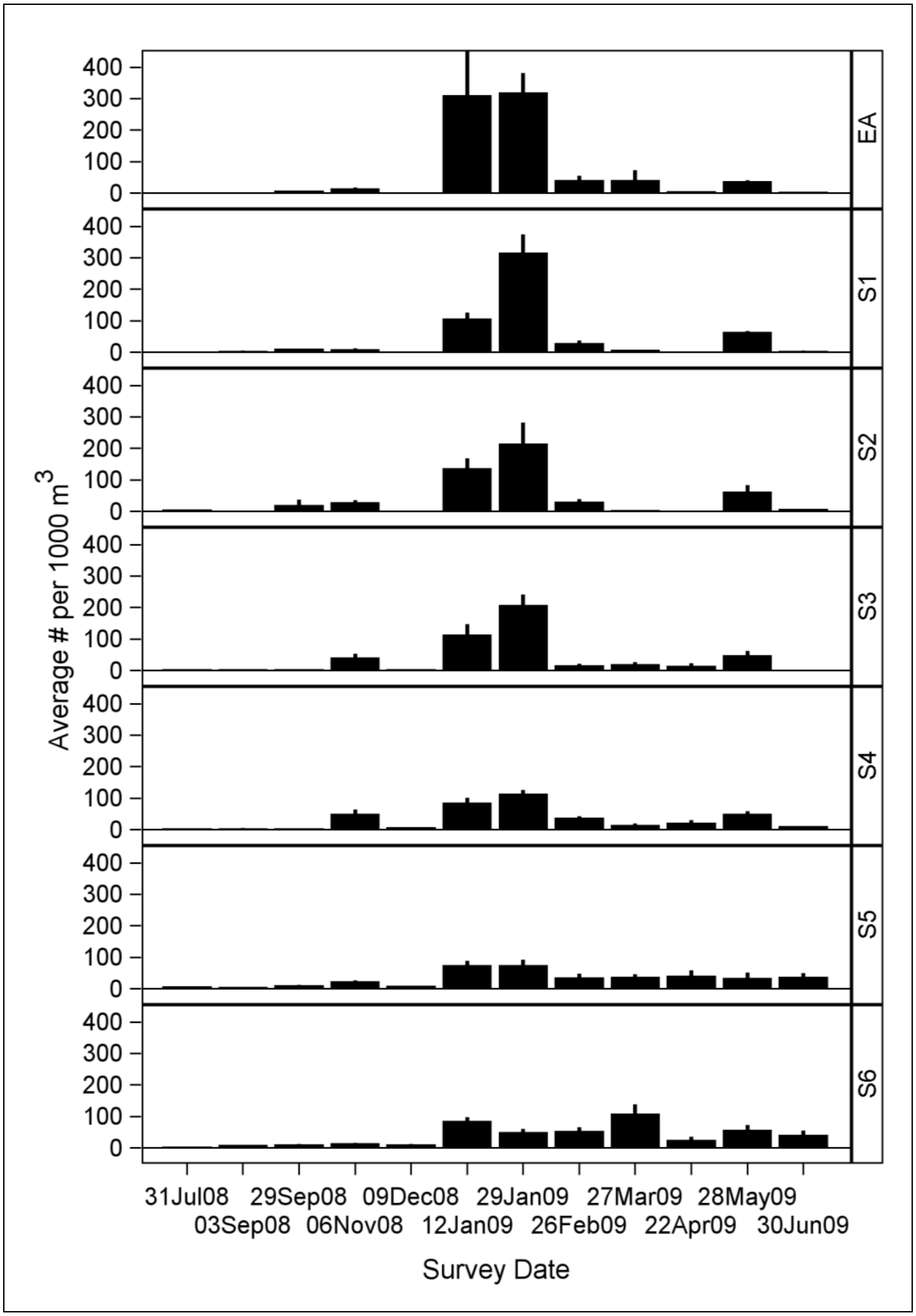


Figure 5-26. Survey mean concentration (#/1,000 m^3) of blue rockfish complex larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

The mean length of 200 specimens proportionally sampled with replacement from the 282 larvae measured was 3.95 mm (0.16 in.) (**Figure 5-27**). The smallest larva of the 282 measured was

2.41 mm (0.09 in.) and the largest was 7.05 mm (0.28 in.). Reported length at birth for blue rockfish, *Sebastes mystinus*, is approximately 3.8 mm (0.15 in.) (Moser 1996), indicating that most of the larvae were recently extruded. The averages from the random samples proportionally drawn from all the measurements resulted in an average length of 3.95 mm (0.16 in.) for the mean length and 3.88 mm (0.15 in.) for the median. The computed hatch length was 3.40 mm (0.13 in.) which is less than the value reported by Moser (1996). Therefore, the first quantile estimate of 3.61 mm (0.15 in.) was used as the estimated hatch length in the *ETM* calculations.

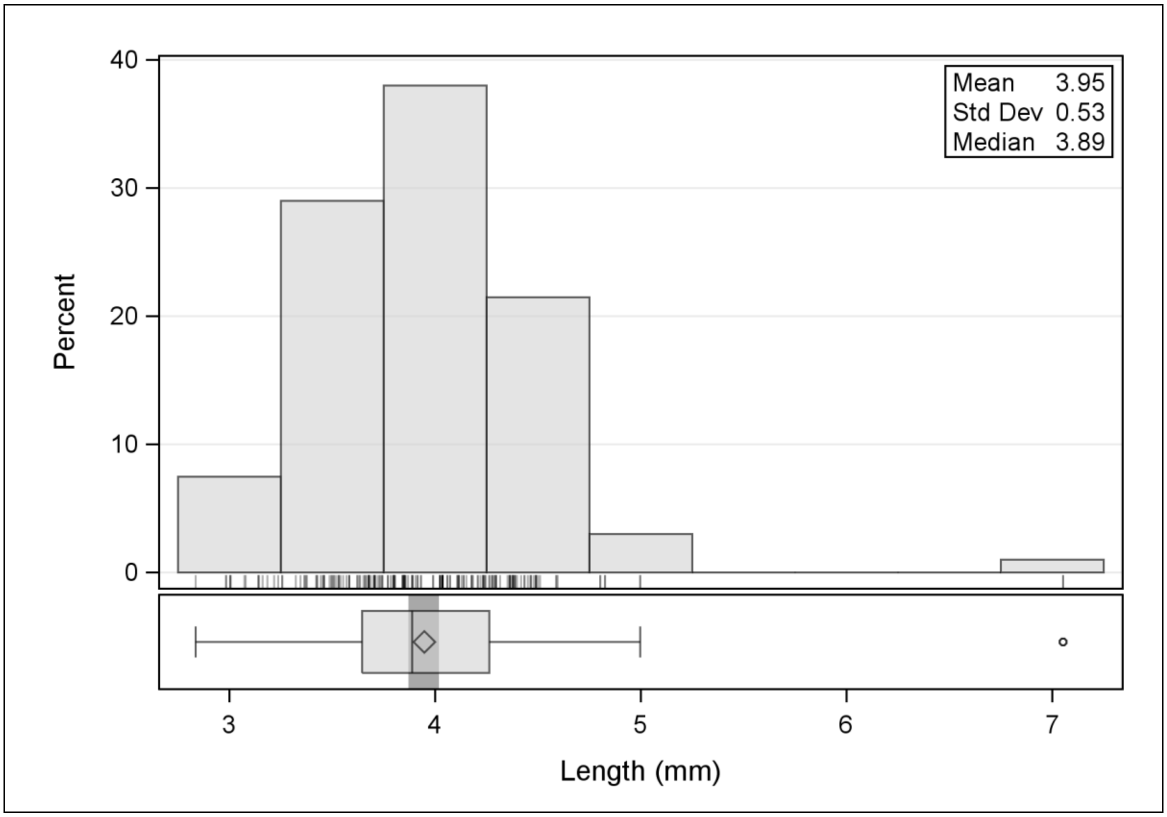


Figure 5-27. Length frequency histogram and statistics for blue rockfish complex larvae based on a sample of 200 larvae proportionally sampled with replacement from the 282 rockfish larvae measured.

Entrainment Effects

An estimated 104.4 million blue rockfish larvae were entrained during the one-year study period (**Table 5-3**). The assessment of effects on blue rockfish included hindcasting the estimate of entrained larvae to reproductive adult female production using *FH* and proportional losses to the population using *ETM*.

An *ETM* estimate of P_M was calculated for this species complex because the results indicate that the sampling provided a reasonable estimate of nearshore larval abundances as the larvae were collected across the entire source water sampling stations (**Figure 5-26**). Estimates of *PE* were also calculated for all but two of the paired entrainment-source water surveys providing a reasonable estimate of P_M. This species is also an important component of the sport and commercial fisheries and it is important to confirm that entrainment is not adding a large source of additional mortality which already occurs on adult stages of this species as a result of fishing. The results of the *ETM* for this taxon will be used in the *HPF* assessment presented in Section 6.0.

The estimated larval growth rate for blue rockfish used in both the *FH* and *ETM* modeling was calculated from information on larval growth presented in Yoklavich et al. (1996) for this species. The data on hatch size, age and growth were used to calculate an average larval growth rate of 0.22 mm/d (0.01 in/d).

Fecundity Hindcasting *(FH)*

The parameters required for the formulation of *FH* estimates for the KGB rockfish complex were compiled from several sources including a recent stack assessment for blue rockfish (Key et al. 2008). The calculation of *FH* requires estimates of the survival of the larvae from the age of release to the age at entrainment as well as the lifetime fecundity of adult females. Survival of larvae from the time of release to entrainment was estimated using a daily mortality rate for blue rockfish larvae up to 15 days of 0.1165 in Yoklavich et al. (1996) modified from data presented in Ralston and Howard (1995). The mortality rate was converted to a daily survival as 0.8900 = $e^{(-0.1165)}$. Survival to the average age at entrainment was calculated by subtracting the computed hatch length of 3.61 mm (0.14 in.) from the mean length of 3.95 mm (0.16 in.) and dividing by the larval growth rate of 0.22 mm/d to calculate that the average number of days the larvae were exposed to entrainment was 1.55 and using this duration with the daily survival to calculate the total survival over the period.

The total lifetime fecundity was calculated over the period from age five years when 50% of the females in the population reach sexual maturity (Key et al. 2008) to the maximum age, which is reported to be 41 years for females (Love et al. 2002; Laidig et al. 2003; Key et al. 2008). Size at age was calculated from von Bertalanffy growth parameters from data in Laidig et al (2003) for samples of blue rockfish collected in nearshore areas. Laidig et al. (2003) found a difference in growth parameters among between rockfish collected in shallow water and ones collected from fishing activity aboard commercial passenger fishing vessels (CPFV). The shallow water samples collected by divers using spears were used since these may be more representative of the fishes entrained by the plant and may have less sampling bias than the fishes collected from CPFVs. The fork length (FL) at age computed from the von Bertalanffy equation were converted to total length (TL) using a conversion in Love et al (2002) (TL=2.495+1.039[FL]) for blue rockfish.

Information on age-, weight-, or length-based estimates of fecundity were not available for blue rockfish. There were several estimates for various sized fishes (25 to 42.5 cm [9.8 to 16.7 in.] TL) in Cailliet et al. (2000) that were used to fit an exponential function (Fecundity = $0.3517(TL)^{3.8471}$) to the available estimates. Finally, Key et al. (2008) assign natural mortality (*M*) at 0.10 for their stock assessment model. The value of *Z* from the combined estimates for *M* and *F* from Key et al. (2008) for 2005 and 2006 were averaged with estimates of *Z* from 2007–2009 from MacCall (pers. comm.), one of the authors of the stock assessment to provide an average *Z* of 0.2406 for the most recent five years (2005–2009). These estimates were combined to estimate that the total lifetime fecundity for a female reaching the age of five years was 969,485 (**Table 5-24**).

Table 5-24. Calculation of total lifetime fecundity for blue rockfish complex larvae. Using von Bertalanffy growth (Laidig et al. 2003), to calculate TL at age and size-based fecundity from data in Cailliet et al (2000) and *Z*=0.33 from Key et al. (2008).

Age (years)	Computed Fork Length FL [cm]) at Age from Growth Equation	Conversion to Total Length (TL [cm]) = 2.495+1.039(FL)	Fecundity = $0.3517(TL)^{3.85}$	Mortality Curve for 10^6 Age 5 Females (*Z*=0.3298)	Fecundity Curve (larvae per 10^6 age 5 females)
4	22.58	23.71	68,437		
5	25.14	26.37	103,078	1,000,000	103,077,548,168
6	27.31	28.63	141,352	786,172	111,126,937,587
7	29.15	30.54	181,243	618,066	112,019,849,688
8	30.71	32.15	221,079	485,906	107,423,466,129
9	32.03	33.53	259,599	382,006	99,168,434,590
10	33.14	34.69	295,934	300,322	88,875,483,161
11	34.09	35.67	329,544	236,105	77,806,923,085
12	34.89	36.50	360,155	185,619	66,851,588,639
13	35.57	37.21	387,688	145,928	56,574,698,680
14	36.15	37.81	412,203	114,725	47,289,873,655
15	36.64	38.31	433,850	90,193	39,130,357,424
16	37.05	38.74	452,834	70,907	32,109,309,975
17	37.40	39.11	469,390	55,745	26,166,332,565
18	37.69	39.41	483,760	43,825	21,201,012,090
19	37.94	39.67	496,185	34,454	17,095,722,435
20	38.16	39.89	506,892	27,087	13,730,214,390
21	38.34	40.08	516,095	21,295	10,990,282,859
22	38.49	40.24	523,987	16,742	8,772,366,204
23	38.62	40.37	530,741	13,162	6,985,481,349
24	38.73	40.49	536,512	10,347	5,551,504,903
25	38.82	40.58	541,437	8,135	4,404,497,799
26	38.90	40.67	545,634	6,395	3,489,536,562
27	38.97	40.73	549,209	5,028	2,761,346,183
28	39.02	40.79	552,250	3,953	2,182,913,237
29	39.07	40.84	554,835	3,108	1,724,179,954
30	39.11	40.89	557,033	2,443	1,360,869,526
31	39.14	40.92	558,899	1,921	1,073,461,489
32	39.17	40.95	560,483	1,510	846,317,437
33	39.20	40.98	561,828	1,187	666,947,060
34	39.22	41.00	562,969	933	525,399,626
35	39.24	41.02	563,936	734	413,764,329
36	39.25	41.03	564,757	577	325,763,177
37	39.26	41.04	565,453	453	256,421,336
38	39.27	41.06	566,043	357	201,801,506
39	39.28	41.07	566,543	280	158,790,783

(continued)

Table 5-24 (continued). Calculation of total lifetime fecundity for blue rockfish complex larvae. Using von Bertalanffy growth (Laidig et al. 2003), to calculate TL at age and size-based fecundity from data in Cailliet et al (2000) and Z=0.33 from Key et al. (2008).

Age (years)	Computed Fork Length (FL [cm]) at Age from Growth Equation	Conversion to Total Length (TL [cm]) = 2.495+1.039(FL)	Fecundity = $0.3517(TL)^{3.85}$	Mortality Curve for 10^6 Age 5 Females (Z=0.3298)	Fecundity Curve (larvae per 10^6 age 5 females)
40	39.29	41.07	566,966	220	124,930,207
41	39.30	41.08	567,325	173	98,278,815
				Sum for 10^6 females =	969,485,058,435
				Total Lifetime Fecundity =	969,485

The estimated number of five-year old adult blue rockfish females whose reproductive output was equivalent to the number of larvae entrained per year at DCPP was 129 (**Table 5-25**). This value could be converted to 258 equivalent adults by assuming a 50:50 sex ratio for the population. The sensitivity analysis indicates that the largest degree of uncertainty in the estimate was associated with the life history parameters.

Table 5-25. Results of FH modeling for blue rockfish complex larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows. 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.

Parameters	Estimates	Std. Errors	FH Lower Estimate	FH Upper Estimate	Range
FH Estimate	129	112	31	536	505
Total Entrainment	104,394,654	2,052,394	125	133	8

Empirical Transport Model *(ETM)*

The estimated period of entrainment exposure of 4.84 d was calculated by dividing the difference between the estimated hatch length of 3.61 mm (0.14 in.) and the size of the 95th percentile value of 4.67 mm (0.14 in.) by the estimated larval growth rate of 0.22 mm/d (0.01 in/d) from Yoklavich et al. (1996).

The data used to calculate the *ETM* estimates for blue rockfish complex larvae show that they occurred throughout the year but were most abundant during the January 2009 surveys (**Table 5-26**). Although both alongshore and offshore extrapolations of the source water populations were calculated since blue rockfish are distributed to depths of 91 m (300 ft) (Miller and Lea 1972) the short larval duration resulted in onshore current vectors that were all within the outer edge of the sampled source water at 2,890 m (9,481 ft) offshore except for the March 2009 survey. The two *ETM* estimates using the CODAR backprojections were different because the alongshore and offshore areas included in the source water extrapolations were slightly different, 6.86 and 7.22 km (4.26 and 4.49 mi) respectively, and the offshore extrapolation included the numbers extrapolated from the regression (**Table 5-27)**. The P_M estimates for the

4.84-day period of exposure were 0.0750 (7.5%) and 0.0521 (5.2%) from the CODAR backprojections (**Table 5-27**).

Table 5-26. *ETM* data for blue rockfish complex larvae using alongshore and offshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from all surveys with *PE* > 0.

Survey Date	Alongshore		Offshore Extrapolated		f_i	Alongshore Displacement (km)
	PE Estimate	*PE* Std. Err.	*PE* Estimate	*PE* Std. Err.		
31-Jul-08	0.00331	0.00117	0.00026	0.00009	0.0099	6.97
3-Sep-08	0.00000	0.00000	0.00000	0.00000	0.0104	3.77
29-Sep-08	0.01146	0.00250	0.00222	0.00048	0.0209	4.01
6-Nov-08	0.00555	0.00080	0.00213	0.00031	0.0703	7.58
9-Dec-08	0.00000	0.00000	0.00000	0.00000	0.0161	6.34
12-Jan-09	0.04554	0.00758	0.03309	0.00551	0.2048	5.54
29-Jan-09	0.01750	0.00139	0.01338	0.00106	0.2170	6.24
26-Feb-09	0.00554	0.00084	0.00272	0.00041	0.0883	7.86
27-Mar-09	0.00443	0.00136	0.00192	0.00059	0.1099	14.01
22-Apr-09	0.00263	0.00044	0.00106	0.00018	0.0597	4.81
28-May-09	0.01073	0.00088	0.00619	0.00051	0.1396	5.28
30-Jun-09	0.00063	0.00023	0.00025	0.00009	0.0530	6.27
Average =	0.01073		0.00632			6.86

Table 5-27. Estimates for ETM models for blue rockfish complex larvae calculated using alongshore and offshore extrapolations based on current data from CODAR backprojected from the survey data with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP.

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	6.86	0.07499	0.01776	0.09274	0.05723
Offshore Extrapolated P_M	7.22	0.05211	0.01756	0.06966	0.03455

5.4.3 Pricklebacks (Stichaeidae)

The pricklebacks (Stichaeidae) are a family of shallow-water species primarily distributed in the northern Pacific Ocean and consists of three subfamilies, 31 genera, and about 60 species (Nelson 1994). Most of the species in the belongs to the subfamily Xiphisterinae, which contains 15 species, several of which are common to the California coast (Miller and Lea 1972).

5.4.3.1 Unidentified Pricklebacks (Stichaeidae)

Unidentified pricklebacks primarily included specimens of *Xiphister* spp. and *Anoplarchus* spp. whose adults are common in intertidal and shallow subtidal rocky habitats. These were combined for analysis along with some specimens that had myomere counts and pigmentation indicative of pricklebacks but could not be matched with available descriptions, and specimens that were damaged but could still be identified as pricklebacks. Because the group includes several species with varying reproduction, age, and growth characteristics, no specific information on these aspects of their life history are presented. The monkeyface prickleback (*Cebidichthys violaceus*) has distinctive larval characteristics and data on this species, which has some commercial and recreational fishery value, are presented in a separate subsection.

Population Trends and Fishery

The smaller species of pricklebacks have no targeted fishery, although the rock prickleback (*Xiphister mucosus*) can reach lengths up to 58 cm (23 in.) and may be caught incidentally in the monkeyface prickleback fishery.

Pricklebacks are one of the most abundant groups of fishes in mixed-substrate intertidal habitats along the Diablo Canyon coastline, and juveniles, in particular, can be seasonally abundant in summer months (Tenera 2002). Intertidal fishes have been sampled in the immediate vicinity of DCPP approximately quarterly since 1979, with additional control stations added to the north and south of DCPP in 1999. Rock prickleback (*Xiphister mucosus*) was the most abundant species to be consistently identified at all stations over all surveys. There was an abrupt decline in abundance in north Diablo Cove after power plant start-up whereas abundances in Field's Cove stayed at moderate levels (**Figure 5-28**). Declines in south Diablo Cove were related to thermal effects and also to a significant change in substrate composition caused by the collapse of an adjacent cliff face in 1983. Periodic spikes in abundance at all stations were due to influxes of juveniles settling from the plankton primarily during summer. The periodic settlement events in Diablo Cove were more common during the early 1990s, but increases occurred in south Diablo Cove in 2007–2008 that raised densities to abundance levels observed prior to plant operation. No rock prickleback recruits were observed in north Diablo Cove since 1995. The south control station had abundances of rock prickleback that were comparable to pre-operation abundances in Diablo Cove and Field's Cove, and have remained relatively constant during the 1999–2008 period.

Black prickleback (*Xiphister atropurpureus*) was not as abundant as rock prickleback but did occur regularly at all intertidal stations over most surveys. There was also an abrupt decline in abundance in north and south Diablo Cove after power plant start-up (**Figure 5-29**). As with rock prickleback, increases occurred in south Diablo Cove from 2007–2008 that brought densities back up to levels similar to abundances before plant operation. This species was usually more abundant at the north control station than the south control station, although both stations had seasonal peaks in the range of 20 or more individuals per station.

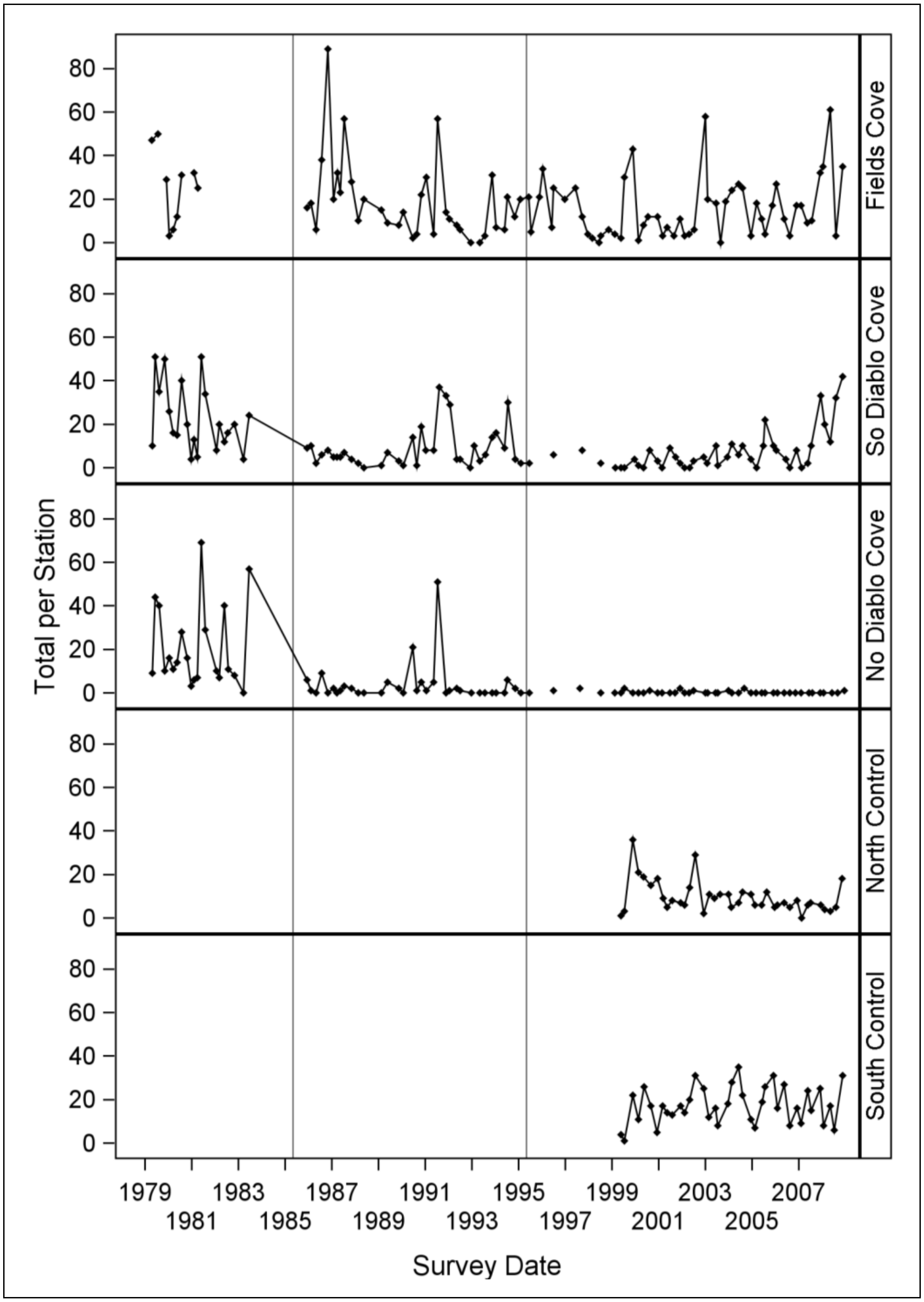


Figure 5-28. Mean abundance of the rock prickleback (*Xiphister mucosus)* at intertidal fish stations, 1979–2008.

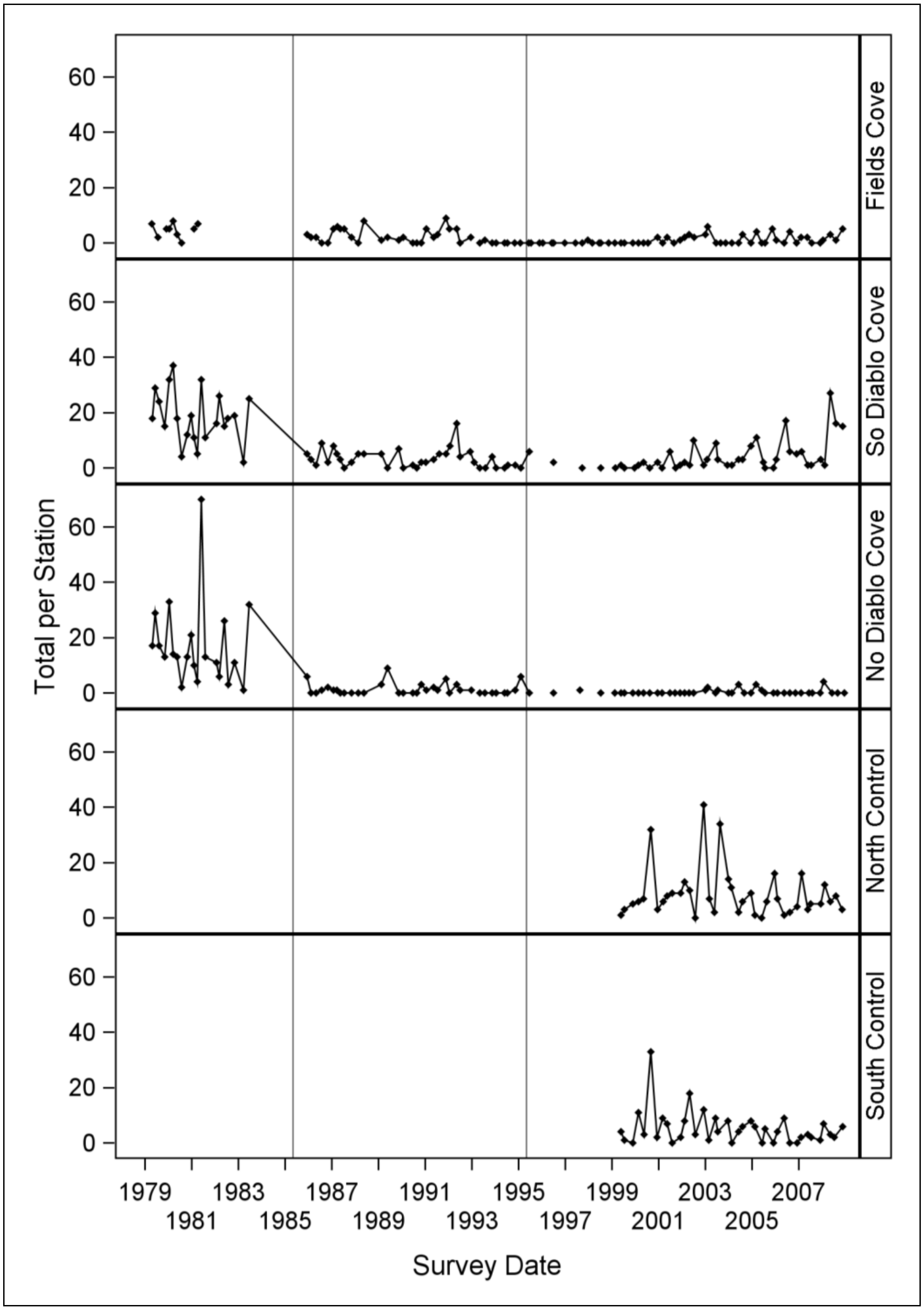


Figure 5-29. Mean abundance of black prickleback (*Xiphister atropurpureus)* at intertidal fish stations, 1979–2008.

Sampling Results

Unidentified prickleback species and those combined for analysis (Stichaeidae) were the eleventh most abundant taxon collected from the entrainment stations and eighteenth most abundant from the source water stations, comprising 4.3% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The larvae were present from February through May, and were most abundant in April. The mean concentration per survey ranged from zero to over 350 larvae per 1,000 m^3 (**Figure 5-30**). Larvae occurred at only the innermost stations with a steep gradient of decreasing abundance with distance offshore (**Figure 5-31**).

The mean length of 200 specimens proportionally sampled with replacement from the 237 larvae measured was 8.03 mm (0.32 in.) (**Figure 5-32**). The smallest larva of the 237 measured was 4.30 mm (0.17 in.) and the largest was 16.10 mm (0.63 in.). The averages from the random samples proportionally drawn from all the measurements resulted in averages of 8.02 mm (0.32 in.) for the mean length and 7.65 mm (0.30 in.) for the median. A hatch length based on the length of the 25^{th} percentile value of the measurements (6.45 mm [0.25 in.]) was used as the estimated hatch length.

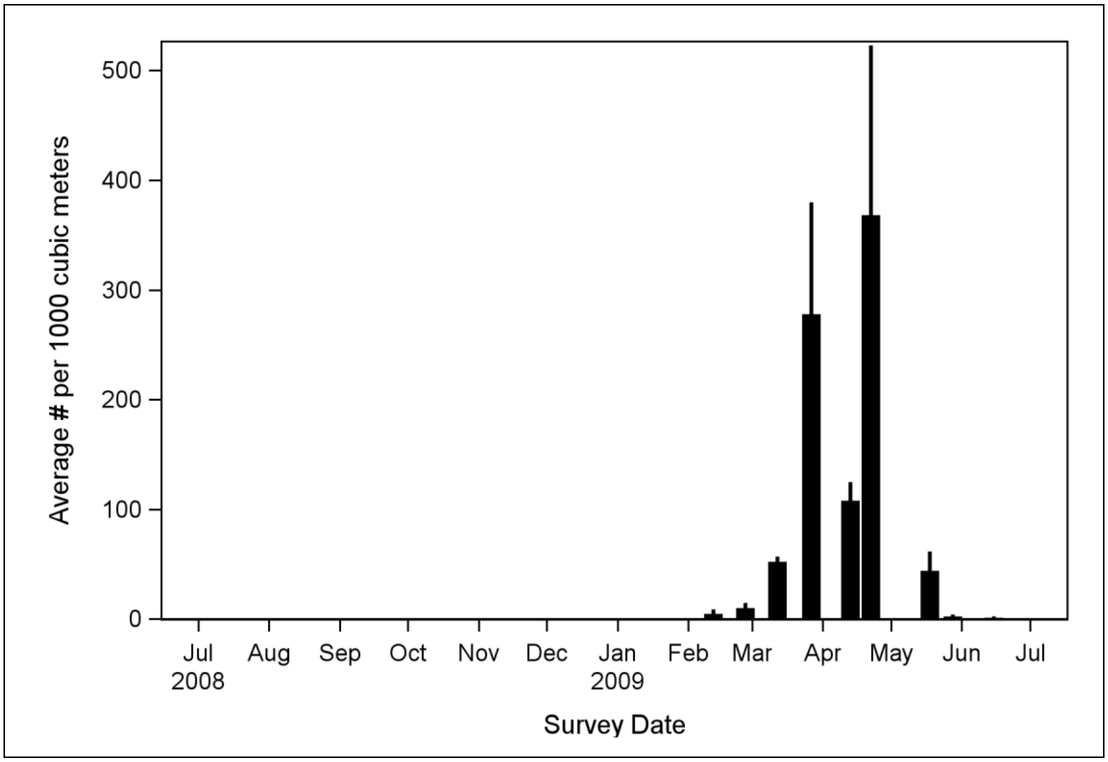


Figure 5-30. Survey mean concentration (#/1,000 m^3) of unidentified prickleback (Stichaeidae) larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

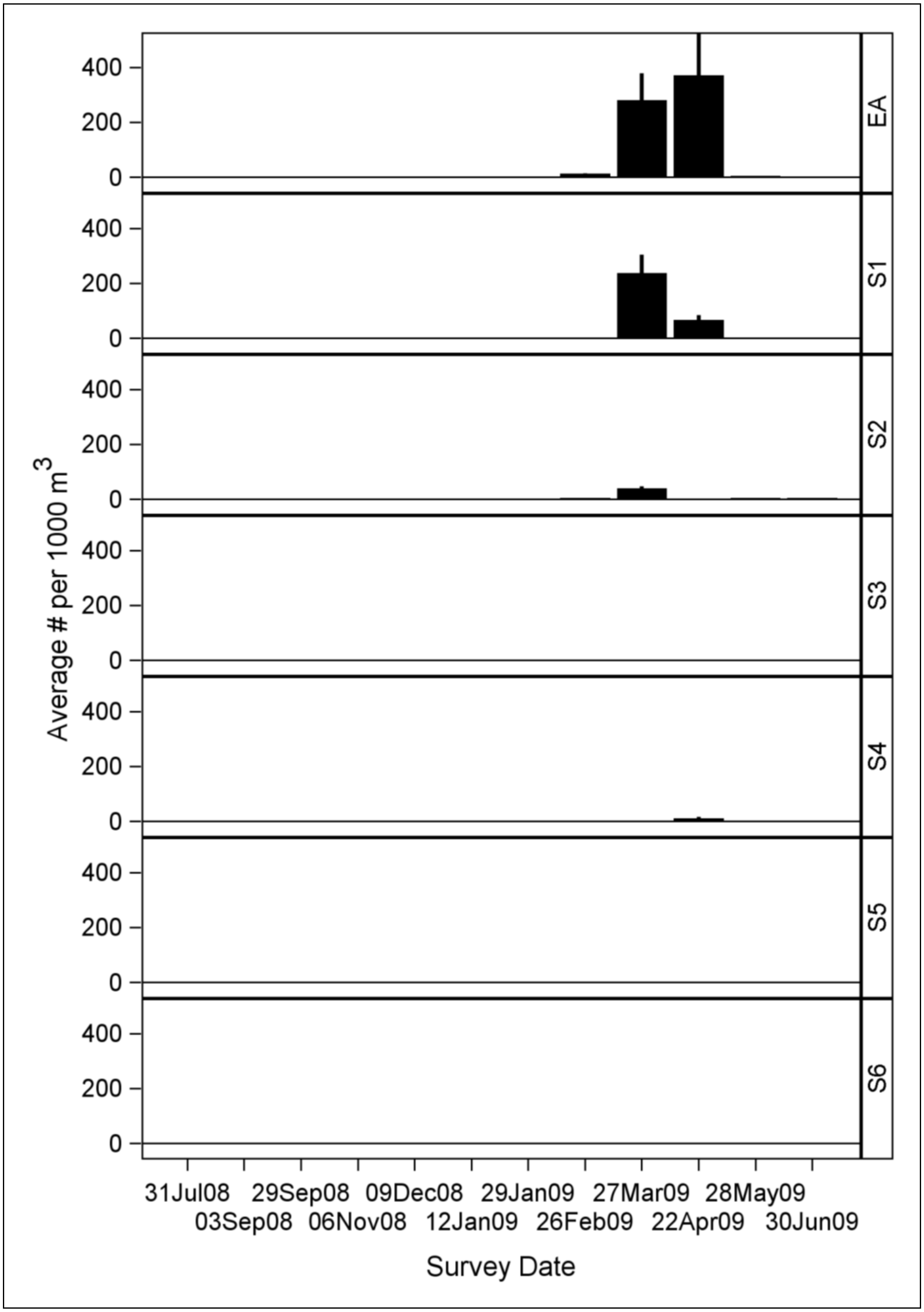


Figure 5-31. Survey mean concentration (#/1,000 m^3) of unidentified prickleback (Stichaeidae) larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

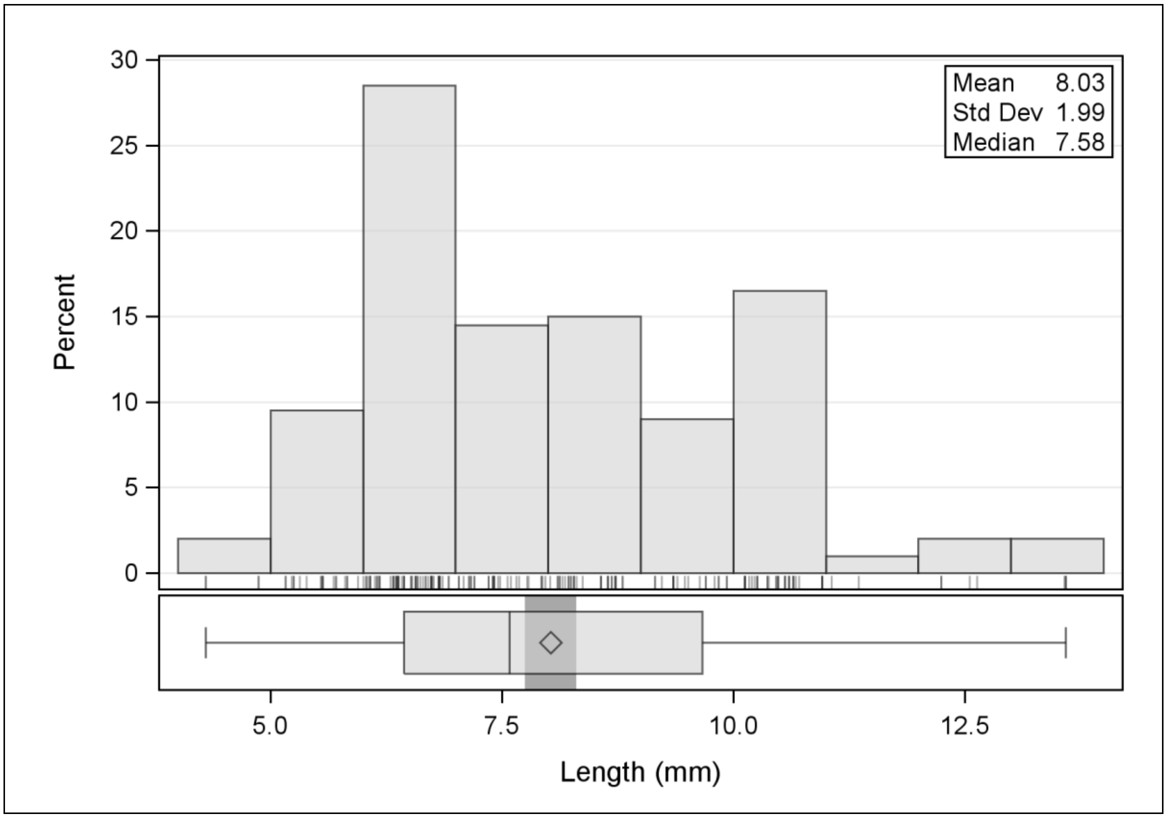


Figure 5-32. Length frequency histogram and statistics for unidentified prickleback (Stichaeidae) larvae based on a sample of 200 larvae proportionally sampled with replacement from the 237 prickleback larvae measured.

Entrainment Effects

An estimated 127 million unidentified prickleback larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary demographic information was not available for this multi-species group. Prickleback larvae were only collected during four of the paired entrainment and source water surveys resulting in a large degree of uncertainty associated with any *ETM* estimates of P_M (**Figure 5-31**). Also, the source water and entrainment sampling was not conducted in areas close to shallow rocky shorelines where prickleback larvae would be expected to be in highest abundance. Therefore, estimates of abundances from the source water sampling would not be expected to be representative of source water populations. For these reasons, *ETM* estimates of P_M where not calculated for this taxon.

5.4.3.2 Unidentified Blennioids/Zoarcoids (Blennioidei/Zoarcoidei – complex)

The larval development sequences of many species in the families Stichaeidae, Pholidae, and Clinidae are undescribed, and even the earliest stages of some described species may share characteristics that do not allow separation with certainty to genus or species. The Blennioidei/Zoarcoidei complex was used to classify larvae that did not have diagnostic melanophore arrangements and had elongate, moderately to strongly compressed bodies with pre-anal lengths in the range of 40–45%. It is likely that the complex was comprised largely of smaller unidentified Stichaeidae because of similarities to Stichaeidae in their distributions, larval occurrences, and size distributions (see Section 5.4.3.1– *Unidentified Pricklebacks*). Because the group potentially includes many species with varying reproduction, age, and growth characteristics, no specific information on their life history are presented.

Sampling Results

The Blennioidei/Zoarcoidei complex was the sixth most abundant taxon collected from the entrainment stations and seventh most abundant taxon at the source water stations, comprising 6.4% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The larvae were present from March through May, and were most abundant in May. The mean concentration per survey ranged from zero to nearly 750 larvae per 1,000 m^3 (**Figure 5-33**). Larvae mainly occurred at the inshore stations with a gradient of decreasing abundance with distance offshore (**Figure 5-34**).

The mean length of 200 measurements proportionally sampled at random with replacement from the 89 larvae measured was 7.27 mm (0.29 in.) (**Figure 5-35**). The smallest larva of the 89 measured was 3.65 mm (0.14 in.) and the largest was 16.10 mm (0.63 in.). The averages from the random samples proportionally drawn from all the measurements resulted in averages of 7.19 mm (0.28 in.) for the mean length and 7.08 mm (0.28 in.) for the median. The computed hatch length from the data was 5.56 mm (0.22 in.).

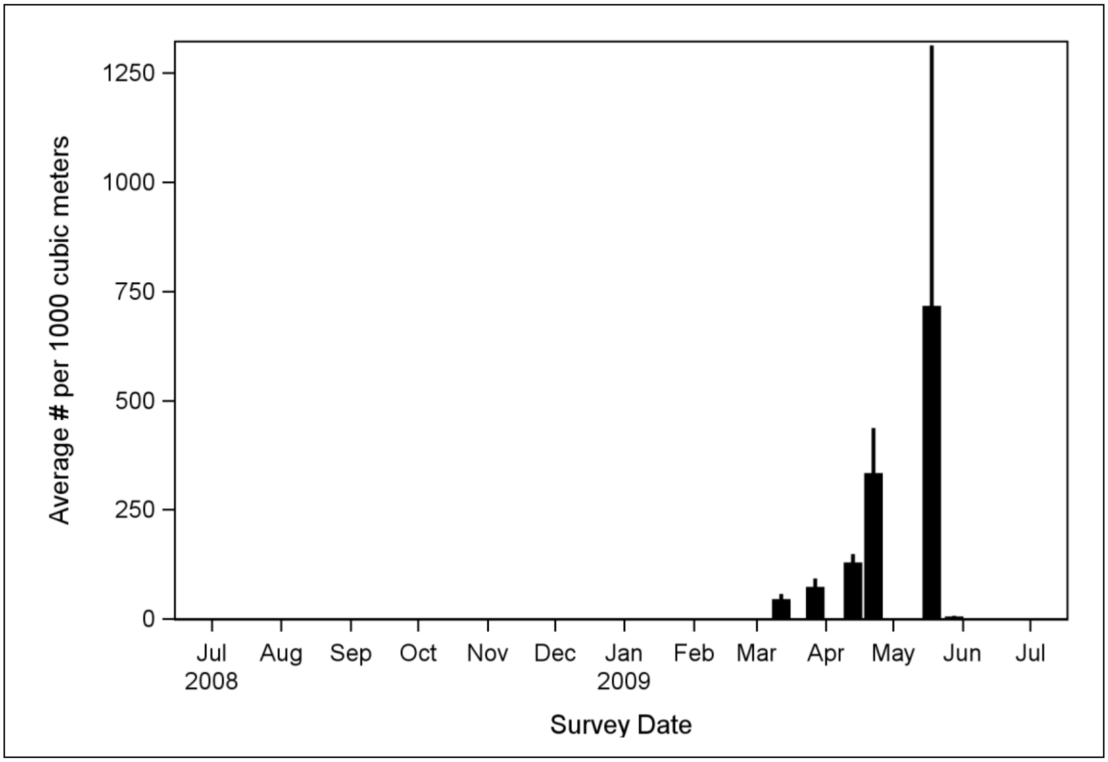


Figure 5-33. Survey mean concentration (#/1,000 m^3) of Blennioidei/Zoarcoidei complex larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

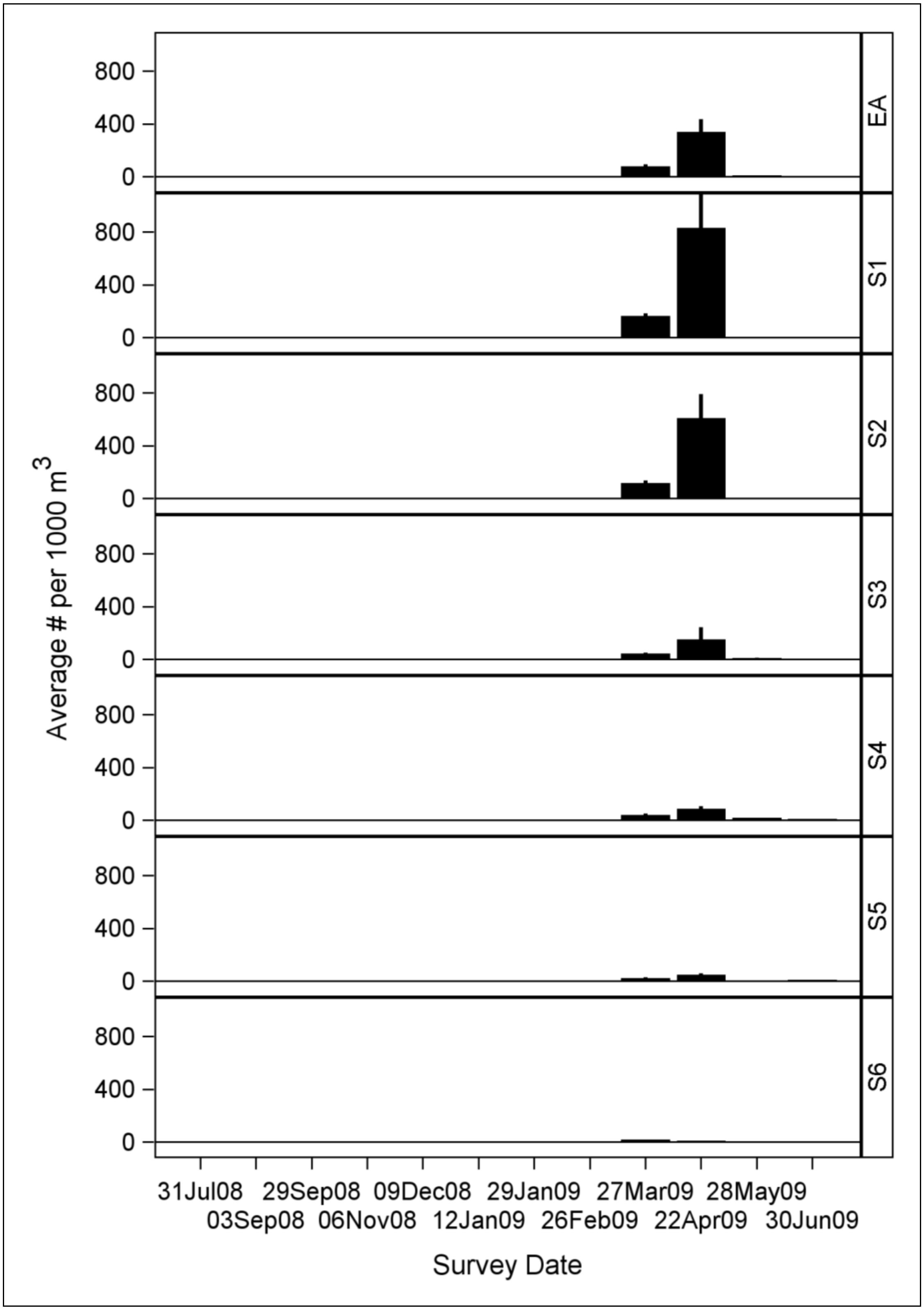


Figure 5-34. Survey mean concentration (#/1,000 m^3) of Blennioidei/Zoarcoidei complex larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

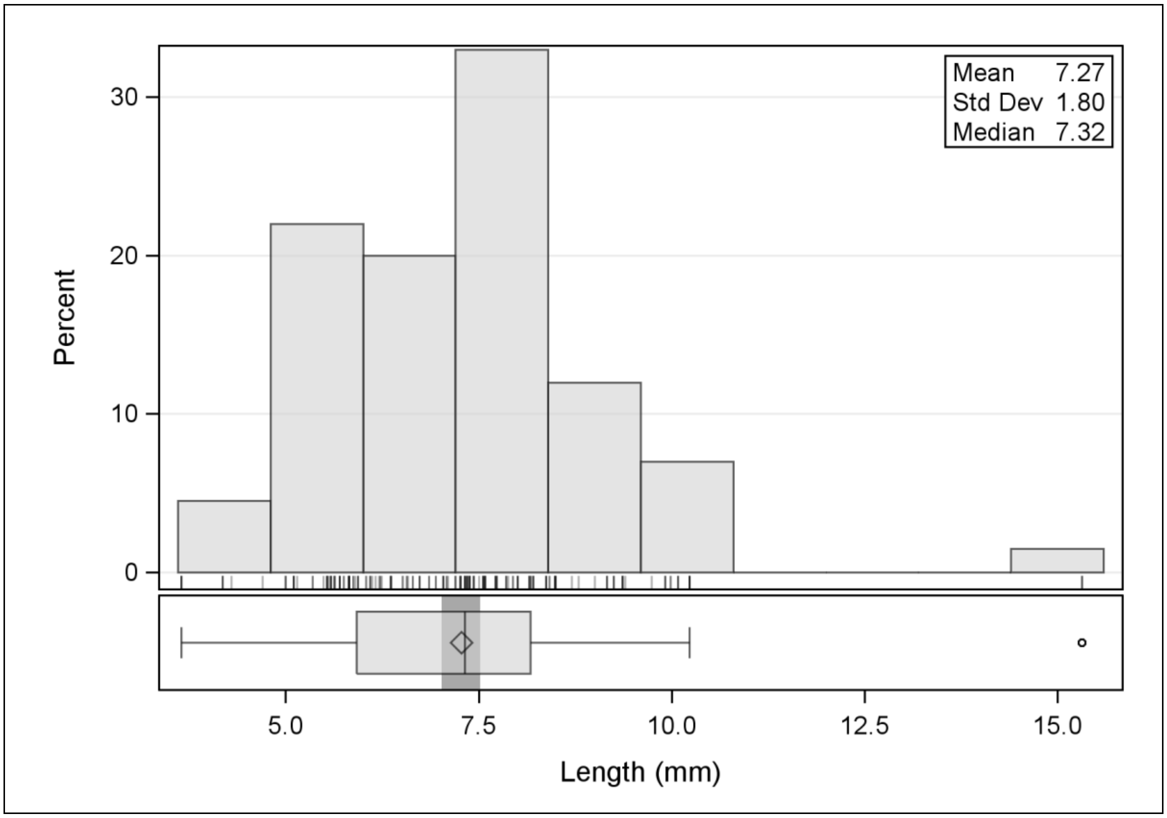
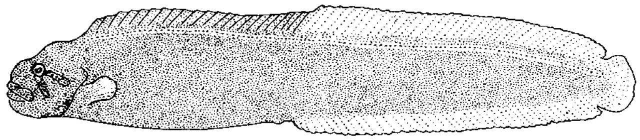


Figure 5-35. Length frequency histogram and statistics for Blennioidei/Zoarcoidei complex larvae based on a sample of 200 larvae proportionally sampled with replacement from the 89 larvae measured.

Entrainment Effects

An estimated 201 million Blennioidei/Zoarcoidei complex larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary life history demographic information was not available for this multi-species group. Blennioidei/Zoarcoidei complex larvae were only collected during three of the paired entrainment and source water surveys resulting in a large degree of uncertainty associated with any *ETM* estimates of P_M (**Figure 5-34**). Due to the uncertainty associated with the taxonomic composition of this group and the small number of *PE* estimates available for calculating *ETM* estimates of P_M, no estimates of impact assessment where calculated for this taxon.

5.4.3.3 Monkeyface Prickleback (Cebidichthys violaceus)



Cebidichthys violaceus (Girard 1854); monkeyface prickleback; length to 76 cm (30 in.); southern Oregon to Bahia San Quintin, north-central Baja California; intertidal to 24 m (79 ft); uniform black, olive, or gray, except for black streaks at eye (Miller and Lea 1972; Eschmeyer et al. 1983).

The monkeyface prickleback (formerly "monkeyface eel") is found as far south as central Baja California, Mexico but is rare south of Point Conception (Burge and Schultz 1973; Love 1996). They are common in crevices and rocks from the upper intertidal to shallow rocky reefs at depths of about 24 m and appear to be highly territorial (Wang 1986; Love 1996). They are not commonly sighted subtidally because of their cryptic nature (Burge and Schultz 1973). In central California, juveniles are most abundant in water about 0.5 m (1.6 ft) above mean lower low water (MLLW) tidal height and commonly found under rocks at low tide (Love 1996). Investigations into the diet of this fish in Diablo Cove showed that adults are herbivorous, feeding mainly on red algal blades (Burge and Schultz 1973).

Reproduction, Age, and Growth

Monkeyface prickleback lay demersal, adhesive eggs (Wang 1986; Fitch and Lavenberg 1971) and exhibit parental egg-guarding behavior (Fitch and Lavenberg 1971; Bane and Bane 1971). Spawning has been reported from January to May (Fitch and Lavenberg 1971; Wang 1986; Love 1996). In Diablo Cove, females were full of eggs in January, contained small undeveloped eggs in July, and had spent ovaries in September (Burge and Schultz 1973). This evidence, coupled with the presence of young-of-the-year (YOY) in fall, suggests late summer spawning (Burge and Schultz 1973). Additionally, maturing ovaries were observed from December through June, mature ovaries from March through May, and spent ovaries from February through August with one in December. Older fish appear to spawn earlier in the season than younger fish (Marshall and Wyllie Echeverria 1991).

Fecundity increases with age and length. Smaller fish produce 6,000 to 8,000 eggs (Fitch and Lavenberg 1971) while larger females produce more. A 41 cm (16 in.) SL female aged at 7 yr produced 17,500 eggs, and a 61 cm (24 in.) SL female aged at 11 yr had 46,000 eggs (Marshall and Wyllie Echeverria 1991).

Monkeyface prickleback larvae are planktonic, but little else is known about the early life history of this species. A related family member, the black prickleback (*Xiphister atropurpureus*), was shown to have marked positive phototaxis (attraction to light) for 3–5 d, after which time they become negatively phototactic (Peppar 1965). There were no data on monkeyface prickleback larval growth rates in the literature.

Longevity of the monkeyface prickleback was estimated at 18 yr from a 67 cm (26 in.) SL fish (Marshall and Wyllie Echeverria 1991). Females 20 cm (8 in.) in length from Monterey Bay, California were aged at 12 to 15 yr (Fitch and Lavenberg 1971). The oldest age estimated from fish collected in Diablo Cove was 14 yr based on two individuals that were approximately 49 cm (19 in.) SL and 64 cm (25 in.) SL (Burge and Schultz 1973). Considering this species reaches 76 cm (30 in.) SL (Eschmeyer et al. 1983), it probably lives longer. Fitch and Lavenberg (1971) reported the age at 50% maturity at 3–4 yr. However, Marshall and Wyllie Echeverria (1991) determined that age at first maturity is 4 yr, age at 50% maturity is 5 yr, and age at 100% maturity is 7 yr.

Population Trends and Fishery

The fishery for monkeyface prickleback is largely recreational although some are sold commercially (Wang 1986; Love 1996). They are usually caught using a fishing method called “poke-poling” among intertidal rocks. Average recreational landings are less than one-half ton annually in San Luis Obispo County, and commercial landings have averaged only 59 lbs (27 kg) annually in central California since 2005 (**Table 5-28**). Because of the limited fishery for this species, there have been no estimates of stock size or adult density.

Table 5-28. Monkeyface prickleback recreational fishing catch in central California, and commercial fishing landings and ex-vessel value in San Luis Obispo County, 2005-2009. Data from RecFIN (2010) and PacFIN (2010).

	Recreational Fishery		Commercial Fishery	
Year	Estimated Catch (No.)	Estimated Weight (lbs)	Landings (lbs)	Ex-vessel Value ($)
2005	434	575	60	$130
2006	401	543	55	$138
2007	1,172	458	47	$148
2008	787	461	56	$144
2009	1,816	2,696	79	$213
Average	922	946	59	$154

Juvenile monkeyface prickleback abundance was highest in 1987 on transects surveyed during the DCPP Receiving Water Monitoring Program intertidal fish stations in Field’s Cove (**Figure 5-36**). It declined over a two-year period and then remained low in the 1990s, increasing slightly in the 2000s.

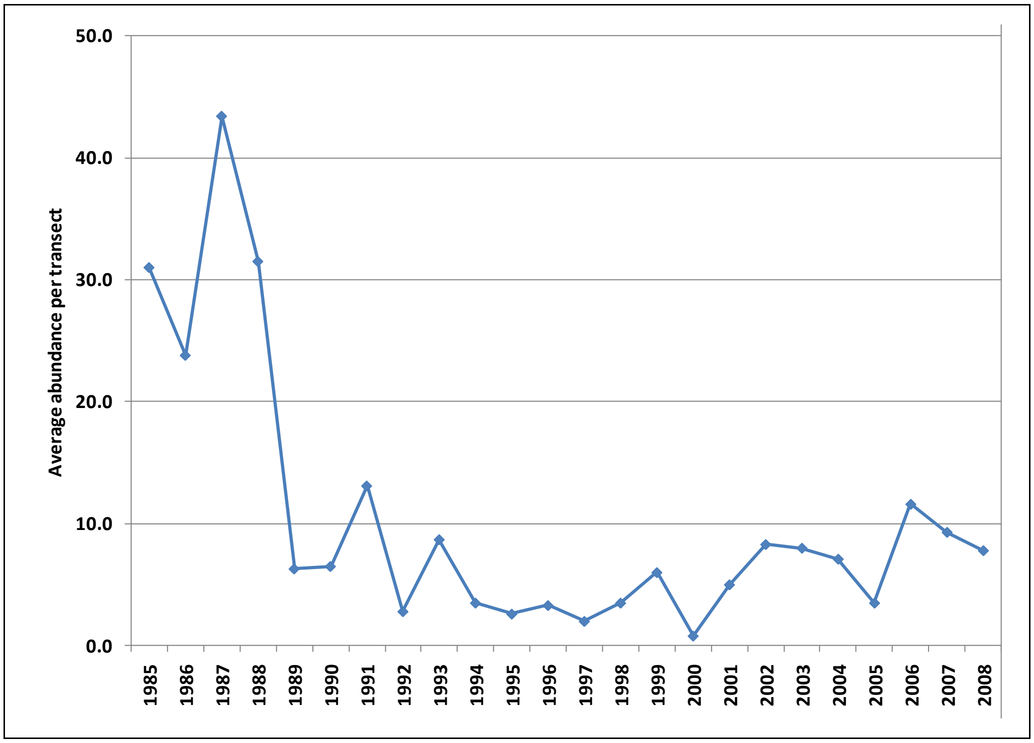


Figure 5-36. Juvenile monkeyface prickleback abundance from Field's Cove intertidal fish station.

Sampling Results

Monkeyface prickleback was the third most abundant taxon collected from the entrainment stations and tenth most abundant from the source water stations, comprising 7.8% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The larvae were present from January through July, and were most abundant in April. The mean concentration per survey ranged from zero to over 800 larvae per 1,000 m^3 (**Figure 5-37**). Larvae occurred at all stations and had a gradient of decreasing abundance with distance offshore (**Figure 5-38**).

The mean length of 200 measurements proportionally sampled at random with replacement from the 364 larvae measured was 7.69 mm (0.30 in.) (**Figure 5-39**). The smallest larva of the 364 measured was 4.54 mm (0.18 in.) and the largest was 17.84 mm (0.70 in.). The averages from the random samples proportionally drawn from all the measurements resulted in values of 7.82 mm (0.31 in.) for the mean length and 7.36 mm (0.29 in.) for the median. The computed hatch length from the data was 6.31 mm (0.25 in.).

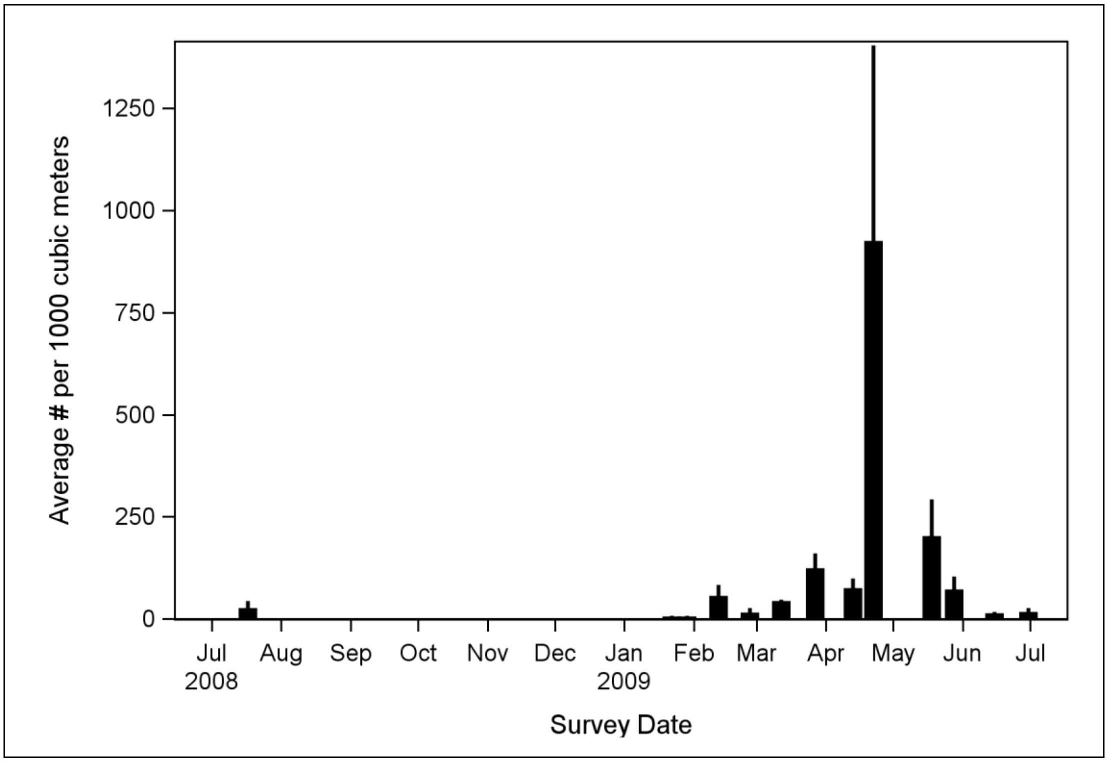


Figure 5-37. Survey mean concentration (#/1,000 m^3) of monkeyface prickleback larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

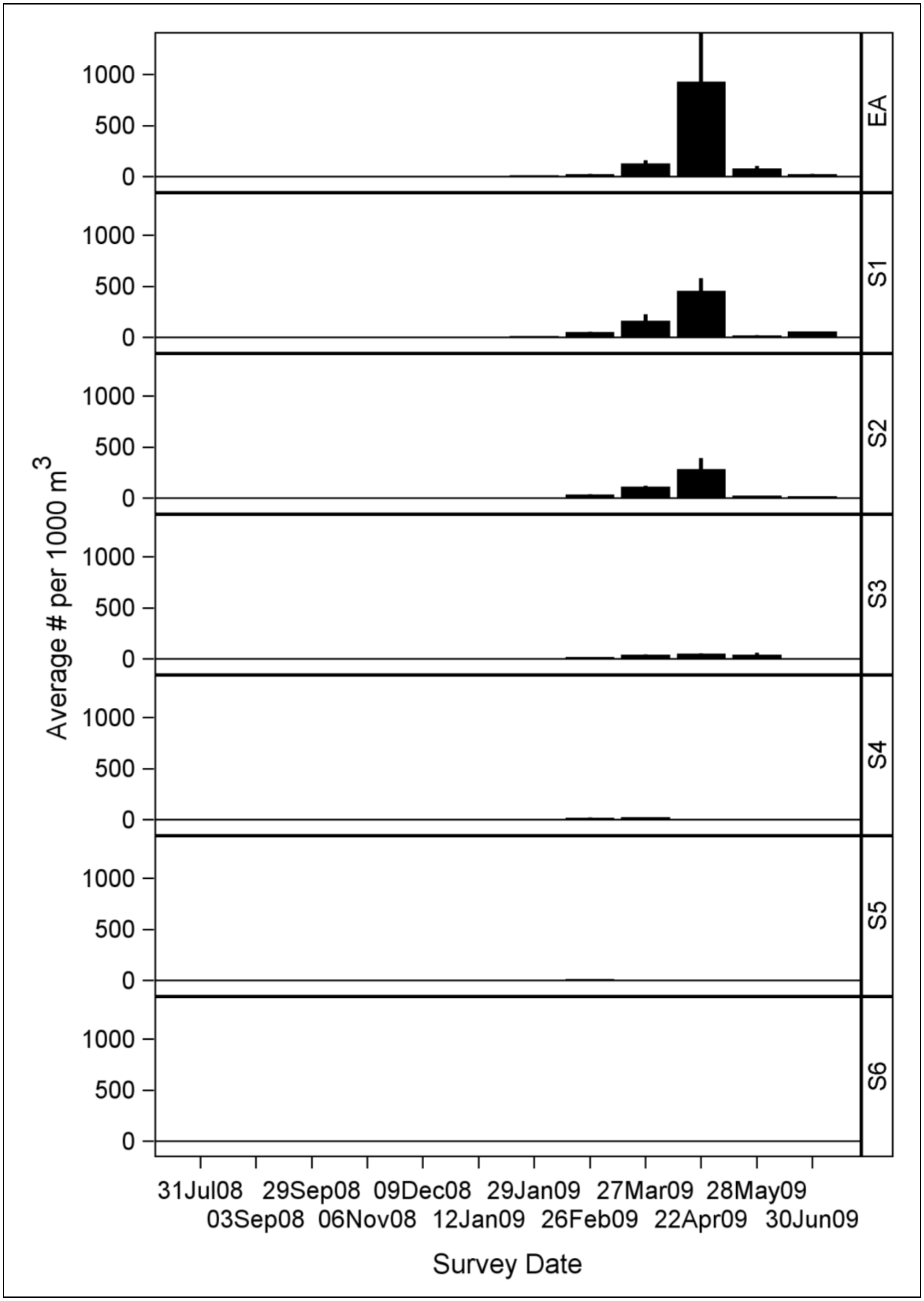


Figure 5-38. Survey mean concentration (#/1,000 m^3) of monkeyface prickleback larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

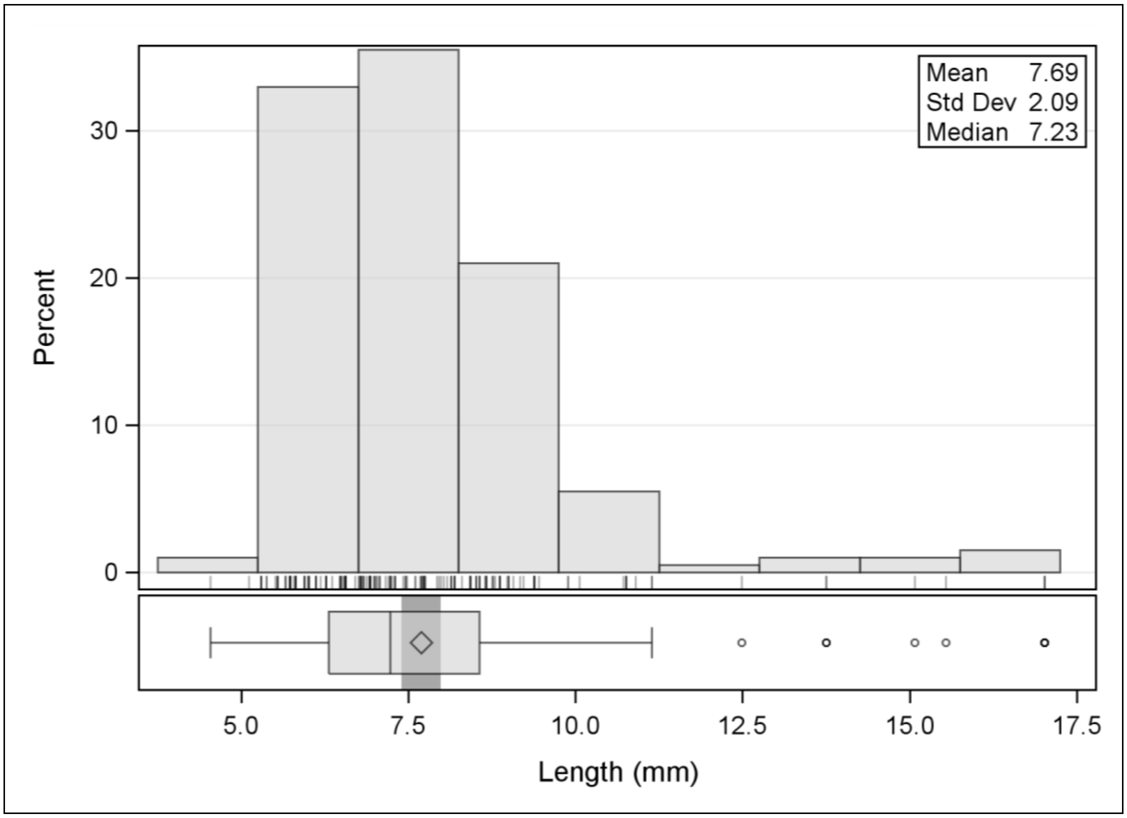


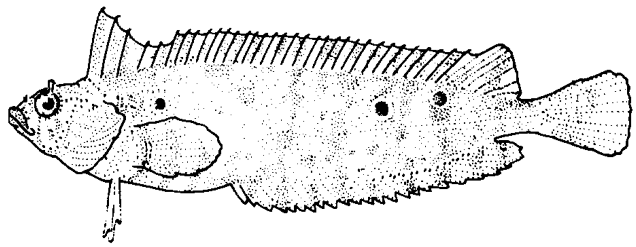
Figure 5-39. Length frequency histogram and statistics for monkeyface prickleback larvae based on a sample of 200 larvae proportionally sampled with replacement from the 364 monkeyface prickleback larvae measured.

Entrainment Effects

An estimated 237 million monkeyface prickleback larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary life history demographic information was not available for this species.

An *ETM* estimate of P_M was not calculated for this species because the summary of the source water results indicated that the sampling did not provide data that would provide a representative estimate of the source water population (**Figure 5-38**). Monkeyface prickleback larvae were more abundant at the entrainment station inside the Intake Cove where the average concentration over the study period was 63.1 larvae per 1,000 m^3. The average concentration over the study period at the source water stations was much less at 18.4 larvae per 1,000 m^3. Although this distribution would be expected due to the nearshore distribution of the adults of this species, the habitat just offshore of the intake where the source water samples were collected is a mix of mostly soft sediments with some hard substrate, which is unlike many of the other nearshore areas north and south of the plant which have large areas of hard substrate that extend out into deeper water. Although the more extensive sampling of these areas in the 1996–1999 Study likely provided a more representative sample of nearshore larval populations, the only samples likely to provide a representative estimate of the larvae for this species would be samples from very close to shore; an area that could not be sampled in either study. Although the larvae were collected in enough of the surveys to provide a reasonable estimate of P_M, the *ETM* analysis was not conducted due to the potential biases in the source water estimates.

5.4.4 Kelp blennies (*Gibbonsia* spp.)



Gibbonsia elegans (Cooper 1864); spotted kelpfish; length to 16 cm (6.3 in.); Piedras Blancas Pt., central California to Bahia Magdalena, southern Baja California, including Isla Guadalupe; to 56 m (180 ft) (Miller and Lea 1972; Eschmeyer et al. 1983); green to brown or tan or reddish, often blotched or streaked (Eschmeyer et al. 1983). *Gibbonsia metzi* Hubbs 1927; striped kelpfish; length to 24 cm (9.5 in.); Vancouver Is., British Columbia to Punta Rompiente, central Baja California; intertidal to 9.1 m (30 ft) (Miller and Lea 1972; Eschmeyer et al. 1983); reddish to light brown with stripes or darker mottling (Eschmeyer et al. 1983). *Gibbonsia montereyensis* Hubbs 1927; crevice kelpfish; length to 15 cm (5.9 in.); British Columbia to Rio Santo Tomas, northern Baja California. 15–37 m (49-120 ft). (Miller and Lea 1972; Eschmeyer et al. 1983); reddish to brown or lavender, plain colored to spotted or striped (Eschmeyer et al. 1983). *G. erythra* is a synonym (Stepien and Rosenblatt 1991).

There are three species of kelp blennies in the genus *Gibbonsia* that occur along the west coast of North America from Baja to British Columbia and another species in the genus *Heterostichus* that occurs only infrequently north of Point Conception (George and Springer 1980; Love 1996). Nelson (1994) indicates that worldwide there are three groups of clinids with about 20 genera and 73 species. Clinids are small (generally <25 cm [9.8 in.] SL; with *H. rostratus* ca. 60 cm [24 in.] SL) being an exception. Adults are primarily demersal residents of nearshore rocky reefs and kelp and seaweed beds in temperate marine waters (Lamb and Edgell 1986; Moser 1996).

Reproduction, Age, and Growth

The three kelp blennies in central California are oviparous (Nelson 1994); probably spawning demersal adhesive eggs (Fitch and Lavenberg 1971; Moser 1996) although Bane and Bane (1971) report striped kelpfish (*Gibbonsia metzi*) as having pelagic eggs. Larval forms are pelagic and are only identifiable to genus in the case of *Gibbonsia* spp. although giant kelpfish can be identified to species at most life stages. Yolk-sac duration in this latter species appears to be 2-3 d (Shiogaki and Dotsu 1972). Bane and Bane (1971) report a fecundity of approximately 2,300 eggs/female for a spotted kelpfish (*G. elegans*). *Gibbonsia* spp. first spawn at 2 yr, may spawn more than once per year, and live to around 7 yr (Fitch and Lavenberg 1975).

There is very little demographic information relating to the early life stages of kelp blennies in general or specifically to the four representatives of the family found in central California. Growth of larval giant kelpfish was estimated by linear regression from data on lab-reared specimens (Stepien 1986) as 0.25 mm/d ± 0.013 (slope ± 1 SE). A similar estimate of growth rate is not available for *Gibbonsia* spp. There is no literature estimates of early life stage survivorship for any of the clinids treated here.

Population Trends and Fishery

There are no catch statistics for these species because they are not commercially or recreationally harvested. The abundance of kelp blennies observed in the DCPP Receiving Water Monitoring Program (RWMP) studies on subtidal fishes showed they have a varied abundance through the years with a decrease in their abundance from the mid 1990's through 2007 (**Figure 5-40**). There was a slight increase in 2008. These data were collected along three 50 m (164 ft) transects in an area approximately 1 km south of Diablo Cove which is not contacted by the plant's thermal discharge. The method is not considered an accurate method for enumerating this species because their small size and cryptic nature, but the data may reflect general trends in the species' abundance over time.

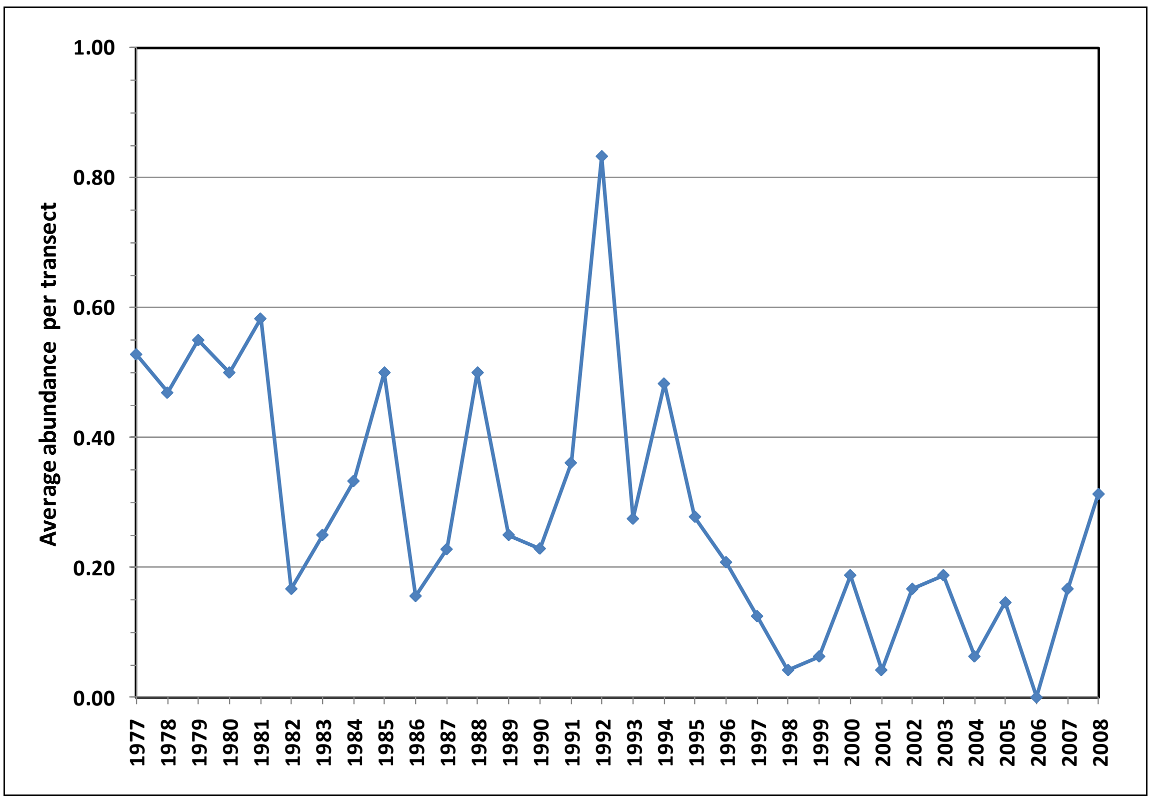


Figure 5-40. Average abundance per 50x4 m transect for kelp blennies at DCPP control site.

Sampling Results

Kelp blennies were the fourth most abundant taxon collected from the entrainment stations and twenty-third most abundant from the source water stations, comprising 7.4% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The larvae were present during all months of the year with peaks in July, December and March (**Figure 5-41**). The mean concentration per survey ranged from approximately 10–200 larvae per 1,000 m^3 with an average concentration of 63 larvae per 1,000 m^3 at the entrainment station. Larvae were highly concentrated at the stations closest to shore with almost none found at Stations S4, S5 of S6 (**Figure 5-42**).

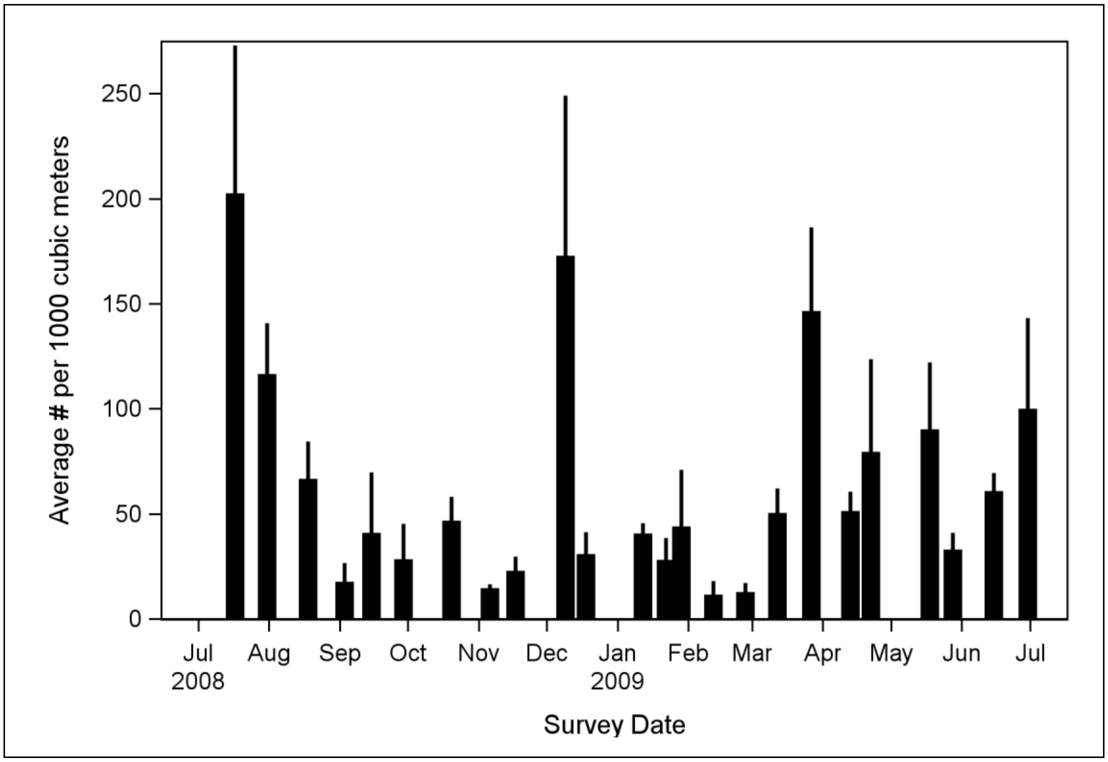


Figure 5-41. Survey mean concentration (#/1,000 m^3) of kelp blenny larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

Larvae that were classified as Blennioidei or Clinidae were probably *Gibbonsia* spp., but because of specimen damage or uncertainties in myomere counts, they were classified into the higher taxonomic categories. Average annual concentrations of Blennioidei and Clinidae combined at the entrainment station were 6 larvae and 0.6 larvae per 1,000 m^3 respectively, as compared to 63 per 1,000 m^3 for *Gibbonsia* spp.

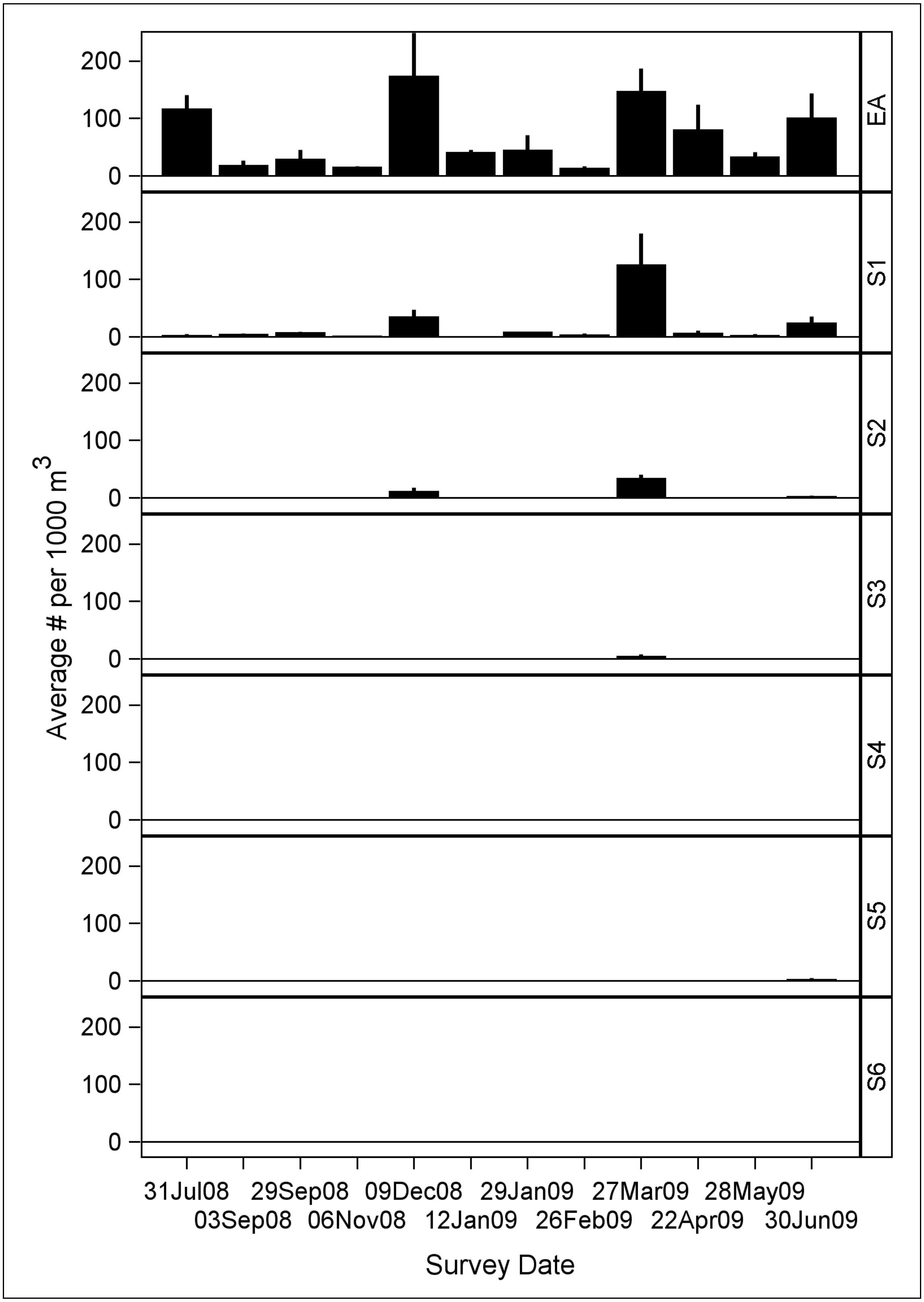


Figure 5-42. Survey mean concentration (#/1,000 m^3) of kelp blenny larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

The mean length of 200 measurements proportionally sampled at random with replacement from the 778 larvae measured was 6.47 mm (0.25 in.) (**Figure 5-43**). The smallest larva of the 778 measured was 2.01 mm (0.08 in.) and the largest was 26.00 mm (1.02 in.). The averages from the random samples proportionally drawn from all the measurements resulted in values of 6.39 (0.25 in.) for the mean length and 6.06 mm (0.24 in.) for the median. The hatch length was estimated based on the 10th percentile value of 4.50 mm (0.18 in.) which is consistent with the value reported from Moser (1996) of 4.5 mm for *Gibbonsia elegans*.

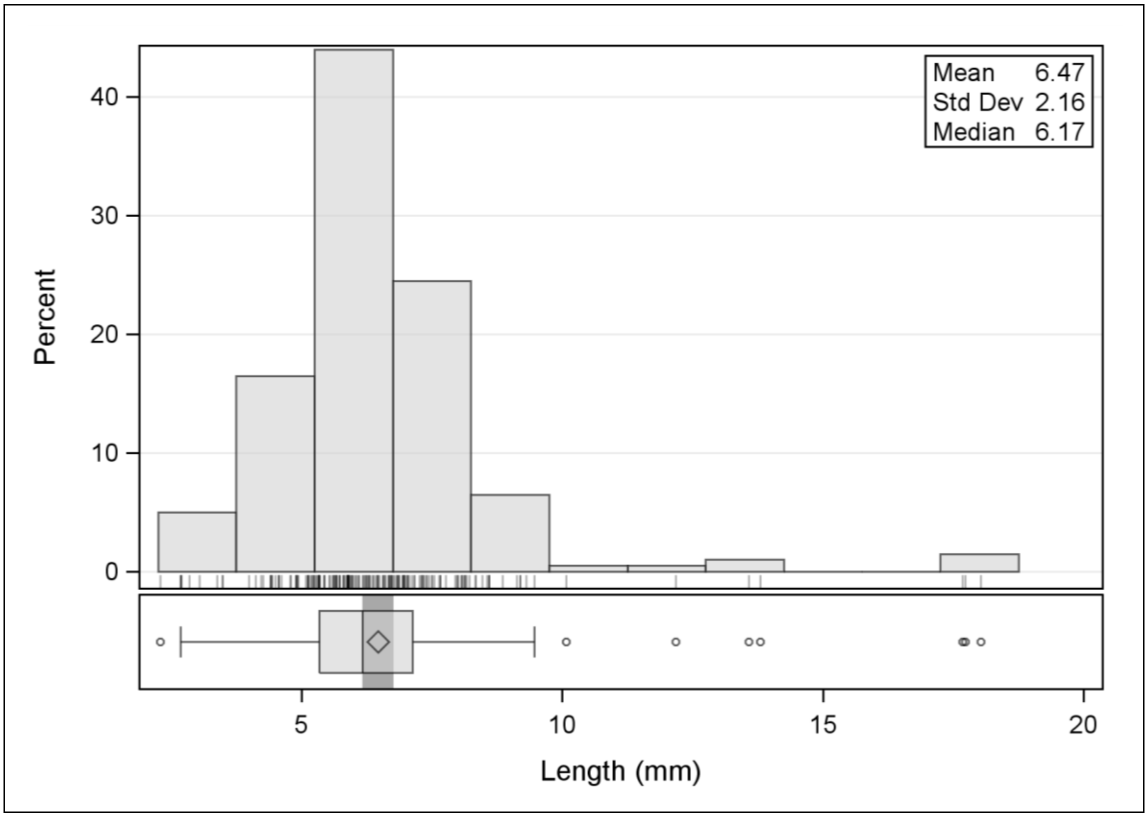


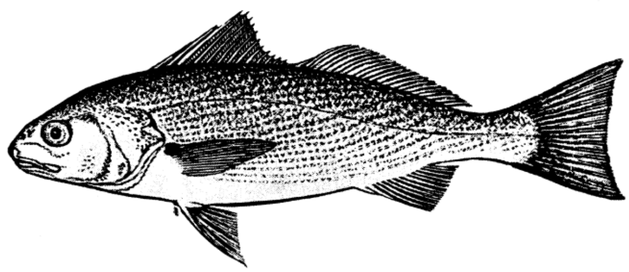
Figure 5-43. Length frequency histogram and statistics for kelp blenny larvae based on a sample of 200 larvae proportionally sampled with replacement from the 778 kelp blenny larvae measured.

Entrainment Effects

An estimated 214 million kelp blenny larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary life history demographic information was not available for this species.

An *ETM* estimate of P_M was not calculated for this species group because the summary of the source water results indicated that the sampling did not provide data that would provide a representative estimate of the source water population (**Figure 5-38**). Kelp blenny larvae were more abundant at the entrainment station inside the Intake Cove where the average concentration over the study period was 66.4 larvae per 1,000 m^3. The average concentration over the study period at the source water stations was much less at 3.78 larvae per 1,000 m^3. Although this distribution would be expected due to the nearshore distribution of the adults of this species, the habitat just offshore of the intake where the source water samples were collected is a mix of mostly soft sediments with some hard substrate, which is unlike many of the other nearshore areas north and south of the plant which have large areas of hard substrate that extend out into deeper water. Although the more extensive sampling of these areas in the 1996–1999 Study likely provided a more representative sample of nearshore larval populations, the only samples likely to provide a representative estimate of the larvae for this species would be samples from very close to shore; an area that could not be sampled in either study. Although the larvae were collected in enough of the surveys to provide a reasonable estimate of P_M, the *ETM* analysis was not conducted due to the potential biases in the source water estimates.

5.4.5 White Croaker (*Genyonemus lineatus*)



Genyonemus lineatus (Ayres 1855); white croaker; length to 41 cm (16 in.); Barkley Sound, British Columbia to Bahia Magdalena, southern Baja California; inshore to 236 m (774 ft); incandescent brownish to yellowish on back, silver below; fins yellow to white (Miller and Lea 1972; Eschmeyer et al. 1983).

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 reported depth range of white croaker is from the surface to depths of 183 m (600 ft) (Miller and Lea 1972, Love et al. 1984); however, in southern California, Allen (1982) found white croaker over soft bottoms between 10 and 130 m (32.8 and 426.5 ft), and it was most frequently collected at 10 m (32.8 ft).

Reproduction, Age, and Growth

White croaker is an oviparous broadcast spawner. They mature between about 130 and 190 mm (5.1 and 7.5 in.) TL, somewhere between the first and fourth years. About one-half of males mature by 140 mm (5.5 in.) TL, and one-half of females by 150 mm (5.9 in.) TL, and all fishes are mature by 190 mm (7.5 in.) TL in their third to fourth year (Love et al. 1984). Off Long Beach, California, 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 in.) female to about 37,200 eggs in a 260 mm (10.5 in.) female, with spawning taking place as often as every five days (Love et al. 1984). In their first and second years, females spawn for three months for a total of about 18 times per season. Older individuals 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, California) to Laguna Beach, California, are considered an important spawning center for this species (Love et al. 1984).

Newly hatched white croaker larvae are 1–2 mm SL (0.04-0.08 in.) and not well developed (Watson 1982). Larvae are principally located within 4 km (2.5 mi) from shore, and as they develop tend to move shoreward and into the epibenthos (Schlotterbeck and Connally 1982). Maximum reported size is 414 mm (16.3 in.) (Miller and Lea 1972), with a life span of 12–15 years (Frey 1971, Love et al. 1984).

Population Trends and Fishery

White croaker have both commercial and recreational fishery value. Love et al. (1984) stated that fishing for white croaker in Monterey Bay occurs on a daily basis year round. The daily catch can range from 400–900 kg (ca. 0.4–0.9 MT) with a maximum catch of 1,800 kg (ca. 1.8 MT) of white croaker. The annual harvest of white croaker in Monterey Bay can then be estimated at approximately 248 MT. However, available evidence suggests that commercial catches of white croaker have been declining since around 1985 in the Monterey Bay area (Starr et al. 1998).

Recreational catch in central California occurs from piers, breakwaters, and private boats. Annual recreational landings in central California from all sources have averaged approximately 28,500 fish per year since 2005 but have declined to an estimated low of 3,511 since a high of 51,129 in 2005 (RecFIN 2010; **Table 5-33**). Commercial landings over the same period were only recorded in San Luis Obispo County during 2006.

Table 5-29. White croaker recreational fishing catch in central California, and commercial fishing landings and ex-vessel value in San Luis Obispo County, 2005-2009. Data from RecFIN (2010) and PacFIN (2010).

	Recreational Fishery		Commercial Fishery	
Year	Estimated Catch (No.)	Estimated Weight (lbs)	Landings (lbs)	Ex-vessel Value ($)
2005	51,129	15,426		
2006	45,856	12,093	2,250	$5,029
2007	33,932	8,416		
2008	8,400	1,917		
2009	3,511	1,364		
Average	28,565	7,843	2,250	$5,029

Sampling Results

White croaker was the fourteenth most abundant taxon collected from the entrainment stations and ninth most abundant from the source water stations, comprising 2.3% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The larvae were present during all months of the year except June and had peak abundances of approximately 100 larvae per 1,000 m^3 in April (**Figure 5-44**). Larvae were present at all stations with the highest concentrations generally being at stations S1–S4 (**Figure 5-45**).

The mean length of 200 measurements proportionally sampled at random with replacement from the 249 larvae measured was 3.36 mm (0.13 in.) (**Figure 5-46**). The smallest larva of the 249 measured was 1.58 mm (0.06 in.) and the largest was 8.42 mm (0.33 in.). The averages from the random samples proportionally drawn from all the measurements resulted in values of 3.38 mm (0.13 in.) for the mean length and 3.09 mm (0.12 in.) for the median. The hatch length was estimated at 2.02 mm (0.09 in.) which is larger than the value reported from Moser (1996) of ca. 1.8 mm (0.07 in.) and represents the average of the 5th percentile values from the random samples proportionally drawn from all the measurements.

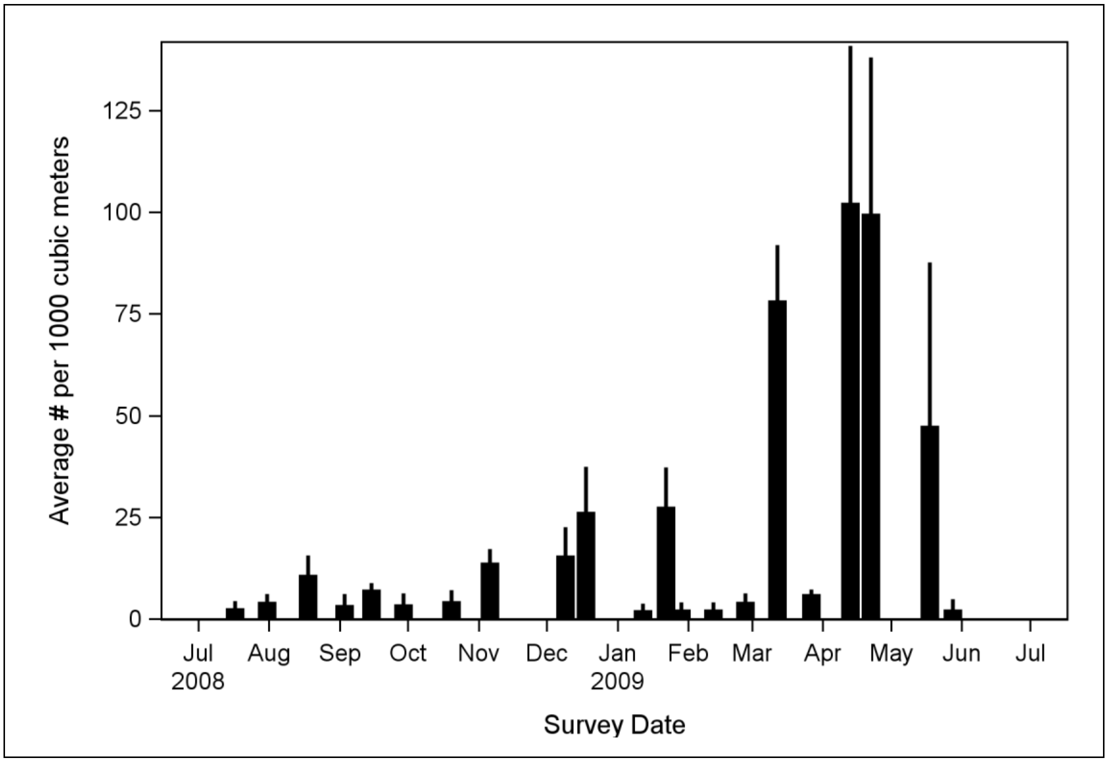


Figure 5-44. Survey mean concentration (#/1,000 m^3) of white croaker larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

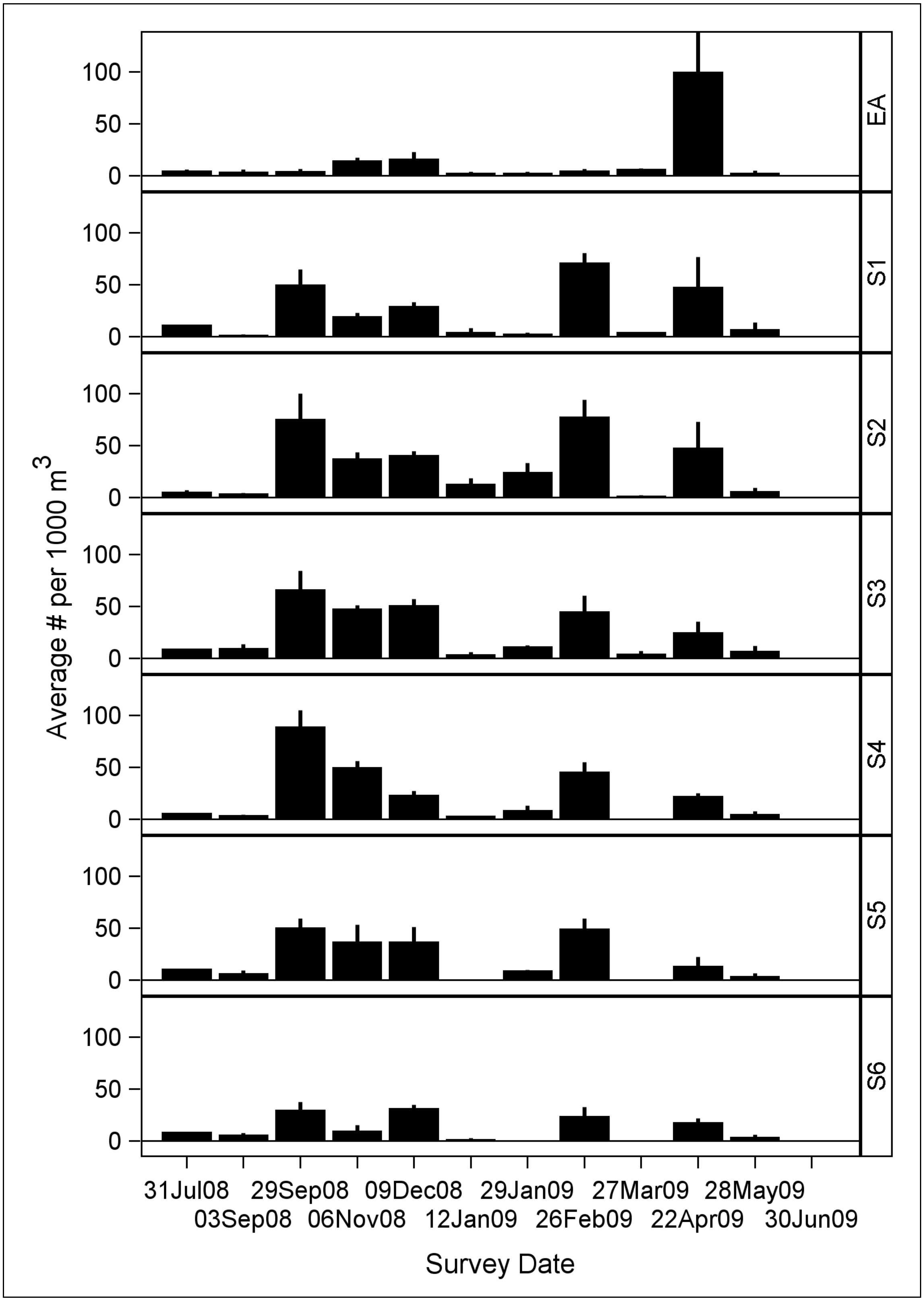


Figure 5-45. Survey mean concentration (#/1,000 m^3) of white croaker larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

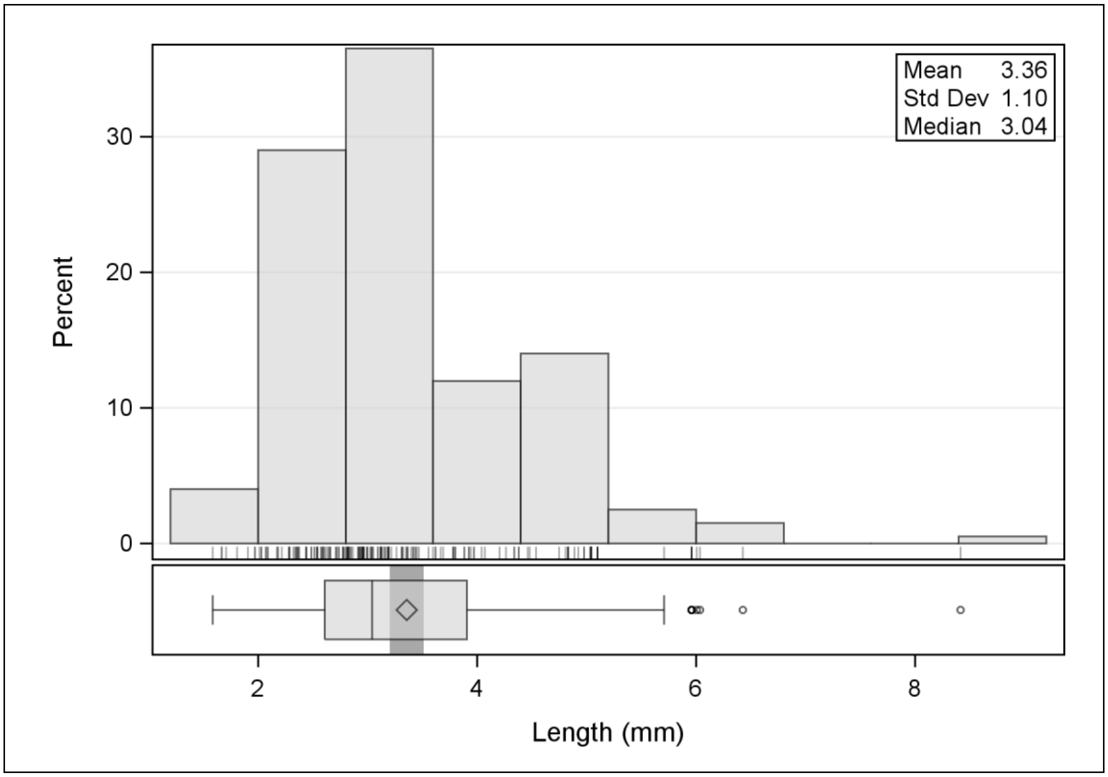


Figure 5-46. Length frequency histogram and statistics for white croaker larvae based on a sample of 200 larvae proportionally sampled with replacement from the 249 white croaker larvae measured.

Entrainment Effects

An estimated 61 million white croaker larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary demographic information was not available for this species.

An *ETM* estimate of P_M was calculated for this species because the results of the source water sampling show that white croaker larvae were collected across all of the source water stations (**Figure 5-45**). The data from the sampling likely provided representative estimates of the source water populations of larvae for the *ETM PE* estimates. The results of the *ETM* will not be used in the *HPF* calculations because the adults of this species are not associated with any specific habitats in the vicinity of the DCPP. In contrast to most of the other fishes included in this assessment that are associated with nearshore rocky reef habitats, white croakers usually occur in the water column over soft bottom and the females release eggs into the water column.

Empirical Transport Model *(ETM)*

There are no specific larval growth data on white croaker, so a larval growth rate was derived from available 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*), which all have larvae that are morphologically similar at small sizes (Moser 1996). Hatch and larval lengths at various number of days after birth presented in Moser (1996) were used to calculate an average daily growth rate from hatching through the flexion stage for Sciaenidae. The growth rate calculated from these data was 0.25 mm/day (0.0098 in/d). The estimated period of entrainment exposure of 13.3 d was calculated by dividing the difference between an estimated hatch length of 2.02 mm (0.08 in.) and the size of the 95th percentile value of 5.31 mm (0.21 in.) by the estimated larval growth rate. The estimated duration of the larvae was added to the estimated duration of the planktonic egg stage of 2.2 d for a total duration of entrainment exposure of 15.4 d. The entrainment exposure duration was calculated from size and growth values with greater decimal precision than those shown, and differs slightly from the duration calculated using these rounded values.

The data used to calculate the *ETM* estimates for white croaker larvae show that they occurred throughout most of the year but were most abundant in late September–December 2008 period and in February 2009 (**Table 5-34**). Both alongshore and offshore extrapolations of the source water populations were calculated since white croaker are distributed in nearshore areas from the surfzone to depths of 238 m (781 ft) (Love et al 2005). The short larval duration resulted in onshore current vectors that were within the outer edge of the sampled source water at 2,890 m (9,481 ft) for all of the surveys except in March and April 2009 (34.64 and 31.53 km [21.5 and 19.6 mi], respectively). The two sets of *PE* estimates for the CODAR-based extrapolations were different due to including the backprojections beyond the 60 m (200 ft) depth contour for all of the surveys (**Table 5-34**). Based on the CODAR-based extrapolations the P_M estimates were 0.0390 (3.9%) and 0.0213 (2.4%) for the alongshore and offshore extrapolation, respectively (**Table 5-35**).

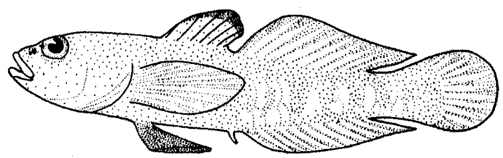
Table 5-30. *ETM* data for white croaker larvae using alongshore and offshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from all surveys with *PE* > 0.

	Alongshore		Offshore Extrapolated			
Survey Date	*PE* Estimate	*PE* Std. Err.	*PE* Estimate	*PE* Std. Err.	f_i	Alongshore Displacement (km)
31-Jul-08	0.00201	0.00031	0.00062	0.00010	0.0477	19.50
3-Sep-08	0.00473	0.00129	0.00107	0.00029	0.0235	10.77
29-Sep-08	0.00043	0.00011	0.00032	0.00008	0.2475	12.55
6-Nov-08	0.00149	0.00016	0.00090	0.00009	0.1573	24.65
9-Dec-08	0.00425	0.00069	0.00282	0.00046	0.1685	8.32
12-Jan-09	0.00487	0.00137	0.00060	0.00017	0.0100	13.75
29-Jan-09	0.00159	0.00041	0.00046	0.00012	0.0231	8.78
26-Feb-09	0.00016	0.00003	0.00011	0.00002	0.1888	25.22
27-Mar-09	0.03229	0.00578	0.00068	0.00012	0.0035	16.96
22-Apr-09	0.01045	0.00159	0.00571	0.00087	0.1086	31.26
28-May-09	0.00174	0.00066	0.00031	0.00012	0.0216	26.00
30-Jun-09	0	0	0	0	0	12.43
Average =	0.00582		0.00124			17.98

Table 5-31. Estimates for *ETM* models for white croaker larvae calculated using alongshore and offshore extrapolations based on current data from CODAR backprojected from the survey data with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP.

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	17.98	0.03899	0.01702	0.05601	0.02197
Offshore Extrapolated P_M	19.61	0.02132	0.01716	0.03847	0.00416

5.4.6 Blackeye Goby (*Rhinogobiops nicholsi*)



Rhinogobiops nicholsi (Bean 1882); blackeye goby; length to 15 cm (5.9 in.); northern British Columbia to south of Punta Rompiente, central Baja California; intertidal to 106 m (348 ft); pale tan with some brown or greenish speckling; small blue dot below eye (Miller and Lea 1972; Eschmeyer et al. 1983).

The family Gobiidae has 1,875 species in 212 genera occurring worldwide in temperate to tropical climates and in a range of habitats from freshwater to brackish and marine environments (Brothers 1975; Nelson 1994). About 21 species and 16 genera occur in the CalCOFI study area from the Oregon-California border to south of Cabo San Lucas, Baja California Sur, Mexico (Moser 1996). Adult blackeye goby (*Rhinogobiops nicholsi* – formerly *Coryphopterus nicholsi*) is common in benthic nearshore marine environments in the vicinity of Diablo Canyon, generally at rock-sand interfaces (Tenera unpubl. data; Miller and Lea 1972; Love 1996).

Reproduction, Age, and Growth

The early life history of blackeye goby is similar to other members of the family Gobiidae. Females are oviparous, laying demersal, adhesive eggs under rocks that the males guard until the planktonic larvae hatch (Love 1996; Moser 1996). Nests containing eggs are found from April to August in southern California (Wiley 1973). Larvae are reported to hatch at 2.8–3.0 mm (0.11-0.12 in.) (Moser 1996), with planktonic durations of approximately 75 d (Steele 1997). Larval transformation occurs at 16–25 mm (0.6-1.0 in.) (Moser 1996), which is within the range of lengths at settlement (15–29 mm [0.63-0.98 in.]) reported by Steele (1997). Blackeye goby demonstrate protogynous hermaphroditism (Cole 1983; Breitburg 1987; Cole and Shapiro 1992), with all animals beginning life as females and transforming to males at around 6.0–7.5 cm (2.3-3.0 in.) (Love 1996). They live approximately 5 yr and mature around 0.5 yr at approximately 4.5 cm (1.8 in.) (Steele 1997). Spawning occurs year-round, peaking between February and October (Matarese et al. 1989; Moser 1996). Females may spawn several times per year with fecundity estimates ranging in southern California from 1,700 eggs/nest (Ebert and Turner 1962) to 3,274–4,788 eggs in Orange County (Wiley 1973).

While the size at age for post-larval blackeye goby has been described (Wiley 1973), size at age for the larvae estimated from planktonic duration and size at settlement are 2–3 mo and 15–29 mm (0.6-1.1 in.), respectively (Steele 1997). Additionally, larval growth has been characterized for three gobiid species (arrow goby: *Clevelandia ios*; cheekspot goby: *Ilypnus gilberti*; shadow goby: *Quietula y-cauda*) from Mission Bay, California (Brothers 1975). Brothers (1975) described the growth coefficient of *C. ios* using the von Bertalanffy Growth Function as k = 0.96 (L_∞ = 36 mm SL), that of *I. gilberti* as k = 0.18 (L_∞ = 60 mm SL), and that of *Q. y-cauda* as k = 0.16 (L_∞ = 70 mm SL).

Population Trends and Fishery

There is no fishery for blackeye goby. The local population of blackeye goby in the vicinity of DCPP has been monitored since 1977 as part of the Thermal Effects Monitoring Program. Blackeye goby densities on transects at South Control, an area unaffected by thermal discharges, have shown low fluctuations in abundance averaging approximately 0.5–1.0 fish per transect until 2002, and then declining to zero thereafter (**Figure 5-47**). Abundances inside Diablo Cove, in areas with increased water temperatures resulting from operation of the DCPP, increased sharply after power plant start-up in 1986, and climbed to high densities in 1989 and again in 2001–2002.

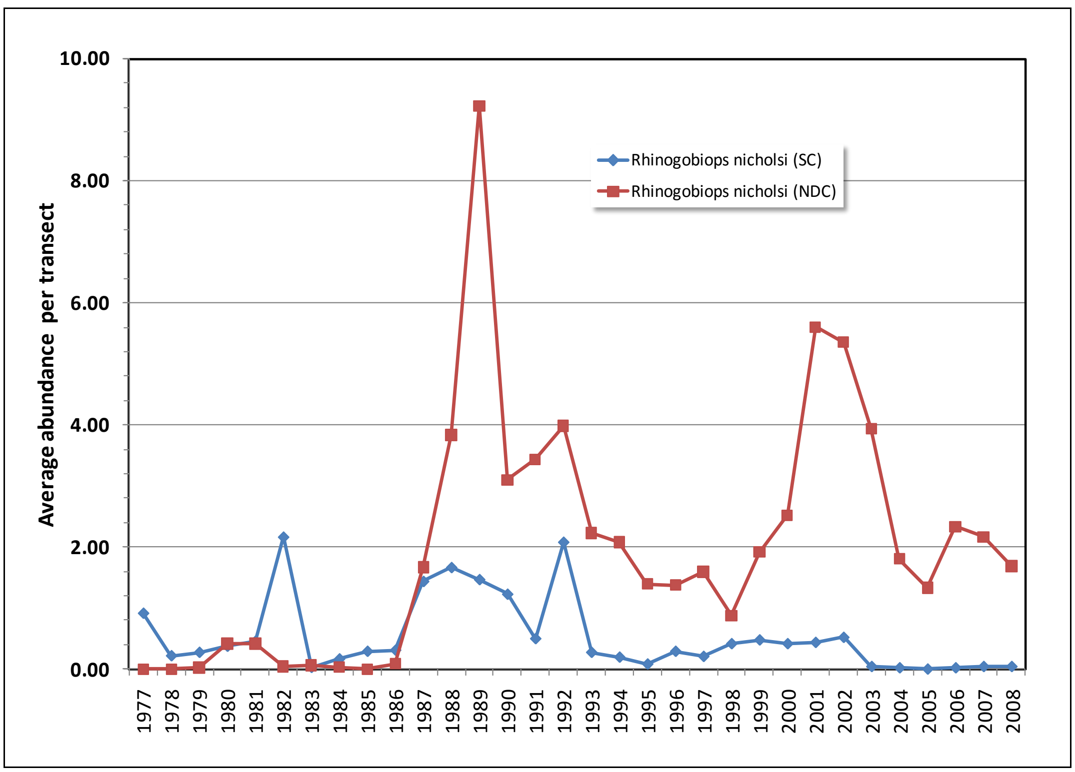


Figure 5-47. Annual abundance per transect of blackeye goby in the vicinity of DCPP based on TEMP monitoring data. SC = South Control and NDC = North Diablo Cove.

Sampling Results

Blackeye goby was the tenth most abundant taxon collected from the entrainment stations and fourteenth most abundant from the source water stations, comprising 4.6% of all of the larvae collected at the entrainment station (**Tables 5-2** and **5-4**). The larvae were mainly present from February through October and had peak abundances of approximately 280 larvae per 1,000 m^3 in late July 2008 (**Figure 5-48**). Larvae were present at all stations but for all surveys per station combined, these goby larvae were most abundant at the entrainment station (**Figure 5-49**). If the July data is not used in the comparison the density is generally similar at all the stations.

The mean length of 200 measurements proportionally sampled at random with replacement from the 428 larvae measured was 2.87 mm (0.11 in.) (**Figure 5-50**). The smallest larva of the 428 measured was 1.91 mm (0.08 in.) and the largest was 5.99 mm (0.24 in.). The averages from the random samples proportionally drawn from all the measurements resulted in values of 2.88 mm (0.11 in.) for the mean length and 2.79 mm (0.11 in.) for the median. The hatch length was estimated at 2.59 mm (0.10 in.) based on the average 25th percentile value from the bootstrap samples, which is closer to the reported hatch length in Moser (1996) than the calculated hatch length of 2.41 mm (0.09 in.).

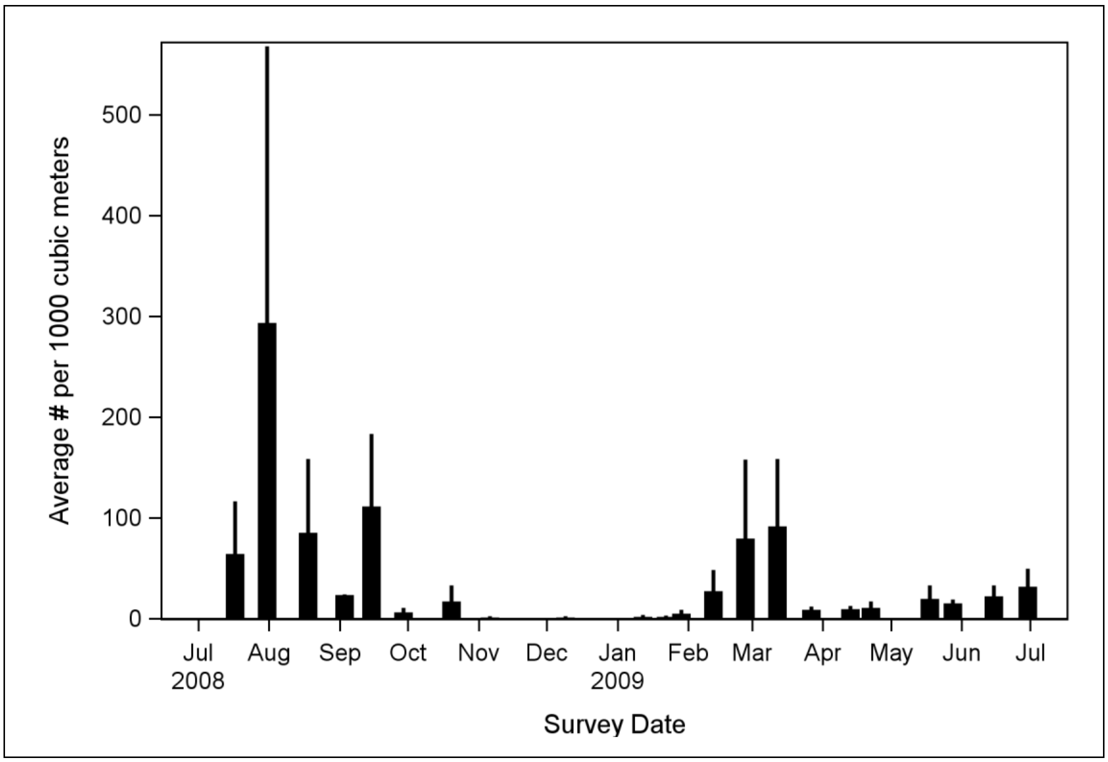


Figure 5-48. Survey mean concentration (#/1,000 m^3) of blackeye goby larvae collected at the DCPP entrainment stations with standard error indicated (+1 SE).

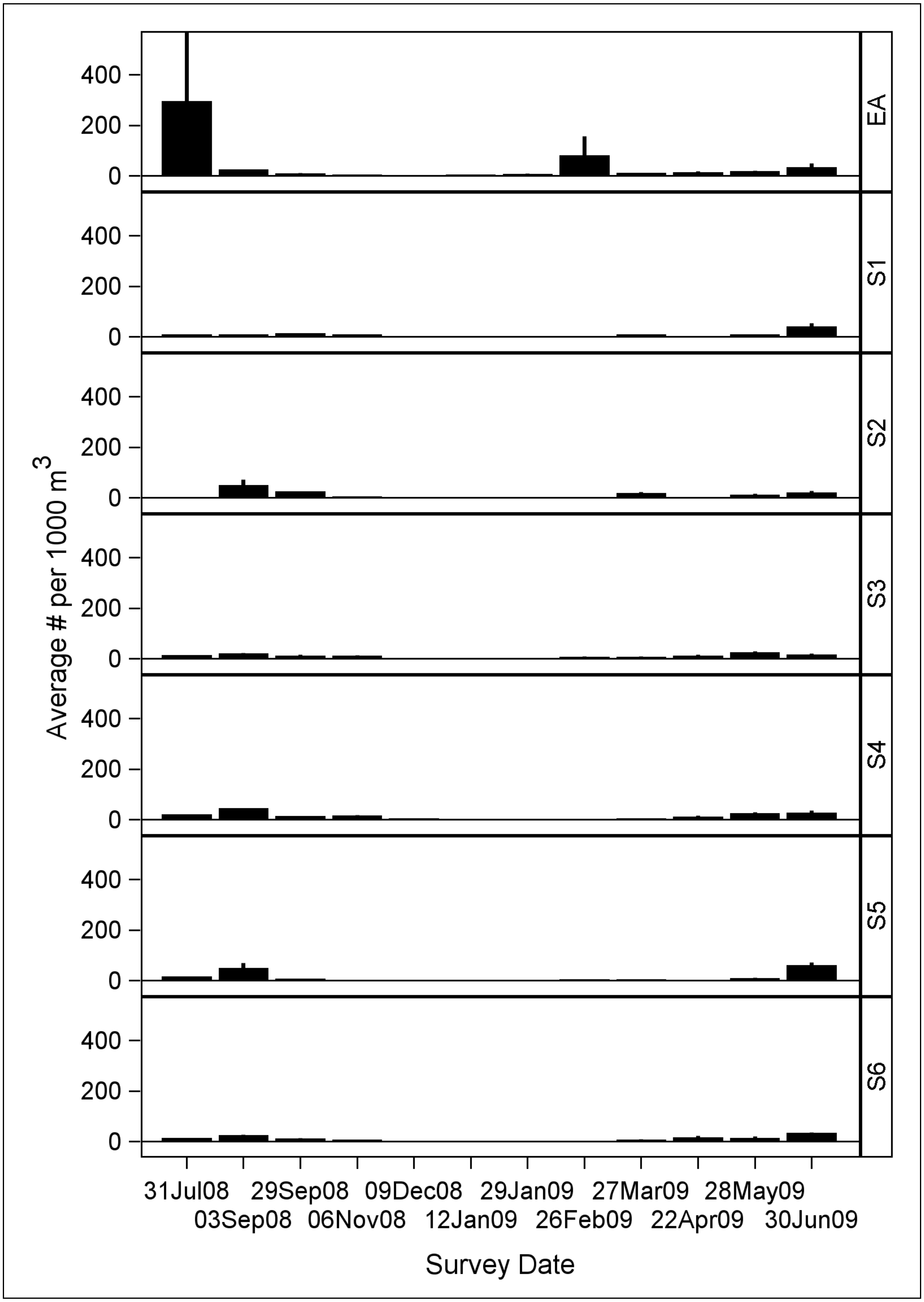


Figure 5-49. Survey mean concentration (#/1,000 m^3) of blackeye goby larvae collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

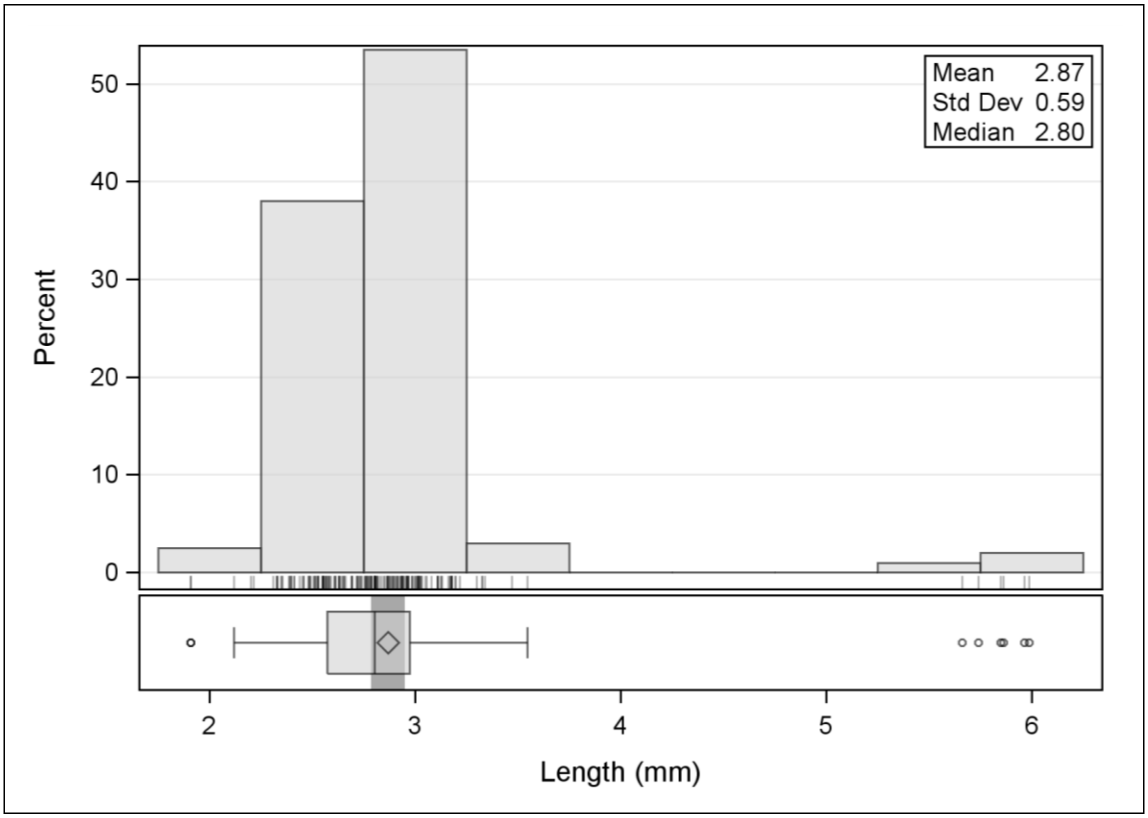


Figure 5-50. Length frequency histogram and statistics for blackeye goby larvae based on a sample of 200 larvae proportionally sampled with replacement from the 428 blackeye goby larvae measured.

Entrainment Effects

An estimated 122 million blackeye goby larvae were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary life history demographic information was not available for this species.

An *ETM* estimate of P_M was calculated for species because the results indicate that the sampling provided a reasonable estimate of nearshore larval abundances because the larvae were collected across the entire source water sampling stations (**Figure 5-49**). Estimates of *PE* were also calculated for all of the paired entrainment-source water surveys providing a reasonable estimate of P_M. The results of the *ETM* for this species will be used in the *HPF* assessment presented in Section 6.0.

Empirical Transport Model *(ETM)*

The estimated larval growth rate for blackeye goby was calculated from information on larval growth in this species presented in Steele and Forrester (2002) and Steele (1997). The data on hatch size, age and growth were used to calculate an average larval growth rate of 0.22 mm/d (0.01 in/d). The estimated period of entrainment exposure of 3.5 d was calculated by dividing the difference between the estimated hatch length of 2.59 mm (0.10 in.) and the size of the 95th percentile value of 3.37 mm (0.13 in.) by the estimated larval growth rate. The entrainment exposure duration was calculated from size and growth values with greater decimal precision than those shown, and differs slightly from the duration calculated using these rounded values.

The data used to calculate the *ETM* estimates for blackeye goby larvae show that they occurred throughout the year but were most abundant during the July–September 2008 and May and June 2009 surveys (**Table 5-36**). Only the alongshore extrapolations of the source water populations were calculated since blackeye goby adults have a shallow inshore distribution (Miller and Lea 1972). The average alongshore displacement for the source water population was 4.8 km (3.0 mi) based on the CODAR backprojections. The P_M estimates for the 3.5 d period of exposure for CODAR data projections was ADCP current displacement and 0.1852 (18.5%) (**Table 5-37**).

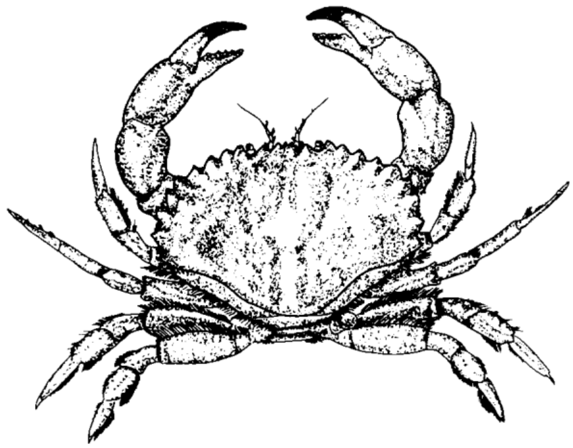
Table 5-32. *ETM* data for blackeye goby larvae using alongshore and offshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from all surveys with *PE* > 0.

Survey Date	Alongshore *PE* Estimate	Alongshore *PE* Std. Err.	f_i	Alongshore Displacement (km)
31-Jul-08	0.35223	0.11682	0.1572	4.05
3-Sep-08	0.01594	0.00115	0.2594	3.35
29-Sep-08	0.01679	0.00443	0.0804	3.02
6-Nov-08	0.00506	0.00185	0.0434	4.83
9-Dec-08	0.05665	0.02742	0.0025	5.76
12-Jan-09	1.00000	0.26622	0.0002	4.69
29-Jan-09	0.58735	0.17242	0.0005	4.47
26-Feb-09	0.29421	0.10913	0.0164	4.93
27-Mar-09	0.01220	0.00187	0.0364	11.18
22-Apr-09	0.04394	0.01231	0.0519	2.92
28-May-09	0.01939	0.00260	0.1136	4.90
30-Jun-09	0.01731	0.00342	0.2382	3.90
Average =	0.20176			4.83

Table 5-33. Estimates for *ETM* models for blackeye goby larvae calculated using alongshore extrapolations based on current data from CODAR backprojected from the survey date with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP.

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	4.83	0.18519	0.03121	0.21640	0.15399

5.4.7 Rock Crabs (Cancridae)



Cancer antennarius Stimpson 1856; Pacific (brown) rock crab; carapace width to 15.5 cm (6.1 in.); Queen Charlotte Sound, British Columbia to Cabo San Lucas, Baja California; intertidal to >100 m (328 ft); mottled dark brown dorsally with red spotting over a white background ventrally (Jensen 1995; Carroll and Winn 1989).

Crabs of the family Cancridae are widely distributed in coastal waters of the west coast of North America (Nations 1975). They occur in intertidal and shallow subtidal habitats on both rock and sand substrate. All of the nine species known to occur in the northeast Pacific were formerly classified into a single genus, *Cancer*, but a taxonomic revision of the family by Schweitzer and Feldmann (2000) based on molecular, fossil, and morphological evidence resulted in dividing the genus into four genera: *Glebocarcinus*, *Romaleon*, *Metacarcinus* and *Cancer*. The following six species of cancrid megalops are known to occur in the vicinity of DCPP, but due to overlapping ranges in sizes and similarities in morphology, the megalops larvae could not be reliably identified to the level of species.

- Pacific (brown) rock crab, *Romaleon antennarius*
- Slender (graceful) crab, *Metacarcinus gracilis*
- Hairy rock crab, *Romaleon jordani*
- Red rock crab, *Cancer productus*
- Yellow crab, *Metacarcinus anthonyi*
- Dungeness (market) crab, *Metacarcinus magister*

Each species has characteristic differences in distribution, preferred habitat, growth rates, and demographic parameters. For example, Pacific rock crab is a relatively large species (carapace width >155 mm [6.10 in.]) that lives primarily at sand/rock interfaces, among kelp forests, but also in bays on sand and shell debris. Slender crab is a smaller species (carapace width >130 mm [5.12 in.]) associated with mixed rock-sand substrates in shallow outer coast habitats. Maximum clutch sizes in cancrid crabs can range from as many as 5,000,000 eggs in yellow crab to approximately 50,000 in *G. oregonensis,* one of the smaller species (Hines 1991). These types of differences imply that specific information on life history parameters cannot readily be generalized among cancrid species.

Reproduction, Age, and Growth

All species of cancrid crabs share certain fundamental life history traits. Eggs are extruded from the ovaries through an oviduct and are carried in a sponge-like mass beneath the abdominal flap of the adult female. After a development period of several weeks, the eggs hatch and a pre-zoea larva emerges, beginning the planktonic life history phase. As in all crustaceans, growth progresses through a series of molts. The planktonic larvae advance through six stages of successive increases in size: five zoea (not including the brief pre-zoea stage) followed by one megalops stage. After several weeks as planktonic larvae, the crabs metamorphose into the first crab stage (first instar) and settle out to begin their benthic life history phase. Maturity is generally attained within 1–2 years. Mature females mate while in the soft shell molt condition and extrude fertilized eggs onto the abdominal pleopods. Females generally produce one or two batches per year, typically in winter. Fecundity per batch increases significantly with female body size (Hines 1991).

The Pacific rock crab primarily inhabits rocky shores and rocky subtidal reefs but may bury in coarse to silty sands adjacent to preferred habitat. Ovigerous Pacific rock crabs have been observed buried in sand at the base of rocks in shallow water and are found more commonly in water less than 18 m (59 ft) deep in southern California. Pacific rock crab females can extrude between approximately 156,000 and 5 million eggs per batch (Hines 1991). Females on average produce a single batch per year; however, due to occasional multiple spawnings, the average number of batches per year may be greater than one (Carroll 1982).

Eggs require a development time of approximately 7–8 weeks from extrusion to hatching (Carroll 1982). Larval development in the Pacific rock crab was described by Roesijadi (1976). Eggs hatch into pre-zoea larvae that molt to first stage zoea in less than 1 hour. Average larval development time (from hatching through completion of the fifth stage) was 36 days at 13.8 °C. Although some crabs molted to the megalops stage, none molted to the first crab instar stage, so the actual duration of the megalops stage is unknown. A reasonable estimate can be derived from studies of slender crab by Ally (1975), who found an average duration of megalops stage of 14.6 days. Therefore, the estimated length of time from hatching to settling for Pacific rock crab is approximately 50 days.

During their planktonic existence, crab larvae can become widely distributed in nearshore waters. In a study in Monterey Bay, Graham (1989) found that Pacific rock crab stage 1 zoea are most abundant close to shore and that subsequent zoeal stages tend to remain within a few kilometers of the coastline. The adult population primarily resides in relatively shallow rocky areas, and the nearshore retention of larvae in Graham’s study (1989) was related to the formation of an oceanographic frontal zone in northern Monterey Bay that prevented substantial offshore transport during upwelling periods.

The nearshore distribution of crab larvae depends upon developmental stage. Shanks (1985) presented evidence that early stage larvae of rock crabs (probably yellow crab in his southern California study) generally occur near the bottom, in depths up to 80 m (262 ft); late stage larvae, however, were more abundant near the surface. He suggested that a combination of physical factors (primarily including wind-generated surface currents and tidally forced internal waves) caused megalopae to be transported shoreward. Late stage larvae (megalops) generally begin to recruit to the nearshore habitat in spring (Winn 1985).

Population Trends and Fishery

Besides the economically valuable Dungeness crab, the three largest species of rock crabs (Pacific rock crab, red rock crab, and yellow crab) contribute to economically significant fisheries in California. There is no commercial fishery for the slender crab. Rock crabs are fished along the entire California coast (Leet et al. 1992). The rock crab fishery is most important in southern California (from Morro Bay south), which produces a majority of the landings, and of lesser importance in northern areas of California where a fishery for the more desirable Dungeness crab takes place. Recreational crabbing is popular in many areas and is often conducted in conjunction with other fishing activities. The commercial harvest has been difficult to assess on a species-by-species basis because the fishery statistics are combined into the general “rock crab” category. Rock crab landings in California in 1990 were 818 MT, including the landings of crab claws only that were converted to estimated whole weight (Leet et al. 1992). Rock crab landings from five ports near the Monterey Bay National Marine Sanctuary averaged 92 MT/yr from 1980–1995 (Starr et al. 1998).

Regulations currently specify a minimum harvest size of 108 mm (4.25 in.) carapace width. A small recreational fishery for rock crabs also exists, with a 102 mm (4.00 in.) minimum carapace width and a personal bag limit of 35 crabs per day. Crabs are collected by divers or shore pickers with hoop nets and crab traps.

Recent catch statistics from the PSMFC PacFIN (commercial) database were examined for the years 2005–2009 for San Luis Obispo county. The average annual commercial catch and ex-vessel revenue from rock crab during this period was approximately 51,000 lbs and $76,000, respectively (**Table 5-38**).

Table 5-34. Rock crab commercial fishing landings and ex-vessel value in San Luis Obispo County, 2005-2009. Data from PacFIN (2010).

	Commercial Fishery	
Year	Landings (lbs)	Ex-vessel Value ($)
2005	30,962	$43,359
2006	60,837	$89,364
2007	56,303	$83,185
2008	73,034	$110,028
2009	34,361	$55,440
Average	51,099	$76,275

Sampling Results

Cancrid megalops occurred at both the entrainment and source water stations (**Tables 5-2** and **5-4**) during most surveys but were only observed from April through June 2009. Peak abundances were in May when concentrations reached nearly 10,000 larvae per 1,000 m^3 (**Figure 5-51**). Larvae were present at all stations during those months but were most abundant at stations S1 and S2 (**Figure 5-52**).

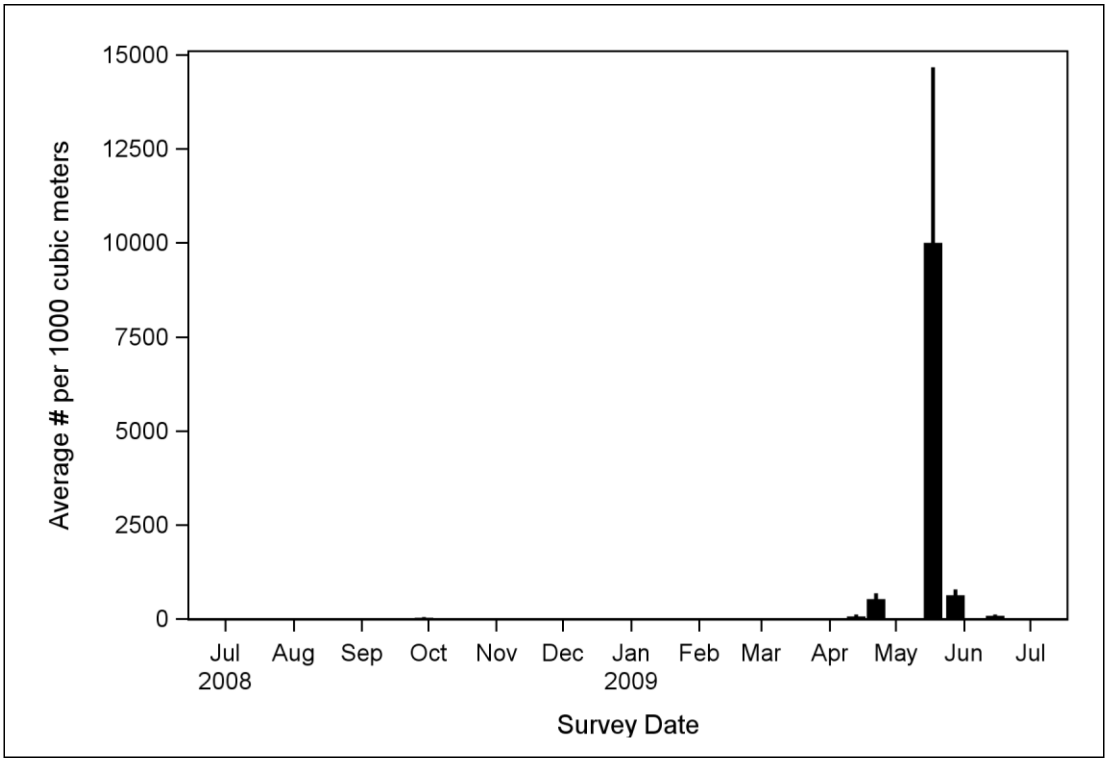


Figure 5-51. Survey mean concentration (#/1,000 m^3) of Cancridae megalops collected at the DCPP entrainment stations with standard error indicated (+1 SE).

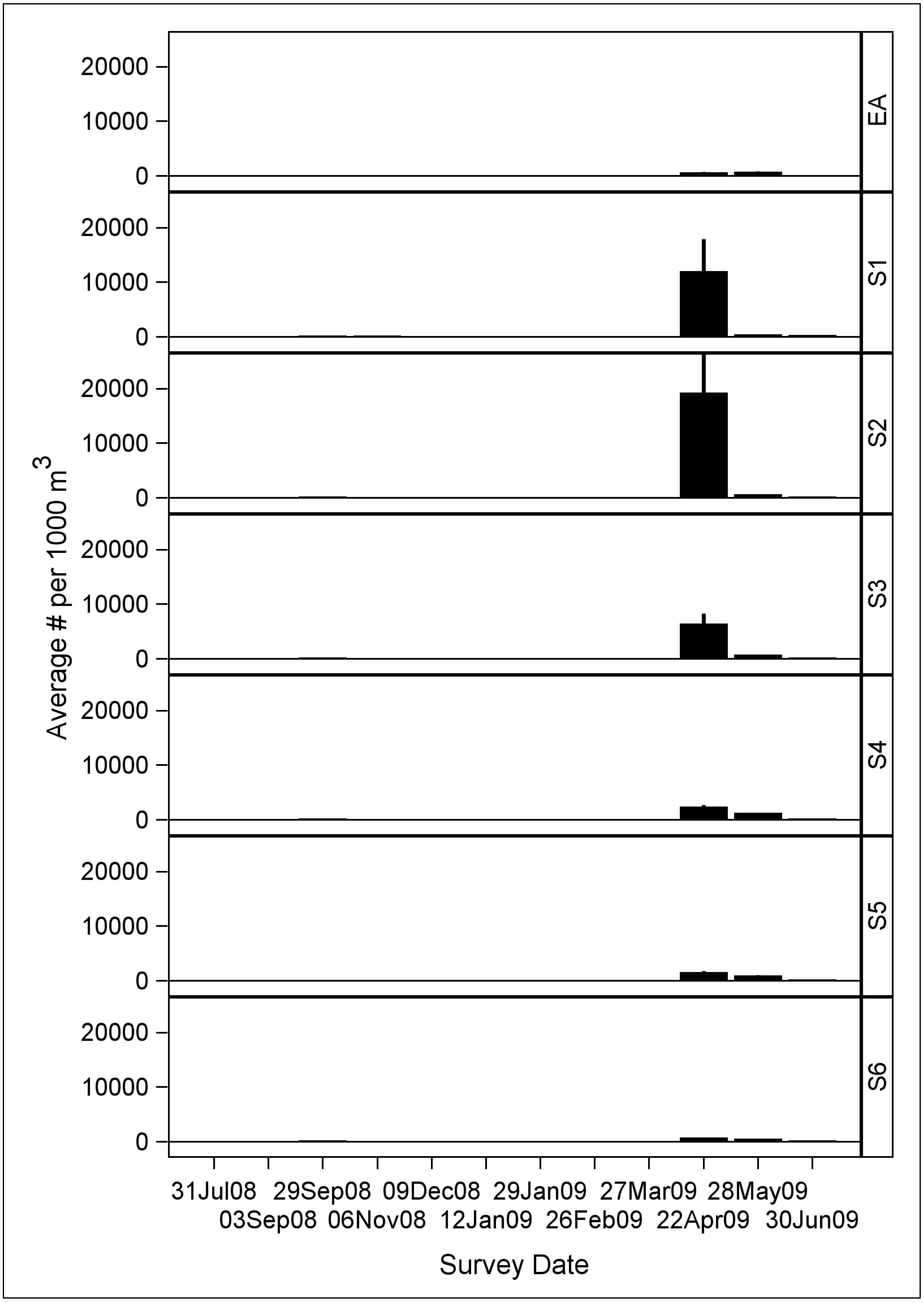


Figure 5-52. Survey mean concentration (#/1,000 m^3) of Cancridae megalops collected at the DCPP entrainment and source water stations with standard error indicated (+1 SE).

Entrainment Effects

An estimated 1,822 million rock crab megalops were entrained during the one-year study period (**Table 5-3**). Estimates of *FH* were not calculated because the necessary demographic information was not available for this species.

ETM estimates were calculated for this taxon as the results of the source water sampling show that crab megalops were collected across all of the source water stations (**Figure 5-52**). The data from the sampling likely provided representative estimates of the source water populations of megalops larvae for the *ETM PE* estimates. The results of the *ETM* will not be used in the *HPF* calculations because the *ETM* was only calculated for this single life stage and it is unknown what effects entrainment may have on other life stages or even if they are in the vicinity of DCPP where they would be subjet to entrainment.

Empirical Transport Model *(ETM)*

The larval duration for rock crab larvae through the megalops stage was assumed to be 45 days based on larval duration estimates for slender crab (Ally 1975) and Pacific rock crab (Roesijadi 1976). The data used to calculate the *ETM* estimates show that they occurred in most months throughout the year but were very abundant during the April 2009 surveys (**Table 5-39**). Alongshore and offshore extrapolations of the source water populations were calculated because cancrid crabs can occur in sand and rock habitats at depths and distances exceeding the offshore boundaries of the sampling area. The two *ETM* displacement estimates alongshore and offshore extrapolations using the CODAR backprojections were 27.35 and 29.86 km (16.99 and 18.55 mi), respectively (**Table 5-39 and 5-40**). The P_M estimates for the 45-day period of exposure were 0.0279 (2.8%) and 0.0256 (2.6%) from the CODAR backprojections (**Table 5-40**). The estimates are similar despite the difference in the estimates of the average alongshore displacement because the surveys with the highest weights (f_i) had different estimates of alongshore excursion, which also affected the estimates of PE_i for those surveys.

Table 5-35. *ETM* data for rock crab megalops using alongshore and offshore extrapolations for the *PE* calculations based on backprojected CODAR data. Average *PE* estimates and alongshore displacement were calculated from all surveys with *PE* > 0.

	Alongshore		Offshore Extrapolated			Alongshore Displacement (km)
Survey Date	*PE* Estimate	*PE* Std. Err.	*PE* Estimate	*PE* Std. Err.	f_i	
31-Jul-08	0.00181	0.00003	0.00029	0.00000	0.0026	28.14
3-Sep-08	0	0	0	0	0.0007	23.89
29-Sep-08	0.00087	0.00016	0.00048	0.00009	0.0177	38.74
6-Nov-08	0.00035	0.00005	0.00015	0.00002	0.0101	26.83
9-Dec-08	0	0	0	0	0.0018	34.06
12-Jan-09	0.00088	0.00025	0.00017	0.00005	0.0022	18.09
29-Jan-09	0.00022	0.00008	0.00007	0.00002	0.0036	18.20
26-Feb-09	0	0	0	0	0.0027	41.23
27-Mar-09	0.00146	0.00022	0.00009	0.00001	0.0013	24.00
22-Apr-09	0.00031	0.00004	0.00030	0.00004	0.7979	32.50
28-May-09	0.00251	0.00022	0.00230	0.00020	0.1433	30.20
30-Jun-09	0.00038	0.00003	0.00024	0.00002	0.0160	29.45
Average =	0.00098		0.00045			27.35

Table 5-36. Estimates for *ETM* models for rock crab megalops larvae calculated using alongshore and offshore extrapolations based on current data from CODAR backprojected from the survey data with adjustments for differences between surface and midwater currents based on data measured at an ADCP located south of DCPP.

Parameter	Average Alongshore Displacement (km)	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
Alongshore P_M	27.35	0.02788	0.01390	0.04178	0.01398
Offshore Extrapolated P_M	29.86	0.02561	0.01393	0.03955	0.01168

6.0 Impact Assessment

The purpose of this study was to assess the effects of the DCPP cooling water intake structure on populations of fishes and selected invertebrates. Effects from the plant's cooling water intake structure can result from impingement of organisms on the intake traveling screens or entrainment into the plant's cooling water intake structure. This study focused on entrainment effects because an earlier evaluation determined that impingement effects were insignificant due to the low numbers and biomass of impinged organisms (PG&E 1988b). Although many marine organisms have planktonic forms that are susceptible to entrainment by the power plant, this study focused on the larvae of fishes, rock crabs, and market squid. Thirteen target taxa were chosen for the detailed assessment, including 12 fish species and rock crabs. The decision to narrow the list to these species was based on criteria that included the entrainment abundances of the taxa, the availability of life-history information to meet assessment model requirements, and criteria outlined in USEPA Draft Guidelines (USEPA 1977). This list was further narrowed for the *HPF* assessment presented in this section of the report.

6.1 Assessment Approach

The assessment of the effects of the DCPP cooling water intake structure on populations of fishes and selected invertebrates includes the *ETM* and *HPF* approach as required by the California OTC Policy. *HPF* is not strictly an assessment approach but is a method for translating the results from an *ETM*-based assessment into an estimate of the area of habitat necessary to fully compensate for the entrainment losses. The scale of the habitat necessary to fully compensate for the entrainment losses may not provide any insight into the magnitude of the effect; the estimate of P_M derived using the *ETM* is more closely related to the magnitude of the effect and therefore represents a better estimate of the population level impact of entrainment. The results from *HPF* are intended to be used for scaling a mitigation project that would fully compensate for estimated entrainment losses.

The estimates of *HPF* are based on the results of the *ETM*, which traditionally has been used to determine if entrainment effects pose any significant risk of "adverse environmental impacts" (AEI) to populations of fish and shellfish in accordance with the Federally mandated definition of the term (USEPA 1977). During the 1996–1999 Study, PG&E, its consultants, and other members of the Entrainment Technical Working Group (ETWG) developed a set of criteria for evaluating AEI. These criteria were specific to the marine environment around Diablo Canyon, and in most cases were unique to marine organisms:

- Environmental trends (climatological or oceanographic);
- Abundance trends (e.g., subtidal fish observations, fishery catch data);
- Life history strategies (e.g., longevity and fecundity);
- Population distribution; and
- Magnitude of effects.

The evaluation of these criteria provided a basis for assessing AEI using USEPA guidelines to determine 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"* (USEPA 1977). The USEPA (1977) also stated that the biological value of a given area to a particular species be based on "*principal spawning (breeding) ground, migratory pathways, nursery or feeding areas, numbers of individuals present, and other functions critical during the life history*."

In contrast to Federal policy, the California OTC Policy focuses on significantly reducing the use of once-through cooling and provides for interim mitigation of entrainment and impingement impacts until compliance with the Policy is achieved. The Habitat Production Foregone (HPF) approach or a similar approach approved by the SWRCB may be used to determine the appropriate habitat scale for interim mitigation. The SWRCB's 2015-0057 Resolution provides a framework for an interim mitigation fee. The *HPF* assessment for this study follows a summary of the entrainment study results.

6.2 Summary and Discussion of Entrainment Results

Composition and abundance of ichthyoplankton and selected shellfish larvae entrained by DCPP were determined by sampling in the immediate proximity of the cooling water intake twice per month from July 2008 through June 2009. The sampling design was consistent with entrainment studies conducted at other power plants in California, but it was not as extensive as the study that was conducted at DCPP during the 1996–1999 period (Tenera 2000). Briefly, the differences included sampling at two of the four original entrainment stations at the cooling water intake inside the Intake Cove, and at a frequency of twice a month at six-hour intervals instead of the weekly sampling at three-hour intervals used previously. Also, the overall time period of the study covered one year instead of 2.5 years and there was a reduced list of larval invertebrate taxa enumerated.

A total of 16,961 entrainable fish larvae from 80 separate taxonomic categories (not including fragments, but including unidentified larval fish) was collected from 383 samples in the 24 entrainment surveys. Eighteen taxa comprised the top 90% of specimens collected. The most abundant taxa were sculpins (Cottidae, *Artedius* spp., and *Orthonopias triacis*), rockfishes (*Sebastes* spp. V_ and V), monkeyface eel (*Cebidichthys violaceus*), kelp blennies (*Gibbonsia* spp.), Blennioidei/Zoarcoidei (largely comprised of unidentified pricklebacks), and blackeye goby (*Rhinogobiops nicholsi*). The most abundant taxa in the samples were from species with shallow nearshore distributions, but larvae from some deepwater species (e.g., northern lampfish [*Stenobrachius leucopsarus*]) were also entrained in smaller numbers. The estimated total annual entrainment based on the actual cooling water flow during the study was 2.86 billion fish larvae (**Table 6-1**).

A total of 7,822 target shellfish larvae composed almost entirely of cancer crabs megalops was identified from the twice monthly entrainment samples. In addition to the megalops, two market squid paralarvae were also collected. Total annual entrainment of target shellfish larvae was estimated to be 1.82 billion cancer crabs megalops and 360,000 squid paralarvae.

Table 6-1. Summary of DCPP entrainment sampling results and model output for fishes and shellfishes based on actual CWIS flows in 2008–2009. *ETM* model estimates provided for CODAR extrapolated estimates of alongshore source water areas.

Taxon	Common Name	Estimated Annual Entrainment (actual flows)	CODAR *ETM* P_M (%)	2●*FH*
Fishes				
Cottidae	unid. sculpins	387,206,952	39.7*	
Artedius spp.	smoothhead sculpins	203,081,623	20.6	
Orthonopias triacis	snubnose sculpin	145,338,931	19.8	
Rhinogobiops nicholsi	blackeye goby	121,557,282	18.5	
Sebastes spp. V_	KGB rockfish complex	279,117,506	14.1*	1,310
Scorpaenichthys marmoratus	cabezon	17,911,195	9.9*	
Sebastes spp. V	blue rockfish complex	104,394,654	6.3*	258
Genyonemus lineatus	white croaker	61,383,451	3.0*	
72 other taxa		1,536,263,685		
	Total larval fish	**2,856,255,279**		
Shellfishes				
Cancridae (megalops)	cancer crabs	1,822,947,583	2.7*	

*Average of alongshore displacement and offshore extrapolated values. All others alongshore displacement only.

There are several differences that need to be considered in comparing the estimates of annual entrainment from the data collected during the 2008–09 study with the estimates from the previous sampling in 1997–99. The actual field sampling methods and net mesh sizes used in the two study periods were identical, but the 2008–09 study had a lower sampling frequency at the intakes (twice per month compared to weekly), fewer entrainment stations (two stations compared to four), and a smaller sampled source water area (offshore transect with six stations compared to a coastwide grid of 64 stations). Some of the consequences of these differences were: 1) a finer temporal resolution in the earlier study that increased the chances of capturing peak larval densities; 2) the collection of a greater number of samples, thereby increasing the chances of sampling rare species; and 3) generally lower estimates of variance and increased confidence in the entrainment estimates due to a greater number of samples collected. There were also some differences between studies in how some specimens of larval fishes were classified during processing. For example, in the present study, many of the smaller specimens that were formerly placed into the family Stichaeidae were re-classified into the Blennioidei/Zoarcoidei taxonomic category.

The total entrainment estimates from the 2008–09 sampling were approximately twice those of the previous comparable one-year periods from the 1997–99 study (**Table 6-2**). The most notable differences among taxa were that sculpins and blennies/zoarcoids (mainly unidentified pricklebacks) were an order of magnitude greater in 2008–09 than during either of the previous study periods, and northern anchovies and sardines, which were very abundant in 1997–98 (over 106 million anchovy and 103 million sardine larvae entrained), were not abundant in both the 1998–99 and 2008–09 sampling periods. The KGB rockfish group abundance was somewhat lower in the 1997–98 period than in the other two periods, but the blue rockfish group was significantly lower (7 million compared to 123 million). California halibut was lower in 2008–09 by at least one order of magnitude, but most of the species that were sampled in low numbers, such as California halibut, could not be confidently compared among periods because of the large amount of variation in the estimates.

The low abundances of blue rockfish larvae in 1997–98 were likely a result of the poor reproductive condition of females due to the El Niño conditions in the previous fall/winter months of 1997. El Niño conditions delay the annual phytoplankton bloom, affect the distribution and abundance of planktonic invertebrates, improve recruitment of southern fish species, cause recruitment failures of rockfish, and cause poor growth and condition of adult rockfish (Lenarz et al. 1995).

Typically, the larval and adult abundances of northern anchovy and Pacific sardine are closely tied to broad oceanographic conditions such as sea surface temperatures, surface currents, mixed layer depths, and plankton biomass levels. As a result, it would be expected that the abundances of these larvae would be greatest during the relatively cooler water regime present during 1998–99, and less abundant during the warmer regimes during the other study periods. Even though the DCPP sampling effort during the 1996–99 study was extensive it is not always possible to correlate changes in abundance on a local scale with oceanographic events occurring at much larger spatial scales. For example, CalCOFI records comparing Pacific sardine egg abundance during April surveys in 1998 and 1999 show much greater abundances in 1999 (Lo et al. 2005) as would be expected due to the record upwelling conditions during the winter and spring of that year (Schwing et al. 2000). Consistent with the pattern of differences in larval abundances between 1997–98 and 1998–99 in the DCPP study, the distribution of Pacific sardine eggs between years shows much higher abundances closer to shore in 1998 relative to 1999 when the peak abundances in the CalCOFI sampling occurred approximately 300 km (180 miles) offshore(Lo et al. 2005). The stronger winds associated with upwelling conditions in 1999 may have resulted in greater abundances of Pacific sardine and other pelagic species such as northern anchovy but upwelling conditions in the area of DCPP usually result in net transport offshore which may help explain the low abundances of those larvae in the DCPP study during the 1998–99 period.

Large differences in the larval abundances of the smaller nearshore demersal fishes among the three study periods (e.g., sculpins and pricklebacks), do not appear to be related to El Niño and La Niña conditions since both regimes occurred in the first study yet these larvae were not abundant in either of those years. The larvae (and adults) of these small benthic species have very restricted nearshore distributions and usually a narrow seasonal range of reproduction in spring months (e.g., see **Figures 5-30** and **5-33**), so important factors affecting their survival would be closely tied to nearshore habitat conditions at this time of year. Why the abundances of these taxa differed in the vicinity of DCPP between periods is not evident, but conditions in the early months of 2009 were clearly favorable for reproduction in these types of fishes. Their high larval abundances also indicate that the number of adult spawners in 2008–09 was probably much higher than in the earlier study, suggesting that entrainment mortality from DCPP does not substantially affect the local adult populations.

Although it is possible to compare the results of the *ETM* models among study periods, differences in the methods for calculating larval durations, the types of ocean current data used to measure larval transport, and differences in the currents among the study periods that affected the relative sizes of the source water area used in calculating the estimates of P_M make direct comparison of the results problematical. In the 2008–09 study, the period of entrainment exposure was calculated using the difference between the estimated hatch length and the length of the 95th percentile, whereas the previous study based the hatch size on the length of the 1st percentile and then calculated two durations, one based on the difference with the average length at entrainment and another based on the 99th percentile which was intended to represent the maximum period of entrainment exposure. The approach used in this study has been used on the more recent intake assessments in California due to the large variation in hatch size apparent in the data from most studies. The 2008–09 study used two sources of current data — permanently mounted ADCP current meters north and south of DCPP that measured currents through the entire water column, and CODAR surface current data. The earlier study only used data from a single S4 current meter moored offshore from the discharge cove that measured currents at a single depth. The current data used in the previous study did not represent the spatial complexity of current patterns possible by the combination of the ADCP and CODAR data used in the present study. While the smaller source water sampling area used in the 2008-09 study did not provide the spatial coverage of the previous 64-station sampling grid, the samples were collected over an entire 24-h period at the same frequency as the entrainment stations. Therefore, the 48 samples per survey from the 2008–09 study represented only 40% of the 128 samples per survey taken in the previous study despite the reduction in the number of stations by over 90%. In addition, the sampling during the 2008–09 study was done with a smaller vessel allowing samples to be taken closer to shore. All of these differences need to be considered when comparing P_M values between studies.

The estimates of P_M estimates between the 2008–09 study and previous study years can be directly compared for several of the taxa that were evaluated during both studies. The estimates for smoothead sculpin, snubnose sculpin, blackeye goby, cabezon, and KGB and blue rockfish complex larvae were all approximately equal or greater for the data collected during the 2008–09 study (**Table 6-1**) when compared with the estimates from the 1997–99 study (**Table 6-3**).

Table 6-2. Comparison of estimated annual larval fish entrainment at DCPP among study periods based on fixed (maximum) flows. Only the most abundant taxa from the 2008–09 study are listed, in addition to selected species that were abundant during the other study periods. Bars depict approximate abundance relative to the greatest value in the table. Abundance of Blennioidei/Zoarcoidei and Stichaeidae were combined for this comparison to provide consistency between studies. Values for July 1997-June 2008 are higher than those presented in the 2000 report because actual cooling water flow was used in the earlier report calculations.

Taxon	CommonName	Jul '08 - Jun '09	Jul '98 - Jun '99	Jul '97 - Jun '98
Cottidae	sculpins	398,997,613	29,486,564	43,038,418
Blennioidei/Zoarcoidei/Stichaeidae	blennies/zoarcoids/pricklebacks	340,986,238	35,359,048	34,618,904
Sebastes spp. V_	KGB rockfish complex	289,113,661	294,214,870	208,013,064
Cebidichthys violaceus	monkeyface prickleback	246,235,382	132,041,503	118,013,273
Gibbonsia spp.	kelpfishes	222,069,865	94,418,006	121,584,994
Artedius spp.	sculpins	210,254,738	110,769,886	109,446,173
larval/post-larval fish	larval fishes	191,868,513	9,057,466	5,642,001
Orthonopias triacis	snubnose sculpin	154,474,150	55,185,666	75,253,148
Rhinogobiops nicholsi	blackeye goby	134,331,694	130,469,817	156,299,633
CIQ goby complex	gobies	126,496,301	22,464,407	76,290,848
Sebastes spp. V	blue rockfish complex	123,147,095	99,736,511	7,016,351
Stenobrachius leucopsarus	northern lampfish	67,431,908	36,850,992	32,273,776
Genyonemus lineatus	white croaker	66,630,820	20,935,413	65,660,099
Oligocottus/Clinocottus spp.	sculpins	54,726,305	68,322,304	38,786,809
Platichthys stellatus	starry flounder	49,490,717	2,951,452	363,651
Cyclopteridae	snailfishes	49,365,874	15,845,867	7,917,269
Bathymasteridae	ronquils	43,662,117	31,817,216	32,405,185
Oxylebius pictus	painted greenling	31,761,018	20,524,941	11,234,578
Scorpaenichthys marmoratus	cabezon	22,521,855	9,782,966	15,028,255
Blennioidei	blennies	19,438,626	2,152,777	467,833
Leptocottus armatus	Pacific staghorn sculpin	15,007,993	1,286,156	1,533,552
Sebastes spp.	other rockfishes	14,068,454	3,131,568	4,062,504
Brosmophycis marginata	red brotula	12,346,006	1,470,788	5,373,624
Pleuronectoidei	flatfishes	10,515,444	1,550,593	4,816,484
Radulinus spp.	sculpins	9,262,747	0	2,124,449
Gobiesocidae	clingfishes	8,703,341	479,965	961,728
Ruscarius creaseri	roughcheek sculpin	7,987,014	23,187,512	7,600,530
Lepidopsetta bilineata	rock sole	7,838,725	0	68,016
Osmeridae	smelts	7,442,639	2,567,789	182,306
Citharichthys spp.	sanddabs	6,669,908	2,585,270	6,233,295
Gobiesox spp.	clingfishes	6,349,896	4,824,812	6,736,611
Pleuronectidae	righteye flounders	6,060,652	707,716	5,771,052
Agonidae	poachers	5,424,722	711,507	87,802
Lepidogobius lepidus	bay goby	5,316,238	4,535,785	14,377,886
Aulorhynchus flavidus	tubesnout	5,184,751	264,780	123,516
Parophrys vetulus	English sole	4,315,304	1,065,718	11,316,611
Sardinops sagax	sardine	1,100,324	146,637	103,563,065
Hypsoblennius spp.	combtooth blennies	1,012,230	10,850,340	7,255,072
Engraulis mordax	Northern anchovy	353,214	3,229,835	106,443,470
Paralichthys californicus	California halibut	308,642	11,594,892	13,696,238
	Other taxa	39,422,521	56,979,513	60,225,665
	Total	**3,017,695,253**	**1,353,558,846**	**1,521,907,737**

The highest P_M estimates in both studies were for small nearshore species. Although the previous study showed that the larval abundances of these fishes, such as sculpins, pricklebacks, and blennies, were generally highest at the nearshore stations, the gradient in abundances from the Intake Cove to Station S6 furthest offshore (see **Figures 5-5**, **5-9**, **5-13**, **5-31**, **5-34**, and **5-38**) was much more apparent in the 2008–09 study. This is probably due to the increased sampling frequency during each survey at each of the source water stations. Although many of the larvae may result from spawning that is occurring from fishes that inhabit the hard concrete and rocky habitats that form the perimeter of the Intake Cove, these fishes also had the longest estimated periods of exposure to entrainment. Therefore, while it is probable that the largest portion of the entrained small larvae for these fishes originated from within the Intake Cove, larvae transported into the Intake Cove were also being entrained. The backprojections extrapolated from the uncorrected surface CODAR data (**Figure 6-1a**) indicate the potential for long-distance dispersal especially for larvae that may migrate to, or be transported in, the surface layers.

Table 6-3. *ETM* estimates of population mortality (P_M) for fishes and crabs for 1997-1998 and 1998-1999 study periods calculated using larval durations based on maximum lengths at entrainment, and alongshore and offshore P_S, and survey proportions of entrainment and source water populations for weights.

Taxa	Common Names	*ETM* Estimate of P_M Alongshore		*ETM* Estimate of P_M Onshore+Alongshore	
		1997-98	1998-99	1997-98	1998-99
Fishes					
Artedius spp.	smoothhead sculpin	11.4	22.6	–	–
Cebidichthys violaceus	monkeyface prickleback	13.8	11.8	–	–
Citharichthys spp.	Sanddabs	1.0	0.8	0.1	0.1
Engraulis mordax	northern anchovy	–	–	<0.1	<0.1
Genyonemus lineatus	white croaker	0.7	3.5	<0.1	0.4
Gibbonsia spp.	kelp blennies	18.9	25.0	–	–
Orthonopias triacis	snubnose sculpin	14.9	31.0	13.9	31.0
Oxylebius pictus	painted greenling	6.3	5.6	5.1	4.3
Paralichthys californicus	California halibut	0.5	7.1	0.1	0.6
Rhinogobiops nicholsi	blackeye goby	11.5	6.5	2.7	3.6
Sardinops sagax	Pacific sardine	–	–	<0.1	–
Scorpaenichthys marmoratus	Cabezon	1.1	1.5	0.9	0.8
Sebastes spp. V	blue rockfishes	0.4	2.8	<0.1	0.2
Sebastes spp. V_	KGB rockfishes	3.9	4.8	0.5	4.3
Shellfishes					
Romaleon antennarius	brown rock crab	0.3	1.0	<0.1	<0.1

One of the assumptions of the *ETM* is that the estimated *PE* is constant within each of the size classes of larvae present during each survey period. Lengths of the larvae from the source water stations were not measured but it is likely that these were generally older and larger at the source water stations for some of the fish taxa. The original formulation of the *ETM* by Boreman et al. (1978, 1981) assigned separate *PE* estimates for the various life stages, which would have likely resulted in reduced estimates of P_M for these fishes. The comparison of the lengths of the larvae between the entrainment and source water stations from the 1997-99 sampling showed that the average lengths were very close for many of the fishes but higher at the source water stations for smoothhead and snubnose sculpins. It is difficult to estimate how the addition of separate *PE* estimates for different larval stages might have affected the results as the *PE* estimates for the smallest, newly hatched larvae might be expected to increase while the estimates for the older larvae would be expected to decrease. These levels of mortality would then need to be applied over the estimated duration of each of the stages.

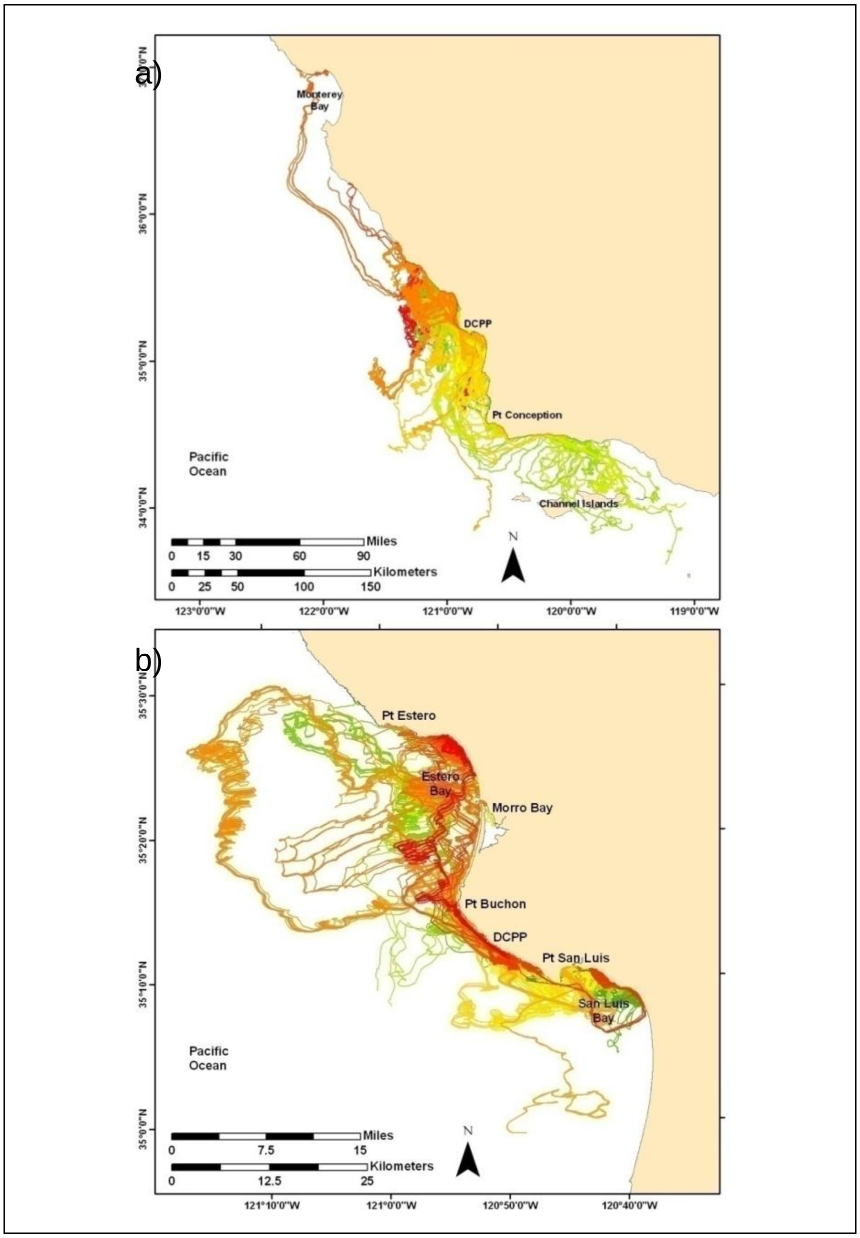


Figure 6-1. Backprojections based on CODAR data for a) surface currents only, and b) water column currents corrected with ADCP data collected south of DCPP. The backprojections are for 46-day periods using the dates of the DCPP paired entrainment – source water surveys as the starting date with 30 randomly assigned starting hours for each survey date.

6.3 *HPF* Assessment

The conservation of fish habitat and the need to integrate ecosystem-based concepts have been recognized by scientists and managers as essential in fisheries management. It is recognized that effective management of essential fish habitat requires knowledge of species-specific habitat requirements, descriptions of the physical environment and available habitats, and estimates of fish populations in the different habitats (Cobb et al. 1999).

While entrainment is not a process that affects or degrades essential fish habitat, it is possible using *HPF* (Steinbeck et al. 2007) to convert entrainment impacts estimated using P_M into something more tangible that is representative of the effective area or habitat that would be necessary to replace the larval production lost due to entrainment. If the goal is to use the estimates to scale a mitigation project to compensate for the losses, then this approach should be limited to fishes that have specific habitats associated with production. These could be habitats used by adults of both sexes, such as rocky reef areas used by the rockfishes and several species of sculpin found in this study, or specific habitats used by females for spawning such as submerged vegetation used by Pacific herring. The approach is not applicable to fishes such as northern anchovy and white croaker that release eggs directly into the water column and for many other fishes with populations that are not generally limited by available habitat. In this study there were several fishes analyzed that were associated with open coast nearshore rocky reef habitat including rockfishes and sculpins. In this case it would be reasonable to average the *HPF* estimates for these fishes as they are all associated with the nearshore rocky reef habitat that dominates the nearshore areas around the DCPP.

When using *HPF* it is important that the estimates be validated against other data since the basis of the calculation is P_M, the estimated proportion of the larval source water population lost due to entrainment. Although P_M may be large, resulting in a large *HPF* estimate, the numbers of larvae may be small, especially relative to the reproductive potential for the population or the numbers of adults in the habitat being evaluated. A simple check is to compare the entrainment estimates with reported levels of fecundity for a taxon. A more rigorous approach would be to use the same entrainment estimates used in the *ETM* to determine the equivalent adults using a demographic modeling approach such as *FH*, if the estimates are available for a taxon. The *HPF* could then be validated by using estimates of the average densities of adult fishes in the habitat associated with the taxon to determine the area necessary to support the number of adult females potentially lost due to entrainment. This requires data on adult fish densities in the specific habitat. For example, *HPF* estimates for the KGB and blue rockfish complexes were validated against the *FH* estimates using data collected on subtidal fishes as part of the NPDES monitoring done for the DCPP thermal discharge.

The use of *HPF* for the results of this study also required that the habitat within the Intake Cove be taken into account in the calculations. The breakwaters provide a highly three-dimensional habitat with large interstitial areas that is very different than the habitat provided by subtidal reefs in the area. It would be difficult to account for this highly structured habitat in the *HPF* calculation that relies on areal estimates of habitat. The breakwaters were created during the construction of DCPP and therefore it does not seem reasonable that production from this habitat be included in the *HPF* estimate. Although this would be difficult to factor into the *ETM* calculations, the results of both the *ETM* and the sampling can be evaluated to ensure that only the taxa where there is a high degree of confidence in the *ETM* estimate of P_M are used in the calculations.

The confidence in the *ETM* estimates of P_M also needs to be considered. The previous intake assessment in 1996–1999 included source water sampling of 64 stations along 17.4 km (10.8 mi) of coastline. As a result, the sampling included a wide range of depths and habitats that were not included in the source water sampling for this study (**Figure 4-3**). This is especially important in determining which taxa to include in the *HPF* estimates. *ETM* estimates of P_M were not calculated for four of the taxa of fish larvae (Blennioidei/Zoarcoidei, Stichaeidae, monkeyface pricklebacks, and kelp blennies) that had some of the highest estimates of annual entrainment. The primary reason for excluding Blennioidei/Zoarcoidei and Stichaeidae from the *ETM* assessment was the limited number of source water surveys they were collected which would affect the levels of confidence associated with the *ETM* estimate of P_M. It was also clear from the data that the sampling did not provide an accurate estimate of the source water population for Stichaeidae, monkeyface pricklebacks (also a member of the family Stichaeidae), and kelp blennies as the larvae for these taxa were most abundant inside the Intake Cove and only occurred in the source water stations closest to shore.

The sampling results for monkeyface prickleback and kelp blennies show that the larvae for these taxa were most abundant at the stations inside the Intake Cove (**Figures 5-38** and **5-42**, respectively). Both taxa inhabit shallow nearshore rocky reef areas as adults, including very shallow rocky intertidal areas for monkeyface prickleback. The rock jetties that form the Intake Cove provide this type of habitat. Giant kelp (*Macrocystis pyrifera*) and demersal foliose algal cover inside the Intake Cove likely contribute to the high abundances of kelp blenny larvae from the Intake Cove stations. As a result, the entrainment sampling within the Intake Cove biased the source water population estimates for these taxa. In addition, there were other shallow nearshore rocky reef taxa that provided better estimates of the effects on nearshore fishes. The results for these other taxa analyzed using *ETM* show patterns of abundance that indicate the sampling provided a reasonable estimate of the source water because the larvae for other taxa were collected across all or most of the source water stations. Therefore *HPF* estimates were only calculated for a subset of the taxa that provided the most robust estimate of *HPF*.

To maintain consistency with the *HPF* approach used with the *ETM* estimates from the 1997–1999 study (Raimondi et al. 2005), *HPF* estimates were not calculated for white croaker or Cancer crabs. These taxa were not included because adult white croaker are not associated with nearshore rocky reef habitat and the Cancer crab group included numerous taxa that occupy a variety of habitats and were also not included in the *HPF* estimates from the 1997–1999 study.

The *HPF* estimates were calculated for each taxon as the product of the *ETM* estimate of P_M and the estimates of nearshore rocky reef habitat within the extrapolated source water areas using the approach described in Section 4.5.3.4. The habitat areas for each survey period were calculated and then a weighted average of the habitat area was calculated for each taxon using the same estimates of the fraction (f_i) of the source population present during each survey period that were used in the *ETM* calculations (**Table 6-4**). The habitat estimates in **Table 6-4** were used with the *ETM* estimates of P_M to calculate the *HPF* estimates in **Table 6-5**. The average *HPF* estimate of nearshore rocky reef habitat necessary to fully compensate for the losses of larvae due to entrainment at the DCPP was 279 ha (690 acres) (**Table 6-5**).

Table 6-4. Estimates of rocky substrate habitat within extrapolated source water areas for seven fish taxa for twelve source water surveys: a) the total estimates of habitat for each survey, and b) estimates weighted using the proportions of the source population of larvae for each taxa present during the survey period (f_i in the *ETM* results). The averages were calculated using the weighted estimates and were used in calculating the estimates of *HPF*.

	Cottidae	*Artedius* spp.	*Orthonopias triacis*	*Scorpaenichthys marmoratus*	*Sebastes* spp. V_	*Sebastes* spp. V	*Rhinogobiops nicholsi*
Survey Dates	unid. sculpins	smoothhead sculpins	snubnose sculpin	cabezon	KGB rockfish complex	blue rockfish complex	blackeye goby
a) Rocky habitat area estimates (m^2) for each survey period							
31-Jul-08	36,037,775	8,843,369	18,678,804	10,763,783	13,430,042	11,035,791	1,298,199
3-Sep-08	33,846,899	5,673,725	10,945,899	4,717,452	4,832,340	4,731,692	1,147,155
29-Sep-08	47,155,786	5,333,412	11,695,575	3,773,422	3,886,612	3,808,832	910,989
6-Nov-08	36,743,173	9,079,192	18,683,100	7,366,904	9,528,188	7,783,649	1,805,466
9-Dec-08	30,342,534	6,102,143	6,696,015	5,423,510	5,347,405	5,423,510	2,389,716
12-Jan-09	28,255,114	5,768,002	12,515,770	7,583,918	8,661,276	7,668,610	1,727,846
29-Jan-09	25,956,683	6,342,890	5,066,930	6,082,595	6,323,599	6,108,890	2,143,478
26-Feb-09	37,472,235	9,329,908	19,235,197	8,250,955	9,862,340	8,301,305	1,941,419
27-Mar-09	49,150,734	5,125,767	11,459,174	21,250,404	19,396,945	22,064,841	8,538,687
22-Apr-09	29,581,047	5,926,103	13,680,531	4,339,816	4,689,083	4,346,246	1,001,246
28-May-09	36,715,377	9,210,938	20,065,956	6,840,760	6,800,930	6,840,760	2,076,894
30-Jun-09	32,925,484	5,802,180	11,816,424	5,526,592	5,897,414	5,610,662	1,348,875
b) Rocky habitat area estimates (m^2) weighted by source water population abundance							
31-Jul-08	1,329,794	215,778	1,092,710	-	1,343	109,254	204,077
3-Sep-08	257,236	117,446	489,282	-	-	49,210	297,572
29-Sep-08	4,088,407	861,879	3,884,101	-	-	79,605	73,243
6-Nov-08	165,344	32,685	360,584	1,514,635	5,717	547,190	78,357
9-Dec-08	94,062	59,191	319,400	1,382,995	-	87,319	5,974
12-Jan-09	107,369	40,953	137,673	838,023	12,126	1,570,531	346
29-Jan-09	153,144	53,915	48,643	1,183,065	115,722	1,325,629	1,072
26-Feb-09	281,042	185,665	448,180	646,050	614,424	733,005	31,839
27-Mar-09	5,229,638	1,113,829	2,389,238	2,348,170	3,165,582	2,424,926	310,808
22-Apr-09	16,305,073	2,123,323	1,928,955	197,462	1,784,665	259,471	51,965
28-May-09	3,252,982	788,456	898,955	-	2,489,140	954,970	235,935
30-Jun-09	3,216,820	483,902	703,077	-	44,820	297,365	321,302
Average Habitat Area (m^2)	34,480,912	6,077,022	12,700,797	8,110,399	8,233,539	8,438,475	1,612,490
Average Habitat Area (ha [acres])	3,448 (8,520)	608 (1,502)	1,270 (3,138)	811 (2,004)	823 (2,035)	844 (2,085)	161 (398)

The highest *HPF* estimate, 1,331 ha (3,289 acres) (**Table 6-5**), was calculated for unidentified sculpins which was likely due to the large abundances of larvae collected in the Intake Cove relative to the other source water stations (**Figure 5-5**). The larvae for this group likely include individuals from numerous taxa which may explain why the larvae were collected across all of the source water stations. This makes the interpretation of the *HPF* estimate for this taxon difficult relative to the other taxa. It may also explain the long duration estimated for the group which resulted in the largest source water area for any of the taxa (**Figure 4-6**). The long duration also increased the *ETM* estimate of P_M for the taxa which directly resulted in the high estimate of *HPF*.

Table 6-5. Estimates of Habitat Production Foregone (*HPF*) for nearshore rocky reef fish larvae based on nearshore *ETM* estimate of P_M based on extrapolated source water areas from CODAR data. For the taxa with depth limits deeper than 61 m (200 ft), the offshore extrapolated estimates of P_M were used in the *HPF* calculations.

Taxon	Common Name	Average alongshore distance (km) used in extrapolated source water	CODAR *ETM* P_M (%)	Depth (m) used in determining source water habitat	Estimate of subtidal rocky reef *HPF* (ha [acres])
Cottidae	unid. sculpins	30.7	38.6	91.4	1,331 (3,289)
Artedius spp.	smoothhead sculpins	24.9	20.6	15.0	125 (309)
Orthonopias triacis	snubnose sculpin	20.6	19.8	30.5	251 (621)
S. marmoratus	cabezon	8.4	8.6	91.4	70 (172)
Sebastes spp. V_	KGB rockfish complex	9.1	12.6	86.0	104 (257)
Sebastes spp. V	blue rockfish complex	7.2	5.2	91.4	44 (109)
Rhinogobiops nicholsi	blackeye goby	4.8	18.5	76.2	30 (74)
				Average *HPF* =	**279.3 (690)**

As previously mentioned, it is important to validate the estimates of *HPF* with other data. In this study, estimates of *FH* were calculated for two taxa of rockfish larvae. Sampling of adult and juvenile KGB rockfishes at DCPP and other locations shows an average adult density of approximately 1.7 fish per 200 m^2, or 85 fishes per ha (2.47 acres). The estimate of *FH* for this taxon of 1,310 adults, indicates losses over an area of 15 ha (38 acres), a much lower number than the *HPF* estimate of 104 ha (257 acres). The estimate for adult blue rockfish based on sampling at DCPP indicates an average adult density of 0.5–2 fish per 200 m^2, or 25–100 fishes per ha (2.47 ac). The estimate of *FH* for this taxon of 258 adults, indicates losses over an area of 2.5–10 ha (6.2–24.7 ac), also a much lower number than the *HPF* estimate of 44 ha (109 ac). Although differences between the *HPF* estimates are somewhat reflective of the differences in the *FH* estimates, the higher *HPF* estimates are also likely to be the result of the effects of population regulation on recruitment for these taxa.

Population regulation or compensation is an important factor that needs to be considered when interpreting *HPF*. *HPF* is an estimate of the area necessary to fully replace the larval losses due to entrainment but it does not provide any information on the effects of the entrainment losses on the current adult population. In fact, there may be very little effect due to entrainment. The very nature of population regulation resulting from habitat limitation in fishes where *HPF* is applicable indicates that density dependent mortality is likely to be an important regulatory process in the population. The comparison of the *FH* and *HPF* estimates for KGB rockfishes indicate that population regulation has a major effect on recruitment. For example, post-settlement mortality has been shown to be strongly density dependent for nearshore rocky reef fishes (see review in Carr and Syms (2006)). For example, post settlement mortality of blackeye gobies on rocky reefs that was largely attributed to predation was estimated to exceed 90% (Steele and Forrester 2002). Steele and Forrester (2002) found that any relationship between densities of post-settlement juveniles and larval supply found in blackeye gobies was eliminated within a day of settlement as a result of predation. Therefore, while *HPF* can be used to estimate the area of habitat necessary to replace the production lost due to entrainment, it may not provide useful insight into how entrainment losses are actually affecting fish populations. This may be especially true for the fishes included in this assessment that are associated with nearshore rocky reef habitat where the effects of population regulation resulting from habitat limitation may be significant. Nevertheless, the estimates of *HPF* in **Table 6-5** could be used to provide guidance on the decision-making process for determining appropriate mitigation for the effects of entrainment by the DCPP CWIS.

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ATTACHMENT 2

TENERA TECHNICAL MEMORANDUM
November 2016

Proposed Calculation for Site-Specific Interim Mitigation Fee for Diablo Canyon

TECHNICAL MEMORANDUM

November 14, 2016

To: Mr. Jearl Strickland, PG&E
Mr. Mark Krausse, PG&E
Mr. Bryan Cunningham, PG&E

From: John Steinbeck, Tenera Environmental

Subject: Proposed Calculation for Site-Specific Interim Mitigation Fee for Diablo Canyon Power Plant (DCPP)

Document: ESLO2016-40

This memorandum provides a proposed approach to calculate a site-specific interim mitigation fee to compensate for the effects of entrainment at the DCPP, as allowed under the Once – Through Cooling Policy (SWRCB Resolution 2010-0020) and SWRCB Resolution No. 2015-0057 (2015 Resolution). The first section (Section 1.0) of this technical memorandum provides background on the existing estimates used to calculate the current default average interim mitigation fee of $4.60 per million gallons (MG) of intake flow. The second section (Section 2.0) provides a basis for adjusting the mitigation fee for the DCPP using corrected estimates of HPF from the 1996–1999 intake assessment and new HPF estimates from a more recent 2008–2009 study. The final section (Section 3.0) provides a proposed interim mitigation fee for the DCPP based on the information in the other sections.

1.0 Background to Proposed SWRCB Fee

The basis for the proposed fee is the entrainment fee of $4.60 per MG provided in the 2015 Resolution. The attachment to the resolution includes a table showing an average estimate of $2.45 per MG. This estimate is lower than $4.60 per MG because it is based on a cost projection using a basis year of 2012, instead of 2016, and a project life of 50 years instead of 30 years. The estimate of $4.60 per MG in the 2015 Resolution can be derived by changing the base year to 2016 and the project life to 30 years.

The Information Sheet for the 2015 Resolution also includes a mitigation fee estimate of $5.17 per MG.[1] That estimate includes an increase of 3% per year for 5 years to account for the time between the start of the mitigation project and the "cost projection year". As pointed out in a report prepared by Dr Stephen Hamilton,[2] there is no economic justification for this increase. If entrainment fees commence in 2015 and were adjusted annually for inflation, the entrainment

[1] Proposed Resolution Delegating Authority To The Executive Director To Approve Interim Mitigation Measures Under The Once-Through Cooling Policy Information Sheet. State Water Resources Control Board 2015.

[2] Memorandum to John Steinbeck, Tenera Environmental from Dr. Stephen F. Hamilton, Ph.D, Cal Poly San Luis Obispo on Economic Assessment of the Proposed SWRCB Entrainment Fee, July 6, 2015.

fees paid in 2015, the year used in the entrainment fee calculation in the 2015 Information Sheet, grow over time to match the escalation in mitigation cost. Escalating costs for 5 years from the base year of the entrainment fee and also adjusting the fee upwards each year to account for inflation amounted to double-counting. An economically accurate entrainment fee is based on 2015 mitigation costs (per MG), adjusted annually for inflation. The SWRCB acknowledged this error and made the necessary correction, which revised the fee to $4.60 as noted in the final resolution.

The estimate of $4.60 per MG in the 2015 Resolution was calculated from projects at five locations. Although the mitigation from all five projects were based on HPF calculations, the target habitat for the mitigation associated with the DCPP was rocky reef, while the mitigation for the other four projects was based on wetland habitat. As provided for in the 2015 Resolution (Section 10.a.i.1), site-specific data can be used to calculate HPF values for a facility rather than using the average value. This is especially appropriate for the DCPP where the habitat associated with mitigation is different from four of the five projects used in calculating the average mitigation fee of $4.60 per MG.

Therefore, the starting point for a site-specific interim mitigation fee at the DPP should be $3.12 per MG in **Table 1**, which is based on data from an intake assessment study at the DCPP conducted from 1996–1999 (1996–1999 Study) and an estimate of mitigation for DCPP that was prepared for the Central Coast Regional Water Quality Control Board (CCRWQCB) in 2005, the Diablo Canyon Power Plant Independent Scientists Recommendations to the Regional Board Regarding Mitigation for Cooling Water Impacts (2005 Independent Scientists Recommendations).

Table 1. Data from table in the attachment to SWRCB Resolution No. 2015-0057 showing calculation of entrainment mitigation fee of $4.60 per MG based on project life of 30 years and use of 2016 as the basis year for the calculations.

Annual Cost Escalator	3%
Estimated Years of Mitigation	30
Estimated Years of Operation	30
Cost of Management (%)	20%
Basis Year for Fee	2016

Project	Daily Intake Flow (mgd)	Annual Flow (MG)	HPF (acres)	Type*	Project Cost ($)	Cost($) per MG per year	Year of Assessment	Years between Assessment and Basis Year	Cost Escalator	Cost Escalator Factor	Cost in 2016 dollars	Prorated 2016 Costs ($)	Cost ($) per MG
MLPP	360	131,400	840	W	15,100,000	114.92	2000	16	3.00%	1.60	184.41	184.41	6.15
MBPP	371	135,415	760	W	13,661,905	100.89	2001	15	3.00%	1.56	157.18	157.18	5.24
Poseidon	304	110,960	37	W	11,100,000	100.04	2009	7	3.00%	1.23	123.03	123.03	4.10
HBGS	126	45,990	66	W	4,927,560	107.14	2009	7	3.00%	1.23	131.77	131.77	4.39
DCPP	**2670**	**974,550**	**543**	**R**	**67,875,000**	**69.65**	**2006**	**10**	**3.00%**	**1.34**	**93.60**	**93.60**	**3.12**
Averages						**98.53**					**138.00**	**138.00**	**4.60**

* – Mitigation Project Type: W = wetland, R = artificial reef, mgd = millions of gallons per day, MG – million gallons, MLPP – Moss Landing Power Plant, MBPP – Morro Bay Power Plant, Poseidon – Poseidon Carlsbad Desalination Project, HBGS – Huntington Beach Generating Station, DCPP – Based on estimates from 1996–1999 Diablo Canyon Power Plant Intake Study

2.0 Basis for Proposed DCPP Interim Mitigation Fee

Although the information in the previous section provides the background on the source of the DCPP $3.12 per MG interim mitigation fee referenced in the appendix to the 2015 Resolution, there are two issues that should be addressed in order to ensure the accuracy of the estimated interim mitigation fee for DCPP. These issues are discussed below and the results incorporated into a revised, more accurate DCPP interim mitigation fee which is discussed in Section 3.

2.1 Clarification - Basis for HPF estimate of acreage in Expert Panel Report for the SWRCB Ocean Plan Amendment

Appendix 1 of the March 14, 2012 report from the Expert Panel on Intake Effects and Mitigation for the SWRCB Ocean Plan Amendment for Desalination - Mitigation and Fees for the Intake of Seawater by Desalination and Power Plants (Desal Amendment Appendix),[3] includes an HPF estimate of 543 acres as the required mitigation for the effects of entrainment by the DCPP using data from the 1996–1999 Study. This is the same HPF estimate used in the 2015 Resolution for the DCPP that, along with estimates of mitigation for other coastal facilities in California, was used in calculating the default average interim mitigation fee that will start be assessed on power plants still utilizing coastal waters for once-through cooling in California that choose to comply with interim mitigation requirements through the flow-based fee option. (**Table 1**). The Desal Amendment Appendix prepared by Dr. Peter Raimondi, does not include any references or background on the source of that estimate.

Attempts were made to recalculate the HPF estimate for the DCPP, using several different methods. However, none of the estimates closely replicated the value of 543 acres. Discussions with Dr. Raimondi were also unable to reconstruct the source of the 543 acres. It was determined that the most likely basis for the number was an error in transferring the number to a spreadsheet, as 593 acres is the acreage equivalent of the estimate of 240 hectares, which is the average of the estimates from the original 2005 Independent Scientists Recommendations for the DCPP.

Dr. Raimondi was the principal author of the 2005 Independent Scientists Recommendations. That report included ten HPF estimates of the mitigation required to compensate for the effects of entrainment by the DCPP. The differences in the HPF estimates were the result of the assumptions used in the source water area used in the calculations and the area of rocky reef within those source water areas. The differences in the source water were the result of the use of data from a single current meter that did not allow for precise resolution of the source water area in the 1996–1999 Study. The current flowing past the current meter could be equated to a length of shoreline, but the uncertainty was due to whether the distance should be centered at the DCPP or biased to the north since the predominant current flow is downcoast. The amount of rocky reef within the source water areas was estimated using the amount of kelp coverage, but there was uncertainty on how much the estimate should be increased to account for rocky reef not represented by the cover of kelp. Estimates of one and two times the surface canopy were used in estimating rocky reef habitat area in the 2005 Independent Scientists Recommendations.

[3] http://www.waterboards.ca.gov/water_issues/programs/ocean/desalination/docs/erp_intake052512.pdf. Accessed on August 8, 2016.

The 2005 Independent Scientists Recommendations used four of the ten HPF estimates in determining an appropriate value. The estimates ranged from 120 – 401 hectares (265 – 991 acres). Averaging the four estimates results in an estimate of 240 hectares, which equates to 593 acres.

Thus, the HPF estimated using the 1998-99 entrainment data should be 593 acres. Using this number in the SWRCB's equation yields a site-specific interim mitigation fee for Diablo Canyon of $3.41. This is higher that the estimate of $3.12 in the 2015 Resolution due to the increase in the cost of the mitigation project from $67,875,000 to $74,125,000 resulting from the increase in acreage. Based on the calculations in **Table 1**, this increases the cost per MG to $76.06 and the cost in 2016 to $102.22 and $3.41 based on a project life of 30 years ($102.22 / 30years = $3.41) as shown below.

HPF (acres)	2006 Cost based on $125,000 per acre	Cost per MG per year	Cost Escalator	Cost Escalator Factor	Cost in 2016 dollars	Mitigation Years	Annual Mitigation Fee
593	$74,125,000	$76.06	3.00%	1.34	$102.22	30	$3.41

2.2 Additional Data - 2008–2009 HPF estimates calculated using estimates of rocky habitat based on kelp coverage

In addition to the HPF estimates from the 1996–1999 Study in the attachment to the 2015 Resolution (**Table 1**), HPF estimates for the DCPP were also calculated from data collected during an intake assessment in 2008–2009. The sampling design for the 2008–2009 intake assessment (2008–2009 Study) was consistent with entrainment studies conducted at several other power plants in California since the earlier DCPP study in 1996–1999. Similar to the 1996–1999 Study, a technical advisory group was convened to review the study design and provide comments on the sampling and analysis methods. This Technical Workgroup (TWG) was composed of staff from PG&E and their consultants, Tenera Environmental Inc, Dr. Peter von Langen from the CCRWQCB and Drs. Gregor Cailliet, Michael Foster, John Largier, and Peter Raimondi, who were consultants to the CCRWQCB. The study plan was submitted to the TWG for review, and was approved following a meeting in May 2008. The sampling for the study began in July 2008.

The source water sampling design for this study, which was approved by the TWG, was similar to other recent studies but was not as spatially extensive as the sampling grid design used in the 1996–1999 Study. The source water sampling was done monthly in both studies and included six of the original 64 source water stations from the 1996–1999 Study. These six stations were positioned along a transect heading straight offshore from the entrainment sampling locations inside the DCPP Intake Cove.

The estimation of the source water for the ETM analysis in the 2008–2009 Study was initially intended to be based on data from two acoustic Doppler current profiler (ADCP) instruments using an approach similar to the 1996–1999 Study. As the study progressed we became aware of the availability of data on surface currents from high frequency radar instruments (CODAR) over a large area of the central coast around the DCPP. The instruments were maintained by scientists and technicians at California Polytechnic State University, San Luis Obispo (Cal Poly). A decision was made to utilize the CODAR data in calculating the source water estimates for the ETM. This decision was made because the CODAR data provided much larger spatial coverage of ocean current data than the ADCPs. This also provided more realistic estimates of the source water due to the use of a combination of ADCP and CODAR data resulting in improved estimates of mortality using the ETM. The final methodology and preliminary results from the study were presented, discussed, and approved by the TWG during a meeting in May 2010.

The improvement due to the addition of CODAR data in the estimates of the source water for the ETM also affected the source water areas used in the calculation of HPF. As noted in the 2005 Independent Scientists Recommendations there was a considerable degree of uncertainty associated with the source water estimates used in the ETM that was directly related to the resolution provided by the ADCP data on ocean currents used in the study. The other large source of uncertainty associated with the HPF estimates was the data used to estimate the areas of habitat in the source water. Data from aerial photographic surveys of kelp beds were used to estimate the area of nearshore rocky reef habitat. In addition to the greater resolution provided by the CODAR data, the habitat estimates in this study used more recent data on bottom habitats collected from GIS data from the Seafloor Mapping Lab at the California State University at Monterey Bay (CSUMB). These data were collected along much of the central California coast as part of the California Department of Fish and Wildlife initiative to develop a network of marine protected areas. The more precise estimates of coastal currents and habitat used in this study greatly improve on the estimates of HPF provided in the 2005 Independent Scientists Recommendations.

The HPF calculations used in the 2005 Independent Scientists Recommendations were based on estimates of surface kelp cover with a multiplier to approximate the total area of subtidal rocky reef. The HPF estimates provided in the 2008–2009 Study were calculated using a more detailed approach that included multiple data sources and adjustments based on the depth distribution of the adults of the seven taxa evaluated (**Table 2**). The estimates of nearshore rocky reef used in the 2008–2009 Study combined data on the surface kelp canopy from the California Department of Fish and Wildlife (CDFW) with data on habitat from nearshore multi-beam surveys conducted by the California State University of Monterey Bay (CSUMB) habitat mapping group that were used in determining the locations of state marine protected areas (**Attachment Table A1**).

Habitat maps for each of the taxa show that the CSUMB hard substrate extends into water deeper than the kelp which tends to be very close to shore (**Attachment Figure A1**). This is one of the factors associated with the increase in the HPF estimate of 690 acres based on the ETM estimates calculated from the entrainment data collected during 2008–2009 Study from the estimate of 593 acres from the 1996–1999 Study. If the 690 acre HPF is used in the SWRCB's interim fee calculation, the result would be a fee of $3.96 per MG as shown below.

HPF (acres)	2006 Cost based on $125,000 per acre	Cost per MG per year	Cost Escalator	Cost Escalator Factor	Cost in 2016 dollars	Mitigation Years	Annual Mitigation Fee
690	$86,250,000	$88.50	3.00%	1.34	$118.94	30	$3.96

Table 2. Estimates of Habitat Production Foregone (*HPF*) for nearshore rocky reef fish larvae based on nearshore *ETM* estimate of P_M and rocky reef habitat within the source water areas extrapolated from CODAR data. For the taxa with depth limits deeper than 61 m (200 ft), the offshore extrapolated estimates of P_M were used in the *HPF* calculations. From "Draft 2008–2009 DCPP Entrainment Assessment Report."

Taxon	Common Name	Average alongshore distance (km) used in extrapolated source water	CODAR *ETM* P_M (%)	Depth (m) used in determining source water habitat	Estimate of subtidal rocky reef *HPF* (ha [acres])
Cottidae	unid. sculpins	30.7	38.6	91.4	1,331 (3,289)
Artedius spp.	smoothhead sculpins	24.9	20.6	15.0	125 (309)
Orthonopias triacis	snubnose sculpin	20.6	19.8	30.5	251 (621)
S. marmoratus	cabezon	8.4	8.6	91.4	70 (172)
Sebastes spp. V_	KGB rockfish complex	9.1	12.6	86.0	104 (257)
Sebastes spp. V	blue rockfish complex	7.2	5.2	91.4	44 (109)
Rhinogobiops nicholsi	blackeye goby	4.8	18.5	76.2	30 (74)
				Average *HPF* =	**279.3 (690)**

The HPF estimates from the two studies are not dramatically different given the potential for large interannual variation in biological populations and the differences in the design of the two studies. The consistency in the results is an expectation of the ETM, which relies on estimates of proportional loss to the source water that should be less subject to variation among years if the intake volume is constant. This also adds to the confidence in the estimates from both studies.

3.0 Proposed DCPP Interim Mitigation Fee

The information above is used to recalculate the interim mitigation fee for the DCPP. As provided for in the 2015 Resolution, site-specific data can be used in calculating the interim mitigation fee. Using a site-specific interim fee for DCPP is appropriate for the following reasons:

- DCPP has data available from two separate comprehensive entrainment assessments. The study approach and data from both studies have been reviewed by an independent technical workgroup;
- The results of the two studies are relatively consistent given the significant interannual variability, which is expected from the ETM approach used in both studies;
- DCPP is the only plant where entrainment impacts are associated with rocky reef habitat and thus, using site-specific data to calculate the fee is reasonable, as it based directly on both the acreage and the type of habitat impacted; and
- Using site-specific data increases the confidence in the estimated interim mitigation fee for the DCPP.

Given that Diablo Canyon has two robust and consistent evaluations of entrainment impacts and determinations of HPF, it is recommended that the DCPP interim mitigation fee be calculated using the average of the two separate studies. As shown in **Table 3**, this would result in an interim mitigation fee of $3.69 per MG, as compared to the $3.12 currently listed in the appendix to the 2015 Resolution.

Table 3. Table showing adjusted mitigation fees for the DCPP using corrections to data presented in the attachment to SWRCB Resolution No. 2015-0057. The data for both the DCPP 1996–1999 and 2008–2009 intake assessments are shown. The estimate for the mitigation fee for the 2008–2009 study is based on scaling the estimates from the 1996–1999 Study based on the differences in the HPF estimate. The HPF estimate for the 1996–1999 Study has been corrected to reflect the information in the 2005 Independent Scientists Recommendations to the CCRWQCB.

Annual Cost Escalator	3%
Estimated Years of Mitigation	30
Estimated Years of Operation	30
Cost of Management (%)	20%
Basis Year for Fee	2016

DCPP Study Year	Daily Intake Flow (mgd)	Annual Flow (MG)	HPF (acres)	Type*	Project Cost ($)	Cost($) per MG per year	Year of Assessment	Years between Assessment and Basis Year	Cost Escalator	Cost Escalator Factor	Cost in 2016 dollars	Prorated 2016 Costs ($)	Cost ($) per MG
1996-1999	2670	974,550	593	R	74,125,000	76.06	2006	10	3.00%	1.34	102.22	102.22	3.41
2008-2009	2670	974,550	690	R	86,250,000	88.50	2006	10	3.00%	1.34	118.94	118.94	3.96
												Average for DCPP	**3.69**

* – Mitigation Project Type: W = wetland, R = artificial reef, mgd = millions of gallons per day, MG – million gallons

1996–1999 – Estimates from 1996–1999 Diablo Canyon Power Plant Intake Assessment Study

2008–2009 – Estimates from 2008–2009 Diablo Canyon Power Plant Intake Assessment Study

Attachment A – Table and maps showing habitat and source water areas for each of the taxa evaluated from the 2008–2009 DCPP Intake Assessment

Table A1. Area estimates from GIS of surface canopy kelp from the California Department of Fish and Wildlife (CDFW) and on hard substrate habitat from nearshore multibean surveys conducted by the California State University of Monterey Bay (CSUMB) habitat mapping group. Area where kelp coverage overlapped hard substrate habitat also presented. Estimates based on data out to depth presented for each taxon.

Taxa	Depth of Source Water Extent (m)	CSUMB Hard Substrate (hectares [acres])	CSUMB Hard and Kelp Overlap (hectares [acres])	Kelp (hectares [acres])	Combined Kelp and Overlap (hectares [acres])	All Hard and Kelp Habitat (hectares [acres])
unidentified sculpins	91	6,429 (15,885)	796 (1,968)	1,007 (2,488)	1,803 (4,456)	8,232 (20,341)
smoothhead sculpin	15	554 (1,369)	380 (939)	485 (1,199)	865 (2,137)	1,419 (3,507)
snubnose sculpin	31	2,108 (5,209)	487 (1,203)	517 (1,277)	1,004 (2,481)	3,112 (7,690)
cabezon	91	2,089 (5,163)	273 (674)	218 (538)	491 (1,213)	2,580 (6,376)
KGB rockfish	86	1,986 (4,908)	298 (736)	223 (551)	521 (1,287)	2,507 (6,195)
blue rockfish	91	2,404 (5,939)	369 (911)	250 (619)	619 (1,530)	3,023 (7,469)
blackeye goby	24	528 (1,304)	256 (632)	212 (524)	468 (1,156)	995 (2,460)

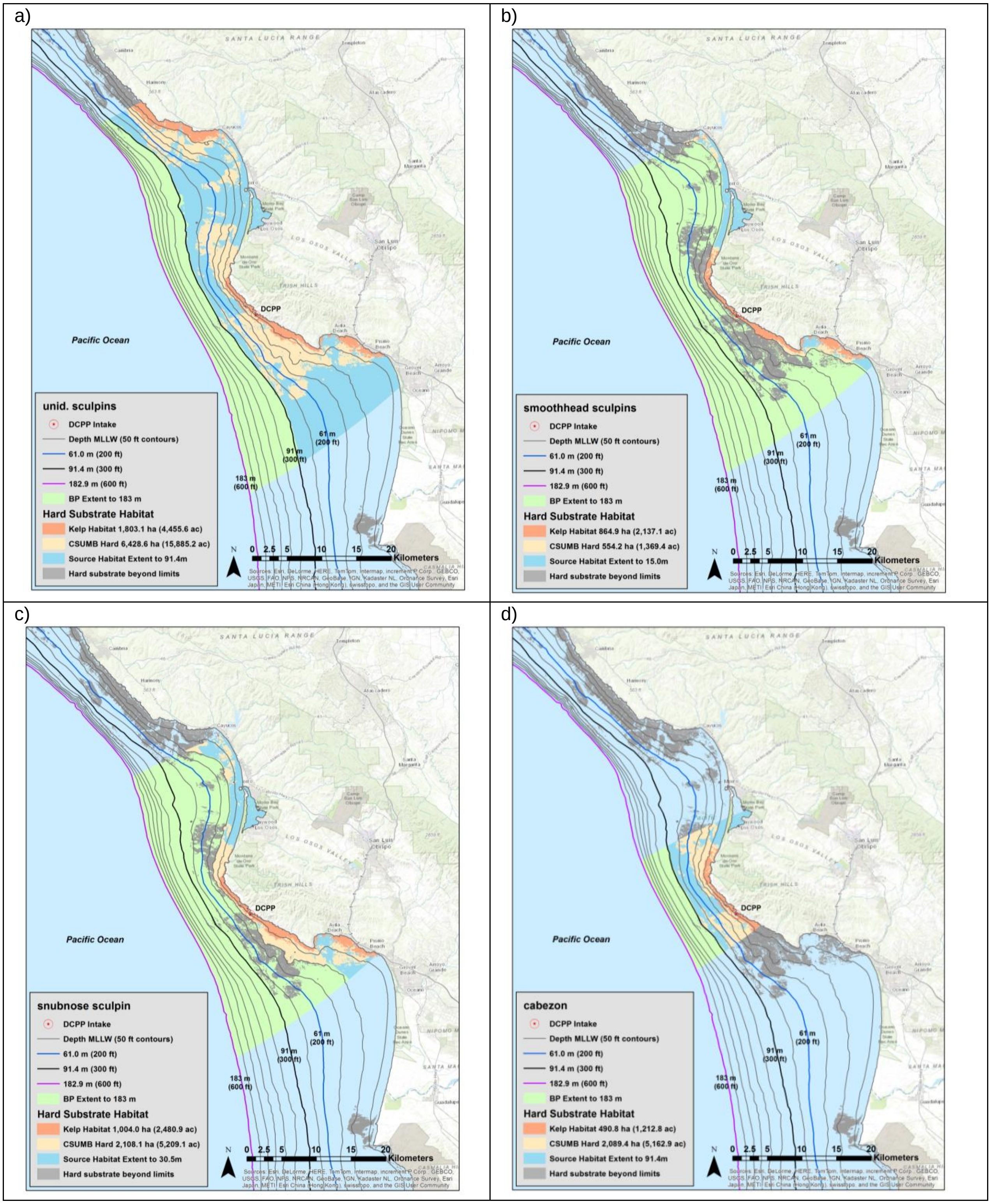

Figure A1. Maps of source water extents and habitat for a) unidentified sculpins, b) smoothhead sculpins, c) snubnose sculpins, d) cabezon, e) KGB rockfish, f) blue rockfish, and g) black eye goby larvae showing habitat areas based on extent of surface canopy kelp cover and hard substrate from multi-beam surveys. Source water extent of back projections (BP) used in ETM shown in blue.

(figure continued)

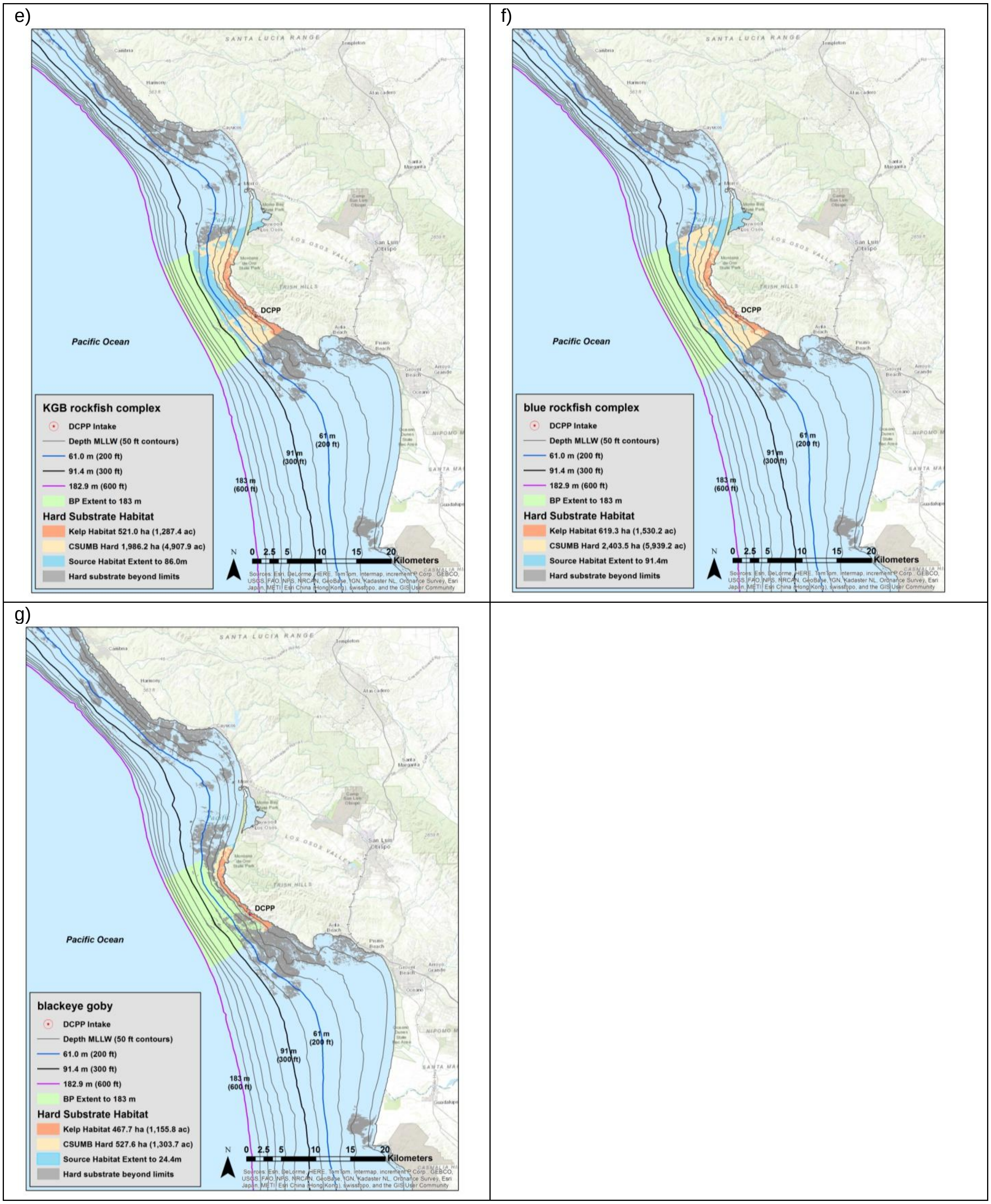

Figure A1 (continued). Maps of source water extents and habitat for a) unidentified sculpins, b) smoothhead sculpins, c) snubnose sculpins, d) cabezon, e) KGB rockfish, f) blue rockfish, and g) black eye goby larvae showing habitat areas based on extent of surface canopy kelp cover and hard substrate from multi-beam surveys. Source water extent used in ETM shown in blue.

Attachment 3

Pacific Gas and Electric Company
Diablo Canyon Monthly Intake Volume
October 1, 2015 – September 30, 2016

Month	OTC Intake Volume (MG)
October 2015	43,648
November 2015	66,330
December 2015	75,237
January 2016	77,066
February 2016	72,094
March 2016	77,066
April 2016	74,475
May 2016	40,530
June 2016	72,038
July 2016	77,066
August 2016	77,066
September 2016	74,580
TOTAL	**827,196**

Power plant operations logs track the start and stop times of individual intake circulating water pumps to the nearest minute. These logs are maintained each operating shift on a continuous basis (24/7/365). Plant OTC intake/effluent volumes are calculated using the hours/minutes each circulating water pump is operated, and the pumping capacity in gallons per minute (gpm) for each respective pump. Monthly intake volumes provided are the sum of the withdrawal volumes calculated for each pump operated during the respective calendar periods.

Due to the size and configuration of the seawater circulating system infrastructure at the Diablo Canyon Power Plant, it is impractical to install a flow metering device for direct monitoring of the intake withdrawal volume. The current method described above is the most reasonable means of obtaining accurate intake volumes for use in calculating the annual interim entrainment mitigation fee.

Additionally, the capacities of individual pumps were developed during early testing and operation of the equipment following installation. In general, pump capacities tend to degrade to some extent over their operating life due to normal wear and tear. Therefore, it is probable the withdrawal volumes derived using the original pump capacities are conservative, as the current capacities of the pumps have likely decreased over time.