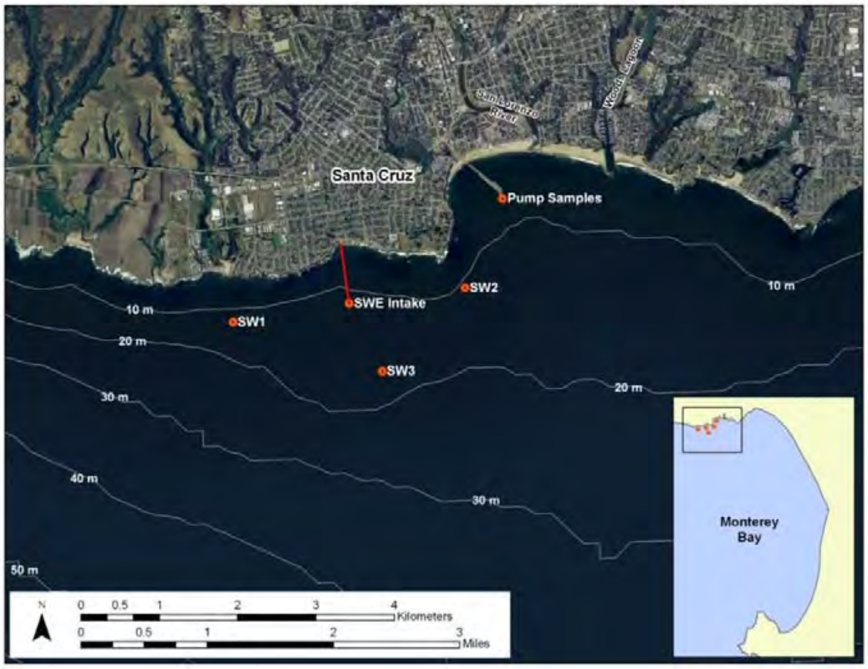
City of Santa Cruz Water Department
& Soquel Creek Water District
scwd^2 Desalination Program

Open Ocean Intake Effects Study



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Glossary

ADCP	Acoustic Doppler Current Profiler.
AEI	Adverse Environmental Impact.
ANOVA	Analysis of Variance.
Benthic	Bottom dwelling.
CalCOFI	California Cooperative Oceanic Fisheries Investigations.
Cancrid crabs	Family of crabs widely distributed in the coastal waters of the west coast of North America.
Caridean shrimps	The largest shrimp group in the world, containing almost 2,800 described species. Thirty-seven species of caridean shrimps are listed as occurring in shallow subtidal and intertidal habitats in California.
CCC	California Coastal Commission.
CDFG	California Department of Fish and Game.
CEC	California Energy Commission.
CeNCOOS	Central and Northern California Ocean Observing System.
CIQ gobies	A group of three goby species (*Clevelandia ios*, *Ilypnus gilberti*, and *Quietula y-cauda*) that cannot be distinguished during their earliest larval stages.
COCMP	Coastal Ocean Currents Monitoring Program.
CPFV	Commercial Passenger Fishing Vessel.
CWA	Clean Water Act.
CWIS	Cooling Water Intake System.
Demersal	Living close to the seafloor (just above the bottom).
DVR	Digital Video Recorder.
EIR	Environmental Impact Report.
Epibenthic	Living on the surface of the bottom.
Entrainment	Passage of planktonic organisms through a water intake system.
Entrapment	The occurrence of organisms within a cooling water intake system that have been entrained but not impinged on traveling screens, and cannot escape the cooling water intake flow.
ETM	Empirical Transport Model. A mathematical model that estimates the total annual probability of mortality (P_m) due to entrainment using PE estimates.

FH	Fecundity Hindcasting. The number of larvae entrained are hindcast to estimate the number of eggs by applying mortality estimates; the number of eggs is then used to estimate the number of adult females that would have produced that quantity of eggs.
Forebay	The exposed area of a seawater intake system directly upcurrent from the trash racks and traveling screens.
Fork Length (FL)	Length of a fish as measured from the tip of the snout to the fork of the caudal fin.
fps	Feet per second.
HF	High frequency.
Impingement	The entrapment of macroscopic fish and invertebrates on intake screens.
IWP	Integrated Water Plan.
KGB rockfish Complex	Guild of nearshore, benthic, or epibenthic rockfishes sharing similar morphology and ecological roles. Includes kelp, gopher, and black-and-yellow rockfishes.
MBARI	Monterey Bay Aquarium Research Institute.
MBNMS	Monterey Bay National Marine Sanctuary.
Megalops	Advanced larval stage of crabs following zoea.
MGD	Million Gallons per Day.
MHHW	Mean Higher High Water.
MLLW	Mean Lower Low Water.
Molt	Periodic shedding of the cuticle (outer skeletal structure) in arthropods (crabs, shrimps, etc.).
MT	Metric Tons.
Nekton	The collection of marine and freshwater organisms that can swim freely and are generally independent of currents, ranging in size from microscopic organisms to whales.
NMFS	National Marine Fisheries Service.
Notochord length (NL)	Straight line distance from tip of snout to posterior tip of notochord.
OMA	Open Normal Mode Analysis.
PCR	Polymerase Chain Reaction.
PE	Proportional Entrainment. A mathematical value comparing the number of larvae entrained to the number of larvae available in the source water body.
Pelagic	Occurring in the open water, between the water surface and the seafloor.
PFMC	Pacific Fishery Management Council.
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans.

Plankton	Any drifting organisms that inhabit the pelagic zone of oceans, seas, or bodies of fresh water:
Ichthyoplankton -	The eggs and larvae of fishes drifting in the water column.
Phytoplankton -	Autotrophic, prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis.
Zooplankton -	Small protozoans or metazoans (e.g. crustaceans and other animals) that feed on other plankton.
P_m	Proportional Mortality Annual probability of mortality due to entrainment.
QA/QC	Quality Assurance/Quality Control.
Recruitment	Measure of the number of fish that enter a class during a specified time period, such as the spawning class. Usually refers to the first year class settling from larvae.
SCCOOS	Southern California Coastal Ocean Observing System.
scwd2	Collectively the City of Santa Cruz Water Department and the Soquel Creek Water District.
Standard Length (SL)	Length of a fish measured from the tip of the snout to the posterior end of the last vertebra (excludes length of caudal fin).
Subpopulations	A group of individuals of a species which interbreeds but is reproductively isolated from other such groups of the same species.
SWFSC	National Marine Fisheries Service’s Southwest Fisheries Science Center.
SWRO	Salt Water Reverse Osmosis.
Total Length (TL)	Length from the tip of the snout to the tip of the longer lobe of the caudal fin.
TWG	Technical Working Group.
UCSC	University of California at Santa Cruz.
Upwelling	Offshore transport of surface waters usually resulting from steady northwest/west winds, causing deep, colder, nutrient-rich water to rise to the surface.
USEPA	United States Environmental Protection Agency.
WWS	Wedgewire Screen.
YOY	Young of year.
Zoea	Early larval stage in crustaceans.

Executive Summary

This report presents an assessment of potential impacts to marine life from water withdrawals associated with a proposed screened, open ocean intake for a 7 million gallon per day (mgd) (2.5 mgd freshwater capacity) seawater reverse osmosis (SWRO) desalination project for the City of Santa Cruz Water Department (City) and the Soquel Creek Water District (District) (collectively **scwd^2**). The intake effects assessment study objectives include:

- establish a baseline characterization of larval fish, fish eggs, caridean shrimps, and cancrid crab species by sampling the species composition, abundance, and variability in the open ocean near the proposed intake, and
- model the potential impacts on local fish, caridean shrimp, and cancrid crab populations caused by the loss of entrained organisms.

Also discussed in the report are the results of four additional investigations conducted during the course of this study:

- an assessment of the operational effectiveness of the proposed narrow-slot cylindrical wedgewire screen intake in preventing entrainment by sampling with a pilot-scale screened intake and an "unscreened intake",
- an underwater videographic study to assess larval impingement on the wedgewire intake screen,
- a dye test study to examine the hydrodynamics near the wedgewire screen during pumping, and
- a corrosion/biofouling study of screening materials.

The City of Santa Cruz Wastewater Treatment Plant has an abandoned 0.9-m (36-inch) diameter wastewater outfall pipe that extends approximately 0.6 km (2,000 ft) offshore between Terrace Point and Point Santa Cruz. This wastewater outfall pipe has been proposed as a potential intake pipeline for the desalination plant. At the time of the study, the proposed approach for the screened, open ocean intake would make use of this existing infrastructure by installing a new pipe within the existing pipe and placing cylindrical wedgewire screens at the point of intake to prevent impingement and reduce entrainment of marine organisms. The abandoned outfall pipe terminates near the inner edge of Santa Cruz Reef at a depth of approximately 12 m (40 ft) (**Figure ES-1**). Brine from the proposed SWRO desalination facility would be combined with the existing effluent stream from the City of Santa Cruz Waste Water Treatment Facility through their approximately 3.2-km (2-mile), 1.8-m (72-inch) diameter outfall structure.

When water is withdrawn from a source water body for industrial or municipal purposes, small planktonic organisms within the water body may be entrained (drawn through the intake system) or impinged (trapped against the outer screening system by incurrent flows). Water intake systems could potentially affect source water populations of marine organisms by uncompensated removal of larvae that are entrained in water flows and removal of larger life stages that are impinged on the intake screens.

This study was undertaken in consideration of State Water Code Section 13142.5(d), which states that, "independent baseline studies of the existing marine system should be conducted in the area that could be affected by a new or expanded industrial facility using seawater, in advance of the carrying out of the development." This study addresses the potential effects of entrainment and examines effects of larval impingement, since the intake system will be designed with very low intake velocities to prevent impingement of larger organisms.

Offshore Intake and Source Water Study

The overall approach of the study was to collect data on the concentrations of fish eggs, and larvae of fishes, caridean shrimps, and cancrid crabs in the source water at the proposed intake by using towed plankton nets, the standard sampling method for these organisms. The number of organisms collected and the volume of seawater sampled were used to calculate sample concentrations for each taxon (i.e., a distinct taxonomic category) of fish eggs, fish larvae, and caridean shrimp and cancrid crab larvae.

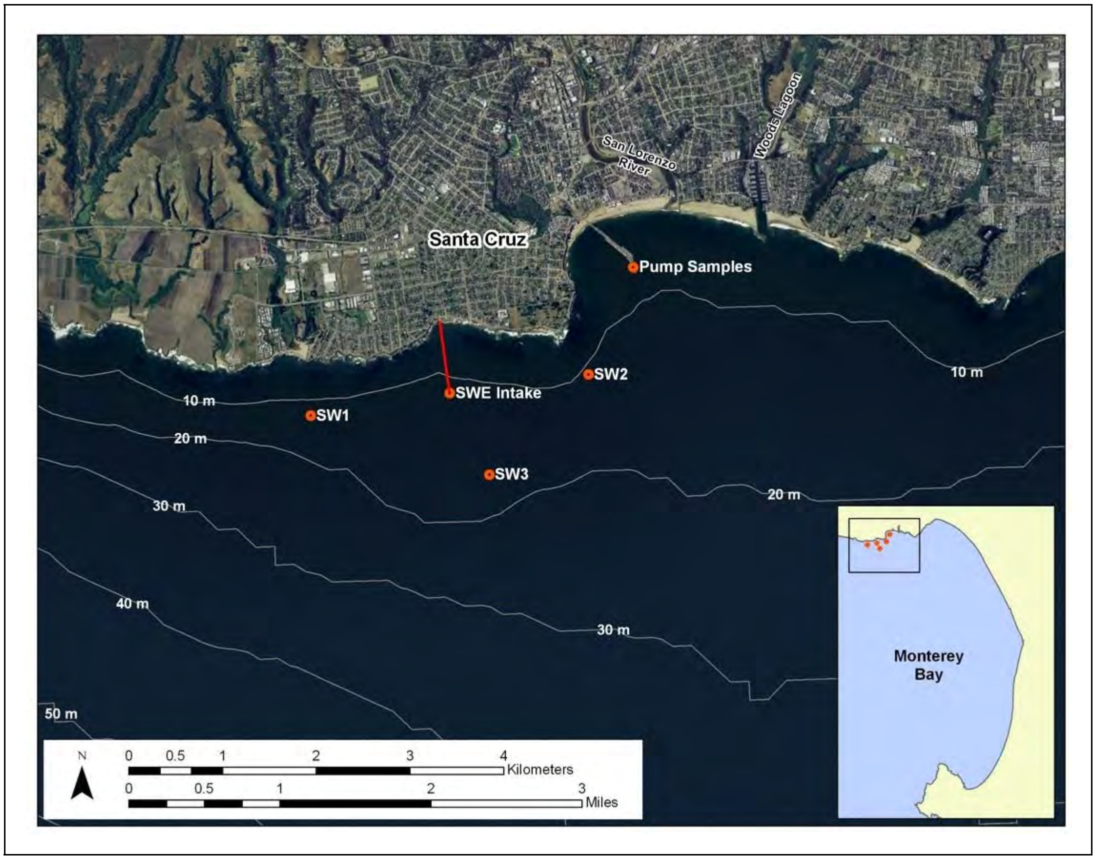


Figure ES-1. Location of intake and source water stations for plankton sampling.

Entrainment effects at power plant and desalination pilot facility intakes in California have been assessed using the Empirical Transport Model (*ETM*), as recommended and approved by the California Energy Commission (CEC), California Coastal Commission (CCC), Regional Water Quality Control Boards, and other regulatory and resources agencies. This model estimates the proportional loss to the standing stock of larvae in the source water due to entrainment using an estimate of mortality calculated as the ratio of the number of larvae entrained to the number estimated in the source water. *ETM* analysis of the **scwd²** entrainment study results conservatively assumed that the intake would not be screened; and therefore, the *ETM* results overestimate the potential entrainment losses to the degree that the appropriate use of narrow-slot screens and low through-screen velocities can reduce entrainment.

The *ETM* approach requires an estimate of population size that is defined by extrapolating larval concentrations of a source water volume estimated by combining larval duration with current speed during the study period and bathymetric data. The source water area and volume used in the calculations of entrainment impacts for the proposed intake were calculated based on the local currents and life-cycle stages of the different larvae found in the area. The linear extent of the source water was estimated as the distance an average-age larva of each entrained species would be transported by currents to the intake screen, during the period of the species' larval life stage, while the larvae are still small enough to be entrained.

Findings of the Offshore Intake and Source Water Study

The two data sets—source water larval fish, caridean shrimp, and cancrid crab concentrations, and the concentrations of these organisms entrained through an unscreened intake and through the test-scale intake screen—were used to evaluate potential entrainment impacts from the proposed project. The results from the pilot-scale screen tests were used to adjust the proportional loss estimate from the *ETM* and estimate the potential reduction of entrainment impacts using the wedgewire screened intake.

The composition and abundance of ichthyoplankton and caridean shrimp and cancrid crab larvae in the proximity of the proposed intake were sampled once per month from April 2009 through May 2010.[1] A total of 2,887 entrainable fish larvae from 45 separate taxonomic categories (not including fragments, but including unidentified larval fishes) was collected from 100 samples at the intake station (SWE). Larval fishes were most abundant from November through March, and least abundant in July through October. Eight taxa comprised the top 82% of the average mean concentration of larval fishes collected at the intake station. The most abundant taxa were white croaker (51.6%), unidentified yolk sac larvae (9.3%), northern anchovy (5.8%), CIQ gobies (5.1%), sanddabs (2.7%), unidentified smelts (2.6%), unidentified ronquils (2.3%), and smoothhead sculpins (2.3%). Most of the commonly entrained taxa were from species with shallow nearshore distributions, but larvae from some deepwater species (e.g., lanternfishes [Family Myctophidae]) were also collected in smaller numbers.

[1] No survey was conducted during April 2010 due to hazardous sea conditions.

A total of 658 cancrid crabs and caridean shrimps was identified from the monthly samples collected at the intake station (Station SWE). Caridean shrimps comprised approximately 55% of the total mean concentration of target invertebrates collected at the intake station.

No endangered, threatened, or listed species were found in the source water and intake samples.

Because the proposed screened, open ocean intake is situated offshore from a rocky shoreline that is adjacent to sand substrate habitat, it follows that the greatest magnitude of effects is likely to occur to species from these types of habitats that produce planktonic larvae. The dominance of white croaker larvae in the samples is consistent with the general oceanographic conditions in northern Monterey Bay that typically produce a counter-clockwise current gyre. These currents transport larvae into the northern edge of the bay from the more sheltered sand bottom habitats south and east of the intake location where white croaker would typically occur. This predominant flow pattern was confirmed by current data showing that movement was generally up-coast in the alongshore direction.

The analyzed taxa have a wide range of habitat, depth, and onshore-offshore distributions. Larvae from fish, caridean shrimp, and cancrid crab species that are typically found in the shallow rock reef and kelp bed habitats in proximity to the proposed intake actually have the least potential effects based on the *ETM* analysis results (see below). The species with the greatest potential entrainment, based on the 2009–2010 sampling results, was white croaker, a species with a wide geographical distribution that typically occurs over shallow sandy bottoms. White croaker spawns pelagic eggs generally from November through May, and prevailing current patterns in the source water tended to transport the eggs and larvae into the vicinity of the proposed intake. Measurements of larvae indicated that white croaker and most of the other target taxa were produced locally and thus would be exposed to entrainment for a relatively short period of time during their larval development.

Assessment of the Impacts of the Proposed Open Ocean Intake

The proposed 2.5 mgd seawater desalination facility would require an intake capacity of approximately 6.3 mgd. To be conservative, the *ETM* calculations below used 7 mgd for the proposed intake flow rate. These results do not take into account any potential reduction in entrainment that could be achieved by screening the intake.

Based on the *ETM* approach, the greatest projected proportional mortality (P_M) of larval entrainment (0.063%) would be on gobies, which are associated with shallow soft substrate habitats; white croaker (0.053%), which is an epibenthic or open water species; and northern anchovy (0.047%), which is a widely-distributed pelagic species (**Table ES-1**).

Table ES-1. Estimated percent incremental mortality for the most abundant fishes, caridean shrimps, and cancrid crabs based on 7 mgd flows and 2009–2010 intake location survey data.

Species	Common Name	*ETM* P_M (%) (7 mgd flow)
Fish Larvae		
CIQ goby complex	gobies	0.063
Genyonemus lineatus	white croaker	0.053
Engraulis mordax	northern anchovy	0.047
Citharichthys spp.	sanddabs	0.033
Artedius spp.	sculpins	0.029
Paralichthys californicus	California halibut	0.027
Sebastes spp. V_	KGB rockfishes	0.010
Target Invertebrates		
Caridean shrimps (post-larval)	caridean shrimps	0.022
Cancridae (megalops)	cancer crab megalops	0.022

In other words, these species would have less than about six-hundredths of one percent of their populations (0.0006) within the source water at risk of entrainment at a projected intake flow rate of 7 mgd. These low P_M values do not represent a significant source of mortality on these populations considering the high temporal variation that these populations typically experience due to a range of environmental conditions, and other anthropogenic and natural sources of mortality that can also affect these species. The natural mortality rate of larvae from these species is approximately 99.9%, and the natural mortality of juvenile fishes of these species is approximately 98%. Therefore, the impacts due to entrainment of the proposed 7 mgd intake flow for the 2.5 mgd seawater desalination facility are considered *de minimis*. All other smaller organisms regarded as food chain species have similarly high or higher natural mortality and generally shorter life cycles. The 7 mgd intake will have a similarly *de minimis* effect on these food chain species, whose very short life cycles sustain very high rates of natural mortality.

Intake Screen Pilot Studies

In parallel with the offshore intake and source water study, a pilot study and evaluation of the proposed narrow-slot cylindrical wedgewire screen was conducted. This pilot study examined the following operational characteristics of the proposed narrow-slot cylindrical wedgewire screen (WWS) *in situ*: 1) larval entrainment, 2) impingement, 3) screen corrosion/biofouling, and 4) hydrodynamics around the screen during pumping.

Larval Entrainment

Data on concentrations of fish and invertebrate larvae were collected from a pilot project pump and screening system tested on a platform near the end of the Santa Cruz Municipal Wharf. The pumping system was designed to collect paired screened and unscreened samples, and screening efficiency was evaluated by comparing larval concentrations from the two types of intakes. A photograph of the pilot-scale WWS intake is provided in **Figure ES-2**.

Intake screen efficiency surveys were conducted monthly over a 13-month period from April 2009 through May 2010. During most of these 24-hour surveys, four plankton samples were collected from the screened intake and four from the unscreened intake with half of the samples collected during the day and half at night. Seawater was pumped from a depth of approximately 4.6–6.1 m (15–20 ft) beneath the sea surface (depending on tide stage) through a system of 10-cm (4-inch) PVC pipe connected to both the screened and unscreened intakes. The pilot-scale WWS intake screen had a 2.0-mm (0.08-inch) slot opening and was sized to ensure a maximum through-screen velocity of 0.1 m/sec (0.33 ft/sec).

Figure ES-2. Pilot-scale narrow-slot wedgewire intake screen.

The pumped water was filtered through 335-µm (0.01-inch) mesh plankton nets which were suspended in water to lessen the chances of damage to the larvae, and calibrated flowmeters were used to calculate the volume of water filtered by each net.

Findings of the Pilot Intake Entrainment Analysis

The data from the pump samples were analyzed to determine if any differences could be detected between concentrations of fish, caridean shrimp, and cancrid crab larvae from the screened and unscreened intakes. The numbers of fish larvae collected were low relative to offshore samples. An analysis combining all of the larval fishes collected was done using taxa counts for each sample. However, only the white croaker was analyzed as a unique taxon, because it was the most abundant taxon of fish larvae in the screened vs. unscreened samples. (White croaker was also the most abundant taxon collected during the offshore intake and source water study.) Three taxa groups of invertebrates were also analyzed: cancrid crab megalops and the later-stage larvae of Crangonidae and Thoridae/Hippolytidae shrimps.

The highest overall mean concentrations of larval fishes occurred in February, March, and May 2010 while the lowest were seen from April 2009 through January 2010. The highest average concentration of target invertebrates from the screened samples occurred in May 2010 and the highest average concentration of target invertebrates from the unscreened samples occurred in November 2009.

Investigations of the pilot-scale passive narrow-slot WWS intake found the following:

- No endangered, threatened, or listed species were entrained.
- The narrow-slot wedgewire intake screen excluded 100% of adult and juvenile fish species in the area. The unscreened intake entrained juvenile and adult fishes.
- No statistically significant reduction in entrainment, due in part to the presence and abundance of larvae with heads smaller than the 2-mm screen opening.
- A smaller slot size, such as 1 mm, would reduce entrainment by the large fraction of larvae with heads smaller than 2 mm but larger than 1 mm. However, the fraction of larvae that would be screened out with a smaller screen are already 10,000^{ths} or less of the source water populations, a truly *de minimis* benefit of a smaller slot screen.
- Annualized screen-test results demonstrated that the screen resulted in 20% reduction in total annual larval fish entrainment.
- Although additional research on the location and orientation of the narrow-slot screen in open-ocean, high wave energy settings might lead to improved screen efficiency, the estimated entrainment impacts of the proposed **scwd^{2}** intake in Mitchell's Cove are so small (10,000^{ths} of source water populations) that improved screen efficiency would be of no ecological consequence. However, screen efficiency measured beneath the Santa Cruz Wharf may not truly represent optimum screen performance in Mitchell's Cove.

In Situ Wedgewire Screen Impingement

To study the possibility of fishes being pulled and held (impinged) on the WWS module, two underwater video cameras were installed to view the surface of the module during operation. One camera was oriented to video a lengthwise view of the screen's surface while a second camera videoed a top view of the screen's surface. Underwater lights were deployed on movable arms and were positioned to minimize particle backscatter interference with video images. Both the cameras and the lights were hardwired to the entrainment sampling deck above, with underwater cables running through conduit tie-wrapped to the piling. Videos were displayed and recorded to a digital video recorder (DVR) when the pump was operated. Data were transferred to a DVD from the DVR for review. **Figure ES-3** is a series of still photographs from the impingement video that show the types of interactions of marine organisms with the operating intake screen.

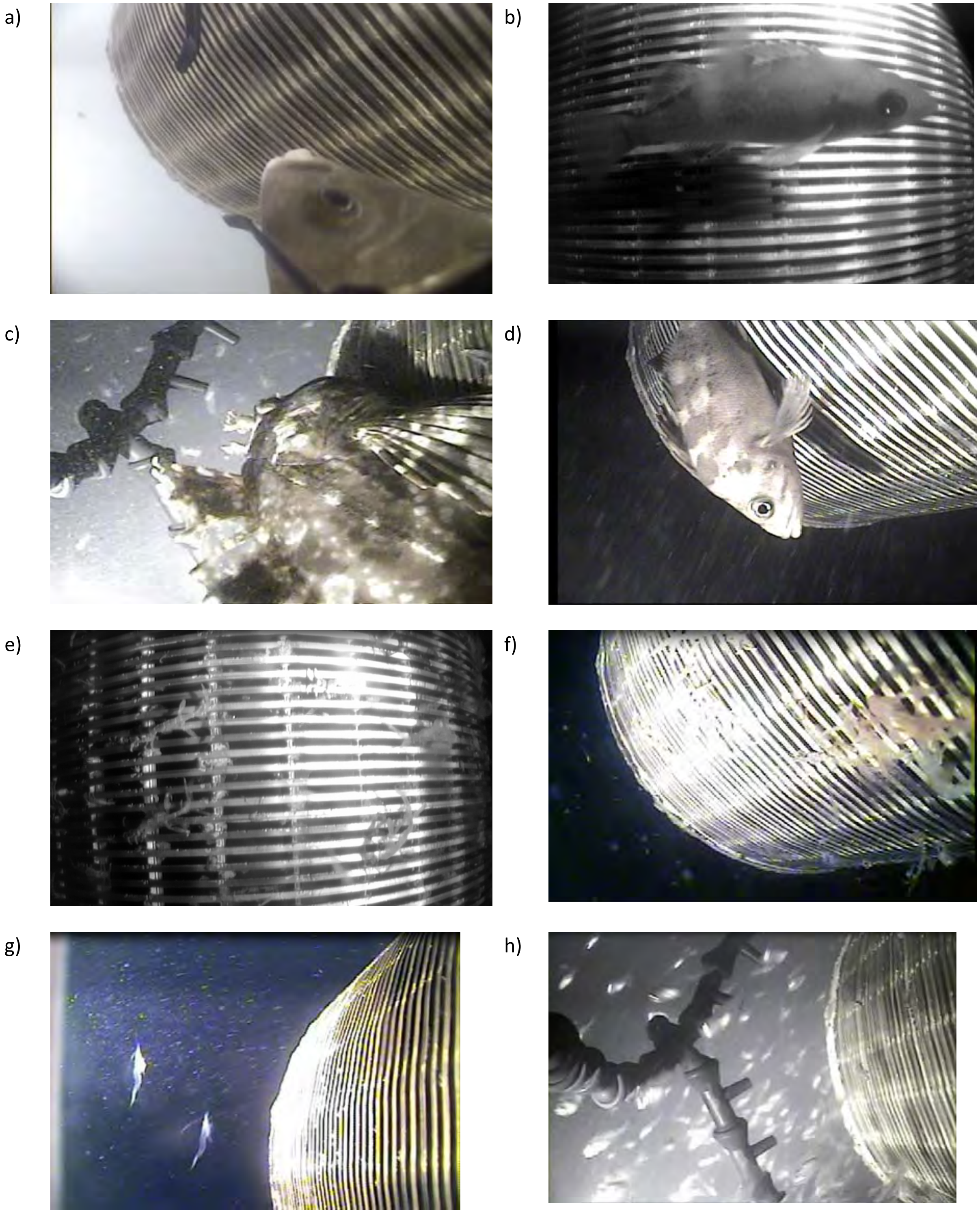


Figure ES-3. Photographs taken during the *in situ* wedgewire screen impingement study with pump operating.

a) perch feeding on invertebrates on screen; b) rockfish swimming close to screen; c) cabezon sitting on screen; d) rockfish sitting on screen; e and f) caprellids crawling on screen; g) shrimps swimming near screen; and h) school of juvenile rockfish swimming near screen.

A total of 15 wedgewire screen impingement surveys was conducted. Of the 262 interactions with fishes recorded during the logging of the wedgewire screen impingement study, fishes contacted the screen in 71 (27%) of the events. The majority of fishes observed were rockfishes. At no time was a fish observed that could not free itself after contacting the screen. Of the 880 observations of invertebrates in the vicinity of the screen, 64% consisted of direct contacts primarily by amphipods crawling on the screen and swimming shrimps bumping into it.

Based on the video observations, it can be concluded that the passive WWS intake, with an intake velocity of 0.33 fps was successful in eliminating impingement in current and wave conditions and species of fish similar to those expected at the proposed intake at Mitchell's Cove.

Screen Biofouling and Corrosion

The corrosion and biofouling study was comprised of two components. The first consisted of visual observations made by divers each month as they cleaned the wedgewire screen prior to the screen efficiency survey. Observations of biofouling were recorded on data sheets and photographs were taken of the wedgewire screen before and after cleaning. On some service visits, the entire cleaning operation was recorded using videographic equipment.

The second component of the study examined the biofouling and corrosion rates of four different metal samples: 1) stainless steel, 2) a duplex alloy, 3) titanium, and 4) a copper-nickel "Z-alloy". (The pilot-scale WWS intake used in this study was fabricated with the Z-alloy material.) Two small, approximately 4 inch by 4 inch, pieces of screens (referred to as "coupons") fabricated from each metal were tested. Prior to deployment, the coupons were weighed to the nearest 0.001 g. The coupons were then mounted on PVC planks and deployed beneath the wharf at the same depth as the wedgewire screen intake. During each survey, the coupons were brought to the surface where they were photographed, and observations were made on the quantity and composition of the biofouling. They were then re-attached so that fouling progression could be followed over time.

Findings of the Biofouling Study

The study findings on the biofouling resistance of selected screen materials were unambiguous—Z-alloy proved to be resistant to biofouling over the 13-month continuous deployment of the intake screen during the entrainment and impingement performance testing. Stainless steel bolts and nuts and the PVC pipe flanges, and the PVC piping of the pilot-scale intake were heavily fouled with encrusting organisms during this same period of time.

The coupon biofouling study also showed the same results. All of the coupons except the Z-alloy experienced heavy biofouling over time. Screens made of materials such as stainless steel, duplex alloy, and titanium would require more frequent cleaning (approximately every 2 to 3 months) than the Z-alloy copper-nickel material screens.

Findings of the Corrosion Study

The change in weight of the coupons between the beginning of the study and their retrieval 211 days later varied by the type of metal. All of the coupons were thoroughly cleaned before final weighing to remove fouling organisms. However, a small amount of the organic material, primarily the base material of barnacles and encrusting bryozoans, could not be removed and contributed to the final weight of the coupons.

Both the duplex and titanium coupons underwent a small (<1.0 g, <1%) increase in weight, though this is most likely due to the small amount of remaining biofouling material. The stainless steel coupon experienced a small (0.66 g, 0.23%) decrease in weight. The two Z-alloy coupons experienced a decrease in weight of 9.61 and 9.51 grams or 6.07% and 5.91%, respectively.

Although the use of Z-alloy narrow-slot screens in the marine environment would be desirable due to its anti-fouling properties, the design and engineering of Z-alloy screens for use in open ocean conditions will need to take the potential corrosion of Z-alloy into consideration.

Screen Hydrodynamics Study

The video equipment that was used for the impingement study was also used to perform a qualitative evaluation of the water hydrodynamics around the intake screen. The intake screen's ability to prevent impingement of marine organisms is enhanced by the presence of ambient currents and wave motion past the screens. The currents and the rapid back and forth motion of the water due to waves passing the fixed intake screens create sweeping flows that transport debris and marine organisms away from the intake. These relatively high water velocities around the intake screen create sweeping currents that act to clean the screen of debris and help prevent impingement.

Video footage of the pilot intake system in operation shows the effectiveness of the local sweeping velocities around the fixed intake screen. The photographs in **Figure ES-4** are a series of still photographs from the intake video that show qualitative dye testing of the current interaction with the intake screens.

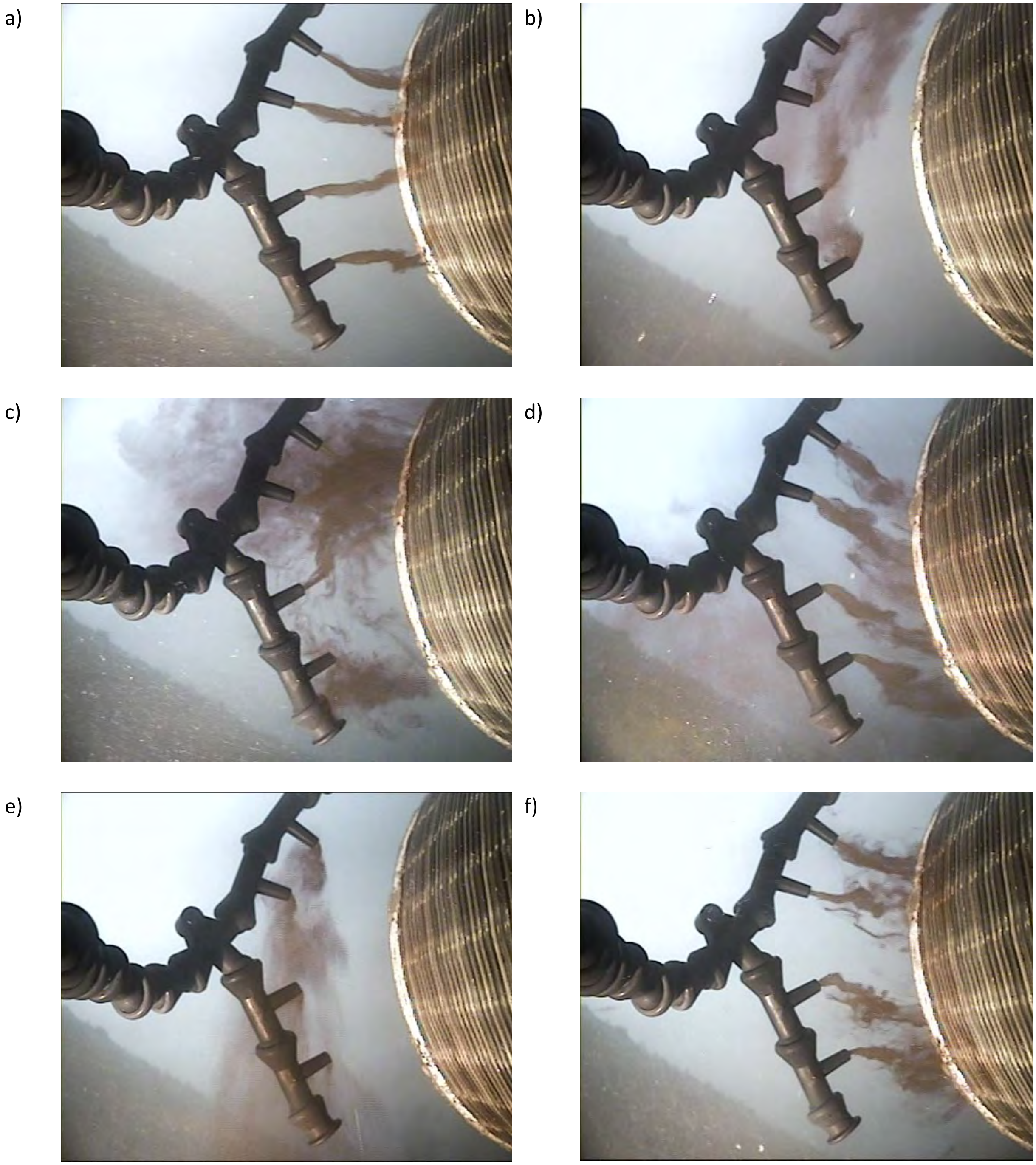


Figure ES-4. Dye testing showing currents interacting with the intake screen.
These images were taken from video at two second intervals.

In the photographs, the screen is operating with an approach velocity of 0.33 fps and the currents and wave induced water motion are pushing the dye back and forth, and up and around the screen. As the wave motion changes direction, the dye moves toward and then away from the intake screen. This qualitative study shows how the local natural water motion around the fixed screen is much greater than the low intake approach velocity, and how the water motion acts to clean the screen and to help prevent impingement of small organisms.

Conclusions

The results and conclusions from the **scwd²** intake effects assessment report include the following:

- No threatened, endangered, or listed species were found in the source water area samples or the pilot intake screen samples.
- The passive 2-mm WWS intake, with an intake velocity of 0.33 fps was successful in eliminating impingement in high wave energy conditions.
- The passive WWS intake prevented entrainment of the adult and juvenile fish species in the source water, which are critical to the reproductive cycle for these species.
- The greatest projected proportional mortality (P_M) for the top 80% of the fish larvae in the source water area for the 7.0 mgd intake flow was 0.06%.
- The greatest projected proportional mortality (P_M) for the caridean shrimp and cancrid crab larvae in the source water area for the 7.0 mgd desalination facility intake flow was 0.02%.
- These low P_M values do not represent a significant source of mortality on these populations considering the natural mortality rates of these species. Therefore, the impacts due to entrainment of the proposed 7.0 mgd seawater intake flow for the 2.5 mgd desalination facility are considered *de minimis*.
- If the absolute numbers of larvae projected to be annually entrained at a 7 mgd rate are compared to fecundity estimates of an individual species such as white croaker, it is evident that the potential larval losses (3.6 million white croaker larvae) obviously are a very small fraction of the reproductive output of the source populations, and are comparable to the total lifetime fecundity of a single female fish.

In summary, none of the populations of fishes or target shrimps and crabs analyzed with the proportional entrainment (*ETM*) modeling would be significantly affected by entrainment from the proposed desalination intake. Therefore, the potential for damage due to entrainment on the biological value of the source water body is very low.

1.0 Introduction

1.1 Background and Overview

This report presents an assessment of potential impacts to marine life from water withdrawals associated with a proposed open ocean intake for a 7 mgd (2.5 mgd freshwater capacity) reverse osmosis (SWRO) plant for the City of Santa Cruz Water Department (City) and the Soquel Creek Water District (District) (collectively **scwd²**). Also discussed in the report are the results of four additional investigations conducted during the course of this study—a screen efficiency study using screened and unscreened intakes, an underwater videographic study to assess larval impingement on the wedgewire intake screen, a dye test study to examine the hydrodynamics near the wedgewire screen during pumping, and a corrosion/biofouling study of screening materials.

Saline water for a full-scale desalination facility could be supplied from either an offshore screened open-water intake or a seabed infiltration intake facility that would withdraw saline water from the shallow sediments along the coastline. A conceptual level study of potential subsurface and screened open-water intake approaches for the **scwd²** Seawater Desalination Project was conducted as part of the work for the City's Integrated Water Plan (IWP). Results of this study indicated that the Santa Cruz coastline does not have favorable geology or geometry to support subsurface wells to provide sufficient feed water for a seawater desalination facility as planned (Hopkins 2001). As a result, the IWP Program Environmental Impact Report (EIR) described a screened open water intake approach for the project. However, because subsurface wells could provide a benefit in minimizing entrainment of marine organisms and provide a level of particulate pretreatment, **scwd²** is continuing to investigate subsurface wells in parallel with a screened open water intake approach.

When water is withdrawn from a source water body for industrial or municipal purposes, organisms within the water body may be entrained or impinged. Water intake systems can affect source water populations by uncompensated removal of larvae that are entrained in water flows and removal of larger life stages that are impinged on the intake screens.

1.2 Regulatory Setting

This study was undertaken in consideration of State Water Code Section 13142.5(d), which states that, "independent baseline studies of the existing marine system should be conducted in the area that could be affected by a new or expanded industrial facility using seawater, in advance of the carrying out of the development." The **scwd²** feedwater withdrawal is not subject to regulation under the Federal Clean Water Act (CWA) Section 316(b) because it does not include a cooling water intake structure (CWIS). However, Regional Water Quality Control Board members and staff recommend that 316(b)-type studies be conducted for open water intakes. Section 316(b) requires that the design and operation of CWISs minimize adverse environmental effects due to impingement and entrainment of aquatic life. Impingement of larger organisms occurs when they are trapped against the screening systems commonly used at CWIS entrances and entrainment occurs when organisms pass through any screening system into a CWIS. This study addressed the potential of entrainment and examined effects of larval impingement since the intake system will be designed to reduce intake velocities to levels that should eliminate any concerns regarding impingement of larger organisms. The entrainment study was conducted using sampling and analysis methods consistent with Section 316(b) studies done throughout California over the past several years.

1.3 Study Objectives

The **scwd²** study plan was based on a survey of available background literature, results of intake system studies at power plants, and results of demonstration studies at other desalination facilities in California. A Technical Working Group (TWG) was formed to review and approve the study plan before sampling began and to provide review throughout the study. The TWG was comprised of representatives of the Coastal Commission, Monterey Bay National Marine Sanctuary, Moss Landing Marine Laboratories, U.C. Santa Cruz, Regional Water Quality Control Board, California Department of Fish and Game, National Marine Fisheries Service, U.S. Fish and Wildlife Service, City of Santa Cruz Water Department, Soquel Creek Water District, Kennedy/Jenks, and Tenera Environmental. A draft study plan was submitted in January 2009, comments were received and addressed, and the final study plan was submitted in April 2009.

The overall approach of the study was to collect data on the concentrations of fish eggs, fish larvae, and target shrimp and crab larvae in the source water at the proposed intake by using towed plankton nets, the standard sampling method for these organisms. The nets were equipped with calibrated flowmeters that measured the volume of water sampled. The number of organisms collected and the volume of seawater sampled were used to calculate sample concentrations for each taxon [a distinct taxonomic category] of fish eggs, fish larvae, and target shrimp and crab larvae. Similar data were also collected from a pilot project pump and screening system tested on a platform near the end of the Santa Cruz Municipal Wharf. One pump was set up on the platform to collect screened and unscreened samples. Screening efficiency was evaluated by comparing larval concentrations from the two intakes.

Entrainment effects at power plant and desalination pilot facility intakes in California have been assessed using the Empirical Transport Model (*ETM*), as recommended and approved by the California Energy Commission (CEC), California Coastal Commission (CCC), Regional Water Quality Control Boards and other regulatory and resources agencies (Steinbeck et al. 2007). This model estimates the proportional loss to the standing stock of larvae in the source water due to entrainment using an estimate of mortality calculated as the ratio of the number of larvae entrained to the number estimated in the source water. The source water is defined as the area or volume of water that could be subject to entrainment. Source water volumes, intake volumes, larval concentrations, and larval durations are the variables used in the *ETM* calculations, which are done for each taxon due to differences in distribution, larval biology, and seasonality of spawning.

The two data sets—source water larval fish and target shrimp and crab concentrations, and the concentrations of these organisms entrained through an unscreened intake and through the test-scale intake screen—are used to evaluate potential entrainment impacts from the proposed project. The results from the testing of the efficiency of the pilot-scale screened intake are used to adjust the annual unscreened entrainment estimates to estimate the potential reduction of entrainment impacts using the wedgewire screened intake.

1.3.1 Target Organisms Selected for Study

The USEPA in its original Section 316(b) guidance lists several criteria for selecting appropriate target organisms for assessment including the following:

1. representative, in terms of their biological requirements, of a balanced, indigenous community of fish, shellfish, and wildlife;
2. commercially or recreationally valuable (e.g., among the top ten species landed—by dollar value);
3. threatened or endangered;
4. critical to the structure and function of the ecological system (i.e., habitat formers);
5. potentially capable of becoming localized nuisance species;
6. necessary, in the food chain, for the well-being of species determined in 1–4; and
7. meeting criteria 1–6 with potential susceptibility to entrapment/impingement and/or entrainment.

In addition to these USEPA criteria, there are certain practical considerations that limit the selection of target organisms such as the following:

1. identifiable to the species level;
2. collected in sufficient abundance to allow for impact assessment (i.e., allowing the model(s) constraints to be met and confidence intervals to be calculated); and
3. having local adult and larval populations (i.e., source not sink species). For example, certain species that may be relatively abundant as entrained larvae may actually occur offshore or in deep water as adults.

The target taxa include the fish eggs and larval fishes that were found to be most abundant in the entrainment samples, the megalopal (final) larval stages of all species of cancrid crabs (which includes the edible species of rock crabs), and the later larval stages of caridean shrimps.

1.4 Report Organization

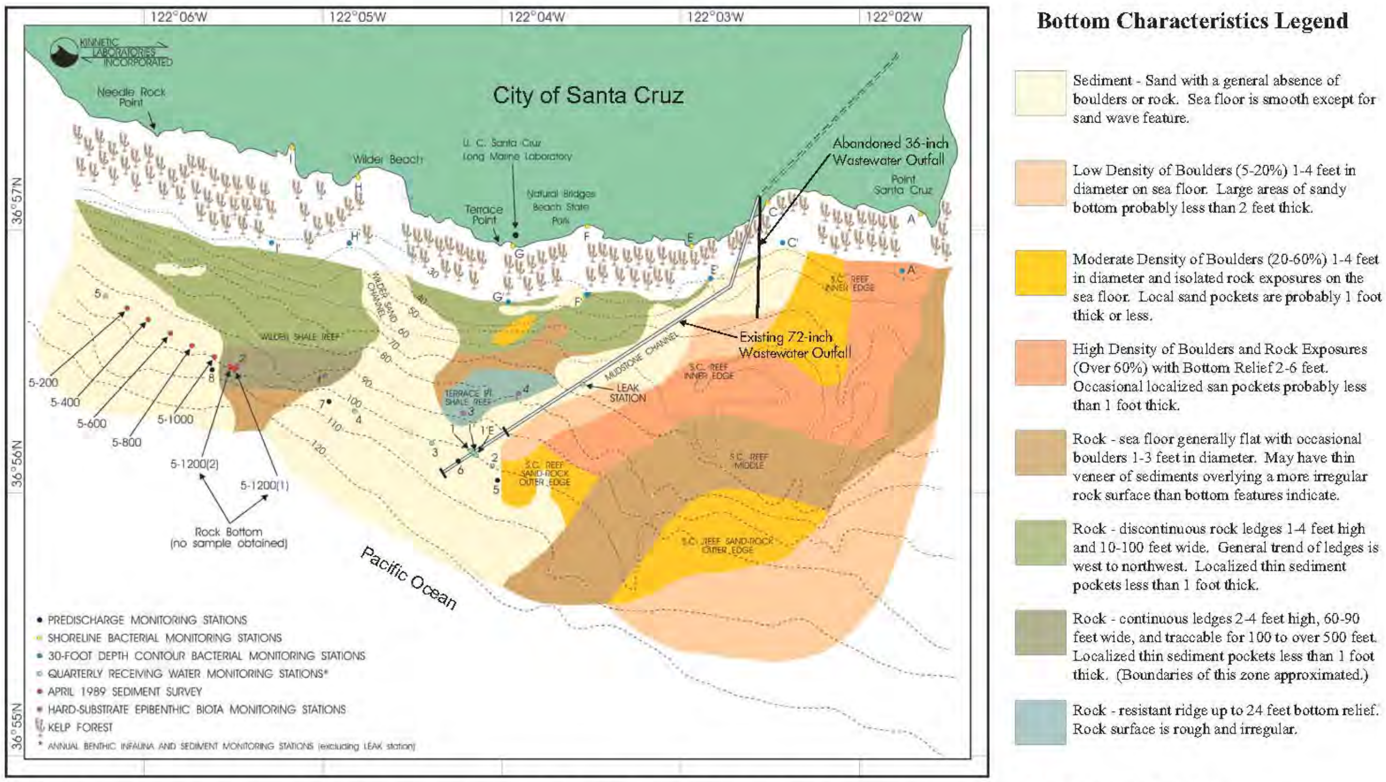
Section 2.0 provides a description of the proposed desalination project and the environmental setting. Section 3.0 presents the results of the source water and intake study and the modeling results for the most abundant fishes and target shrimps and crabs collected during the surveys. The results of the screen efficiency study, the underwater videographic study, the dye test study, and the corrosion/biofouling study of screening materials are provided in Section 4.0. A discussion of impacts is provided in Section 5.0, and the literature cited in the report is listed in Section 6.0. Appendix A provides the impact assessment modeling formulation, Appendix B provides ocean surface current information, Appendix C presents the **scwd^2** desalination project intake and source water data by survey, and Appendix D provides the data collected during the screened and unscreened pump sampling.

2.0 Description of the Proposed Project and Environmental Setting

The City of Santa Cruz and the Soquel Creek Water District have implemented water conservation measures, evaluated recycled water, and have partnered to implement the **scwd^2** Seawater Desalination Program with the goal of improving water supply reliability to better serve the residential and business customers of both agencies. The **scwd^2** Seawater Desalination Program would initially provide 2.5 million gallons per day (MGD) of local, reliable, drought-proof water to help the District reduce over-pumping of the Purisima Aquifer during non-drought years and to help the City meet its water needs during drought. Section 2.1 describes the proposed s**cwd^2** desalination project and a description of the environmental setting of Monterey Bay is provided in Section 2.2.

2.1 Description of the Project

The City of Santa Cruz Wastewater Treatment Plant has an abandoned 0.9-m (36-in.) wastewater outfall pipe that extends approximately 0.6 km (2,000 ft) offshore between Terrace Point and Point Santa Cruz. This wastewater outfall pipe has been proposed as the intake pipeline for the desalination plant. The open intake approach would make use of this existing infrastructure by installing a new pipe within the existing outfall pipe and placing cylindrical wedgewire screens near the terminus. The abandoned outfall pipe terminates near the inner edge of Santa Cruz Reef in approximately 12 m (40 ft) of water (**Figure 2.1-1**). Brine from a full-scale SWRO would be combined with the existing effluent stream from the City of Santa Cruz Waste Water Treatment Facility through their approximately 3.2-km (2-mi), 1.8-m (72-in.) diameter outfall structure. **Figure 2.1-1** shows the location of the existing and abandoned City of Santa Cruz wastewater outfalls and the surrounding sea bottom characteristics.



NOTE: Location of Santa Cruz predischarge monitoring stations (5, 6, 7, and 8), out fall shoreline bacterial monitoring stations (A, C, E, F, G, H, and I), 30-foot depth contour bacterial monitoring (A', C', E', F', G', H', and I'), quarterly receiving water monitoring stations (1, 2, 3, 4, 5, and LEAK), benthic infauna and sediment stations locations (1, 2, 3, 4, and 5), April 1989 sediment survey (Stations 5-200 through 5-1200(2)), and hard-substrate epibenthic biota monitoring stations (Wilder Reef: *1* and *2*; and Terrace Point Reef: *3* and *4*).

Source: Kinematic Laboratories Inc. 2003

N 0 500 1000 2000 METERS
Depth Contours in Feet

Figure 2.1-1. Location of the existing and abandoned City of Santa Cruz wastewater outfalls and surrounding sea bottom characteristics. *Source: Kinnetic Laboratories, Inc. 2003 in EDAW. 2005. City of Santa Cruz Water Department Integrated Water Plan. Environmental Impact Report.*

2.2 Environmental Setting

Descriptions of Monterey Bay's physical and biological characteristics are provided in sections 2.2.1 and 2.2.2, respectively.

2.2.1 Physical Description

2.2.1.1 Geographic Setting

The Santa Cruz and Gabilan mountain ranges dominate the land topography in the region near Santa Cruz, California. Two major rivers (San Lorenzo and Pajaro rivers) and a major creek (Scott Creek) enter Monterey Bay from these highlands through well-defined valleys. Elkhorn Slough, located at the midpoint of the Bay's shoreline, extends inland from Moss Landing for more than 10 km (6 mi) and is formed by tidal channels and salt marshes. The broad, extensive Salinas Valley and the northern Santa Lucia Range are the dominant topographic features in the southern half of the Monterey Bay region; the Salinas River is the major drainage system and enters the Bay south of Elkhorn Slough.

Monterey Bay is located 150 km (93 mi) south of San Francisco in central California. Santa Cruz lies at the northernmost part of Monterey Bay (**Figure 2.2-1**). Monterey Bay is a long westward opening embayment that extends 36 km (22 mi) from Point Santa Cruz southeast to Point Pinos at Monterey. Point Santa Cruz is located approximately 1.3 km (0.8 mi) east of the proposed offshore desalination intake. The defining feature of Monterey Bay is the Monterey Submarine Canyon (MSC) (**Figure 2.2-2**) that divides a broad expanse of soft sediments originating from the San Lorenzo, Pajaro and Salinas rivers. Rocky outcrops are found mostly at the northern and southern portions of the Bay, but also along the MSC margins.

2.2.1.2 Physical Features

The physical features of the Monterey Bay offshore area are summarized at http://montereybay.noaa.gov. The central segment of the Monterey Bay National Marine Sanctuary (MBNMS) extends from the Point Año Nuevo area to south of Point Sur (**Figure 2.2-1**). It contains a geologically diverse seafloor with dramatic features such as the Ascension-Monterey Canyon system, which has extensively dissected the continental shelf and slope in the Monterey Bay area, and the many heads of Sur Canyon, which have cut the continental slope just south of Point Sur. Depths exceeding 1,000 m (3,281 ft) occur near the mouth of the Monterey Bay as the canyon cuts through the continental shelf and extends offshore to depths exceeding 3,000 m (9,843 ft) (**Figure 2.2-2**). South of Santa Cruz, the prominent east-west canyon is accompanied north and south by numerous smaller canyons, with a ridge located to the north of the canyon. In addition to the extensive erosional dissection, active faulting is evident with large gashes across the seafloor resulting from tectonic movement along offshore faults.

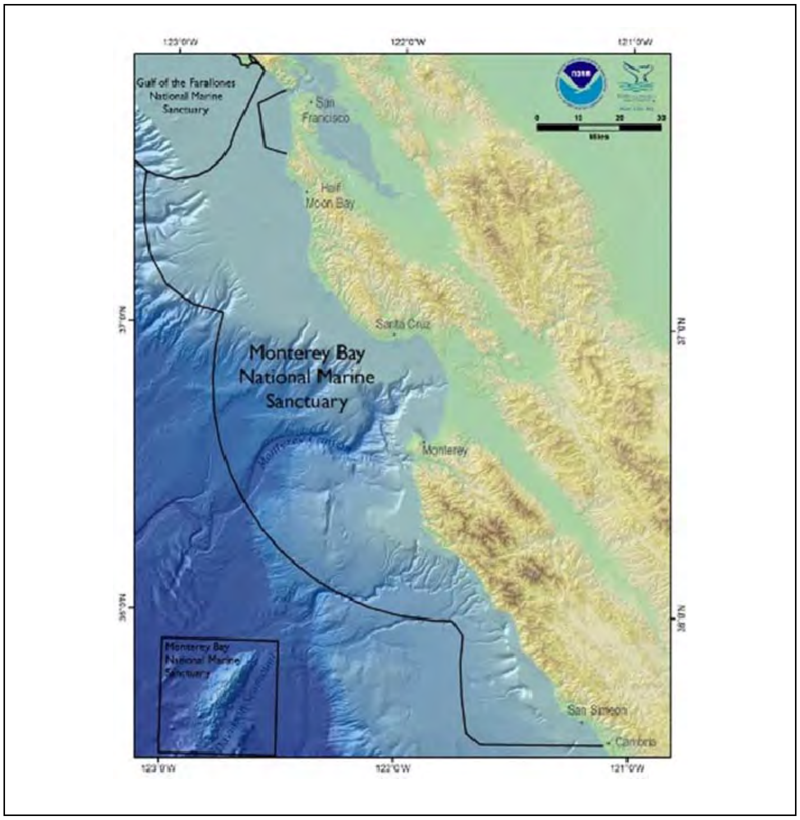


Figure 2.2-1. Seafloor physiography from NOAA Seabeam bathymetric data showing outline of Monterey Bay National Marine Sanctuary. (Source: http://montereybay.noaa.gov).

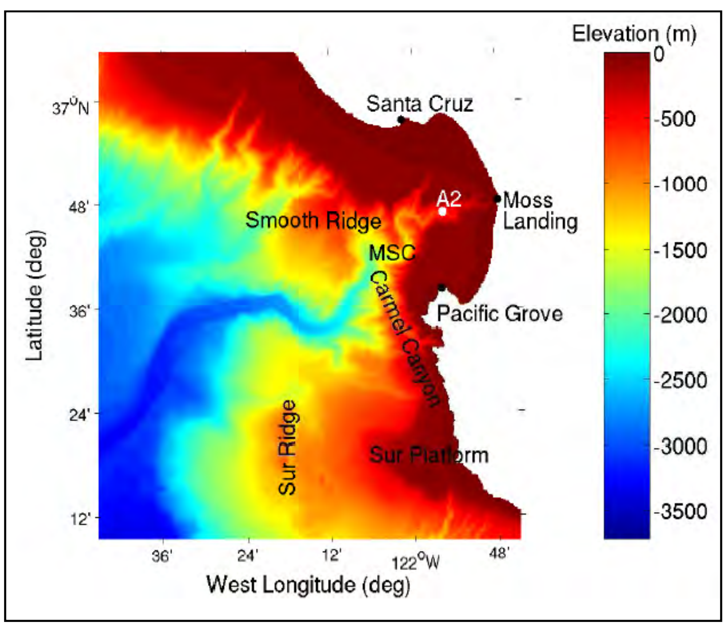


Figure 2.2-2. Bathymetry of Monterey Bay and surrounding area. (Source: Jachec 2007).

Coastal erosion is a continuous process but the rate of erosion is accelerated during times of severe storm activity. Manmade structures such as breakwaters and groins can protect some coastal segments from erosion but increase it in others, depending on current patterns and wave activity. Eroded sediments are eventually transported along the coast to canyon heads where they move downslope and are lost from the shelf sedimentary system. Material transport can be seen as coarse sand bands on the continental shelf (Chin et al. 1988). Transported material can travel down canyons as turbidity currents, especially during earthquakes. These sediments are deposited as overbank features and sand waves at the base of the continental slope.

Rivers and streams entering Monterey Bay also carry considerable quantities of eroded sediments to the sea and these eventually settle on the MBNMS seafloor. In addition to natural eroded detritus, anthropogenic material and waste products are transported through these drainages, and often end up concentrating along the MBNMS coast and the nearshore seafloor.

The nearshore area near the proposed offshore desalination intake is formed by rocky headlands and coastal terraces extending in an east-west direction (**Figure 2.2-3**). Subtidal rock ridges trending in a north-south direction are interspersed with sand channels and are subjected to significant wave action, especially during winter swell episodes originating in the northeastern Pacific. In a study of the area by Hardy (1972), the substrate consisted of low relief mudstone pavement that was smooth with rounded hummocks to a maximum height of 15 cm (6 in.). Higher relief occurred immediately west of the site with boulders to 76 cm (30 in.) high, and sandy-mud overlaid the mudstone in places with a layer 2–15 cm (1–6 in.) deep.

2.2.1.3 Temperature and Salinity

In Monterey Bay, salinity is typically highest and temperature lowest in the spring and the reverse in fall. Pennington and Chavez (2000) examined the time series of temperature, salinity, nitrate, primary production and chlorophyll over 1989–1996 at Station H3/M1 in central Monterey Bay. The general conclusions were that surface water (0-5 m) was coldest and saltiest in spring (~ 10-11°C [50-52°F]; 33.4-33.8 ppt), warmed during summer (~ 14°C [57°F]), remained warm but freshened in fall (S = 33.3-33.4 ppt), and cooled and freshened further in winter (~ 13°C [55°F]; 32.9-33.3 ppt). Nitrate time series showed high concentrations (10-20 μM) present at the surface during spring and summer with low concentrations (< 1 μM) occurring sporadically during fall and winter. The 1989–1996 time series is warmer and fresher than earlier time series to at least 100 m (328 ft), particularly during non-upwelling seasons, and shows a later onset of upwelling. These differences are indicative of changes associated with a 'regime shift' documented for the California Current. During the period of the current study, sea temperatures at NOAA Station 46042, located 42 km (26 mi) west of Monterey Bay, ranged from a low of 9.8°C (49.6°F) in April 2009 to a high of 17.3°C (63.1°F) in June 2009 (**Figure 2.2-4**). Sea surface temperatures can vary widely across the Monterey Bay region due to upwelling and wind-driven circulation cells (**Figure 2.2-5**).

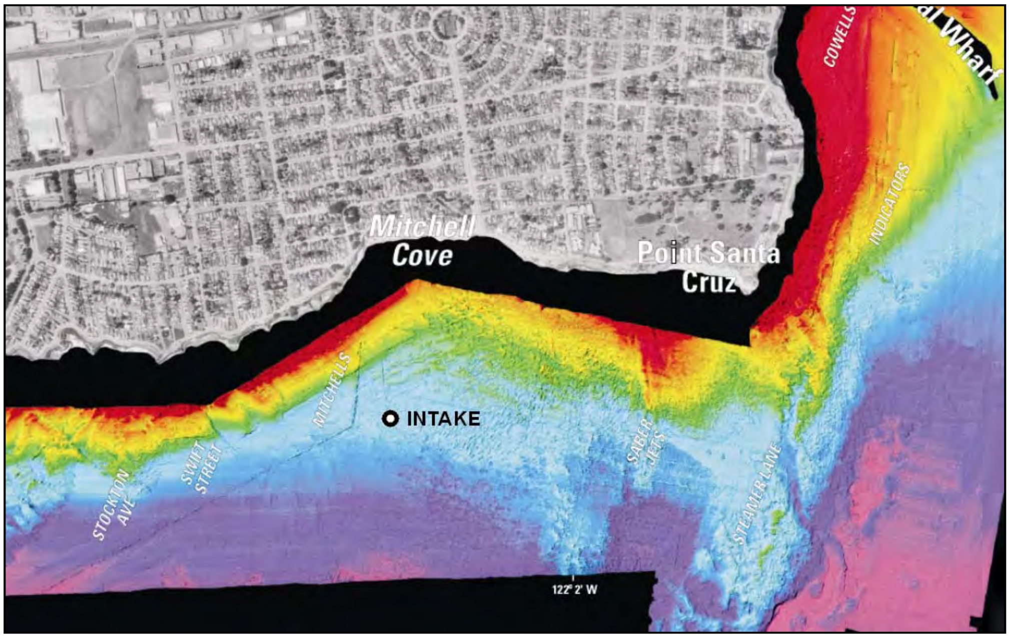


Figure 2.2-3. Bathymetry in vicinity of proposed intake location. Colored depths vary from 2-25 m (7-82 ft) MLLW. (Source: Storlazzi et al. 2008).

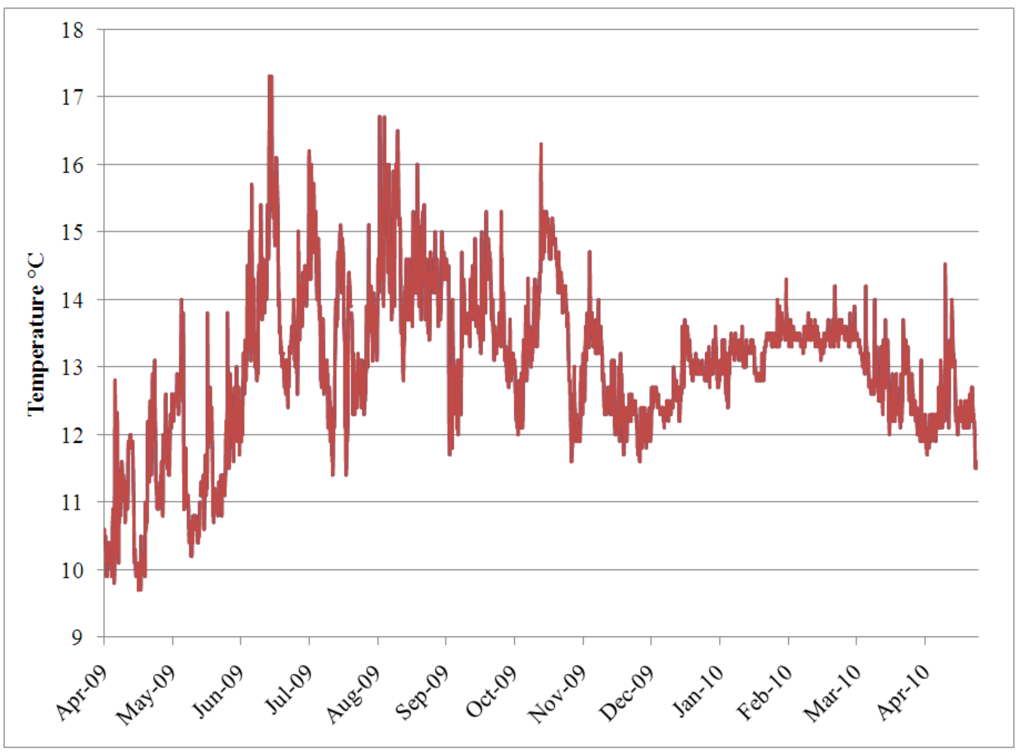


Figure 2.2-4. Hourly surface water temperatures at NOAA Station 46042, 42 km west of Monterey Bay, California from April 2009 through April 2010. (Source: National Data Buoy Center 2010).

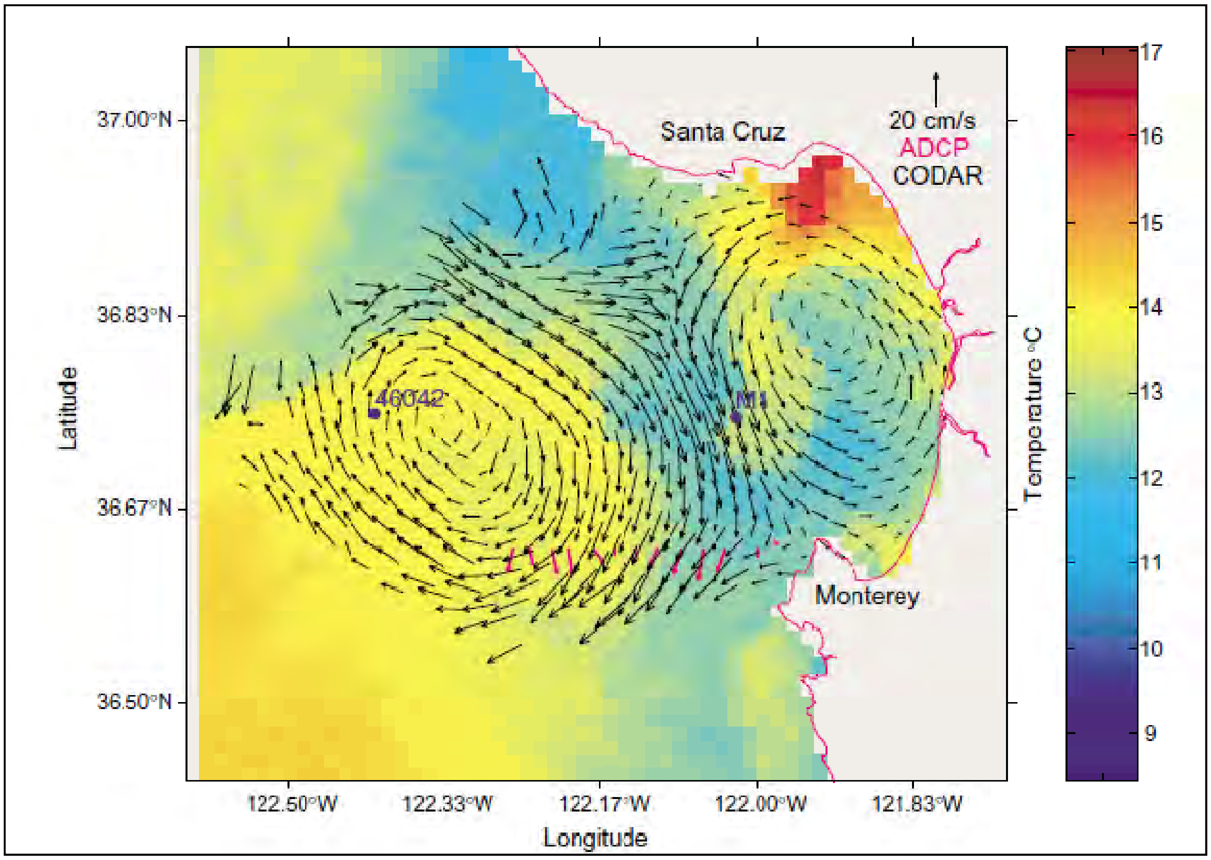


Figure 2.2-5. Surface currents and sea surface temperatures in Monterey Bay during upwelling in August 1994. (Source: Paduan and Rosenfeld 1996). Position of NOAA buoy 46042 is also indicated.

2.2.1.4 Currents

Current regimes in Monterey Bay and offshore areas are summarized at http://montereybay.noaa.gov. The oceanography of the MBNMS is influenced by the California Current, a 1,200-km (745-mi) broad and 300-m (985-ft) deep surface current that transports water of subarctic origin southward along the North American coast at 15 to 30 centimeters per second (cm/s) (5.9 to 11.8 in./sec). Beneath this surface current and within about 100 km (62 mi) of the coast, the California Undercurrent transports waters of subtropical origin northward at about four cm/s. In winter, this current surfaces, where it mixes with California Current waters and is called the Inshore Countercurrent, or Davidson Current. Together, these currents are termed the California Current System, and the sanctuary lies wholly within this system. Thus, the surface and intermediate-depth water masses in the sanctuary are a mixture of subarctic Pacific water with low salinity and cool temperatures together with warmer, saltier Pacific Equatorial water. The pelagic organisms of the sanctuary originate and travel north- or southwards in these different water masses.

Three oceanographic seasons that were originally described for Monterey Bay in the 1940s and are still in common use today: the upwelling period from early spring to late summer (February to July), when surface waters are cool; the oceanic, or California Current, period from late summer to early fall (August to October), characterized by wind relaxation; and the Davidson Current period from late fall to late winter (November to January) characterized by winter storm conditions.

During the spring and summer, upwelling occurs along much of the coast within the sanctuary, but Point Año Nuevo and Point Sur "anchor" areas of especially strong upwelling. These upwelling centers are readily observed in satellite images as cool zones, typically 3 to 5°C (5.4 to 9°F) cooler than waters 100 km (62 mi) offshore. Satellite images often show a tongue of cool water originating at the Año Nuevo center and flowing southwards across the mouth of Monterey Bay. This upwelling plume spins off eddies circulating both offshore and within the Bay.

There are a number of active hydrographic stations near the proposed offshore intake location. The Partnership for Inter-disciplinary Studies of the Coastal Oceans (PISCO) maintains physical monitoring stations[2] that include Acoustic Doppler Current Profiler (ADCP) measurements (stations TPT001 and SHB001) as well as thermistor stations (**Figure 2.2-6**). A recent deployment of a Seafloor Observatory in 9–11 m (30–35 ft) depth 46 m (150 ft) off the end of the Santa Cruz municipal wharf includes a number of sensors to detect near seabed changes. The Observatory is equipped with an underwater Prosilica camera, Sontek ADCP and ADV, a Seabird Microcal CTD, OBS turbidity sensors, a pulse coherent Sontek ADCP, and Imagenex proofing and scanning sonars.

Water circulation near the proposed offshore intake is affected by a combination of open coastal circulation, wave-induced turbulence, and the Monterey Bay Gyre (**Figure 2.2-7**). The prevailing current direction in the shallow, nearshore areas of Santa Cruz is dependent on the circulation pattern within the Bay.

Jenkins and Wasyl (2008) modeled dilution and dispersion at the proposed open ocean intake by numerical simulation of worst-case and long-term scenarios using hydrodynamic measurements from Monterey Bay Aquarium Research Institute (MBARI) ADCPs. The conclusions of Jenkins and Wasyl (2008) concerning the effects of currents on the water quality at the proposed intake and discharge locations include the following:

1) The discharge plumes from floods of the Pajaro and Salinas rivers do not materially influence water quality in the vicinity of the proposed intake, even for a worst-case scenario of combined maximum discharge from the four largest neighboring watersheds. Because storm water is buoyant, it must be mixed downward into the water column by the action of wind and currents before it can be entrained by the intake suction. In the

[2] http://www.piscoweb.org/data/catalog/phys_ocean

process, the storm water will be diluted more than the values represented by the worst case scenarios on the sea surface; and

2) Co-registration of the modeled solutions with detailed bathymetry charts of the Santa Cruz area show no impingement of the combined brine/wastewater plume on shore facilities, tide pools, or sensitive hard-bottom near shore habitat. The high energy, well-ventilated coastal waters off Santa Cruz are well suited for brine disposal, especially in combination with a wastewater outfall fitted with a high performance diffuser.

Storlazzi et al. (2003) provide a good description of how spring-summer upwelling-relaxation and winter storms affect mixing in the Monterey Bay area. ADCP stations near the proposed desalination intake (Station SHB) and at the south part of Monterey Bay (Station HMS) were coordinated with thermistor chains in conjunction with SST imagery and CODAR surface currents. Main findings were:

1) Subsurface current velocities at both SHB and HMS sites were parallel to shore and out of the Bay (to the northwest), roughly opposite of the wind driven surface flow.

2) Current and temperature records are dominated by semi-diurnal and diurnal internal tidal signals that lag the surface tides by roughly three hours on average. These flows over the course of an internal tidal cycle are very asymmetric, with the flow during the flooding internal tide to the southeast typically lasting only one-third as long as the flow during the ebbing internal tide to the northwest.

3) The transitions of the internal tide from ebb to flood cycle are very rapid and bore-like in nature; they are also typically marked by rapid increases in temperature and high shear.

4) During the spring and summer when thermal stratification was high, almost 2,000 high frequency internal waves, in packets of 8–10, were observed and typically followed the heads of these bore-like features.

Drake et al. (2005) remarked how the annual cycle of inner shelf currents near the Monterey Bay's northern shore was markedly different from prior long-term observations on the northern California shelf. Currents were approximately out of phase with the annual wind signal, with currents flowing northwestward during both spring and fall, in direct opposition to the southeastward wind stress.

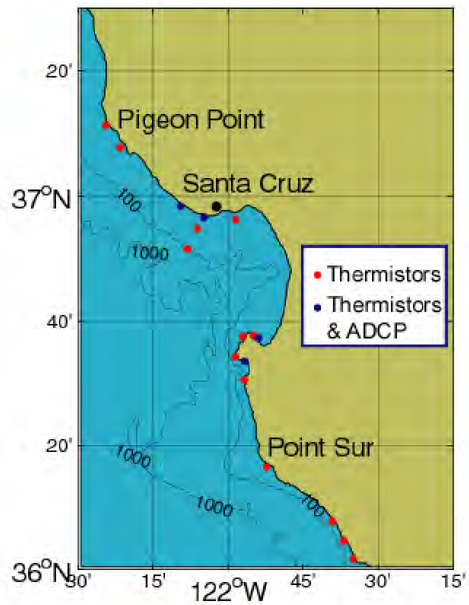


Figure 2.2-6. PISCO thermistor and ADCP stations in Monterey vicinity. (Adapted from PISCO 2008a).

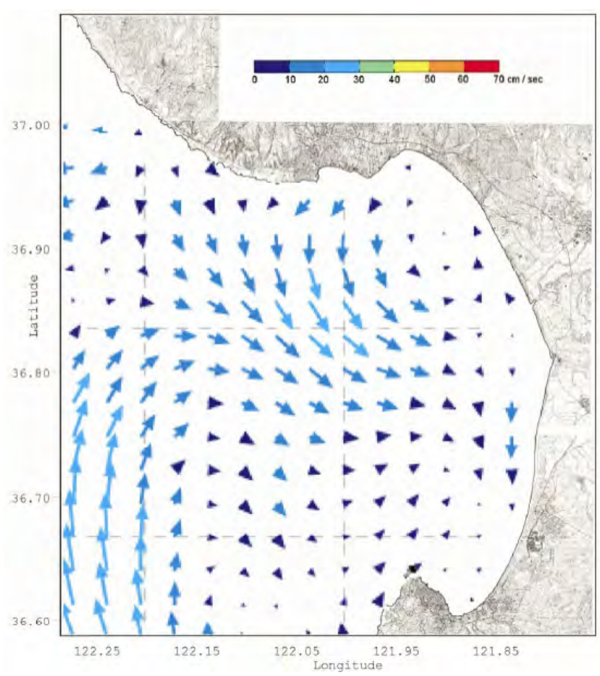


Figure 2.2-7. Simulation of Monterey Bay Gyre at 100 arc-second grid resolution (Source: Jenkins and Wasyl 2008).

2.2.1.5 Tides

Monterey Bay and the central California coast have mixed semi-diurnal tides. Tides at Santa Cruz, in the northern part of Monterey Bay, as predicted by NOAA using a reference station at Monterey are shown in **Figure 2.2-8** for the 2009–2010 study period. The corrections applied are for times: high (-0 hr 6 min), low (-0 hr 11 min), and for heights: high (0.97 ft Mean Lower Low Water [MLLW]) and low (0.99 ft MLLW). At Santa Cruz, the average range of tides is 3.50 ft, mean higher high water (MHHW) is 5.30 ft and the mean tide level is 2.80 ft referenced to MLLW.

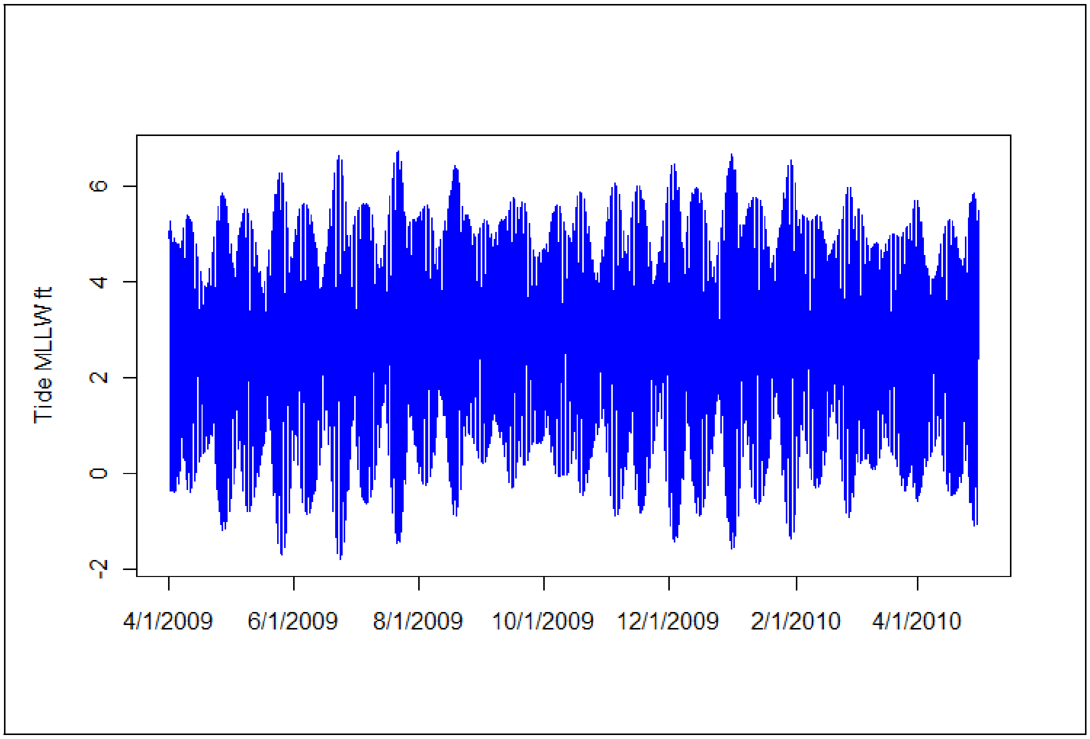


Figure 2.2-8. Tides at Santa Cruz, Monterey Bay, from April 2009 through April 2010 (Source: Nobeltec® Tides and Currents software).

2.2.2 Biological Communities

Monterey Bay is a biologically diverse marine system that encompasses several major habitat types within its boundaries. The following brief description of biological communities and resources within the Bay focuses on the northern segment of the Bay within which the proposed offshore intake is located. Although features such as the Monterey Submarine Canyon and other deep-water habitats are important within the Bay system, the shallower nearshore areas have a direct link to the productivity and larval abundances that are potentially affected by entrainment through an open ocean intake system.

Most marine organisms within the Bay have temperate-water affinities with geographic ranges extending far beyond the immediate area. The fishes are classified as part of the Oregonian faunistic province (Horn and Allen 1978), which ranges from southern Canada to Point Conception. However, during warm-water years some species with primarily southern affinities may be transported by northward-flowing ocean currents and become established within the Bay. As noted in the physical description of the Bay, the northern Bay, in which the proposed offshore intake is located, is protected from the prevailing northwesterly winds while the south and central Bay are directly exposed. The northern Bay has been found to be consistently warmer and has lower nutrient concentrations in comparison with the central and southern sections of the Bay. An excellent overview of the habitats along the greater coastline area of the Monterey Bay National Marine Sanctuary can be found at http://montereybay.noaa.gov/sitechar/main.html.

The pelagic habitat of Monterey Bay includes the entire water column within the Bay. Organisms found in this habitat include a myriad of planktonic organisms (phytoplankton, zooplankton, and ichthyoplankton that have little or no swimming ability to resist ocean currents), and nektonic organisms, such as bony fishes and sharks that can be highly mobile in local and oceanic currents. Meroplankton includes the larval stages of fishes and invertebrates that are only planktonic during their larval period, while holoplankton includes organisms that are planktonic for their entire life cycle. The productivity of the pelagic habitat varies seasonally due to upwelling, day length, and short-term fluctuations in ocean currents, while long-term cycles such as El Nino events and decadal climate shifts can broadly affect productivity in the Bay. The pelagic habitat also supports large numbers of pinnipeds (including Pacific harbor seal and California sea lion), cetaceans (such as gray whale, bottlenose dolphin, and common dolphin), and birds, including California brown pelican, terns, and gulls.

Intertidal habitat within the Monterey Bay is divided between rocky habitats at the southern and northern margins of the Bay, with mostly sand substrates in between—Moss Landing is located at the center. The semi-diurnal tidal cycle exposes intertidal invertebrates and algae to large fluctuations in temperature, desiccation, and wave action twice per day. A substantial fraction of the several hundred marine species found on the rocky shore or along sand beaches are found only intertidally, although they may be represented in nearshore waters by their planktonic larvae that disperse in the waves and currents. Although natural rock outcrops form the majority of rocky intertidal habitat in the Santa Cruz vicinity, man-made harbor jetties and breakwaters contribute a small portion.

Kelp forests are a prominent habitat feature of the Monterey Bay and extend throughout most of the nearshore waters where there is rocky substrate shallower than approximately 25 m (82 ft) depths, depending on water clarity. Surface canopies are mainly comprised of the giant kelp (*Macrocystis pyrifera*), and the bull kelp (*Nereocystis luetkeana*). Bull kelp tolerates high wave action and is more common along exposed rocky shores, whereas giant kelp is abundant in all rocky areas except the most exposed, shallow sites. Spectrographic aerial imaging of kelp canopies along the Santa Cruz coastline shows that most of the surface canopy occurs in areas shallower than depths of 10 m (33 ft) (**Figure 2.2-9**). The absence of surface canopies in a shallow zone that would otherwise support kelp may indicate the presence of sand substrate where kelp plants cannot attach to the bottom.

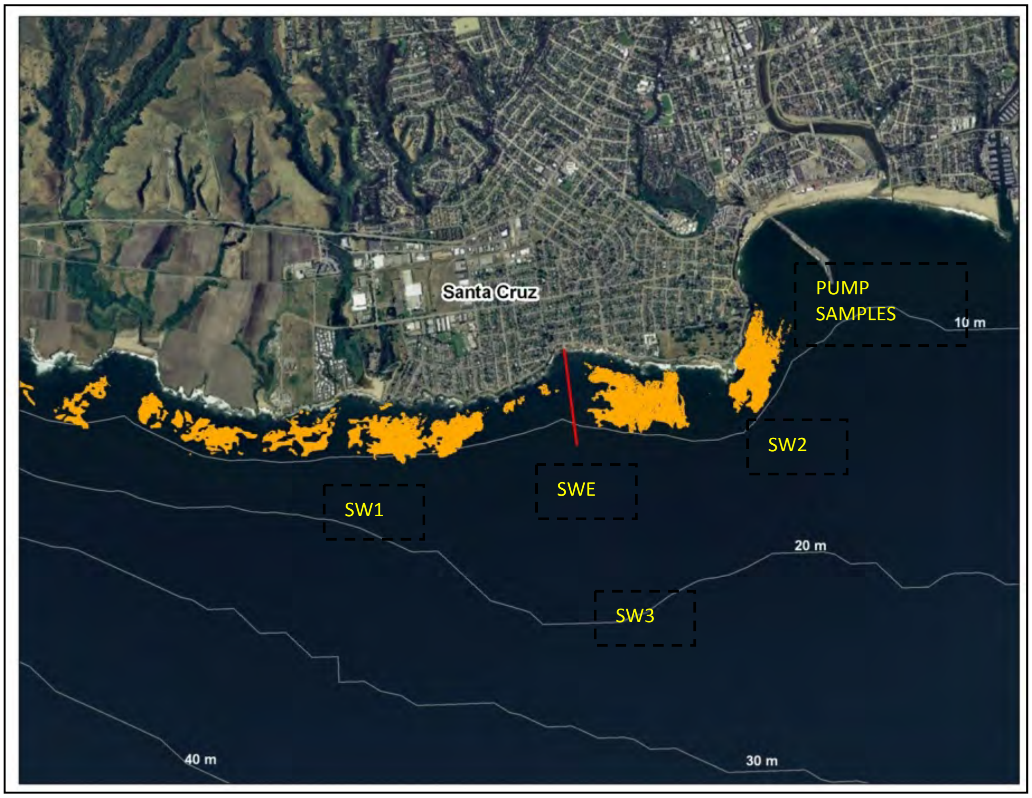


Figure 2.2-9. Distribution of kelp canopies along Santa Cruz shoreline in 2006. (Source: http://www.dfg.ca.gov/marine /gis/naturalresource.asp).

Fish species observed in the kelp forest habitat at Terrace Point, 2.3 km (1.4 mi) west of the proposed offshore intake, included ten species of surfperches and eleven rockfish taxa (**Table 2.2-1**). Of the 34 taxa enumerated at the site, 68% produce pelagic larvae potentially at risk of entrainment. Diversity of larval fishes in the water column of a kelp forest can be substantially higher than the local adult fish populations due to larval transport by ocean currents. For example, over 200 taxa of larval fishes were recorded along a reach of rocky shoreline in central California near Diablo Canyon (Tenera 2000a) that included rockfishes, sculpins, anchovies, and gobies as some of the most abundant taxa in the nearshore waters (**Table 2.2-2**). Several species with adult populations that are characteristic of deeper midwater habitats, such as lampfishes and blacksmelts, also occurred as larvae in shallow water habitats.

A high proportion of soft-bottom benthos live permanently in the sediments either beneath ('infauna') or on the surface ('epifauna') of the seafloor. The soft-bottom habitat also supports several species of algae, macrofauna (including crabs, snails, sea stars, urchins, and sea cucumbers), and fishes. A biological survey of the area was conducted by Hardy (1972) when the pipeline functioned as the wastewater outfall for the City of Santa Cruz. Sampling was done from the surface using a 1/20 m^2 ponar grab, and by direct observations on the bottom by biologist-divers. The habitat types encountered during this survey, although rocky, were not suitable for extensive development of sessile organisms due to the lack of high relief in the station areas. The observed sand intrusion over the mudstone substrate limited settling of larval organisms and drastically reduced the sessile communities. Only four genera of algae were observed and these were small individuals found growing on polychaete worm tubes. Most of the animals recorded during the survey were sand-associated species taken in sediment samples from the muddy sand overlying the mudstone. The most obvious macroinvertebrates observed at these stations were anemones, polychaete tube worms, hermit crabs, and sea stars. Station SC-3 (150 m [492 ft] east of the discharge) in Hardy's (1972) study had the only rock substrate that appeared relatively free from sand intrusion and this was reflected in some of the sessile species encountered. Mollusks, arthropods and polychaetes made up 65 to 88% of the animal species diversity recorded for each of the stations. Over 100 taxa, not including fishes, were recorded from the immediate vicinity of the discharge (**Table 2.2-3**).

Table 2.2-1. Fish species recorded in kelp forest transects off Terrace Point, Santa Cruz County, 2000-2006 (PISCO 2008b).

Scientific Name	Common Name	Pelagic Larvae
Atherinopsis californiensis	jacksmelt	•
Aulorhynchus flavidus	tubesnout	•
Brachyistius frenatus	kelp surfperch	
Citharichthys stigmaeus	speckled sanddab	•
Cymatogaster aggregata	shiner surfperch	
Embiotoca jacksoni	black surfperch	
Embiotoca lateralis	striped surfperch	
Hexagrammos decagrammus	kelp greenling	•
Hexagrammos lagocephalus	rock greenling	•
Hyperprosopon ellipticum	silver surfperch	
Hypsurus caryi	rainbow surfperch	
Lepidogobius lepidus	bay goby	•
Ophiodon elongatus	lingcod	•
Oxyjulis californica	senorita	•
Oxylebius pictus	painted greenling	•
Paralichthys californicus	California halibut	•
Phanerodon furcatus	white surfperch	
Rhacochilus toxotes	rubberlip surfperch	
Rhacochilus vacca	pile perch	
Rhinogobiops nicholsi	blackeye goby	•
Sebastes atrovirens	kelp rockfish	•
Sebastes atrovirens/ S. carnatus/ S. chrysomelas (yoy)	kelp/gopher/black-and-yellow rockfish	•
Sebastes caurinus	copper rockfish	•
Sebastes chrysomelas	black-and-yellow rockfish	•
Sebastes melanops	black rockfish	•
Sebastes miniatus	vermilion rockfish	•
Sebastes mystinus	blue rockfish	•
Sebastes paucispinis	bocaccio	•
Sebastes pinniger	canary rockfish	•
Sebastes rastrelliger	grass rockfish	•
Sebastes serranoides/S. flavidus/ S. melanops (yoy)	olive/yellowtail/black rockfish	•
Scorpaenichthys marmoratus	cabezon	•
Syngnathus spp.	pipefish	
Zalembius rosaceus	pink surfperch	

Note: yoy is young-of-the-year.

Table 2.2-2. Taxa composition of larval fishes collected nearshore at Diablo Canyon, central California, 1997–1999 (Tenera Environmental 2000a).

Rank	Scientific Name	Common Name	Percent Composition
1	*Sebastes* spp. V_De	rockfishes	16.11%
2	*Engraulis mordax*	northern anchovy	8.36%
3	*Gibbonsia* spp.	clinid kelpfishes	6.90%
4	*Coryphopterus nicholsi*	blackeye goby	6.26%
5	*Cebidichthys violaceus*	monkeyface eel	5.62%
6	*Sardinops sagax*	Pacific sardine	5.14%
7	*Stenobrachius leucopsarus*	northern lampfish	4.46%
8	*Artedius lateralis*	smoothhead sculpin	4.41%
9	*Genyonemus lineatus*	white croaker	4.22%
10	*Sebastes* spp. V	rockfishes	4.00%
11	*Orthonopias triacis*	snubnose sculpin	3.50%
12	Cottidae unid.	sculpins	2.83%
13	Gobiidae unid.	gobies	2.67%
14	Stichaeidae unid.	pricklebacks	2.11%
15	Bathymasteridae unid.	ronquils	2.10%
16	*Scorpaenichthys marmoratus*	cabezon	1.98%
17	*Oligocottus* spp.	sculpins	1.22%
18	*Oxylebius pictus*	painted greenling	1.06%
19	*Liparis* spp.	snailfishes	0.93%
20	*Hypsoblennius* spp.	blennies	0.83%
21	*Oligocottus maculosus*	tidepool sculpin	0.74%
22	larval fish fragment	larval fish fragment	0.73%
23	*Ruscarius creaseri*	roughcheek sculpin	0.67%
24	Chaenopsidae unid.	tube blennies	0.59%
25	*Sebastes* spp. V_D	rockfishes	0.59%
26	*Triphoturus mexicanus*	Mexican lampfish	0.59%
27	*Clinocottus analis*	wooly sculpin	0.58%
28	Pleuronectidae unid.	righteye flounders	0.56%
29	*Bathylagus ochotensis*	popeye blacksmelt	0.52%
30	*Parophrys vetulus*	English sole	0.51%
31	*Sebastes* spp. VD	rockfishes	0.51%
32	*Artedius* spp.	sculpins	0.50%
33	*Sebastes* spp.	rockfishes	0.47%
34	*Paralichthys californicus*	California halibut	0.44%
35	*Lepidogobius lepidus*	bay goby	0.40%
36	*Typhlogobius californiensis*	blind goby	0.39%
37	*Tarletonbeania crenularis*	blue lanternfish	0.31%
38	Pleuronectiformes unid.	flatfishes	0.28%
39	*Neoclinus* spp.	fringeheads	0.27%
40	Osmeridae unid.	smelts	0.26%
41	larval/post-larval fish, unid.	larval/post-larval fish, unid.	0.24%
42	Pholididae unid.	gunnels	0.24%
43	*Brosmophycis marginata*	red brotula	0.23%
44	Sciaenidae unid.	croakers	0.23%
45	*Nannobrachium* spp.	lanternfishes	0.23%
46	*Merluccius productus*	Pacific hake	0.22%
47	*Sebastes* spp. V_D_	rockfishes	0.22%
48	*Leptocottus armatus*	staghorn sculpin	0.20%
49	Hexagrammidae unid.	greenlings	0.19%
50	*Gobiesox* spp.	clingfishes	0.19%
		162 other taxa	3.21%

Table 2.2-3. Taxa composition of major plant and invertebrate groups near the City of Santa Cruz wastewater discharge in 1972 (Hardy 1972).

Classification	Common Name	No. Taxa
Algae	kelps, seaweeds	4
Porifera	sponges	3
Coelenterata	anemones, hydroids, cup corals	13
Nemertea	ribbon worms	1
Polychaeta	segmented worms	31
Sipunculida	peanut worms	1
Arthropoda	crabs, shrimps, amphipods, and allies	19
Mollusca	snails, clams, nudibranchs	25
Echinodermata	sea stars, urchins	6
Ascideacea	sea squirts	1

2.2.3 Fisheries Overview

The marine resources of Monterey Bay have historically supported a variety of sport and commercial fisheries (Starr et al. 1998). Fisheries decline and expand with the cycles of abundance and scarcity of the targeted species. Regulation of fish harvest, entry into a fishery, gear usage, and season length can have a pronounced effect on landings. Long-term over-exploitation of many fish stocks along the Pacific Coast has decreased the abundance of adult fishes and recently led to more restrictive regulation of harvest levels. Because of the complexity of the forces driving fish harvest in the Monterey Bay area, generalizations about fish abundance based on landings data must be made carefully.

Fishes and invertebrates are harvested from the Monterey area using a variety of fishing methods. Historically, a majority of the fishes landed in Monterey ports was taken with purse seine and trawl nets. Set gillnets have traditionally been used to harvest California halibut (*Paralichthys californicus*), rockfishes (*Sebastes* spp.), white croaker (*Genyonemus lineatus*), and a variety of sharks. Commercial fishermen use trolling gear to harvest salmon and albacore during the seasons when they are abundant in the area. Hook-and-line gear has traditionally been used to harvest rockfishes and lingcod (*Ophiodon elongatus*) over rocky reefs near the canyon. Set longlines, which are now prohibited in nearshore waters, are used in the Monterey canyon area to take sablefish (*Anoplopoma fimbria*) and grenadier (Family Macrouridae). Fish traps of hook and line are used in the live rockfish fishery. Traps are also used to take rock crabs (Family Cancridae) and Dungeness crab (*Metacarcinus magister*). Purse seining is used to harvest pelagic species such as market squid (*Loligo opalescens*), Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), Pacific mackerel (*Scomber japonicus*) and jack mackerel (*Trachurus symmetricus*). Market squid has consistently been one of the top two species by tonnage landed in the Monterey area.

Historically, nearshore rocky reef and kelp habitats were fished more heavily by recreational than commercial fisheries. Nearshore rocky areas became more important to commercial fisheries in the early 1980s, however, because of increased participation in the open-access hook-and-line fisheries, and later because of the more lucrative live-fish fishery (Starr et al. 2002). Rockfishes are the predominant component of catches in nearshore rocky reef and kelp habitats with about 15 rockfish species commonly caught, including grass rockfish (*Sebastes rastrelliger*), gopher rockfish (*S. carnatus*), brown rockfish (*S. auriculatus*), and china rockfish (*S. nebulosus*). Fishes are taken from the intertidal zone down to depths of 30 m (100 ft) with hook-and line-gear or traps and kept alive in holding tanks. Kelp greenling (*Hexagrammos decagrammus*), cabezon (*Scorpaenichthys marmoratus*), and lingcod are also commonly landed in addition to rockfishes. Annual commercial landings of fishes from shallow rocky habitats averaged about 730,000 lb/yr from 1991–1998, almost twice that of the annual landings in the 1980s. The high catches in nearshore reef and kelp habitats in the 1990s were probably not sustainable, and appeared to have reduced abundance of nearshore fishes in the MBNMS, as evidenced by declining catch rates (Starr et al. 2002).

Commercial landings data from Santa Cruz County from 2005–2009 show that Dungeness crab, Chinook salmon, sablefish, albacore, and California halibut have been the most abundant and lucrative fisheries in recent years (PacFIN 2010) (**Table 2.2-4**). However, the Pacific Fishery Management Council (PFMC) and the National Marine Fisheries Service (NMFS) adopted a complete closure of commercial and sport Chinook salmon fisheries off California for the 2008 and 2009 seasons. The closures were aimed at conserving Sacramento River Fall-run Chinook salmon. These salmon make up the bulk of the salmon caught in the Sacramento River system and off California’s coast. The fishery closure significantly impacted fleets such as those based in Santa Cruz that had historically depended on salmon for a large part of their fishery revenue. A significantly limited commercial season and reduced sport season was re-opened in 2010.

Recreational fisheries based out of Santa Cruz harbor harvested over 55 species of fishes in 2009 based on catch statistics compiled by Pacific States Marine Recreational Fisheries Monitoring surveys (RecFIN 2010). Rockfishes of six species (gopher, brown, black, black and yellow, blue, vermilion, and yellowtail) comprised approximately 61% of all fishes landed (**Table 2.2-5**). These are generally shallow-water species that primarily use areas in proximity to rock reefs and kelp forests as habitat.

Table 2.2-4. Commercial fishery landings (lb) and revenue in Santa Cruz County from 2005–2009. Source: PacFIN 2010.

Species	2005	2006	2007	2008	2009	Average Annual Landings (lb)	Average Annual Revenue ($)
Dungeness crab	238,279	95,699	85,301	70,317	71,407	112,201	$283,866
Chinook salmon	289,792	42,841	81,620	–	–	82,851	$289,900
sablefish	18,331	14,828	12,635	15,594	21,195	16,517	$23,320
albacore	5,875	24,000	16,236	–	18,783	12,979	$18,609
California halibut	14,322	13,456	2,684	6,582	7,371	8,883	$31,811
chub mackerel	–	13,020	5,806	–	–	3,765	$1,155
lingcod	7,543	3,734	2,097	1,775	1,083	3,246	$6,190
miscellaneous fish	5,609	4,442	–	–	–	2,010	$4,738
blackgill rockfish	1,123	1,679	1,319	4,124	1,080	1,865	$2,658
petrale sole	9,190	–	–	–	–	1,838	$2,568
white seabass	–	–	2,843	1,985	4,334	1,832	$6,437
unsp. smelt	3,348	3,913	–	–	–	1,452	$677
unsp. sanddabs	6,132	–	–	–	–	1,226	$928
rock crab	5,036	–	–	–	–	1,007	$676
widow rockfish	–	654	2,340	1,573	–	913	$1,329
vermillion rockfish	1,360	796	876	478	815	865	$1,465
common thresher shark	3,616	111	–	240	–	793	$463
jack mackerel	–	3,564	–	–	–	713	$226
bocaccio		–	663	1,127	930	744	693
chilipepper	–	1,300	853	920	–	615	$990
starry flounder	1,906	844	–	–	–	550	$470
yellowtail rockfish	–	393	–	730	794	383	$673
blue rockfish	258	1,073	–	–	–	266	$786
unsp. flatfish	1,191	–	–	–	–	238	$306
brown rockfish	220	319	257	349	–	229	$792
red rockfish	170	–	524	–	–	139	$296
sand sole	331	146	–	–	–	95	$102
soupfin shark	–	401	–	–	–	80	$93
bank rockfish	–	–	209	–	–	42	$57
black rockfish	–	118	–	89	–	41	$77
unsp. mackerel	–	–	150	–	–	30	$12
splitnose rockfish	–	73	–	–	–	15	$18
	615,637	230,073	218,884	107,694	129,615	258,374	$682,647

Table 2.2-5. Percent composition of recreational fishery landings in Santa Cruz County in 2009 based on port sampling data. Source: RecFIN 2010.

Rank	Species	Number sampled	Percent composition
1	gopher rockfish	1,174	18.97
2	brown rockfish	982	15.86
3	black rockfish	532	8.59
4	black and yellow rockfish	448	7.24
5	jacksmelt	345	5.57
6	blue rockfish	300	4.85
7	lingcod	285	4.60
8	Pacific sanddab	281	4.54
9	Pacific sardine	246	3.97
10	California halibut	202	3.26
11	vermilion rockfish	186	3.00
12	yellowtail rockfish	174	2.81
13	chub (pacific) mackerel	164	2.65
14	albacore	128	2.07
15	white croaker	114	1.84
16	copper rockfish	72	1.16
17	grass rockfish	71	1.15
18	barred surfperch	58	0.94
19	kelp greenling	49	0.79
20	china rockfish	43	0.69
21	cabezon	32	0.52
22	olive rockfish	32	0.52
23	rosy rockfish	32	0.52
24	shiner perch	31	0.50
25	greenspotted rockfish	20	0.32
26	walleye surfperch	18	0.29
27	canary rockfish	16	0.26
28	dungeness crab	16	0.26
29	kelp rockfish	16	0.26
30	striped bass	13	0.21
31	bocaccio	12	0.19
32	silver surfperch	11	0.18
33	black perch	10	0.16
34	widow rockfish	8	0.13
35	calico surfperch	7	0.11
36	starry rockfish	6	0.10
37	striped seaperch	6	0.10
38	northern anchovy	5	0.08
39	sand sole	5	0.08
40	starry flounder	5	0.08
	15 other species	35	0.56
	Total	**6,190**	**100.00**

Studies of larval fishes along the California coast, including Monterey Bay, have been conducted in previous years. The California Cooperative Oceanic Fisheries Investigations (CalCOFI) has conducted a wide variety of physical and biological surveys since 1949 along the Pacific coast from Baja California to the California Oregon border. Their sampling is conducted along parallel transects where samples are presently collected from only a portion of the historically covered area. These investigations were originally designed to study sardine populations but results have generally reported for all fish eggs and larval fishes. Results of these studies have been presented in a large number of scientific reports and publications including the CalCOFI Report Series (Loeb et al. 1983a, 1983b, and 1983c, Moser et al. 1987, 2000, and 2001, Moser and Smith 1993, Moser and Pommeranz 1999). Moser (1996) summarized CalCOFI information on fish eggs and larvae in the California Current. Yoklavich et al. (1996) reported on larval rockfish assemblages off Davenport (just to the north of this study's sampling location) and Daly (1997) discussed differences in abundance and distribution of larval fishes in the same area in his master's thesis. Other studies, including Wold (1991) and Moreno (1990, 1993), have focused mainly on larval rockfish identification in the Monterey Bay area. Additional relevant information from these earlier studies will be presented in the individual taxa summaries in Section 3.0 of this report.

3.0 Offshore Intake and Source Water Study

3.1 Introduction

The purpose of the sampling associated with this part of the study was to determine the extent of potential impacts from entrainment of fishes and selected shrimp and crab larvae (target species) due to the operation of a screened offshore intake. Entrainment refers to the withdrawal of aquatic organisms from the source water into and through a feedwater intake system. Sampling occurred at one station in the vicinity of the proposed intake (Station SWE) and at three source water stations (SW1–SW3). To determine the potential effects of the proposed offshore intake on these stages of the target organisms, data from the 2009–2010 study were analyzed using intake flow volumes of 11,356 m^3 (3 mgd), 26,498 m^3 (7 mgd), and 41,640 m^3 (11 mgd).

3.1.1 Species to be Analyzed

A diverse array of planktonic organisms are susceptible to entrainment. The intent of this study was to estimate entrainment effects on two types of organisms: fish larvae and late-stage invertebrate larvae of cancrid crabs and caridean shrimps. Assessment of potential entrainment effects was limited to the target invertebrate larvae and to the most abundant larval fish taxa collected and those with recreational or commercial importance.

3.2 Methods

3.2.1 Field sampling

Field data on the composition and abundance of potentially entrained larval fishes, fish eggs, and target shrimp and crab larvae were collected monthly to provide baseline characterization of the potentially entrainable organisms at the proposed intake location and in the surrounding source water. Sample collection methods were similar to those developed and used by the California Cooperative Oceanic and Fisheries Investigation (CalCOFI) in their long-term studies of larval fishes in the California Current (Smith and Richardson 1977), and subsequently used in nearshore source water studies at Moss Landing (Tenera 2000b) and at several other coastal locations in California.

Plankton samples were collected at four stations offshore of Santa Cruz. One station was located at the site of the proposed intake (SWE) and the three others were in close proximity (**Figure 3.2-1**). Station SW1 was approximately 1.5 km (0.9 mile) to the west, SW2 was about 1.5 km (0.9 mile) to the east, and SW3 was about 1.0 km (0.6 mile) to the south of Station SWE. The water depth at stations SWE, SW1, and SW2 was approximately 12.8 m (42 ft) MLLW, and SW3 was approximately 18.3 m (60 ft) MLLW. The following water quality measurements were recorded vertically at two-meter intervals at each station once per sampling cycle using a calibrated instrument: temperature, pH, salinity, dissolved oxygen, and turbidity.

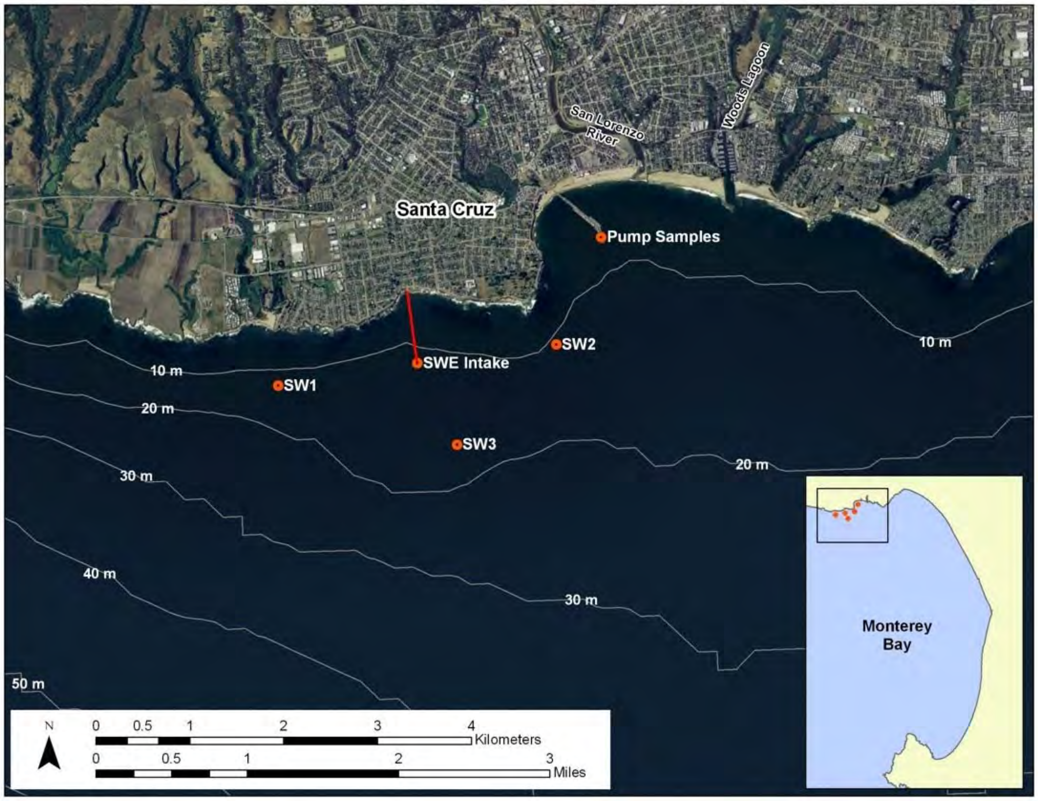


Figure 3.2-1. Location of intake and source water stations for plankton sampling.

Plankton samples were collected at the intake location (SWE) and three source water stations (SW1–SW3) by towing a bongo frame with two 0.71 m (2.3 ft) diameter openings, each equipped with a 335-µm (0.13 in.) mesh plankton net, codend, and flowmeter (**Figure 3.2-2**). The water volume filtered through the nets was measured using a calibrated flowmeter mounted in the center of the opening of each net frame. The nets were lowered from the surface to a depth within approximately 1 m (3.3 ft) from the bottom and towed back to the surface at a speed of 0.5–1.0 m/sec (1.6–3.3 ft/sec). If the target volume of at least 40 m^3 (10,567 gal) per net was not filtered after the first deployment (based on the flowmeter readings), then additional tows were made until the target volume was either reached or exceeded. Prior to and after each tow, the flowmeter counter values were recorded on sequenced waterproof datasheets to allow a calculation of the volume of water filtered by each net. Each sampling event (referred to as a "survey") included samples collected during one daytime and one nighttime cycle to characterize potential diel variation. During each sampling cycle, the bongo frame and nets were deployed twice at Station SWE and once at each of the other three stations.

At the completion of each tow, the frame and nets were retrieved from the water and all of the collected material was rinsed into the end of each net (codend). The contents of each net were kept separate in labeled jars, with one sample preserved in a 5–10% solution of buffered formalin and the other sample preserved in 95% non-denatured ethanol in preparation for potential DNA testing of individual larvae to confirm species identifications. When the volume of filtered material was large, it was divided into several jars that were all labeled as sample fractions. Each sample was given a serial number based on the location, date, and time. The serial number allowed each sample to be tracked through laboratory processing, data analyses, and reporting.

Figure 3.2-2. Bongo frame and plankton nets used to collect fish, shrimp and crab larvae at the proposed intake and in the source water.

Field data were recorded on preprinted data sheets formatted for entry into a computer database for analysis and archiving. All field data recorded on sequenced datasheets were entered into an Access® computer database that was verified for accuracy against the original data sheets.

A Quality Assurance/Quality Control (QA/QC) program was implemented for the field component of the study. The field survey procedures were reviewed with all personnel prior to the start of the study and all field staff were given printed copies of the procedures. In addition to ongoing training and periodic review of sampling procedures, quality control assessments were completed during the study to ensure that the field sampling continued to be conducted properly.

3.2.2 Laboratory Analysis

Samples from the field were returned to the laboratory, and after approximately 72 hours, the samples that had been preserved in formalin were transferred into a solution of 70–80% ethanol. Samples preserved in 95% ethanol had this liquid removed and fresh 95% ethanol was added to the sample jars. Processing consisted of examining the collected material under a dissecting microscope, and removing and counting larval fishes, megalopal stages of cancrid crabs, and later larval stages of caridean shrimps. These target taxa conformed to the taxa enumerated in similar studies completed at other locations in California. Fish eggs were processed from the samples collected through the seventh survey in October 2009. The organisms were placed in labeled vials and then identified to the lowest taxonomic level possible. The developmental stage of fish larvae (yolk-sac, preflexion, flexion, postflexion, transformation) was also recorded.

When samples had large numbers of fish eggs, crab megalops, or shrimp larvae only a portion of the sample was processed for these groups. When high numbers of fish eggs were encountered, a 10% aliquot was removed from the sample and the eggs were removed from that portion. When high numbers of megalops or shrimp larvae were encountered, the sample was split into four equal portions using a plankton splitter and ¼ of the original sample was sorted for these organisms. An estimate of the total number of fish eggs or invertebrate larvae that were in the sample was calculated by multiplying the number observed by the percentage not sorted. No sample splitting or sub-sampling was conducted for fish larvae.

Fish specimens that could not be identified to the species level were identified to the lowest taxonomic classification possible (e.g., genus and species are lower levels of classification than order or family). Crab megalops were generally identified to combination categories because of overlapping size ranges between species, and shrimp larvae were identified to the family level. Myomere and pigmentation patterns were used to identify the larval fishes, however, this can be problematic for some species. For example, several species of the Gobiidae family of fishes share similar characteristics during early life stages, making identification to the species level uncertain (Moser 1996). Standard genetic testing was used to determine the most likely species identity of morphometrically similar larval rockfishes collected in the first few surveys that could not otherwise be classified visually.

DNA testing on rockfish *Sebastes* spp. was conducted by Dr. John Hyde at the National Marine Fisheries Service's Southwest Fisheries Science Center (SWFSC) in La Jolla, California. Only those *Sebastes* larvae that had been preserved in 95% non-denatured ethanol were tested as formalin and denatured alcohol degrade the DNA in the specimens. Tenera ichthyologists placed each specimen in an individually numbered vial. The DNA from each larva was extracted by placing either a portion of or the entire larva 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 as the sequence data for it had already been sequenced 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 labeled the DNA for sequencing. The sequences were run on the sequencer and then edited and checked for quality. Once the sequences were completed, a phylogenic analysis was preformed that clustered the unknown larva's sequence with the set of reference sequences and the identification of each larva was determined. It should be noted that separation of two closely related nearshore rockfishes (*S. carnatus* [gopher rockfish] and *S. chrysomelas* [black-and-yellow rockfish]) cannot be reliably performed using this technique and when found, these specimens were left as a group category containing both species.

Notochord length (NL) was determined for a representative number of individuals of larval fish taxa. These measurements were determined and recorded for up to 50 specimens from each taxon during each survey using a video capture system and image analysis software. These data were used to determine the duration at risk of entrainment for the larvae, and for screening efficiency studies. Individuals longer than 30 mm (1.2 in.) in length were considered non-entrainable because they would not normally be susceptible to entrainment. Fishes that were considered non-entrainable were not used in the determination of the annual entrainment estimate.

Laboratory data were recorded on preprinted data sheets formatted for entry into a computer database for analysis and archiving. All laboratory data recorded on sequenced datasheets were entered into an Access® computer database and verified for accuracy against the original data sheets.

A detailed QA/QC program was also applied to all laboratory processing. The laboratory procedures were reviewed with all personnel prior to the start of the study and all personnel were given printed copies of the procedures. The first ten samples sorted by an individual were re-sorted by a designated QC sorter. In order to "pass" a QC re-sort, a sorter was allowed to miss only one fish larva in a sample when the total number of larvae was less than 20. For samples with 20 or more larvae, the sorter was required to maintain a sorting accuracy of 90%. After a sorter completed ten consecutive samples with greater than 90% accuracy, the sorter had one of their next ten samples randomly selected for a QA/QC check. If the sorter failed to achieve an accuracy level of 90%, their samples were re-sorted by the QC sorter until ten consecutive samples met the required level of accuracy. If the sorter maintained the required level of accuracy, one of their next ten samples was re-sorted by QC personnel.

A similar QA/QC program was conducted for the taxonomists identifying the samples. The first ten samples of fishes identified by an individual taxonomist were completely re-identified by a designated QA/QC taxonomist. At least 50 individual fish larvae from at least five taxa must be present in these first ten samples; if not, additional samples were re-identified until this criterion was met. Taxonomists were required to maintain a 95% identification accuracy level in these first ten samples. After the taxonomist identified ten consecutive samples with greater than 95% accuracy, the taxonomist had one of their next ten samples checked by a QA/QC taxonomist. If the taxonomist maintained an accuracy level of 95%, then they continued to have one of ten samples checked by a QA/QC taxonomist. If they fell below this level, then the next ten consecutive samples they identified were checked for accuracy. Samples were re-identified until ten consecutive samples met the 95% criterion. Identifications were verified with taxonomic voucher collections maintained by Tenera.

3.2.3 Data Analysis

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

3.2.3.1 Entrainment Estimates

Entrainment estimates were calculated using the daily average larval concentrations from the field samples and the proposed flow of 26,498 m^3 per day (7 mgd) for the desalination intake. The estimates of the daily average concentrations and associated variance were calculated based on a stratified random design with two cycles (day and night) and two replicates per cycle. The estimates of larval entrainment at the **scwd²** proposed offshore intake were based on monthly sampling where E_T is the estimate of total entrainment for the study period and E_i is the monthly entrainment estimate calculated from the average concentration calculated for the day sampled within each survey period. The average concentration and variance calculated for the day was extrapolated across the days within each sampling period. Estimates of proportional mortality using the Empirical Transport Model (*ETM*) were also calculated using daily entrainment estimates calculated using daily intake flows of 11,356 m^3 (3 mgd) and 41,640 m^3 (11 mgd).

3.2.3.2 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 intake (SWE) and three source water stations (SW1–SW3) (**Figure 3.2-3**). 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 using the average from the samples collected during the two temporal cycles at each station. The associated variance for the survey was calculated using the two cycles. An estimate of the larval concentration in areas OW and OE were interpolated using average of the concentrations at the three other adjoining stations. This was done to allow for a rectangular-shaped source water area that could be extrapolated using alongshore current displacement, otherwise the layout of the sampling locations would have required separate source water estimates for the offshore (OW and OE) station areas. The estimates of the daily concentration for the stations were multiplied by the volume of each station area (**Table 3.2-1**) calculated from bathymetric data to calculate the population for the day. The estimates from the source water stations were combined to provide an estimate of the total number in the source water sampling area that was then extrapolated to estimate the entire source population at risk to entrainment.

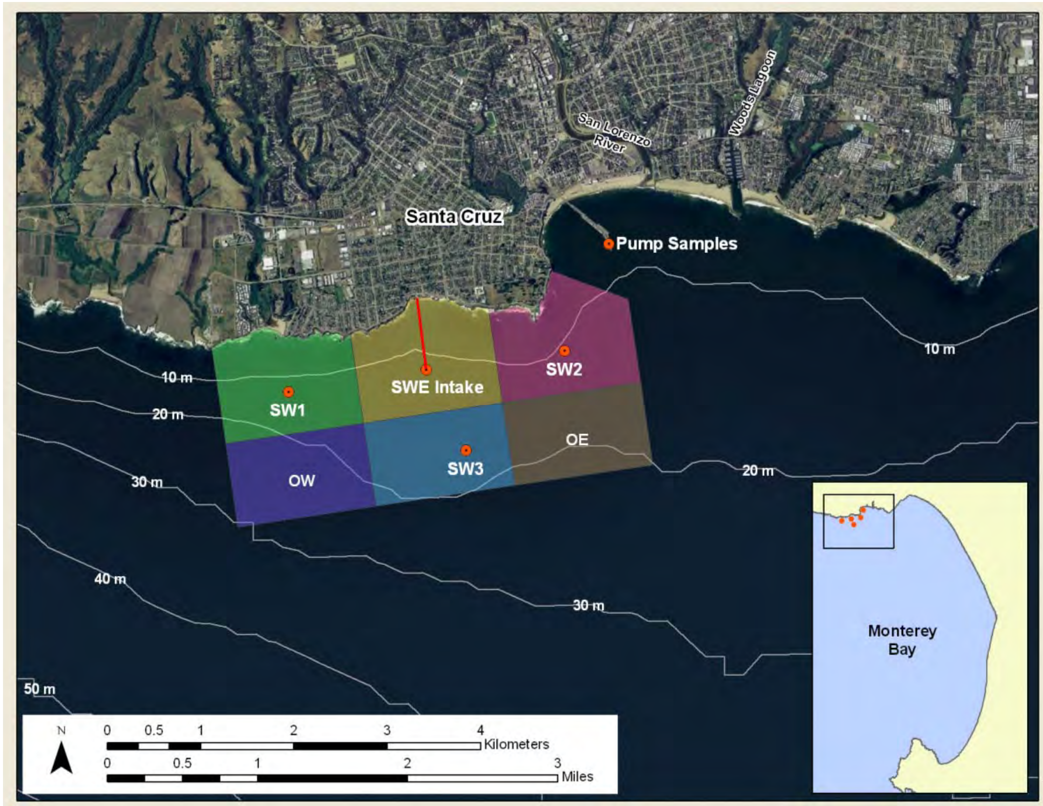


Figure 3.2-3. Bathymetry and areas used in calculating source water volumes for *ETM* calculations.

Table 3.2-1. Area, volume, and average depth of **scwd^2** sampling locations, including the values for the two extrapolated source water areas, OW and OE.

Station	Area (m^2)	Volume (m^3)	Average Depth (m)
SWE	1,643,350	44,734,827	8.21
SW1	1,585,303	55,734,490	10.60
SW2	1,579,859	45,999,484	8.77
SW3	1,351,136	83,786,894	18.90
OW	1,348,003	101,751,885	23.04
OE	1,348,558	77,064,308	17.43

3.2.3.3 Entrainment Impact Assessment

Assessment of entrainment effects were limited to the most abundant fish taxa (target taxa) that together comprised approximately 70% of the total estimated fish larvae sampled during the April 2009–May 2010 study period.[3] This included the following seven taxonomic groups (taxa) of fishes: white croaker, a complex of two species of gobies (arrow goby *Clevelandia ios* and shadow goby *Quiteula y-cauda*), northern anchovy, sanddabs, sculpins (*Artedius* spp.), KGB-complex rockfishes, and California halibut. Data on later-stage larvae from the following three invertebrates were also analyzed: cancrid crabs, bay shrimps (*Crangon* spp.), and tidepool shrimps (families Thoridae/Hippolytidae). Data for the target taxa from sampling at the intake and source water stations were used to calculate estimates of proportional entrainment (*PE*) which were used to estimate the probability of mortality (P_m) due to entrainment using the *ETM*. Detailed mathematical formulation of the *ETM* model is presented in **Appendix A**.

3.2.3.3.1 Larval Lengths

To represent the distribution of the lengths of the entrained larvae, a random sample of 200 measurements from all of the measured larvae for a taxa was drawn with replacement (bootstrap) 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 boxplot histograms using SAS Graph® (SAS Institute). An explanation of the legend accompanying the histograms is shown in **Figure 3.2-4**, and may be referred to for interpreting the length frequency dispersion statistics for selected taxa that are presented in Section 3.3.4–*Analysis of Individual Taxa*. The tick marks below the histogram represent the data from the bootstrap sampling. 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. Those statistics were calculated from 1,000 random draws of 100 samples drawn with replacement.

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 size at hatching and the size at the 95th percentile by a larval growth rate obtained from the literature. The duration of the egg stage was added to this value for species with planktonic eggs. The 95th percentile value was used to eliminate outliers from the calculations. The size at hatching was estimated as follows:

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

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

[3] No survey was conducted during April 2010 due to dangerous sea conditions.

smaller-sized larvae and usually resulted in a value close to the hatch size reported in the literature. The length frequency distributions for several of the fishes did not follow this pattern and the length of the 10^{th} percentile of the distribution was used as the hatch length for these taxa to eliminate outlier values.

The *ETM* requires an estimate of the age of the larvae being entrained that is then used to estimate the period of time that the larvae are exposed to entrainment. This estimate was obtained by measuring a representative number of larvae of each of the target taxa from the intake samples and using published larval growth rates. The number of larvae collected and measured from intake 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 with the samples 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. Statistics and percentile values from each of the 100 samples were computed and the average of those values were used in calculating the period of time that the larvae were exposed to entrainment.

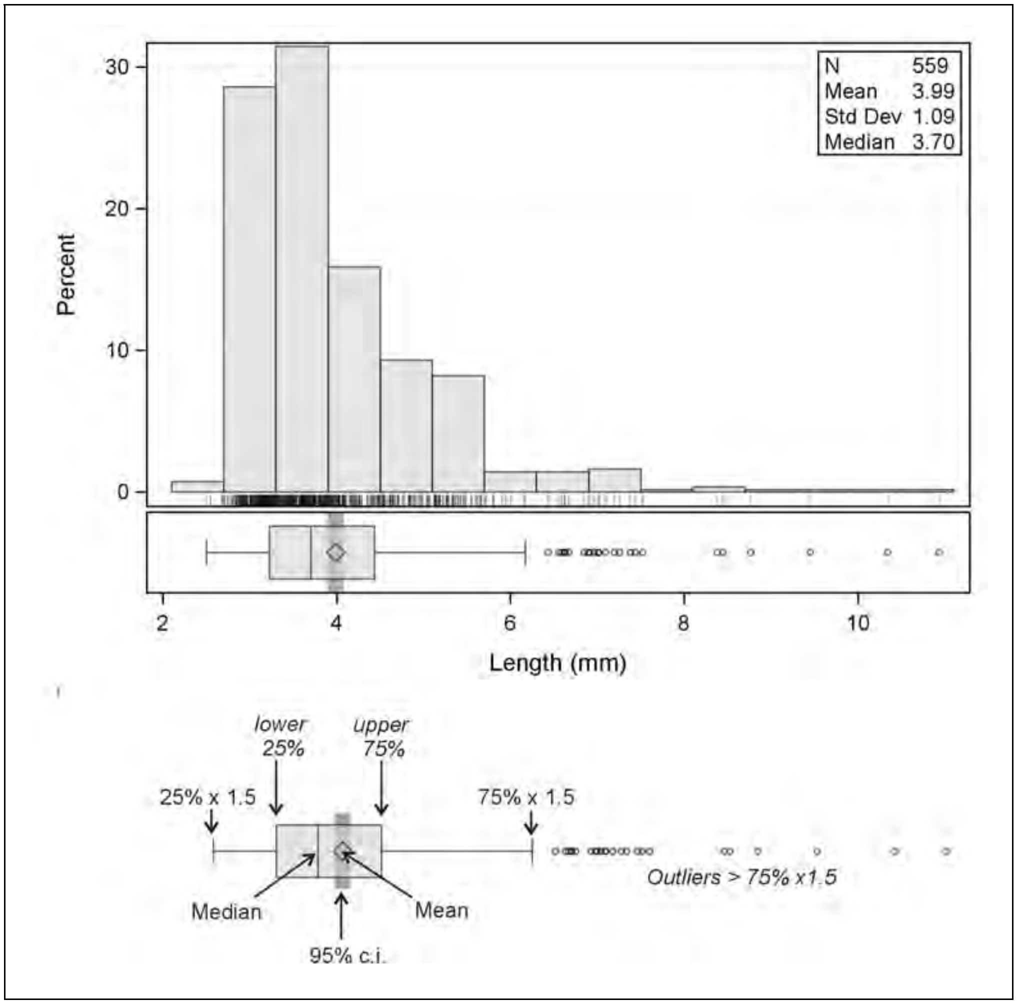


Figure 3.2-4. Explanation of dispersion statistics for length frequency histograms.

3.2.3.3.2 ETM

The *ETM* was proposed by the U.S. Fish and Wildlife Service to estimate mortality rates resulting from circulating water withdrawals by power plants (Boreman et al. 1978, and subsequently in Boreman et al. 1981). The *ETM* provides an estimate of incremental mortality (a conditional estimate of entrainment mortality in absence of other mortality [Ricker 1975]) based on estimates of the fractional loss to the source water population represented by entrainment. The conditional mortality is represented as estimates of proportional entrainment (*PE*) that are calculated for each survey and then 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 studies at California power plants (MacCall et al. 1983, Parker and DeMartini 1989, Tenera 2000a, b, Steinbeck et al. 2007).

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

$$PE_i = \frac{N_{E_i}}{N_{S_i}} = \frac{\overline{\rho}_{E_i} V_{E_i}}{\overline{\rho}_{S_i} V_{S_i}}, \quad (1)$$

where N_{E_i} and N_{S_i} are the estimated numbers of larvae entrained and in the sampled source water per day in survey period *i*, $\overline{\rho}_{E_i}$ and $\overline{\rho}_{S_i}$ are the average concentrations of larvae from the intake 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 feedwater flow and sampled source water per day in survey period *i*. While a reasonably accurate estimate of the volume of the 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. The *PE* estimated using Equation 1 is then adjusted based on the proportion of the sampled source water population to the total source population (P_S) (Steinbeck et al. 2007).

The extrapolated source water areas used in the *PE* estimates were calculated using data on current displacement during the survey period prior to the survey day. 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 statistics derived from length data from the intake samples for each taxon. The maximum age was calculated as the average upper 95th percentile value from the 100 draws of 100 measurements from the samples. The maximum age at entrainment was calculated by dividing the difference between the upper 95th percentile values of the lengths and the estimated hatch length or 10th percentile value of the lengths, depending on the taxa, by an estimated larval growth rate.

The estimate of the total source water area was calculated using only the alongshore current displacement during the period prior to the sampling date. The ratio (P_S) of the extrapolated source water alongshore based on current displacement to the alongshore distance (4.5 km [2.8 mi]) of the sampled source water stations calculated for each survey was used in the *ETM* calculations to adjust the estimate of PE_i. Using the extrapolated estimate of the source water population in the calculation of *PE*, the proportional mortality (P_M) for each taxa was calculated as follows:

$$P_M = 1 - \sum_{i=1}^{13} f_i (1 - PE_i P_{S_i})^d, \quad (2)$$

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.

3.2.3.3.3 Current Data Sources and Analysis

The current data used in extrapolating the source water populations were from an Acoustic Doppler Current Profiler (ADCP; RDI Workhorse 600 kHz, Teledyne Inc.) maintained by the University of California, Santa Cruz as part of the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). The instrument was located upcoast from the proposed intake location at Terrace Point (36.943421 °N and 122.080450 °W) at the 18-m (59 ft) isobath. The ADCP data collected at two-minute intervals were averaged to provide currents for every one meter (3.3 ft) of depth through the water column. The coastline near Terrace Point where the ADCP is located is oriented approximately 105° from north. The east and north components of the two-minute water column averages of Terrace Point currents measured from February 13, 2009 to May 13, 2010 were rotated 15 degrees counter-clockwise in order to align currents with the coastline. The rotated data were then were converted to vectors that measured alongshore and onshore current displacement and averaged across the water column.

3.3 Results

3.3.1 Ocean currents

The data from the ADCP located at Terrace Point show that alongshore current speeds are generally faster than onshore-offshore current speeds (**Figure 3.3-1**). Also, surface currents are generally stronger than currents at depth. A progressive current vector showing current displacement using the coast-aligned averages shows that movement was generally upcoast in the alongshore direction except from December to February 2010 when currents went onshore and downcoast (**Figure 3.3-2**).

Surface currents are measured hourly off the entirety of the coastline of the State of California using high frequency (HF) radar by a network of CODAR Ocean Sensors, Ltd. SeaSondes® operated by the member institutions of the Central & Northern California Ocean Observing

System (CeNCOOS) and Southern California Coastal Ocean Observing System (SCCOOS) consortia of the Coastal Ocean Currents Monitoring Program (COCMP). **Appendix B** shows the surface currents in the Santa Cruz and Monterey Bay vicinity using hourly averages and 24-hour trajectories corresponding to 13 sampling days at the source water and intake stations. The figures in **Appendix B** were provided by the CeNCOOS website http://www.cencoos.org/sections/conditions/currents/index.shtml from April 2009 to May 2010.

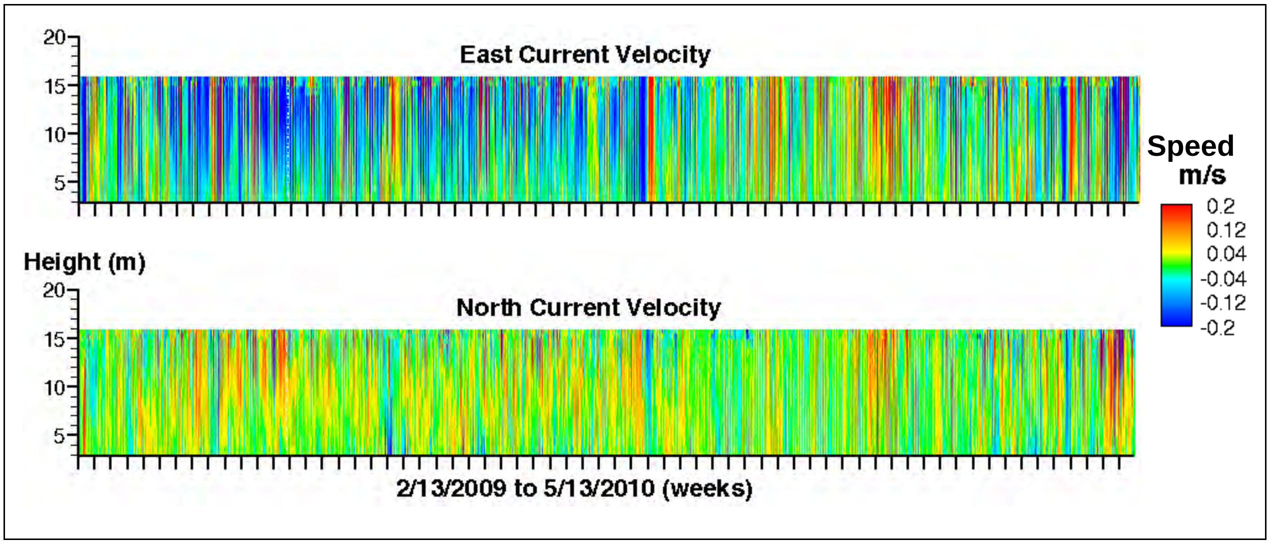


Figure 3.3-1. Velocity (m/s) of east and north components of Terrace Point currents measured from February 13, 2009 to May 13, 2010. Height is measured from a bottom mounted 600 kHz RDI ADCP at a depth of 18 m (59 ft) MLLW.

Data collected by the Partnership for Interdisciplinary Studies of Coastal Oceans: a long-term ecological consortium funded by the David and Lucile Packard Foundation and the Gordon and Betty Moore Foundation. Data at http://data.piscoweb.org/DataCatalogAccess/DataCatalogAccess.html.

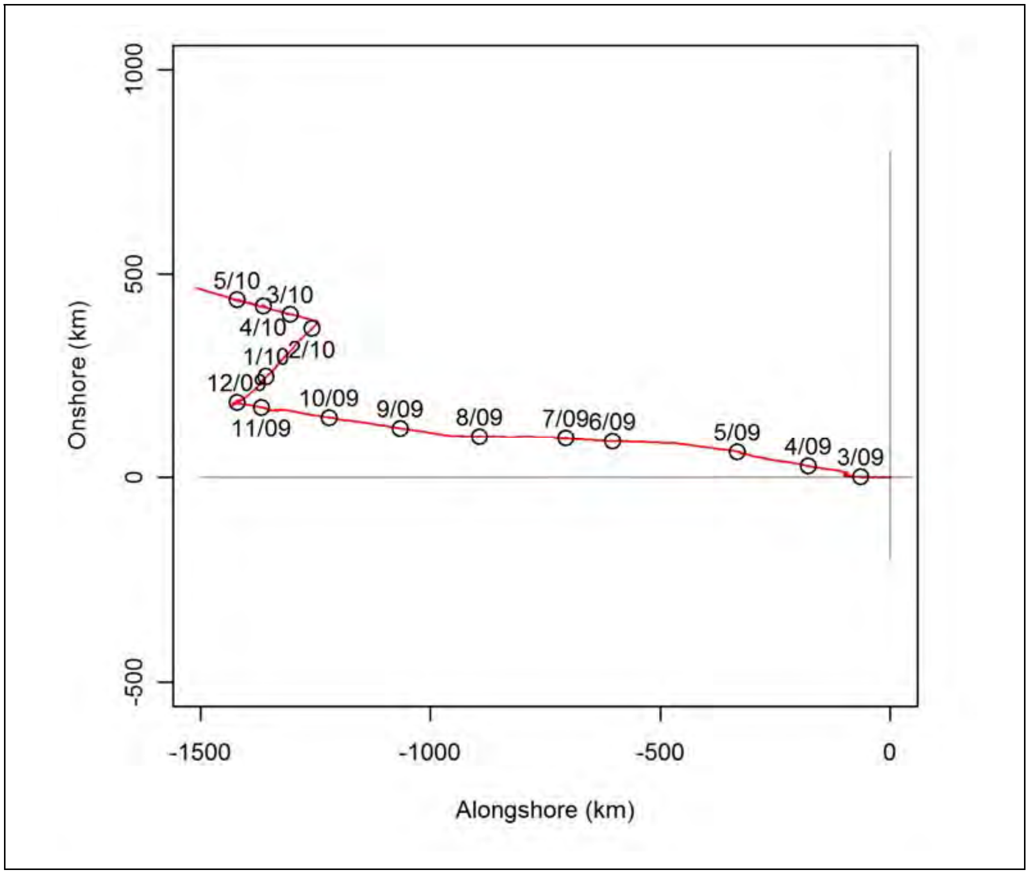


Figure 3.3-2. Coast-aligned Terrace Point water column average currents measured from February 13, 2009 to May 13, 2010, showing current displacement in a progressive vector. Movement was generally upcoast in the alongshore direction.

3.3.2 Larval Abundances at Proposed Offshore Intake Location

The following section presents intake and source water larval fish and target shrimp and crab concentrations collected from April 2009–May 2010. Estimates of entrainment were derived from samples collected near the proposed offshore intake location. Source water estimates were derived from samples collected at three stations located near the proposed intake (**Figure 3.2-1**). Complete data by survey, along with water quality data collected during the sampling periods, are presented in **Appendix C**.

A total of 100 samples was collected and processed from the site of the proposed intake (Station SWE) (**Table 3.3-1**). Only four daytime samples were collected during Survey 10 due to unsafe sea conditions at night.

Table 3.3-1. Summary of the number of towed plankton samples collected at intake (SWE) and source water stations (SW1–SW3).

		Number of samples collected by station			
Survey	**Date**	**SWE**	**SW1**	**SW2**	**SW3**
SCEN01*	04/16/09	8	4	4	2
SCEN02	05/12/09	8	4	4	4
SCEN03	06/16/09	8	4	4	4
SCEN04	07/14/09	8	4	4	4
SCEN05	08/11/09	8	4	4	4
SCEN06	09/16/09	8	4	4	4
SCEN07	10/16/09	8	4	4	4
SCEN08	11/17/09	8	4	4	4
SCEN09	12/15/09	8	4	4	4
SCEN10**	01/15/10	4	2	2	2
SCEN11	02/23/10	8	4	4	4
SCEN12	03/19/10	8	4	4	4
SCEN13	05/03/10	8	4	4	4
	Total	**100**	**50**	**50**	**48**

*During the Survey 1, the daytime sampling at Station SW3 could not be conducted due to high winds and large ocean swell conditions.

**During Survey 10 only the daytime samples could be collected. The boat used to collect samples could not safely leave the marina due to a sand bar at the marina's mouth and a large ocean swell.

A total of 2,887 fish larvae in 45 taxonomic groups (including unidentified and damaged larvae) was collected from the 13 intake station (SWE) surveys during the April 2009–May 2010 study period (**Table 3.3-2**). The following four fishes were considered to be too large to be entrained: one unidentified goby (Family Gobiidae) (31 mm [1.2 in.]), one pygmy poacher (*Odontopyxis trispinosa*) (66 mm [2.6 in.]), one night smelt (*Spirinchus starksi*) (70 mm [2.8 in.]), and one pipefish (*Syngnathus* spp.) (152 mm [6.0 in.]). These four fishes were not listed in **Table 3.3-2** and they were not included in estimates of annual entrainment. The total estimated number of fish larvae that would be entrained annually, based on the 2009–2010 data and a proposed intake volume of 7 mgd, was 6,553,502 (**Table 3.3-3**). The estimated entrainment was proportionally lower at an intake volume of 3 mgd, and proportionally higher at the projected maximum intake volume of 11 mgd (**Table 3.3-3**). Eight taxa comprised approximately 82% of the total mean concentration of fish larvae during the study period: white croaker (*Genyonemus lineatus*), unidentified yolk sac larvae, northern anchovy (*Engraulis mordax*), unidentified gobies (CIQ complex),[4] sanddabs (*Citharichthys* spp.), unidentified ronquils (Family Bathymasteridae),

[4] The CIQ goby complex includes the following three species: (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*) (Moser 1996). All three are considered common in southern California (Miller and Lea 1972), but only the arrow and cheekspot typically occur as far north as Monterey Bay. Since it was not possible to determine whether shadow goby were collected in the samples, we refer to this goby complex as CIQ.

unidentified smelts (Family Osmeridae), and sculpins (newly hatched larvae of several species of *Artedius*). White croaker comprised over half of the total abundance. The life histories and potential impacts from entrainment on the local populations of white croaker, northern anchovy, CIQ goby complex, sanddabs, sculpins (*Artedius* spp.), KGB rockfish complex,[5] and California halibut (*Paralichthys californicus*), several of which are important recreational and commercial species, are analyzed in greater detail in this report.

Fish eggs were only enumerated and identified from the April through October 2009 samples plus four samples from the November 2009 survey because over 70% could only be classified as "undeveloped/unfertilized." Eleven taxa of fish eggs were identified from these samples (**Table 3.3-2**).

The highest overall concentrations of larval fishes occurred in November and December 2009, and February and March 2010, while the lowest concentrations were seen from July through October (**Figure 3.3-3**). The peak concentration occurred in March at 2,091/1,000 m^3. Peak concentration of eggs (17,371/1,000 m^3) occurred in June 2009 (**Figure 3.3-4),** but as discussed earlier, the sorting and identification of eggs from samples after November 2009 was discontinued due to the high proportion of eggs that could not be classified to taxonomic groups.

Four taxa of cancrid crab megalops were identified from the samples collected at the intake station (SWE). They comprised 45.2% of the total mean concentration of target invertebrates. The remainder of the target invertebrate larvae were mainly from four different families of shrimps (**Table 3.3-2**). Most of the shrimp specimens, although in advanced stages of larval development, could only be reliably identified to the family level. Based on the proposed pumping rate of 7 mgd, it was estimated that the total annual entrainment of these target invertebrates would be 905,999 individuals (**Table 3.3-3**).

[5] The KGB rockfish complex is comprised of the following three species: kelp (*Sebastes atrovirens*), gopher (*S. carnatus*), and black-and-yellow (*S. chrysomelas*).

Table 3.3-2. Counts and concentrations of fish larvae, fish eggs, and target shrimp and crab larvae collected at the intake station (SWE) from April 2009 through May 2010.*

	Taxon	Common Name	Total # Collected	Mean Conc. (#/1,000 m^3)	Percent of Total Mean Conc.	Cumul. Percent
Fish Larvae						
1	*Genyonemus lineatus*	white croaker	1,501	340.80	51.57%	51.57%
–	unidentified yolksac stage	yolksac stage	262	61.37	9.29%	60.85%
2	*Engraulis mordax*	northern anchovy	169	38.47	5.82%	66.67%
3	CIQ goby complex	gobies	136	33.95	5.14%	71.81%
4	*Citharichthys* spp.	sanddabs	76	17.64	2.67%	74.48%
5	Bathymasteridae	ronquils	52	15.43	2.33%	76.81%
6	Osmeridae	smelts	76	16.90	2.56%	79.37%
7	*Artedius* spp.	sculpins	62	15.40	2.33%	81.70%
–	larval fish - damaged	damaged larval fishes	69	15.04	2.28%	83.98%
8	*Cottus asper*	prickly sculpin	64	14.33	2.17%	86.14%
9	Cottidae	sculpins	60	12.57	1.90%	88.05%
10	*Leptocottus armatus*	Pacific staghorn sculpin	45	10.53	1.59%	89.64%
11	Pleuronectoidei	flatfishes	33	6.92	1.05%	90.69%
12	*Sebastes* spp. V_	KGB rockfishes	34	6.78	1.03%	91.71%
13	*Oxylebius pictus*	painted greenling	24	5.30	0.80%	92.51%
14	Myctophidae	lanternfishes	24	5.56	0.84%	93.35%
15	*Oligocottus/Clinocottus* spp.	sculpins	24	5.60	0.85%	94.20%
16	*Paralichthys californicus*	California halibut	23	4.67	0.71%	94.91%
17	*Neoclinus* spp.	fringeheads	20	4.21	0.64%	95.55%
18	*Rhinogobiops nicholsi*	blackeye goby	19	3.82	0.58%	96.12%
19	Pleuronectidae	righteye flounders	13	3.24	0.49%	96.61%
20	Cyclopteridae	snailfishes	14	3.01	0.46%	97.07%
21	*Gibbonsia* spp.	kelpfishes	11	2.83	0.43%	97.50%
22	*Cebidichthys violaceus*	monkeyface prickleback	10	2.14	0.32%	97.82%
23	*Orthonopias triacis*	snubnose sculpin	8	1.91	0.29%	98.11%
24	Agonidae	poachers	8	1.85	0.28%	98.39%
25	Gobiesocidae	clingfishes	6	1.26	0.19%	98.58%
26	*Lepidogobius lepidus*	bay goby	6	1.30	0.20%	98.78%
27	*Ruscarius creaseri*	roughcheek sculpin	4	0.93	0.14%	98.92%
28	*Lepidopsetta bilineata*	rock sole	6	1.18	0.18%	99.10%
29	*Ammodytes hexapterus*	Pacific sand lance	4	0.83	0.13%	99.22%
30	Blennioidei	blennies	3	0.61	0.09%	99.31%
31	Atherinopsidae	silversides	2	0.53	0.08%	99.39%
32	*Pleuronichthys verticalis*	hornyhead turbot	2	0.50	0.08%	99.47%
33	Stichaeidae	pricklebacks	3	0.59	0.09%	99.56%
34	*Scorpaenichthys marmoratus*	cabezon	2	0.44	0.07%	99.63%
35	*Sebastes* spp. V	rockfishes	2	0.44	0.07%	99.69%
36	*Brosmophycis marginata*	red brotula	2	0.37	0.06%	99.75%
37	*Syngnathus* spp.	pipefishes	2	0.35	0.05%	99.80%
38	Pholidae	gunnels	1	0.22	0.03%	99.84%
39	*Gillichthys mirabilis*	longjaw mudsucker	1	0.25	0.04%	99.87%
40	*Isopsetta isolepis*	butter sole	1	0.24	0.04%	99.91%

(table continued)

Table 3.3-2 (continued). Counts and concentrations of fish larvae, fish eggs, and target shrimp and crab larvae collected at the intake station (SWE) from April 2009 through May 2010.*

	Taxon	Common Name	Total # Collected	Mean Conc. (#/1,000 m³)	Percent of Total Mean Conc.	Cumul. Percent
–	unid. larval/post-larval fish	larval fishes	1	0.20	0.03%	99.94%
41	*Chilara taylori*	spotted cusk-eel	1	0.20	0.03%	99.97%
42	*Sebastes* spp.	rockfishes	1	0.20	0.03%	100.00%
			2,887	**660.91**	**100.00%**	
Fish Eggs*						
–	fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	12,771	2,544.79	70.38%	70.38%
1	*Citharichthys* spp. (eggs)	sanddab eggs	4,433	891.07	24.64%	95.02%
2	Sciaenidae/Paralichthyidae (eggs)	fish eggs	317	66.17	1.83%	96.85%
3	*Paralichthys californicus* (eggs)	California halibut eggs	211	41.56	1.15%	98.00%
4	*Genyonemus lineatus* (eggs)	white croaker eggs	110	25.04	0.69%	98.69%
5	Engraulidae (eggs)	anchovy eggs	104	19.54	0.54%	99.23%
–	unidentified fish eggs	fish eggs	40	7.50	0.21%	99.44%
6	Paralichthyidae (eggs)	sand flounder eggs	34	6.96	0.19%	99.63%
7	Pleuronectidae (eggs)	righteye flounder eggs	35	6.81	0.19%	99.82%
–	fish eggs (damaged)	damaged fish eggs unid.	16	3.23	0.09%	99.91%
8	*Pleuronichthys* spp. (eggs)	turbot eggs	7	1.21	0.03%	99.94%
9	Pleuronectoidei (eggs)	flatfish eggs	5	1.03	0.03%	99.97%
10	*Parophrys vetulus* (eggs)	English sole eggs	4	0.82	0.02%	99.99%
11	poss. Bathylagidae (eggs)	poss. blacksmelt eggs	1	0.18	<0.01%	100.00%
			18,088	**3,615.91**	**100.00%**	
Target Shrimp and Crab Larvae						
1	*Romal. ant./Meta. gracilis* (meg)	Cancer crab megalops	244	49.23	37.97%	37.97%
2	Thoridae/Hippolytidae	shrimps	181	35.89	27.68%	65.64%
3	Crangonidae	sand shrimps	176	33.45	25.80%	91.44%
4	*Metacarcinus anthonyi* (meg)	yellow crab megalops	24	4.80	3.70%	95.14%
5	Cancridae (meg)	Cancer crab megalops	16	2.98	2.30%	97.44%
6	*Cancer prod./Romal.* spp. (meg)	rock crab megalops	9	1.58	1.22%	98.66%
7	Alpheidae	shrimps	7	1.56	1.20%	99.86%
8	Pandalidae	shrimps	1	0.18	0.14%	100.00%
			658	**129.67**	**100.00%**	

*Fish eggs were only enumerated and identified from the April through October 2009 samples plus four samples from the November 2009 survey.

Table 3.3-3. Estimated annual entrainment of fish larvae and target shrimp and crab larvae at an open-ocean unscreened intake based on data collected at the intake station (SWE) from April 2009 through May 2010 for three intake volumes.

			Estimated Annual Entrainment		
	Taxon	**Common Name**	**11,356 m³ (3 mgd)**	**26,498 m³ (7 mgd)**	**41,640 m³ (11 mgd)**
Fish Larvae					
1	*Genyonemus lineatus*	white croaker	1,541,221	3,596,272	5,651,324
–	unidentified larvae, yolksac	yolksac larvae	277,848	648,328	1,018,808
2	*Engraulis mordax*	northern anchovy	162,916	380,146	597,376
3	CIQ goby complex	gobies	137,208	320,160	503,112
4	*Citharichthys* spp.	sanddabs	78,673	183,575	288,477
5	Bathymasteridae	ronquils	71,594	167,057	262,520
6	Osmeridae	smelts	64,470	150,434	236,398
7	*Artedius* spp.	sculpins	60,404	140,946	221,487
–	larval fish - damaged	damaged larval fishes	45,910	107,125	168,341
8	*Cottus asper*	prickly sculpin	38,261	89,277	140,293
9	Cottidae	sculpins	35,903	83,775	131,647
10	*Leptocottus armatus*	Pacific staghorn sculpin	29,134	67,981	106,829
11	Pleuronectoidei	flatfishes	24,514	57,201	89,888
12	*Sebastes* spp. V_	rockfishes	22,105	51,579	81,053
13	*Oxylebius pictus*	painted greenling	21,393	49,918	78,443
14	Myctophidae	lanternfishes	20,582	48,025	75,469
15	*Oligocottus/Clinocottus* spp.	sculpins	20,309	47,388	74,467
16	*Paralichthys californicus*	California halibut	18,744	43,738	68,732
17	*Neoclinus* spp.	fringeheads	17,581	41,024	64,467
18	*Rhinogobiops nicholsi*	blackeye goby	15,370	35,864	56,358
19	Pleuronectidae	righteye flounders	14,387	33,571	52,754
20	Cyclopteridae	snailfishes	13,025	30,391	47,758
21	*Gibbonsia* spp.	kelpfishes	12,493	29,151	45,809
22	*Cebidichthys violaceus*	monkeyface prickleback	8,004	18,676	29,348
23	*Orthonopias triacis*	snubnose sculpin	7,852	18,321	28,790
24	Agonidae	poachers	7,097	16,561	26,024
25	Gobiesocidae	clingfishes	5,731	13,373	21,015
26	*Lepidogobius lepidus*	bay goby	3,787	8,836	13,885
27	*Ruscarius creaseri*	roughcheek sculpin	3,721	8,684	13,646
28	*Lepidopsetta bilineata*	rock sole	3,066	7,155	11,243
29	*Ammodytes hexapterus*	Pacific sand lance	2,911	6,793	10,674
30	Blennioidei	blennies	2,765	6,452	10,140
31	Atherinopsidae	silversides	2,414	5,633	8,852
32	*Pleuronichthys verticalis*	hornyhead turbot	2,292	5,348	8,404
33	Stichaeidae	pricklebacks	1,974	4,606	7,238
34	*Scorpaenichthys marmoratus*	cabezon	1,974	4,606	7,238
35	*Sebastes* spp. V	rockfishes	1,678	3,916	6,154
36	*Brosmophycis marginata*	red brotula	1,645	3,838	6,032
37	*Syngnathus* spp.	pipefishes	1,529	3,567	5,606
38	Pholidae	gunnels	1,138	2,656	4,175
39	*Gillichthys mirabilis*	longjaw mudsucker	1,104	2,575	4,047
40	*Isopsetta isolepis*	butter sole	1,074	2,506	3,939

(table continued)

Table 3.3-3 (continued). Estimated annual entrainment of fish larvae and target shrimp and crab larvae at an open-ocean unscreened intake based on data collected at the intake station (SWE) from April 2009 through May 2010 for three intake volumes.

			Estimated Annual Entrainment		
	Taxon	Common Name	11,356 m^3 (3 mgd)	26,498 m^3 (7 mgd)	41,640 m^3 (11 mgd)
–	unid. larval/post-larval fish	larval fishes	938	2,189	3,439
41	*Chilara taylori*	spotted cusk-eel	932	2,175	3,419
42	*Sebastes* spp.	rockfishes	904	2,110	3,315
			2,808,575	**6,553,502**	**10,298,433**
Target Shrimp and Crab Larvae					
1	*Romaleon antennarius / Metacarcinus gracilis*	Cancer crabs	171,483	400,136	628,790
2	Thoridae / Hippolytidae	shrimps	103,358	241,175	378,992
3	Crangonidae	sand shrimps	75,132	175,313	275,493
4	*Metacarcinus anthonyi*	yellow crab megalops	18,070	42,165	66,260
5	*Cancer productus* / *Romaleon* spp.	rock crab megalops	6,848	15,979	25,109
6	Alpheidae	shrimps	6,637	15,486	24,335
7	Cancridae	Cancer crab megalops	6,512	15,195	23,878
8	Pandalidae	shrimps	236	550	864
			388,276	**905,999**	**1,423,721**

Note: Fish eggs were only enumerated from the April through October 2009 samples plus four sample from the November 2009 survey. Therefore, no estimated annual entrainment was calculated for fish eggs.

3.3.3 Source Water Summary

A total of 3,193 fish larvae in 55 taxonomic categories was collected during the April 2009–May 2010 study (**Table 3.3-4**); an additional 411 unidentified yolk sac/larval/post-larval and damaged specimens were also collected. The following eight taxa comprised about 80% of the total mean concentration of larval fishes collected in the source water samples: white croaker (47.6%), unidentified yolk sac larvae (11.1%), northern anchovy (6.7%), CIQ goby complex (4.1%), sanddabs (3.1%), sculpins (*Artedius*–3.0% and Cottidae–2.8%), and ronquils (2.0%). The peaks in abundance of larval fishes at the source water stations occurred during November and December 2009, and March 2010 and lowest concentrations occurred from July through October 2009 (**Figure 3.3-5**). Complete data by survey, along with water quality data collected during the sampling periods, are presented in **Appendix C**.

A total of 29,044 fish eggs was removed from samples collected from April through October 2009 plus one sample collected in November. The majority of these eggs (76.2%) were categorized as undeveloped/unfertilized (**Table 3.3-4**). Sanddab eggs were the second most abundant (18.2%). Based on the high percentage of fish eggs that were unidentifiable, the enumeration and identification of fish eggs was discontinued.

The number of targeted invertebrate larvae collected during this study was 1,248 (**Table 3.3-4**). Cancrid crab megalops are identified by size and shape, but some of them overlap in their dimensions, making it unreliable to visually separate them to the species level. Most of the shrimp larvae could not be identified to a level lower than family, except for fully-developed juvenile specimens, because of a lack of published larval descriptions for most of the species.

Information regarding the diel distribution of larval fishes, fish eggs, and target shrimp and crab larvae is shown in the following figures. There were generally higher concentrations of larval fishes collected during the night sampling than during the day (**Figure 3.3-7**). Fish egg concentration was similar during the day and night sampling or slightly higher during the day (**Figure 3.3-7**). The plots of day-night concentration of the target shrimps and crabs are presented in the individual taxa sections that follow.

Table 3.3-4. Counts and concentrations of larval fishes, fish eggs, and target shrimp and crab larvae collected at three source water stations (SW1, SW2, and SW3) from April 2009 through May 2010.*

	Taxon	Common Name	Total # Collected	Mean Conc. (#/1,000 m^3)	Percent of Total Mean Conc.	Cumul. Percent
Fish Larvae						
1	*Genyonemus lineatus*	white croaker	1,707	246.01	47.60%	47.60%
–	unidentified larvae, yolksac	yolksac larvae	374	57.11	11.05%	58.65%
2	*Engraulis mordax*	northern anchovy	258	34.85	6.74%	65.40%
3	CIQ goby complex	gobies	148	21.13	4.09%	69.48%
4	*Citharichthys* spp.	sanddabs	110	15.80	3.06%	72.54%
5	*Artedius* spp.	sculpins	111	15.72	3.04%	75.58%
6	Cottidae	sculpins	105	14.65	2.83%	78.42%
7	Bathymasteridae	ronquils	71	10.12	1.96%	80.38%
8	*Rhinogobiops nicholsi*	blackeye goby	65	9.03	1.75%	82.12%
9	*Sebastes* spp. V_	KGB rockfishes	69	8.89	1.72%	83.84%
10	Myctophidae	lanternfishes	46	7.41	1.43%	85.28%
11	Pleuronectoidei	flatfishes	43	6.76	1.31%	86.59%
12	*Scorpaenichthys marmoratus*	cabezon	47	6.51	1.26%	87.84%
–	larval fish - damaged	damaged larval fishes	36	5.60	1.08%	88.93%
13	*Lepidogobius lepidus*	bay goby	36	4.90	0.95%	89.88%
14	*Leptocottus armatus*	Pacific staghorn sculpin	28	4.73	0.92%	90.79%
15	Osmeridae	smelts	29	3.99	0.77%	91.56%
16	*Neoclinus* spp.	fringeheads	32	3.90	0.75%	92.32%
17	*Oligocottus/Clinocottus* spp.	sculpins	27	3.73	0.72%	93.04%
18	*Oxylebius pictus*	painted greenling	28	3.67	0.71%	93.75%
19	Pleuronectidae	righteye flounders	21	3.66	0.71%	94.46%
20	*Paralichthys californicus*	California halibut	27	3.51	0.68%	95.14%
21	Agonidae	poachers	23	3.22	0.62%	95.76%
22	*Sebastes* spp. V	rockfishes	15	1.93	0.37%	96.13%
23	*Ammodytes hexapterus*	Pacific sand lance	17	1.79	0.35%	96.48%
24	Cyclopteridae	snailfishes	11	1.63	0.32%	96.80%
25	*Cebidichthys violaceus*	monkeyface prickleback	10	1.57	0.30%	97.10%
26	Gobiesocidae	clingfishes	11	1.45	0.28%	97.38%
27	*Gibbonsia* spp.	kelpfishes	11	1.42	0.27%	97.65%
28	*Ruscarius meanyi*	Puget Sound sculpin	10	1.32	0.26%	97.91%
29	*Orthonopias triacis*	snubnose sculpin	9	1.24	0.24%	98.15%
30	*Sebastes* spp.	rockfishes	5	0.76	0.15%	98.30%
31	*Hemilepidotus spinosus*	brown Irish lord	6	0.75	0.15%	98.44%
32	*Lepidopsetta bilineata*	rock sole	6	0.74	0.14%	98.59%
33	Blennioidei	blennies	5	0.71	0.14%	98.72%
34	*Pleuronichthys verticalis*	hornyhead turbot	4	0.69	0.13%	98.86%
35	*Ruscarius creaseri*	roughcheek sculpin	5	0.64	0.12%	98.98%
36	Atherinopsidae	silversides	2	0.50	0.10%	99.08%
37	*Chilara taylori*	spotted cusk-eel	3	0.41	0.08%	99.16%
38	*Pleuronichthys* spp.	turbots	3	0.41	0.08%	99.24%
39	*Gillichthys mirabilis*	longjaw mudsucker	3	0.39	0.08%	99.31%
40	*Porichthys notatus*	plainfin midshipman	3	0.36	0.07%	99.38%
41	*Cottus asper*	prickly sculpin	3	0.35	0.07%	99.45%
42	*Syngnathus* spp.	pipefishes	2	0.32	0.06%	99.51%

(table continued)

Table 3.3-4 (continued). Counts and concentrations of larval fishes, fish eggs, and target shrimp and crab larvae collected at three source water stations (SW1, SW2, and SW3) from April 2009 through May 2010.*

	Taxon	Common Name	Total # Collected	Mean Conc. (#/1,000 m^3)	% of Total Mean Conc.	Cumul. Percent
43	Paralichthyidae	sand flounders	2	0.31	0.06%	99.57%
44	Lyopsetta exilis	slender sole	2	0.30	0.06%	99.63%
45	*Hypsoblennius* spp.	combtooth blennies	2	0.26	0.05%	99.68%
46	*Parophrys vetulus*	English sole	2	0.25	0.05%	99.73%
47	*Brosmophycis marginata*	red brotula	2	0.24	0.05%	99.77%
48	*Blennioidei/Zoarcoidei*	blennies/zoarcoids	1	0.15	0.03%	99.80%
49	Hexagrammidae	greenlings	1	0.15	0.03%	99.83%
50	Sciaenidae	croakers	1	0.14	0.03%	99.86%
51	*Bathylagus* spp.	blacksmelts	1	0.14	0.03%	99.89%
52	Stichaeidae	pricklebacks	1	0.13	0.03%	99.91%
–	unid larval/post-larval fish	larval fishes	1	0.13	0.03%	99.94%
53	Clupeiformes	herrings and anchovies	1	0.12	0.02%	99.96%
54	Gobiidae	gobies	1	0.11	0.02%	99.98%
55	*Sebastolobus* spp.	thornyheads	1	0.10	0.02%	100.00%
			3,604	**516.81**	**100.00%**	
Fish Eggs*						
–	fish eggs (undeveloped/unfertilized)	undeveloped / unfertilized fish eggs	22,226	2,932.41	76.17%	76.17%
1	*Citharichthys* spp. (eggs)	sanddab eggs	5,261	701.24	18.21%	94.38%
2	Sciaenidae/Paralichthyidae (eggs)	fish eggs	502	68.66	1.78%	96.17%
3	*Genyonemus lineatus* (eggs)	white croaker eggs	363	53.22	1.38%	97.55%
4	Paralichthyidae (eggs)	sand flounder eggs	266	37.86	0.98%	98.53%
5	Engraulidae (eggs)	anchovy eggs	192	23.35	0.61%	99.14%
6	*Paralichthys californicus* (eggs)	California halibut eggs	95	12.90	0.34%	99.47%
7	Pleuronectoidei (eggs)	flatfish eggs	45	6.74	0.18%	99.65%
8	Pleuronectidae (eggs)	righteye flounder eggs	35	4.53	0.12%	99.77%
9	*Pleuronichthys* spp. (eggs)	turbot eggs	29	4.41	0.11%	99.88%
–	unidentified fish eggs	fish eggs	24	3.79	0.10%	99.98%
10	poss. *Microstomus pacificus* (eggs)	poss. Dover sole eggs	3	0.39	0.01%	99.99%
–	fish eggs (damaged)	damaged fish eggs.	2	0.28	0.01%	100.00%
11	poss. Bathylagidae (eggs)	poss. blacksmelt eggs	1	0.15	<0.01%	100.00%
			29,044	**2,849.93**	**100.00%**	
Target Shrimp and Crab Larvae						
1	*Romal. anten.*/*Meta. grac.* (meg)	Cancer crabs	510	67.90	39.94%	39.94%
2	Thoridae/Hippolytidae	shrimps	368	50.32	29.60%	69.54%
3	Crangonidae	sand shrimps	243	34.86	20.51%	90.05%
4	*Metacarcinus anthonyi* (meg)	yellow crab megalops	49	6.46	3.80%	93.85%
5	Cancridae (meg)	Cancer crab megalops	39	5.35	3.15%	96.99%
6	*Cancer productus*/*Romaleon* spp.	rock crab megalops	25	3.15	1.85%	98.85%
7	Alpheidae	shrimps	11	1.70	1.00%	99.85%
8	Caridea	caridean shrimp	1	0.13	0.08%	99.92%
9	*Metacarcinus magister* (meg)	dungeness crab megalops	1	0.13	0.08%	100.00%
			1,248	**170.00**	**100.00%**	

*Fish eggs were only identified and enumerated from the April through October 2009 samples plus one sample from the November 2009 survey.

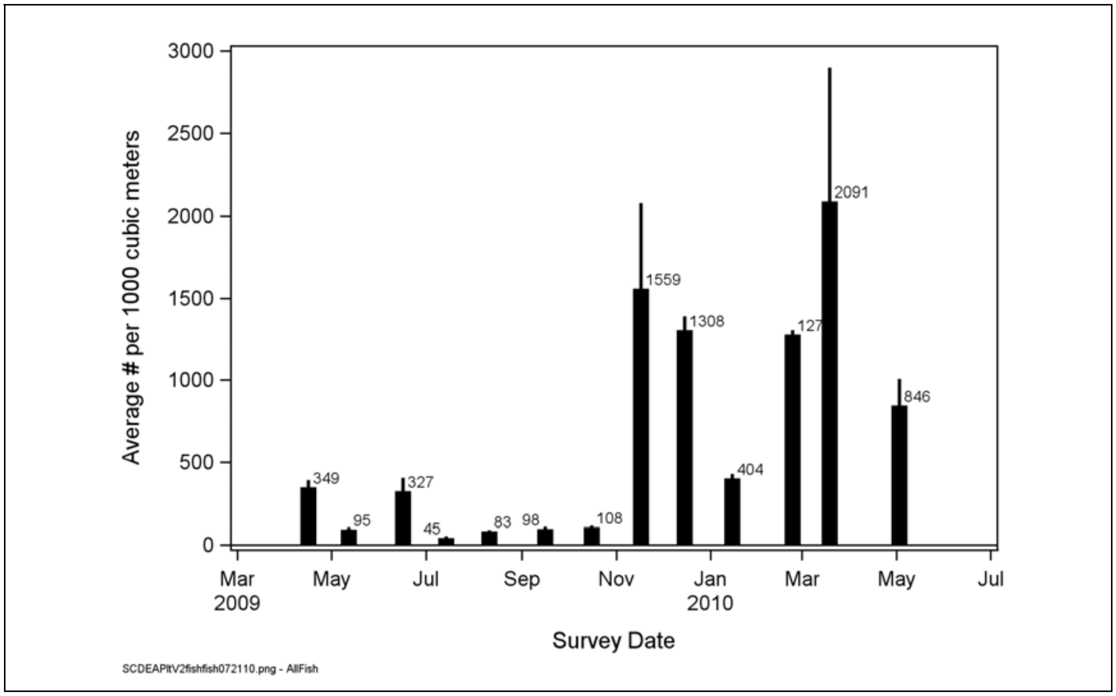


Figure 3.3-3. Mean concentration (#/1,000 m^3) and standard error for all larval fishes collected at the intake station (SWE) from April 2009 through May 2010.

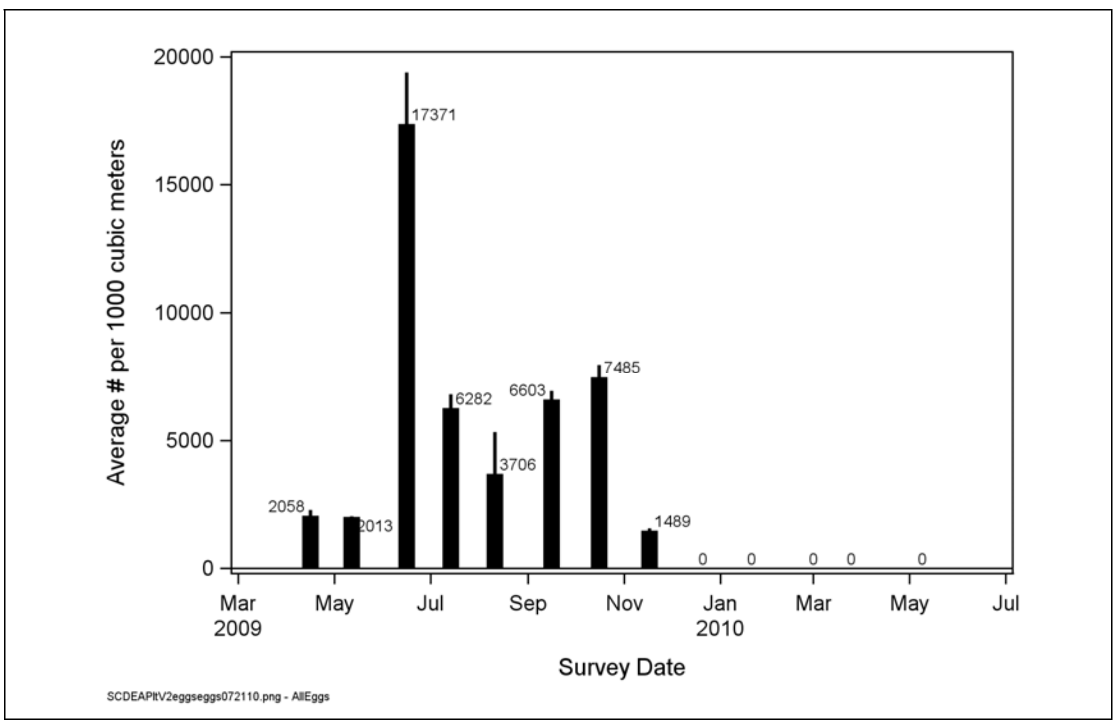


Figure 3.3-4. Mean concentration (#/1,000 m^3) and standard error for fish eggs collected at the intake station (SWE) from April 2009 through November 2009.

Note: Only four of the eight samples collected in November 2009 were processed for fish eggs.

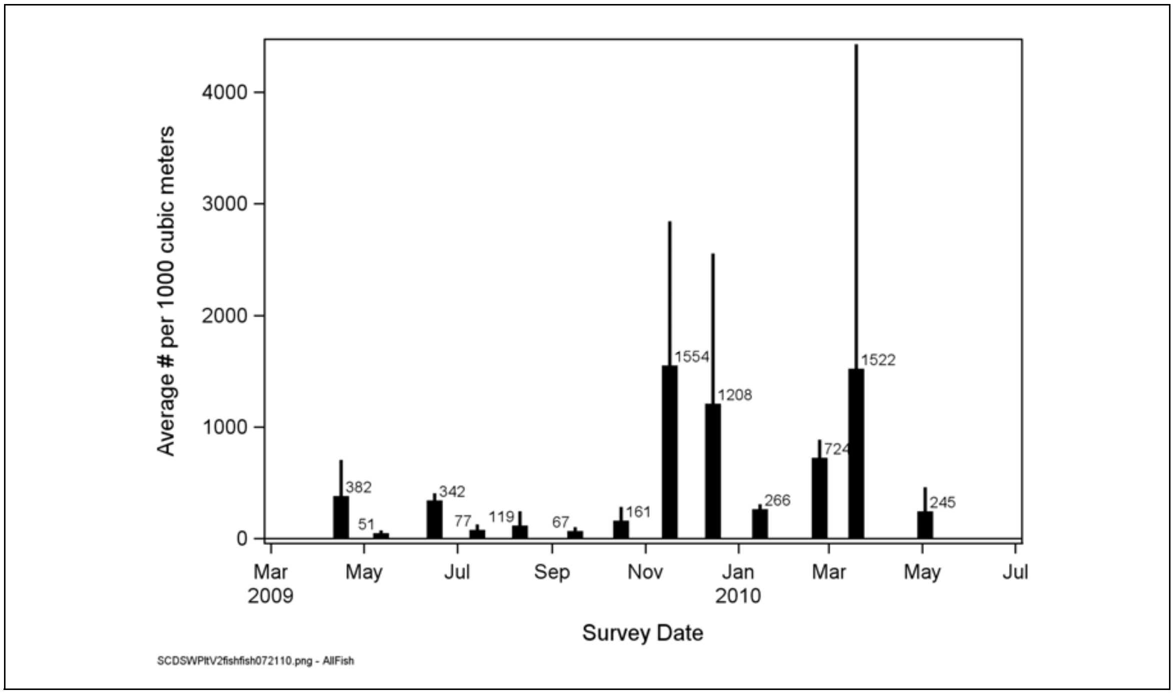


Figure 3.3-5. Mean concentration (#/1,000 m^3) and standard error for all larval fishes collected at source water stations (SW1, SW2, SW3) from April 2009 through May 2010.

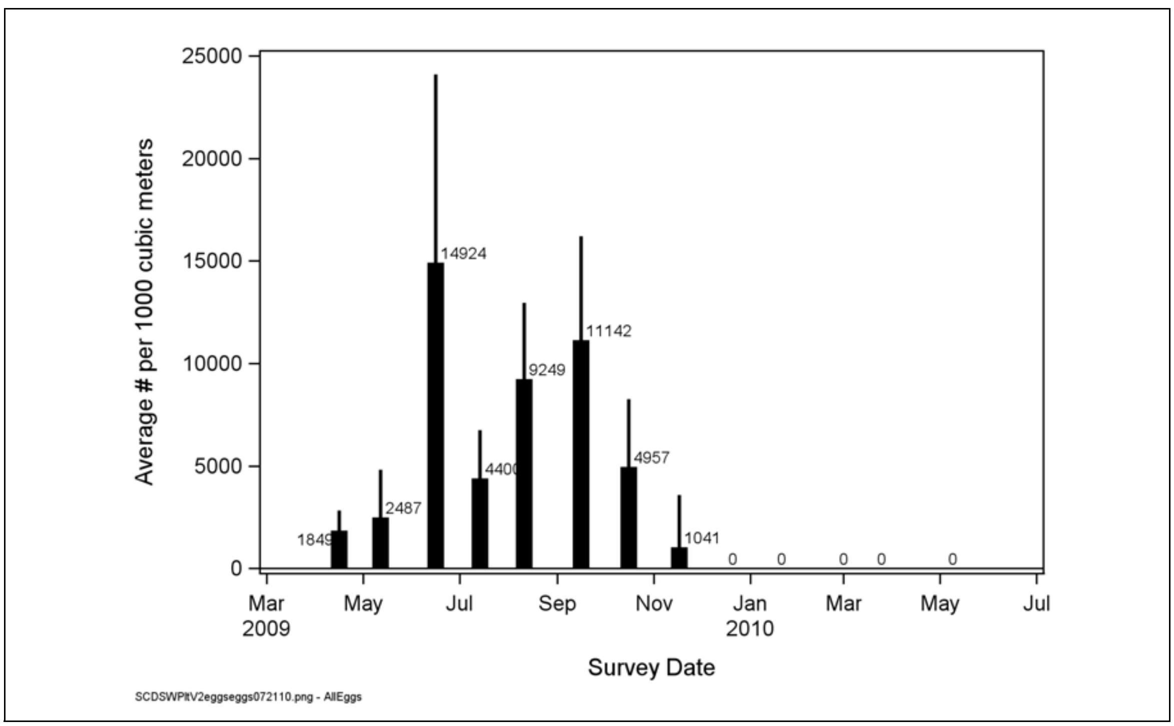


Figure 3.3-6. Mean concentration (#/1,000 m^3) and standard error for fish eggs collected at source water stations (SW1, SW2, SW3) from April 2009 through November 2009.

Note: Only one of the 12 samples collected in November 2009 were processed for fish eggs.

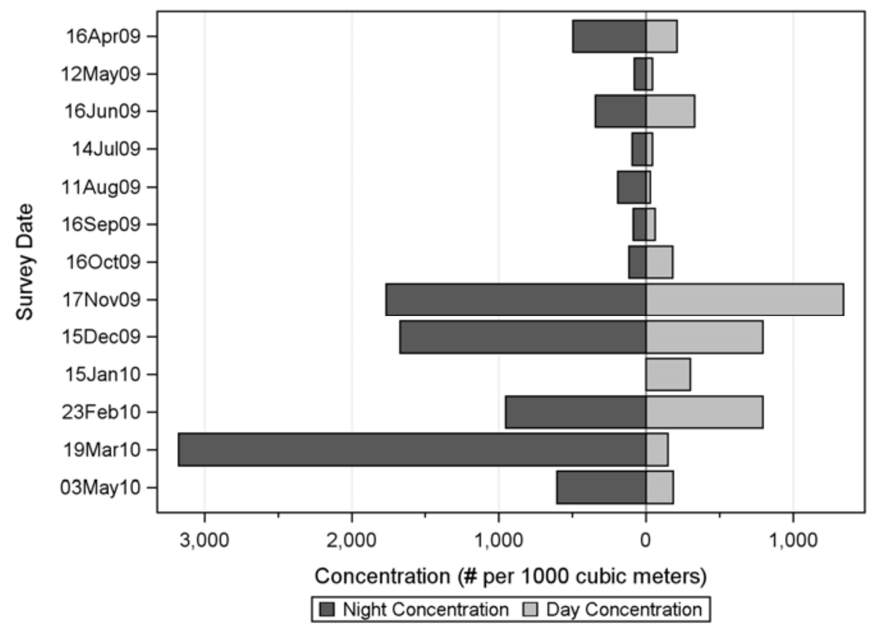


Figure 3.3-7. Mean concentration (#/1,000 m^3) in night and day samples for all larval fishes collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.

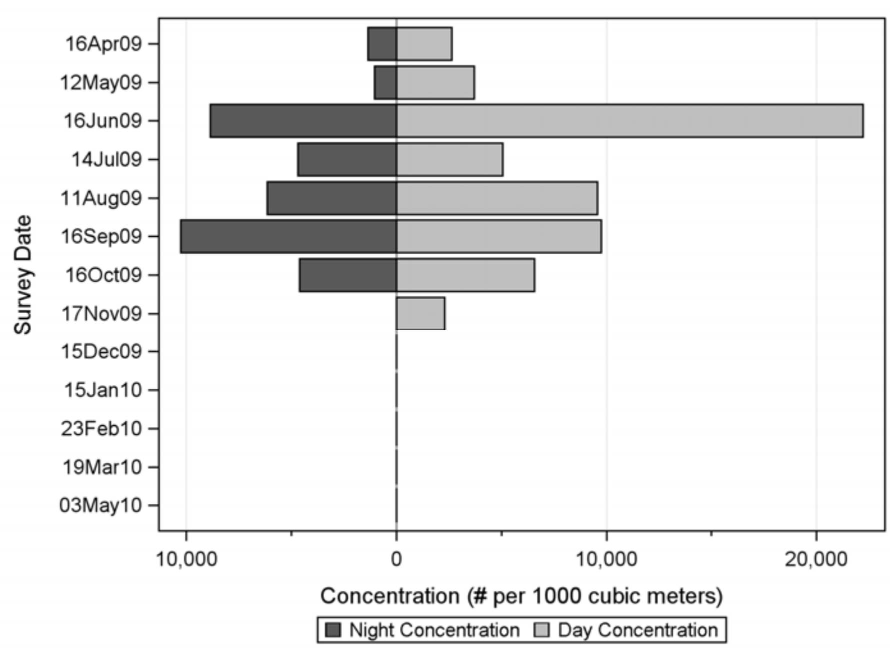


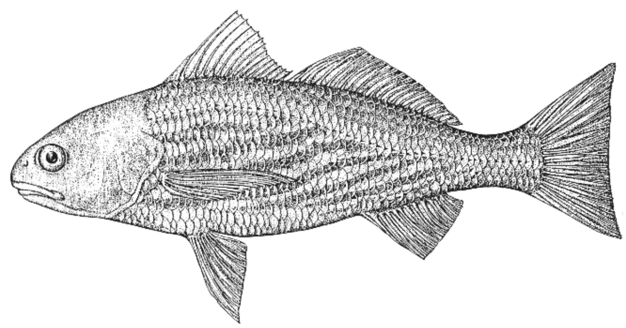
Figure 3.3-8. Mean concentration (#/1,000 m^3) in night and day samples for fish eggs collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through November 2009.

Note: Only five of the 20 samples collected in November 2009 were processed for fish eggs.

3.3.4 Analysis of Individual Taxa

Based on their high estimated average concentration and/or importance to recreational and commercial fisheries, seven larval fish taxa that comprised approximately 70% of the larval fish population at the location of the proposed intake were selected for detailed analysis. The taxa included for detailed analysis based on high estimated average concentrations were white croaker, northern anchovy, CIQ goby complex, sanddabs, and smoothhead sculpins. Two additional taxa, KGB rockfishes and California halibut, were analyzed based on their recreational and commercial fishery importance. Rock crab megalops were the only target invertebrate taxon collected in large enough abundances to be assessed for potential entrainment impacts. No endangered, threatened, or listed species were collected during the 2009–2010 study.

3.3.4.1 White Croaker (*Genyonemus lineatus*)



White croaker (*Genyonemus lineatus*) range from Magdalena Bay, Baja California, north to Vancouver Island, British Columbia (Miller and Lea 1972). They are one of eight species of croakers (Family Sciaenidae) found off California. The 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).

3.3.4.1.1 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.) total length (TL), somewhere between the first and fourth year. About one-half of males mature by 140 mm (5.5 in.) TL, and one-half of females by 150 mm (5.9 in.) TL, and all fish are mature by 190 mm (7.5 in.) TL in their third to fourth year (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. Moser (1996) states that white croaker spawning in the CalCOFI area is most abundant from December–April with peak spawning occurring in March. In southern California, white croaker larvae were generally more abundant in the upper 30 m (98 ft) of the water column at their inshore stations (Moser and Pommeranz 1999). 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 year, 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). 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).

Newly hatched white croaker larvae are 1–2 mm standard length (SL) (0.04–0.08 in.) and are 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).

3.3.4.1.2 Population Trends and Fishery

White croaker have both commercial and recreational fishery value in Monterey Bay, and California in general, although no commercial landings were reported for Santa Cruz County during 2005–2009 (PacFIN 2010). Recreational catch in central California occurs from piers, breakwaters, and private boats (Love 1996). The average estimated annual catch from 2005–2009 from all sources in central California was 28,565; highest estimated catch of 51,129 occurred in 2005 and lowest (3,511) occurred in 2009 (RecFIN 2010; **Table 3.3-5**).

Table 3.3-5. White croaker recreational fishing catch in central California from 2005–2009. Data from RecFIN (2010).

	Recreational Fishery	
Year	**Estimated Catch (No.)**	**Estimated Weight (lb)**
2005	51,129	15,426
2006	45,856	12,093
2007	33,932	8,416
2008	8,400	1,917
2009	3,511	1,364
Average	**28,565**	**7,843**

3.3.4.1.3 Sampling Results

White croaker was the most abundant taxon collected from both the intake and source water stations. It comprised 51.6% and 47.6% of the total mean concentration of larvae at the intake and source water stations, respectively (**Tables 3.3-2** and **3.3-4**). At the intake station (SWE) white croaker larvae were collected during nine of the 13 surveys, with peak concentration (1,870/1,000 m^3) occurring in March 2010 (**Figure 3.3-9**). No white croaker larvae were collected at the intake station during the May, July, September, and October 2009 surveys. At the source water stations (SW1–SW3) white croaker larvae were collected during ten of the 13 surveys, with peak concentration (1,277/1,000 m^3) also occurring in March 2010 (**Figure 3.3-10**). No white croaker larvae were collected at the source water stations during the May, August, and September 2009 surveys. The low concentrations observed in January 2010 may have occurred because no nighttime samples could be collected at either the intake station or the source water stations due to unsafe sea conditions. White croaker larvae were generally more abundant during the night sampling than during the day (**Figure 3.3-11**).

A total of 278 white croaker was measured. The smallest larva of those measured was 1.4 mm (0.06 in.) NL and the largest was 9.4 mm (0.37 in.) NL. The mean length of the bootstrap sample of 200 proportionally drawn from the 278 larvae measured was 4.66 mm (0.18 in.) notochord length (NL) (**Figure 3.3-12**). The overall size distribution of the larvae collected at all stations was bimodal with about 40% of the larvae being less than 3 mm (0.12 in.) and about 30% being between about 6 and 7 mm (0.24–0.28 in.). The averages from the 1,000 random samples of 100 proportionally drawn from all the measurements resulted in a median length of 4.6 mm (0.18 in.). The hatch length was estimated at 3.1 mm (0.12 in.), which is larger than the value reported from Moser (1996) of approximately 1.8 mm (0.07 in.). As a result, the average 10th percentile value of 1.8 mm (0.07 in.) from the set of random samples was used in calculating the period of exposure to entrainment.

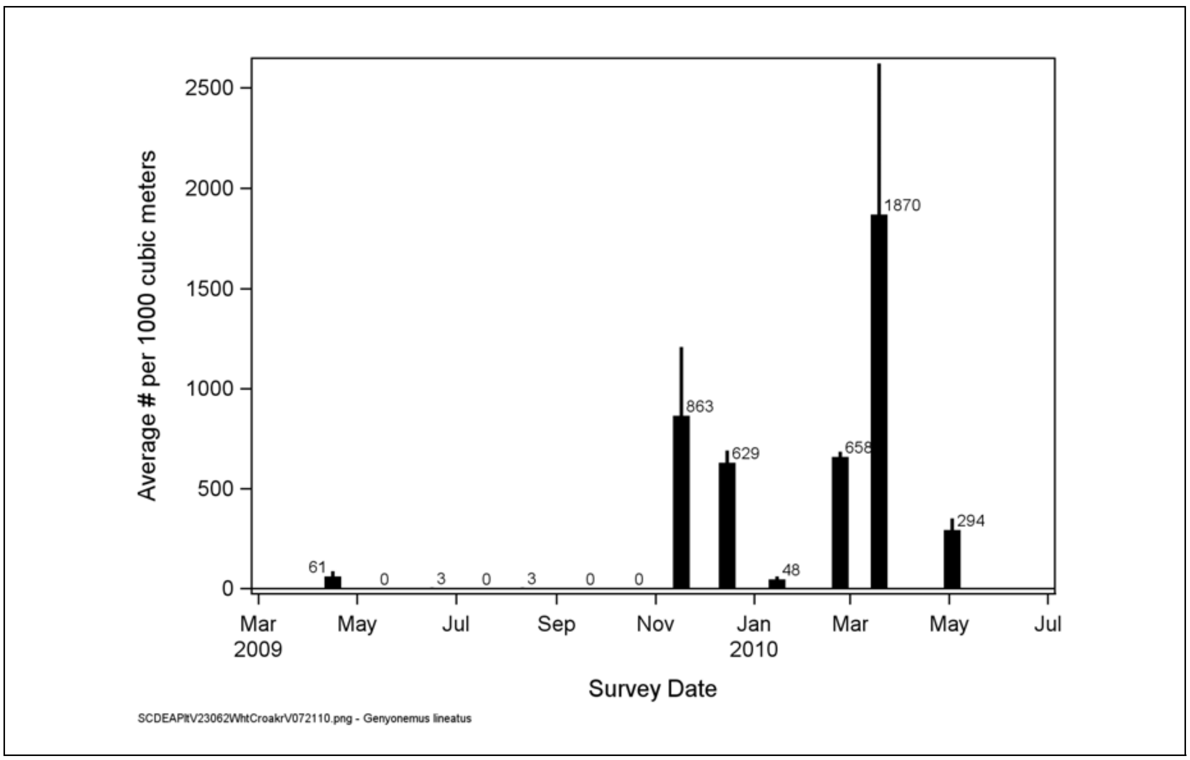


Figure 3.3-9. Survey mean concentration (#/1,000 m^3) of white croaker larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

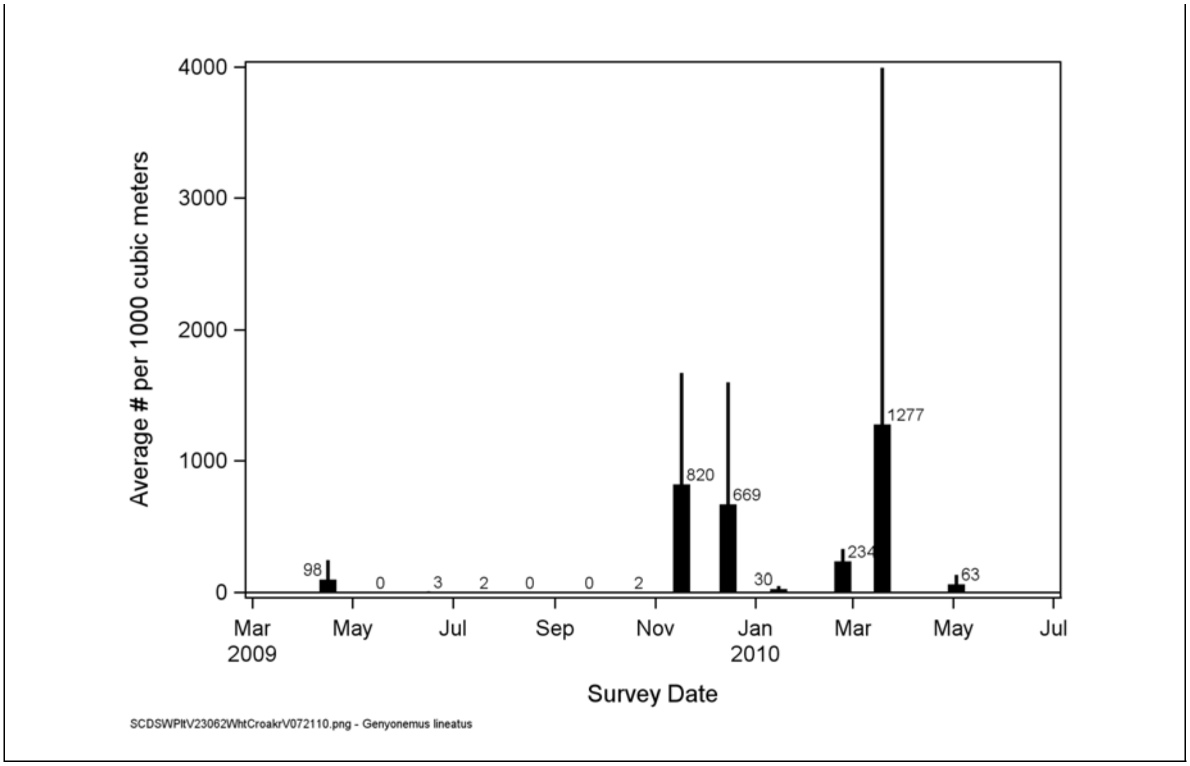


Figure 3.3-10. Survey mean concentration (#/1,000 m^3) of white croaker larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

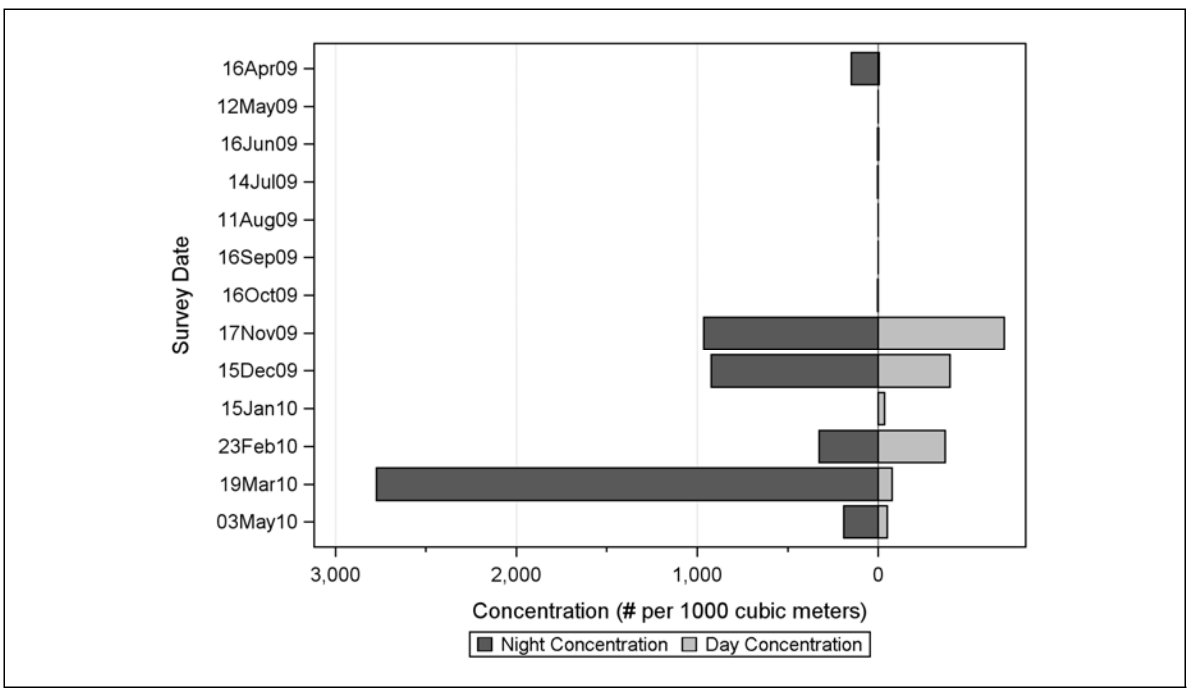


Figure 3.3-11. Mean concentration (#/1,000 m^3) in night and day samples for white croaker larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.

Note: No nighttime samples were collected during the January 2010 survey.

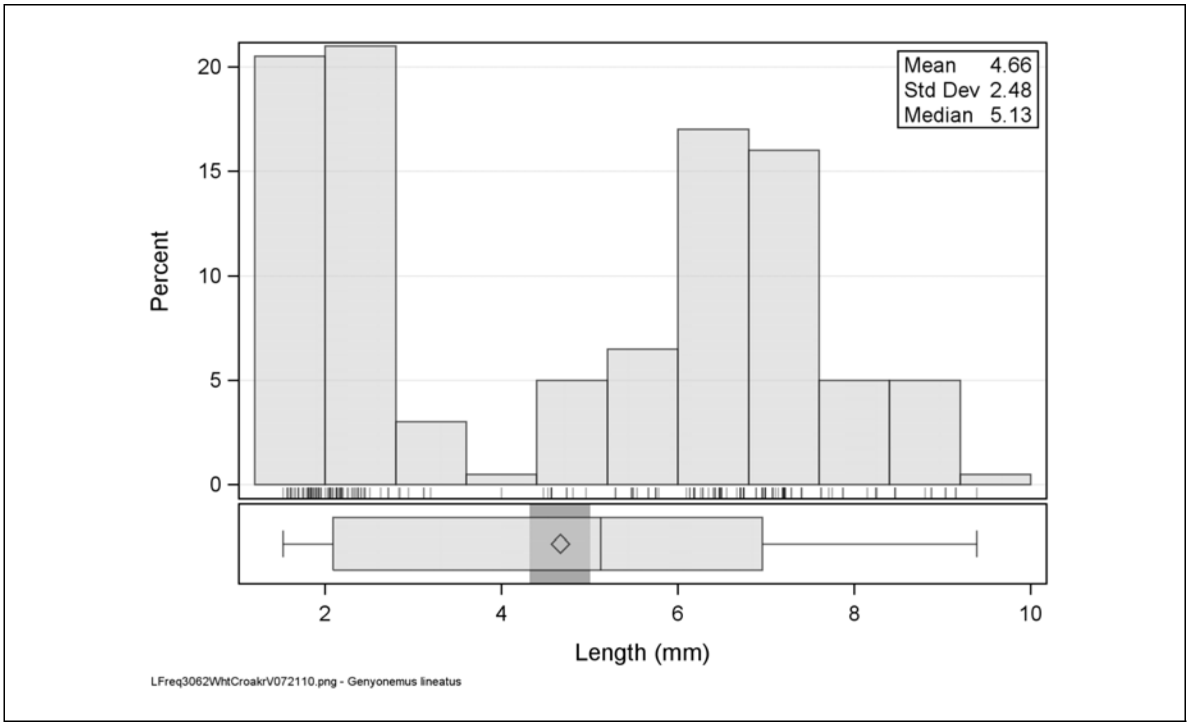


Figure 3.3-12. Length frequency histogram (NL) and statistics for white croaker larvae at all stations based on a sample of 200 larvae proportionally sampled with replacement from the 278 white croaker larvae measured.

3.3.4.1.4 Impact Assessment

An estimated 3.60 million white croaker larvae would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake.

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 (0.01 in./d). The estimated period of entrainment exposure of 26.8 days (d) was calculated by dividing the difference between an estimated hatch length of 1.8 mm (0.07 in.) and the size of the 95th percentile value of 8.5 mm (0.33 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 29.0 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 were in highest abundance in the source water in March 2010 (**Figure 3.3-10** and **Table 3.3-6**). The 30 d period of larval exposure resulted in an average alongshore displacement of 120 km (75 mi) for all of the surveys and just over 100 km (62 mi) when white croaker larvae were present at the source water stations. During the March 2010 survey, which had the highest weight due to the abundances in the source water, the current displacement was only 83.5 km (52 mi) indicating slower average currents during the period preceding this survey. The low intake volumes result in P_M estimates for the 29 d period of exposure which range from 0.00023 (0.023%) to 0.00084 (0.084%) (**Table 3.3-7**).

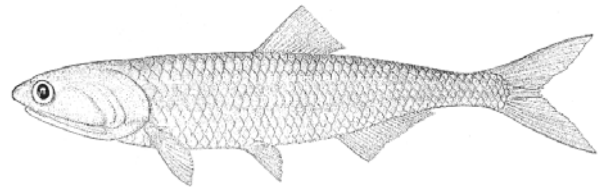
Table 3.3-6. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for white croaker using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000037	0.000009	0.000085	0.000020	0.000134	0.000032	0.0270	182.78	0.0246
5/12/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	182.21	0.0247
6/16/09	0.000084	0.000059	0.000196	0.000138	0.000307	0.000217	0.0010	167.07	0.0269
7/14/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0004	118.62	0.0379
8/11/09	0.000357	0.000345	0.000833	0.000805	0.001309	0.001264	0.0003	159.94	0.0281
9/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	173.46	0.0259
10/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0004	175.27	0.0257
11/17/09	0.000103	0.000036	0.000241	0.000084	0.000378	0.000132	0.2135	88.39	0.0509
12/15/09	0.000094	0.000032	0.000219	0.000075	0.000345	0.000117	0.1710	68.52	0.0657
1/15/10	0.000116	0.000023	0.000271	0.000054	0.000426	0.000086	0.0123	47.40	0.0949
2/23/10	0.000176	0.000016	0.000411	0.000037	0.000645	0.000058	0.0987	36.97	0.1217
3/19/10	0.000126	0.000075	0.000294	0.000175	0.000461	0.000274	0.4430	83.52	0.0539
5/3/10	0.000231	0.000071	0.000540	0.000165	0.000849	0.000259	0.0324	79.19	0.0568
Average >0	0.000147		0.000343		0.000539			101.53	
Average	0.000102		0.000238		0.000373			120.26	

Table 3.3-7. *ETM* estimates for white croaker larvae calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00023	0.00177	0.00199	0.00000
7 mgd (26,498 m^3)	0.00053	0.00412	0.00465	0.00000
11 mgd (41,640 m^3)	0.00084	0.00647	0.00731	0.00000

3.3.4.2 Northern Anchovy (*Engraulis mordax*)



Northern anchovy (*Engraulis mordax*) range from British Columbia to southern Baja California (Emmett et al. 1991). Juveniles are generally more common inshore and in estuaries. Eggs are found from the surface to 50 m (164 ft), and larvae are found from the surface to 75 m (246 ft) in epipelagic and nearshore waters (Garrison and Miller 1982). Northern anchovy larvae feed on dinoflagellates, rotifers, and copepods (MBC 1987), while juveniles and adults feed on zooplankton, including planktonic crustaceans and fish larvae (Fitch and Lavenberg 1971, Frey 1971, Hart 1973, PFMC 1983). Northern anchovy feed largely during the night, though they were previously thought to feed mainly during the day (Allen and DeMartini 1983). Three genetically distinct subpopulations are recognized for northern anchovy: (1) Northern subpopulation, from northern California to British Columbia; (2) Central subpopulation, off southern California and northern Baja California; and (3) Southern subpopulation, off southern Baja California (Emmett et al. 1991).

3.3.4.2.1 Reproduction, Age, and Growth

Northern anchovy spawn throughout the year off southern California, with peak spawning between February and May (Brewer 1978). Moser and Smith (1993) analyzed the CalCOFI larval fish data from 1951–1984 and found that northern anchovy generally spawned from January–April with peak spawning in March. The Central California region is an area of overlap between the northern and central anchovy stocks (Parrish et al. 1985). A fall spawning stock may occur in central California and the offshore areas of the Southern California Bight. Most spawning takes place within 100 km (62.1 mi) from shore (MBC 1987). On average, female anchovy off Los Angeles spawn every 7–10 days during peak spawning periods, approximately 20 times per year (Hunter and Macewicz 1980, MBC 1987). In 1979, it was determined that most spawning occurs at night (2100 to 0200 hr), with spawning complete by 0600 hr (Hunter and Macewicz 1980). Northern anchovy off southern and central California can reach sexual maturity by the end of their first year of life, with all individuals being mature by four years of age (Clark and Phillips 1952, Daugherty et al. 1955, Hart 1973). The maturation rate of younger individuals is dependent on water temperature (Bergen and Jacobsen 2001). Love (1996) reported that they release 2,700–16,000 eggs per batch, with an annual fecundity of up to 130,000 eggs per year in southern California. Parrish et al. (1986) and Butler et al. (1993) stated that the total annual fecundity for one-year-old females was 20,000–30,000 eggs, while a five-year-old could release up to 320,000 eggs per year.

The northern anchovy egg hatches in two to four days, has a larval phase lasting approximately 70 days, and undergoes transformation into a juvenile at about 35–40 mm (1.4–1.6 in.) (Hart 1973, MBC 1987, Moser 1996). Larvae begin schooling at 11–12 mm (0.43-0.47 in.) standard length (SL) (Hunter and Coyne 1982). Moser and Pommeranz (1999) found about 90% of the northern anchovy larvae occurred in the upper 30 m (98 ft) of the water column. In their bongo net collections, the majority of these larvae were less than 6 mm (0.24 in.) in length. Collins

(1969) presented age at length and weight at length regressions based on data from the southern California reduction fishery from which an average age 1 fish is estimated as 115 mm (4.5 in.) weighing 14.9 g (0.5 oz). Northern anchovy reach 102 mm (4 in.) in their first year, and 119 mm (4.7 in.) in their second (Sakagawa and Kimura 1976). In the area occupied by the central stock, growth during the juvenile phase shows considerable variation among regions (Parrish et al. 1985). There were significant differences in growth to age 1½. Fastest growth occurred in the north, and the slowest was in the south. Mean standard length at 1½ yrs of age was 123.6 mm (4.9 in.) in the Central California region, 113.4 mm (4.5 in.) in the San Pedro Channel region, and 103.6 mm (4.1 in.) in the Cape San Quentin region. Growth in length is most rapid during the first four months, and growth in weight is most rapid during the first year (Hunter and Macewicz 1980, PFMC 1983). They mature at 78–140 mm (3.1–5.5 in.) in length, in their first or second year (Frey 1971, Hunter and Macewicz 1980). Maximum size is about 230 mm (9 in.) and 60 g (2.1 oz) (Fitch and Lavenberg 1971, Eschmeyer et al. 1983). Maximum age is about seven years (Hart 1973), though most live less than four years (Fitch and Lavenberg 1971).

3.3.4.2.2 Population Trends and Fishery

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

Historically, estimates of the central subpopulation averaged about 325,700 metric tons (MT) (359,000 tons) from 1963 through 1972, then increased to over 1,542,200 MT (1.7 million tons) in 1974, then declined to 325,700 MT (359,000 tons) in 1978 (Bergen and Jacobsen 2001). Anchovy biomass in 1994 was estimated at 391,900 MT (432,000 tons). The stock is thought to be stable, and the size of the anchovy resource is largely dependent on natural influences such as ocean temperature. Annual landings in the Monterey region since 2005 have varied from a high of over 12,000 MT (27 million lb) in 2008 to a low of 978 MT (2.2 million lb) in 2009 (**Table 3.3-8**), with an average of 15.3 million lb annually. There are no commercial landings of northern anchovy listed for Santa Cruz County in the PacFIN database.

Table 3.3-8. Annual landings and revenue for northern anchovy from Monterey County for 2005–2009 (PacFIN 2010).

Year	Landed Weight (MT)	Landed Weight (lb)	Revenue ($)
2005	6,176	13,614,907	$375,769
2006	7,624	16,808,634	$559,778
2007	7,699	16,972,451	$801,169
2008	12,215	26,928,268	$1,305,479
2009	978	2,156,994	$107,850
Average	**6,938**	**15,296,251**	**$630,009**

3.3.4.2.3 Sampling Results

Northern anchovy was the second abundant taxon collected from both the intake and source water stations. It comprised 5.8% and 6.7% of the total mean concentration of larvae at the intake and source water stations, respectively (**Tables 3.3-2** and **3.3-4**). At the intake station (SWE) northern anchovy larvae were collected during ten of the 13 surveys, with peak concentration (140/1,000 m^3) occurring in February 2010 (**Figure 3.3-13**). No northern anchovy larvae were collected at the intake station during the April, May and August 2009 surveys. At the source water stations (SW1–SW3), northern anchovy larvae were collected during eight of the 13 surveys, with peak concentration (126/1,000 m^3) also occurring in February 2010 (**Figure 3.3-14**). No northern anchovy larvae were collected at the source water stations during the April, May, July, August, and October 2009 surveys. The low concentrations observed in January 2010 may have occurred because no nighttime samples could be collected at either the intake station or the source water stations due to unsafe sea conditions. Northern anchovy larvae were generally more abundant during the nighttime sampling than during the daytime (**Figure 3.3-15**).

A total of 126 northern anchovy was measured. The mean, maximum, and minimum sizes from measured northern anchovy were 13.2, 32.4, and 1.8 mm (0.46, 1.28, 0.07 in.), respectively. Statistical analysis of a random sample of 200 proportionally drawn from the 126 measured larvae was used to estimate a mean length of 11.7 mm (0.46 in.) (**Figure 3.3-16)**. This figure is based on a sample of 200 larvae proportionally sampled with replacement from the 126 northern anchovy larvae that were measured. The length frequency distribution of the proportionally drawn random sample of 200 lengths from the 126 measured northern anchovy larvae shows a tri-modal distribution with approximately 55% being less than 5 mm (0.20 in.), about 27% being between about 15-21 mm (0.59-0.83 in.), and about 10% being larger than 27 mm (1.1 in.).

The averages from the 1,000 random samples of 100 proportionally drawn from all the measurements resulted in a median length of 6.0 mm (0.23 in.). The hatch length was estimated at 3.9 mm (0.15 in.), which is larger than the value reported from Moser (1996) of 2.5–3.0 mm (0.10–0.12 in.). As a result, the average 10th percentile value of 2.3 mm (0.09 in.) from the set of random samples was used in calculating the period of exposure to entrainment.

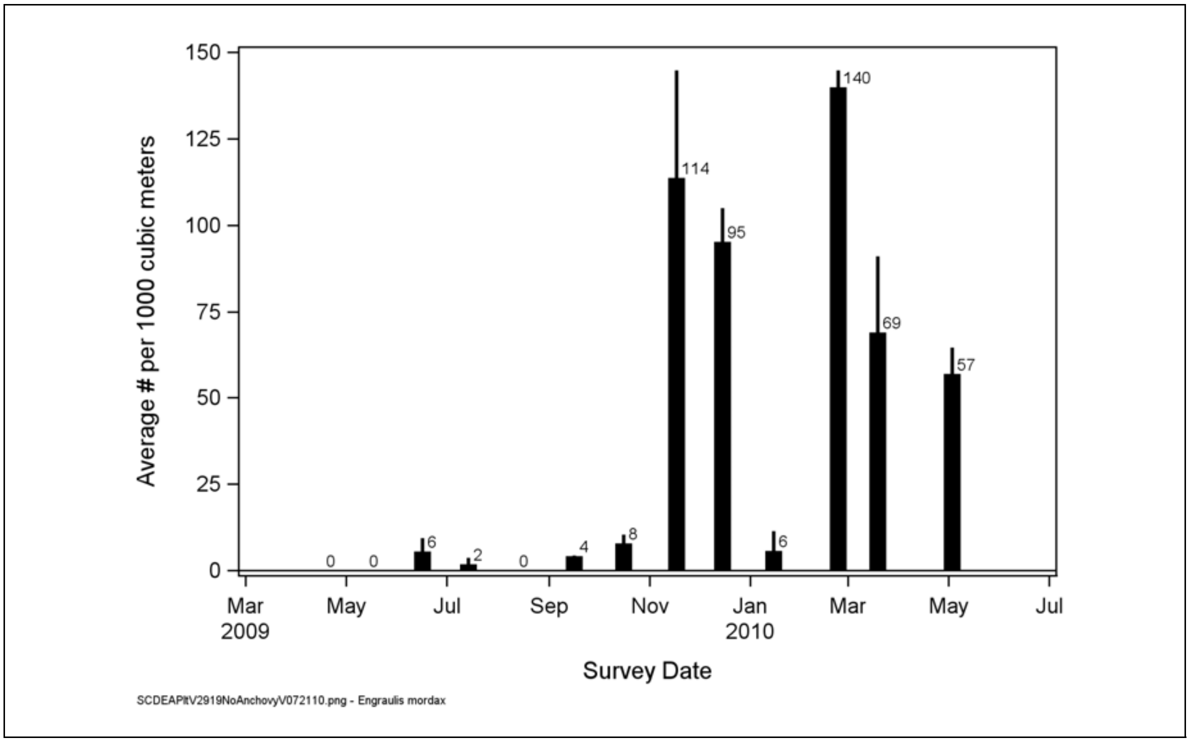


Figure 3.3-13. Survey mean concentration (#/1,000 m^3) of northern anchovy larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

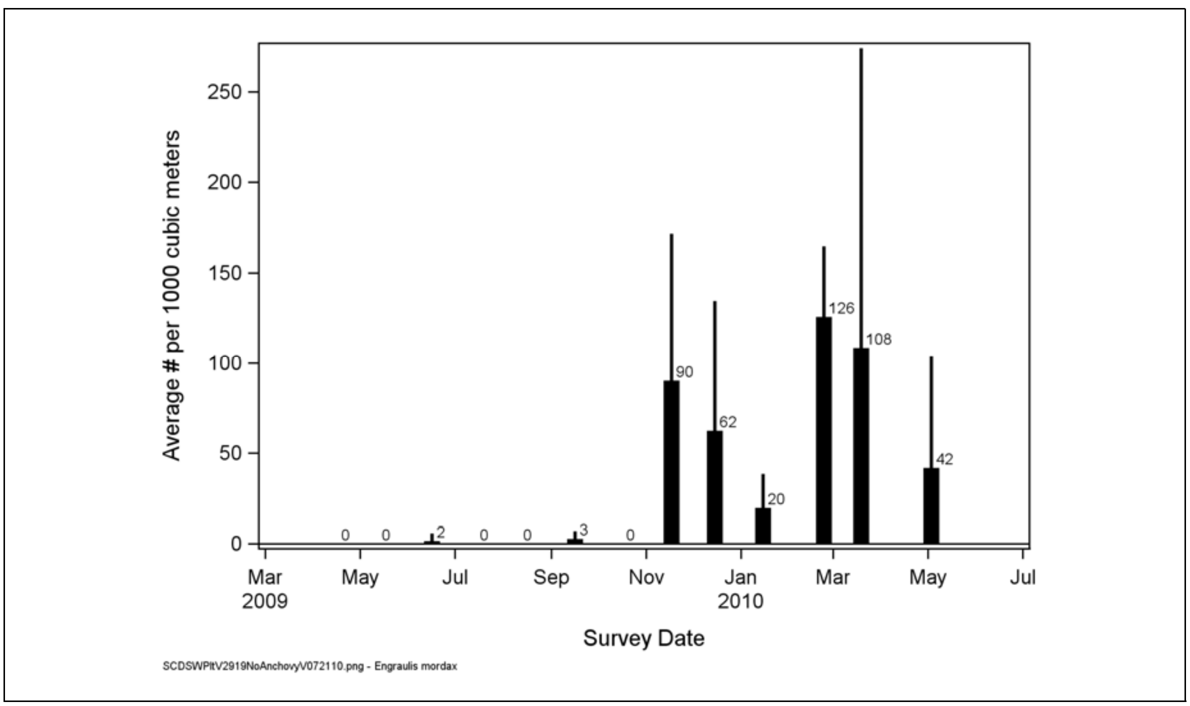


Figure 3.3-14. Survey mean concentration (#/1,000 m^3) of northern anchovy larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

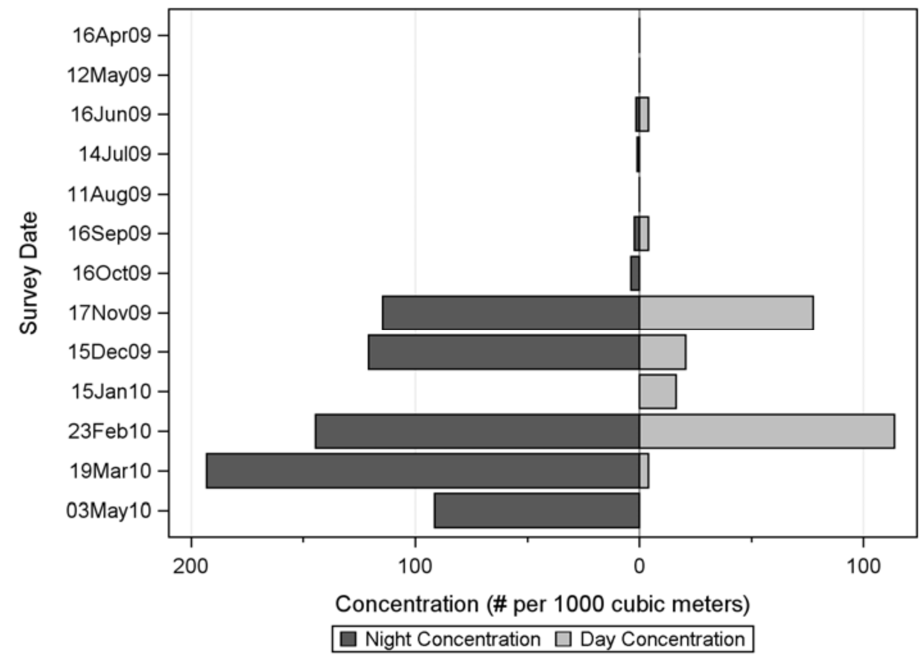


Figure 3.3-15. Mean concentration (#/1,000 m^3) in night and day samples for northern anchovy larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010. *Note: No nighttime samples were collected during the January 2010 survey.*

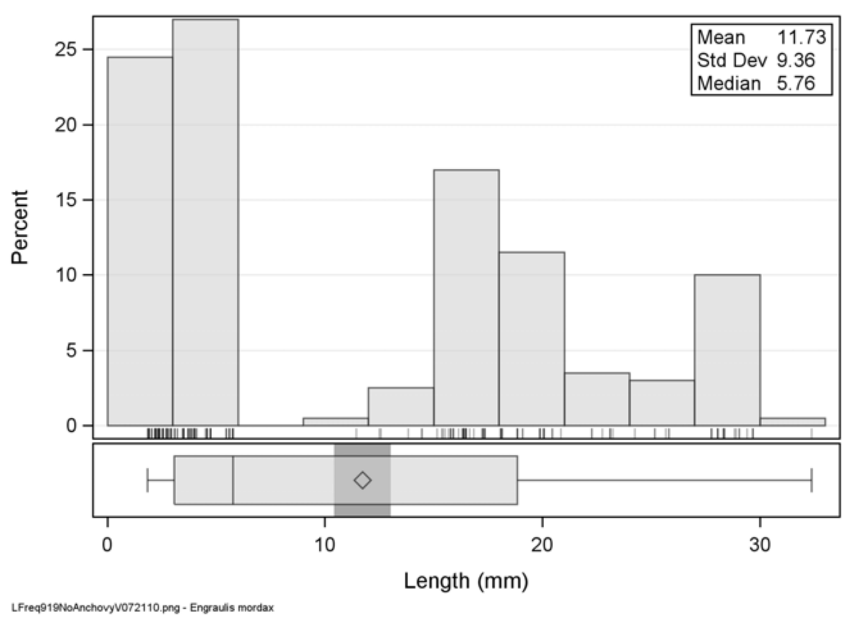


Figure 3.3-16. Length frequency histogram (NL) and statistics for northern anchovy larvae at all stations based on a sample of 200 larvae proportionally sampled with replacement from the 126 northern anchovy larvae measured.

3.3.4.2.4 Impact Assessment

An estimated 380,000 northern anchovy larvae would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake.

Empirical Transport Model (*ETM*)

The estimated period of entrainment exposure for northern anchovy larvae was calculated by dividing a larval growth rate of 0.4 mm/day (0.02 in./day) from Methot and Kramer (1979) into the difference between the estimated hatch length of 2.3 mm (0.09 in.) and the size of the 95th percentile value of 28.2 mm (1.11 in.). The estimated larval duration of 52.9 d was added to the estimated duration of the planktonic egg stage of 2.9 d for a total duration of entrainment exposure of 55.8 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 northern anchovy larvae show that they were in highest abundance in the source water in February and March 2010 (**Figure 3.3-14** and **Table 3.3-9**). The 56 d period of larval exposure resulted in an average alongshore displacement of 226 km (140 mi) for all of the surveys and just over 209 km (130 mi) when northern anchovy larvae were present at the source water stations. During the February and March 2010 surveys, which had the highest weights due to the abundances in the source water, the current displacement was less indicating slower average currents during the period preceding these surveys. The low intake volumes result in P_M estimates for the 56 d period of exposure that range from 0.00020 (0.020%) to 0.00074 (0.074%) (**Table 3.3-10**).

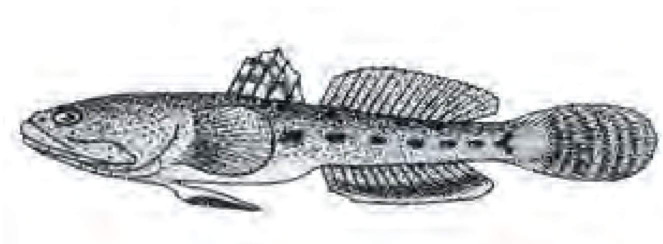
Table 3.3-9. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for northern anchovy larvae using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	225.49	0.0200
5/12/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	352.17	0.0128
6/16/09	0.000191	0.000101	0.000446	0.000236	0.000701	0.000371	0.0058	376.36	0.0120
7/14/09	0.000331	0.000320	0.000773	0.000747	0.001215	0.001173	0.0010	265.60	0.0169
8/11/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	268.94	0.0167
9/16/09	0.000145	0.000073	0.000338	0.000171	0.000532	0.000268	0.0063	318.45	0.0141
10/16/09	0.000357	0.000301	0.000833	0.000702	0.001309	0.001103	0.0044	334.48	0.0135
11/17/09	0.000118	0.000034	0.000275	0.000080	0.000432	0.000125	0.1882	251.07	0.0179
12/15/09	0.000114	0.000040	0.000265	0.000094	0.000416	0.000147	0.1634	82.82	0.0543
1/15/10	0.000027	0.000019	0.000063	0.000044	0.000098	0.000070	0.0485	107.14	0.0420
2/23/10	0.000101	0.000011	0.000235	0.000026	0.000369	0.000041	0.2800	117.68	0.0382
3/19/10	0.000072	0.000039	0.000169	0.000091	0.000265	0.000143	0.2169	105.73	0.0426
5/3/10	0.000130	0.000064	0.000302	0.000149	0.000475	0.000235	0.0856	132.49	0.0340
Average >0	0.000159		0.000370		0.000581			209.18	
Average	0.000122		0.000285		0.000447			226.03	

Table 3.3-10. *ETM* estimates for northern anchovy larvae calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00020	0.00098	0.00118	0.00000
7 mgd (26,498 m^3)	0.00047	0.00229	0.00276	0.00000
11 mgd (41,640 m^3)	0.00074	0.00360	0.00434	0.00000

3.3.4.3 Unidentified Gobies: CIQ Goby Complex



Most adult gobies are small (<10 cm [3.9 in.]) and inhabit bays, estuaries, lagoons, and nearshore open coastal waters (Allen 1985, Moser 1996). Marine gobies occupy a variety of habitats, including mudflats and reefs. Many of the soft-bottom species live in burrows where they shelter from predators, escape desiccation during low tides, and brood eggs (Brothers 1975).

Larval gobiids are distinctive and unlikely to be confused with other larval fishes, but positive identification of larval gobies to the species level based on pigmentation characteristics remains difficult. Three co-occurring species cannot be differentiated with certainty during early larval stages: arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*) (Moser 1996). All three are considered common in southern California (Miller and Lea 1972), but only the arrow and cheekspot typically occur as far north as Monterey Bay. The three species were combined into the CIQ goby complex for analysis. Descriptions of the life histories of arrow, cheekspot, and shadow gobies were compiled from Brothers (1975) and were used to parameterize the analysis models.

3.3.4.3.1 Reproduction, Age, and Growth

Arrow goby mature at approximately one year post-settlement, but cheekspot and shadow gobies mature at about three years (Brothers 1975). Gobies are oviparous, and the demersal eggs are elliptical, typically adhesive, and about 2–4 mm (0.08–0.16 in.) long (Moser 1996). Primary spawning activity of arrow goby occurs from March through June (Prasad 1958), but protracted spawning can occur in arrow, shadow, and cheekspot gobies (Brothers 1975). High abundances of arrow goby larvae in southern California were seen from March to September corresponding to the timing of settlement (Brothers 1975). Settlement of shadow and cheekspot gobies typically occurs in late summer and early fall (Brothers 1975).

Arrow goby grows faster than cheekspot and shadow gobies (Brothers 1975). After maturity, however, growth rate in the arrow goby declines. Shadow and cheekspot gobies settle at smaller sizes and grow more slowly, but the growth rate is relatively constant for their entire life. Shadow and cheekspot gobies can live up to four years, while arrow goby rarely live longer than three years. In southern California, arrow goby reaches maximum lengths of 32 mm SL (1.25 in.), shadow goby 40 mm SL (1.57 in.), and cheekspot goby 46 mm SL (1.8 in.) (Brothers 1975). Brothers (1975) estimated that the population mortality of arrow goby in Mission Bay following settlement was 91% in the first year and nearly 99% thereafter. He also calculated that the annual mortality rates after settlement were 66–74% for cheekspot goby and 62–69% for shadow goby.

CIQ goby larvae hatch at a size of 2–3 mm (0.08–0.12 in.) (Moser 1996). Using data available in Brothers (1975), the average growth rate of this group was estimated at 0.16 mm/day

(0.006 in./day) for the 60-day period from hatching until settlement. Brothers (1975) estimated that larval mortality for this period was 98.3% for arrow goby, 98.6% for cheekspot, and 99.2% for shadow goby. Based on the total mortality for this period, average daily survival was calculated at 0.93 for the three species. Juveniles settle to the bottom at a size of about 10–15 mm (0.39–0.59 in.) SL (Moser 1996).

3.3.4.3.2 Population Trends and Fishery

There is no recreational or commercial fishery for gobies and no population estimates or trends were available for the area around Santa Cruz. Densities of arrow goby in southern California embayments are reported to range seasonally from 0.72 to 4.53 individuals/m^2 at the Golden Shore Marine Reserve (MBC 2003), while MacDonald (1975) reported densities of arrow goby in Anaheim Bay of 4–5/m^2, though investigation of individual burrows resulted in much higher densities (up to 20/m^2) in some locations.

3.3.4.3.3 Sampling Results

The CIQ goby complex was the third most abundant taxon during the study period at both the intake and source water stations. They comprised about 5.1% and 4.1% of the total mean concentration of larval fishes at the intake and source water stations, respectively (**Tables 3.3-2** and **3.3-4**). At the intake station (SWE) CIQ goby larvae were collected during all 13 surveys, with peak concentration (123/1,000 m^3) occurring in December 2009 (**Figure 3.3-17**). At the source water stations (SW1–SW3) CIQ goby larvae were collected during 12 of the 13 surveys, with peak concentration (62/1,000 m^3) in October 2009 (**Figure 3.3-18**). No CIQ goby larvae were collected at the source water stations during the May 2009 survey. The low concentrations observed in January 2010 may have occurred because no nighttime samples could be collected at either the intake station or the source water stations due to unsafe sea conditions. During most surveys, there was a higher concentration of CIQ gobies collected during the nighttime samples than during the daytime samples. (**Figure 3.3-19**).

A total of 131 CIQ gobies was measured. The mean, maximum, and minimum sizes for the 131 measured larvae were 5.9, 25.6, and 2.2 mm (0.23, 1.00, 0.09 in.), respectively. Statistical analysis of the random sample of 200 proportionally drawn from the 131 measured larvae was used to estimate a mean length of 6.04 mm (0.24 in.) (**Figure 3.3-20**). The length frequency distribution of the proportionally drawn bootstrap sample of 200 lengths shows that the majority of the larvae were small. The averages from the 1,000 random samples of 100 proportionally drawn from all the measurements resulted in a median length of 4.4 mm (0.17 in.). The hatch length estimated at 3.6 mm (0.14 in.) was larger than the value reported from Moser (1996) of 2.0 to 3.0 mm (0.08 to 0.12 in.). As a result, the average 1st percentile value of 2.8 mm (0.11 in.) from the set of random samples was used in calculating the period of exposure to entrainment.

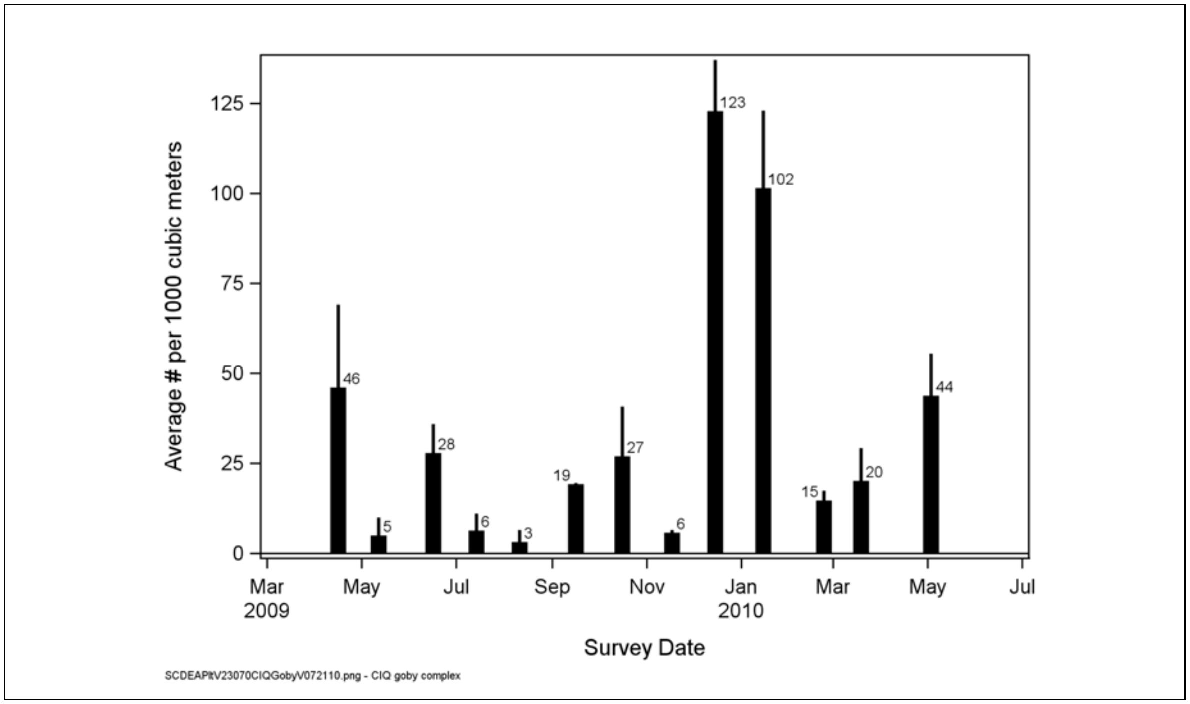


Figure 3.3-17. Survey mean concentration (#/1,000 m^3) of CIQ goby larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

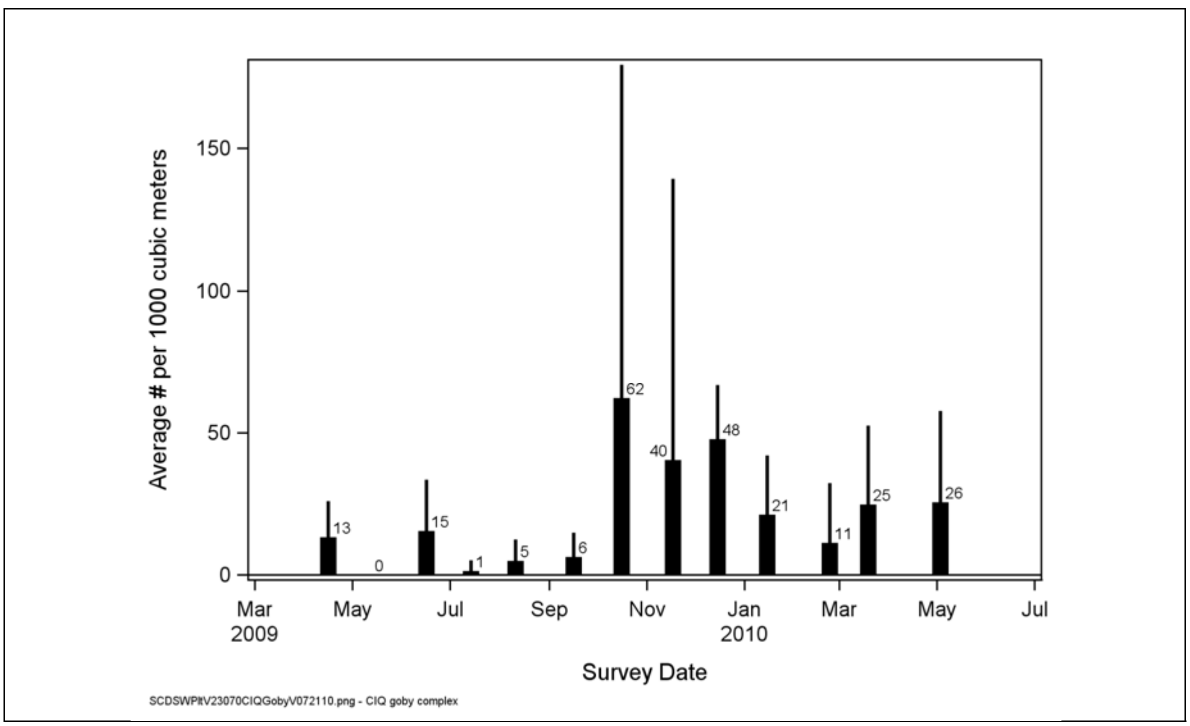


Figure 3.3-18. Survey mean concentration (#/1,000 m^3) of CIQ goby larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

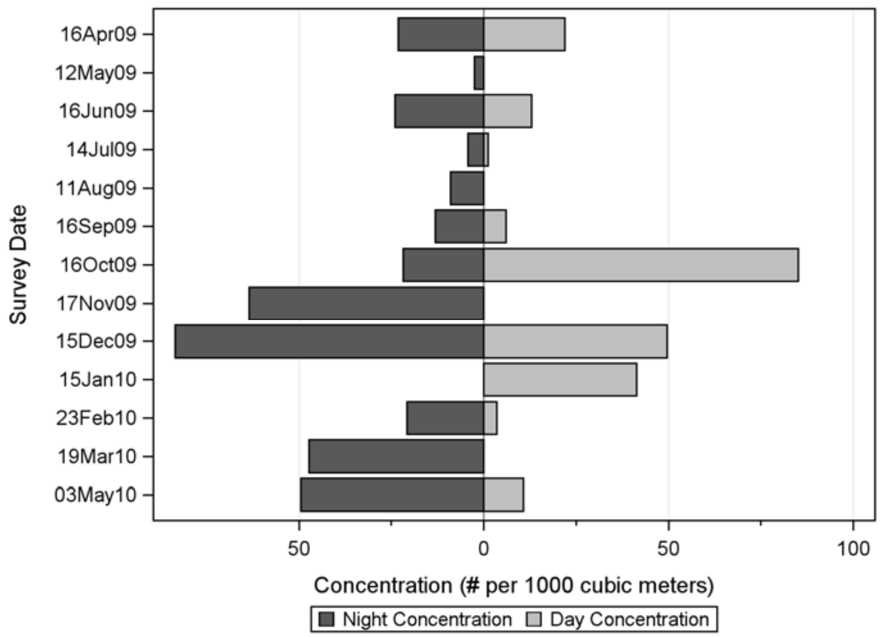


Figure 3.3-19. Mean concentration (#/1,000 m^3) in night and day samples for CIQ goby larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.

Note: No night samples were collected during the January 2010 survey.

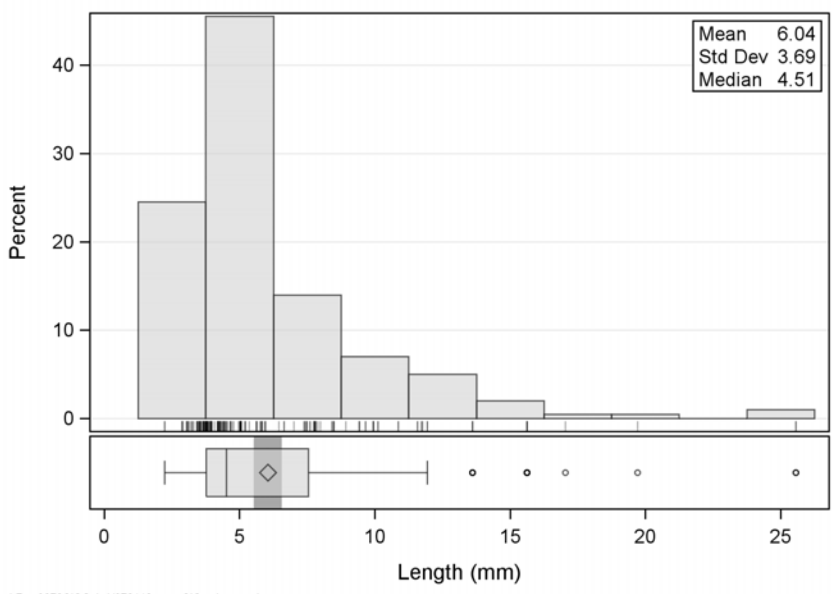


Figure 3.3-20. Length frequency histogram and statistics for CIQ goby larvae at all stations based on a sample of 200 larvae proportionally sampled with replacement from the 131 CIQ goby larvae measured.

3.3.4.3.4 Impact Assessment

An estimated 320,000 CIQ goby complex larvae would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake.

Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for CIQ goby complex was based on the difference between the estimated hatch length of 2.8 mm (0.11 in.) and the length of the 95th (12.9 mm [0.51 in.]) percentile divided by a larval growth rate of 0.16 mm/day (0.006 in./day) estimated from Brothers (1975) using his reported transformation lengths for the three species and an estimated transformation age of 60 days. These values were used to estimate that CIQ goby larvae were vulnerable to entrainment for a period of approximately 64 days.

The data used to calculate the *ETM* estimates for CIQ goby complex larvae show that they were in highest abundance in the source water in October and December 2009 (**Figure 3.3-18** and **Table 3.3-11**). The 64 d period of larval exposure resulted in an average alongshore displacement of 260 km (161 mi) when goby larvae were present at the source water stations. During the December 2009 survey, which had the highest weight due to the abundances in the source water, the current displacement was less indicating slower average currents during the period preceding this survey. The low intake volumes result in P_M estimates for the 64 d period of exposure which range from 0.00027 (0.027%) to 0.00099 (0.099%) (**Table 3.3-12**).

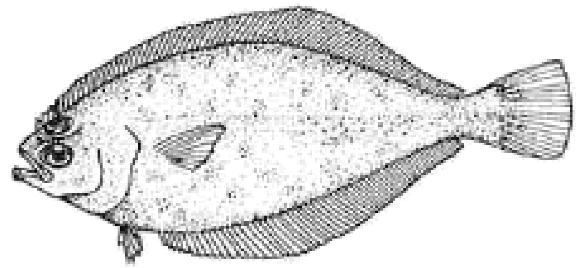
Table 3.3-11. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for CIQ goby complex larvae using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000163	0.000041	0.000380	0.000095	0.000597	0.000149	0.0539	276.66	0.0163
5/12/09	0.000357	0.000345	0.000833	0.000805	0.001309	0.001264	0.0044	358.72	0.0125
6/16/09	0.000132	0.000037	0.000308	0.000087	0.000484	0.000137	0.0655	418.16	0.0108
7/14/09	0.000242	0.000118	0.000564	0.000274	0.000886	0.000431	0.0075	358.61	0.0125
8/11/09	0.000059	0.000042	0.000137	0.000098	0.000215	0.000154	0.0179	309.50	0.0145
9/16/09	0.000197	0.000037	0.000461	0.000086	0.000724	0.000136	0.0323	376.62	0.0119
10/16/09	0.000059	0.000034	0.000138	0.000079	0.000216	0.000125	0.1425	391.98	0.0115
11/17/09	0.000023	0.000019	0.000054	0.000045	0.000084	0.000071	0.0749	281.44	0.0160
12/15/09	0.000170	0.000041	0.000396	0.000095	0.000622	0.000150	0.2180	121.23	0.0371
1/15/10	0.000243	0.000036	0.000567	0.000085	0.000891	0.000133	0.1467	107.14	0.0420
2/23/10	0.000133	0.000060	0.000311	0.000139	0.000489	0.000219	0.0343	128.71	0.0350
3/19/10	0.000075	0.000037	0.000176	0.000087	0.000277	0.000137	0.0940	105.73	0.0426
5/3/10	0.000122	0.000046	0.000284	0.000108	0.000446	0.000170	0.1082	142.66	0.0315
Average >0	0.000152		0.000354		0.000557			259.78	
Average	0.000152		0.000354		0.000557			259.78	

Table 3.3-12. *ETM* estimates for CIQ goby complex larvae calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00027	0.00076	0.00103	0.00000
7 mgd (26,498 m^3)	0.00063	0.00178	0.00241	0.00000
11 mgd (41,640 m^3)	0.00099	0.00279	0.00378	0.00000

3.3.4.4 Sanddabs (*Citharichthys* spp.)



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

3.3.4.4.1 Life History and Ecology

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

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

The larvae are 1.3–2.6 mm [0.05–0.10 in.] NL upon hatching and can occur from the Bering Sea to Southern Baja California (Moser 1996). Speckled sanddab larvae are common from August to December, with a peak in October, and Pacific sanddab larvae are common from January to February, and August to October (Moser 1996). Moser and Smith (1993) stated that *Citharichthys* spp. larvae were found from June–October with peak abundance in October in the CalCOFI samples collected from 1951–1984. The majority of the sanddabs collected by Moser and Pommeranz (1999) were 1.0–3.0 mm (0.4–1.1 in.) in length. Sanddabs have a lengthy larval duration, with Pacific sanddab larvae being in the water for 271 days and speckled sanddab larvae for 324 days (Sakuma and Larson 1995). Larval transformation occurs at a length of approximately 24–40 mm (0.94–1.57 in.) SL (Moser 1996) at which time the young fish settle to the bottom. Females mature at 2–3 years and 19–22.5 cm (7.5–8.9 in.) SL (Love 1996). Pacific sanddab may reach 41 cm (16 in.) while speckled sanddab is smaller reaching a maximum length of 17. 8 cm (7 in.) (Love et al. 2005). Love (1996) stated that sanddabs can live to an age of at least 11 years.

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

3.3.4.4.2 Population Trends and Fishery

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

Although sanddabs are not as important to California fisheries as some other species of flatfishes, they are caught in fairly substantial numbers in both commercial and recreational fisheries. Most landings of sanddabs are taken commercially by otter trawls and some by hook and line, particularly off San Francisco and Eureka. Early landings during the 1920s were fairly high, while annual landings from 1930 to 1974 were below 454,000 kg (1 million lb) (Allen and Leos 2001). Since 1975, landings have gradually risen and increased rapidly during the mid- to late-1990s. Notable drops in commercial catches have occurred during strong El Nino events, and have also been affected by a shift in effort towards more desirable flatfish species. In the Monterey and Santa Cruz area, there have been no reported commercial landings since 2005 (PacFIN 2010).

Sanddabs are targeted in recreational fisheries aboard private boats and in the commercial passenger fishing vessel (CPFV) fishery. A recreational fishery in southern California developed during the early 1990s and annual catches averaged below 2,000 fishes until 1998 when recreational catches increased to 80,000 fishes annually and peaked at 244,000 in 2001 (Dotson and Charter 2003). While the cause for the upsurge in sanddab catches remains uncertain, a combination of factors such as tight restrictions on the rockfish fishery during winter months, a large increase in sanddab numbers, or a more recent discovery of the fishery may have contributed to this increase. In central California (San Luis Obispo County to Santa Cruz County), recreational catches have averaged approximately 50,000 fishes annually between 2005 and 2009, with a high of 77,000 fishes in 2006 (RecFIN 2010).

3.3.4.4.3 Sampling Results

Sanddabs were the fourth most abundant taxon collected during this study at both the intake and source water stations. They comprised about 2.7% and 3.1% of the total mean concentration of larval fishes collected at the intake and source water stations, respectively (**Tables 3.3-2** and **3.3-4**). At the intake station (SWE) sanddab larvae were collected during seven of the 13 surveys, with peak concentration (110/1,000 m^3) occurring in December 2009 (**Figure 3.3-21**). Sanddab larvae were not collected April, May, August, September 2009 and March and May 2010. At the source water stations (SW1–SW3) sanddab larvae were collected during seven of the 13 surveys, with peak concentration (79/1,000 m^3) also in December 2009 (**Figure 3.3-22**). No sanddab larvae were collected at the source water stations during the April, May, August 2009 and January, March and May 2010. The lack of sanddabs at the source water stations and the low concentration at the intake station observed in January 2010 may have occurred because no nighttime samples could be collected at either the intake station or the source water stations due to unsafe sea conditions. There was no consistent trend in abundance between day and night samples (**Figure 3.3-23**).

A total of 51 sanddabs was measured. The mean, maximum, and minimum sizes for the 51 measurements were 2.5, 3.7, and 1.3 mm (0.10, 0.14, 0.05 in.), respectively. Statistical analysis of the bootstrap sample of 200 proportionally drawn from the 51 measured sanddab larvae was used to estimate a mean length of 2.5 mm (0.10 in.) (**Figure 3.3-24)**. The length frequency distribution of the proportionally drawn bootstrap sample of 200 lengths encompassed a narrow range between 1.4 mm and 3.6 mm (0.06 and 0.14 in.) NL indicating that the majority of the larvae were recently hatched based on the reported hatch length of 1.3–2.6 mm [0.05–0.10 in.] (Moser 1996). The averages from the 1,000 samples of 100 proportionally drawn from all the measurements resulted in a median length of 2.5 mm (0.10 in.). The hatch length estimated at 1.93 mm (0.08 in.) was larger than the value reported from Moser (1996), so the average 10th percentile value of 1.66 mm (0.07 in.) from the set of random samples was used with the average 95th percentile length of 3.5 mm (0.14 in.) in calculating the period of exposure to entrainment.

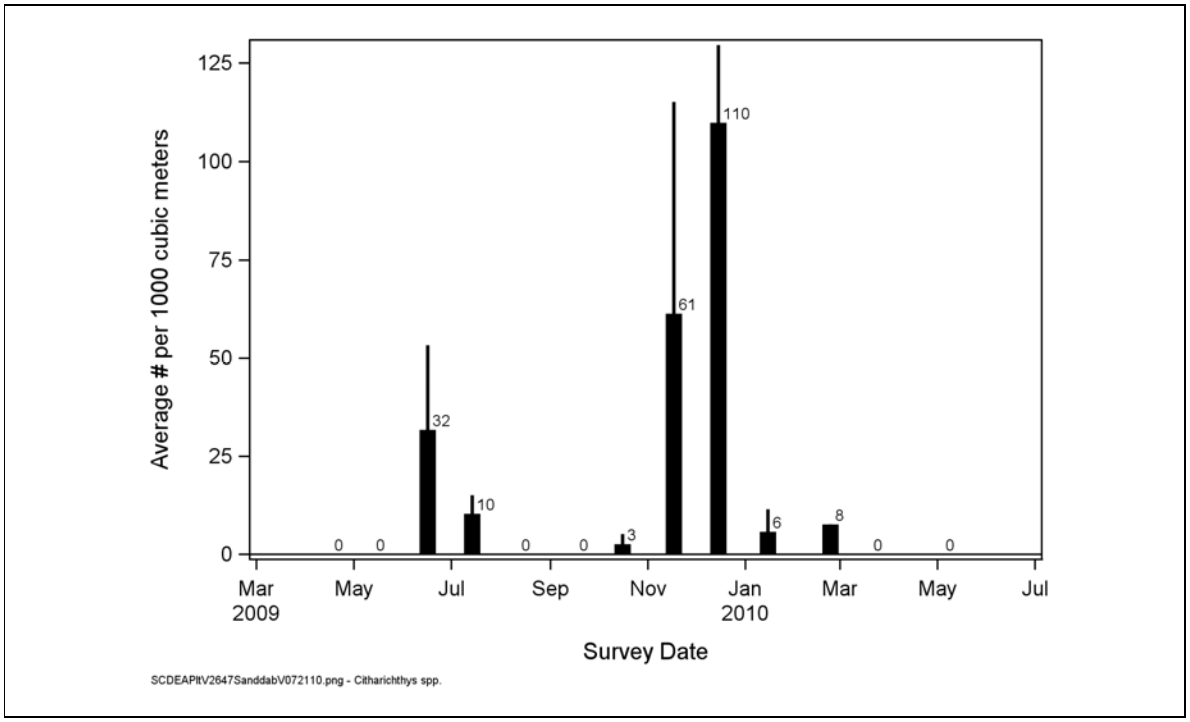


Figure 3.3-21. Survey mean concentration (#/1,000 m^3) of sanddab larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

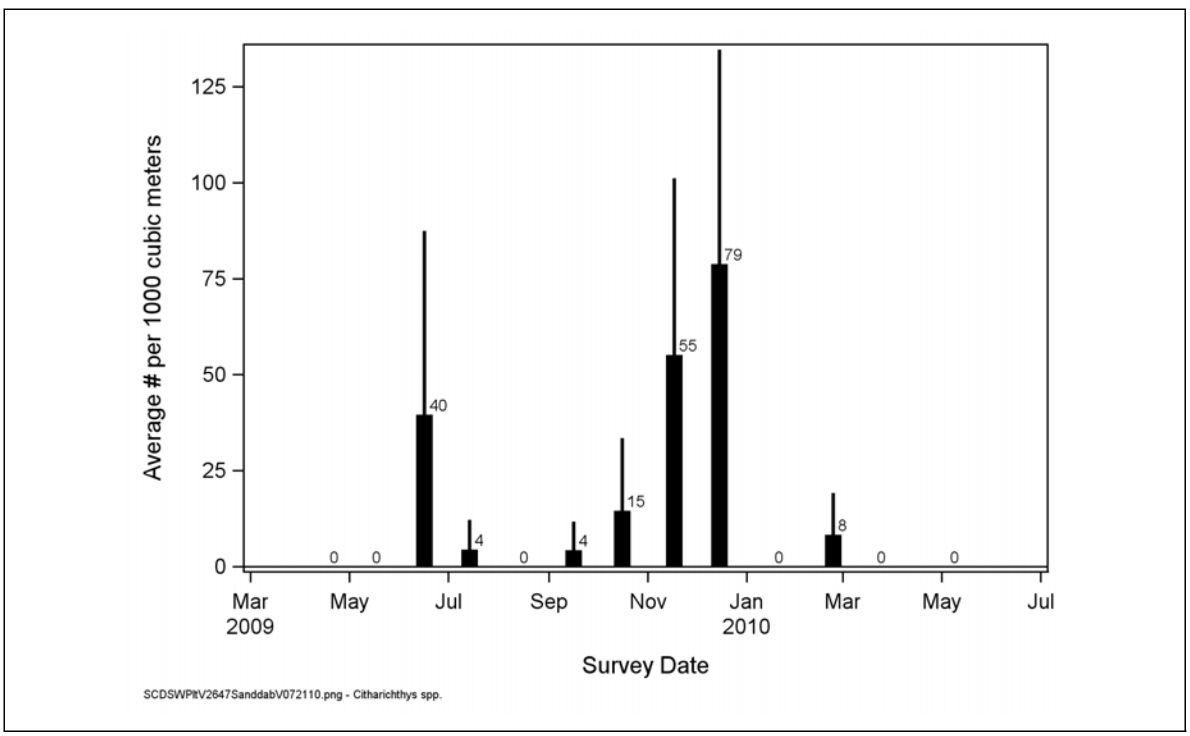


Figure 3.3-22. Survey mean concentration (#/1,000 m^3) of sanddab larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

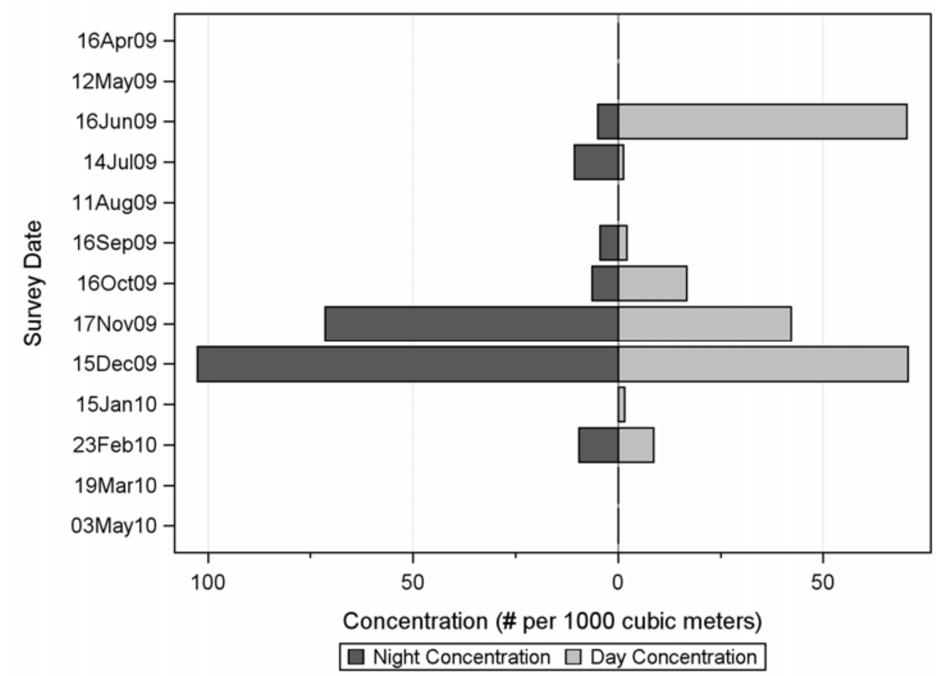


Figure 3.3-23. Mean concentration (#/1,000 m^3) in night and day samples for sanddab larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.
Note: No night samples were collected during the January 2010 survey.

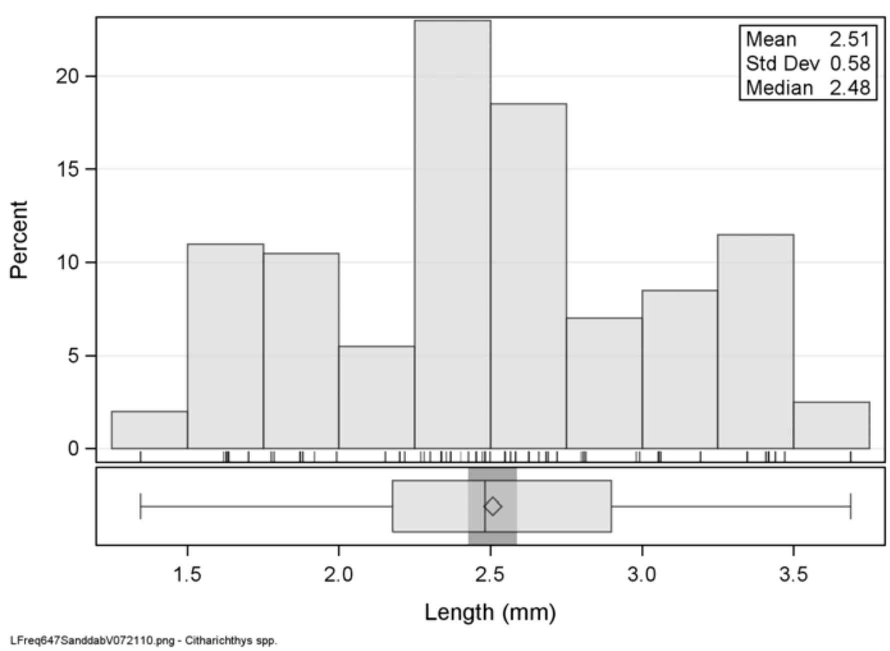


Figure 3.3-24. Length frequency histogram (NL) and statistics for sanddab larvae at all stations based on a sample of 200 larvae proportionally sampled with replacement from the 51 sanddab larvae measured.

3.3.4.4.4 Impact Assessment

An estimated 184,000 sanddab larvae would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake.

Empirical Transport Model (*ETM*)

We were unable to any information for determining a larval growth rate for sanddabs, so a larval growth rate from California halibut of 0.1857 mm/d (Gadomski and Peterson 1988, Gadomski et al. 1990) was used in calculating a period of exposure of 9.7 d for the larvae collected at the intake station using the difference between the estimated hatch length of 1.7 mm (0.07 in.) and the size of the 95th percentile value of 3.5 mm (0.14 in.) by the estimated larval growth rate. The estimated duration of the larvae was added to an estimated duration of the planktonic egg stage of 2.2 d that was also from data on California halibut (Gadomski et al. 1990, Emmett et al. 1991, Gadomski and Cadell 1996) for a total duration of 11.8 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 sanddab larvae show that they were in highest abundance at the source water stations during the November and December 2009 surveys (**Figure 3.3-22** and **Table 3.3-13**). The 12 d period of larval exposure resulted in an average alongshore displacement of 52 km (32 mi) when sanddab larvae were present at the source water stations. During the November 2009 survey, which had a high weight (f_i) due to the abundances in the source water, the current displacement was less indicating slower average currents during the period preceding this survey. The low intake volumes result in P_M estimates for the 12 d period of exposure which range from 0.00014 (0.014%) to 0.00052 (0.052%) (**Table 3.3-14**).

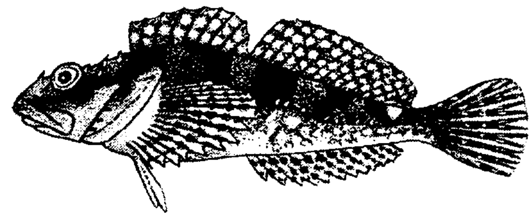
Table 3.3-13. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for sanddab larvae using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	80.74	0.0557
5/12/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	115.04	0.0391
6/16/09	0.000070	0.000036	0.000163	0.000085	0.000257	0.000133	0.1898	54.37	0.0828
7/14/09	0.000138	0.000067	0.000322	0.000157	0.000505	0.000247	0.0283	85.33	0.0527
8/11/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	58.52	0.0769
9/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0189	80.37	0.0560
10/16/09	0.000021	0.000015	0.000050	0.000036	0.000079	0.000056	0.0510	99.60	0.0452
11/17/09	0.000096	0.000052	0.000225	0.000121	0.000353	0.000190	0.2584	20.00	0.2250
12/15/09	0.000110	0.000020	0.000256	0.000048	0.000402	0.000075	0.4071	49.20	0.0915
1/15/10	0.000332	0.000235	0.000774	0.000548	0.001217	0.000861	0.0082	25.08	0.1795
2/23/10	0.000084	0.000037	0.000196	0.000087	0.000307	0.000136	0.0384	32.32	0.1393
3/19/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	36.31	0.1240
5/3/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	55.45	0.0812
Average >0	0.000122		0.000284		0.000446			52.27	
Average	0.000065		0.000153		0.000240			60.95	

Table 3.3-14. *ETM* estimates for sanddab larvae calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00014	0.00069	0.00083	0.00000
7 mgd (26,498 m^3)	0.00033	0.00160	0.00193	0.00000
11 mgd (41,640 m^3)	0.00052	0.00251	0.00303	0.00000

3.3.4.5 Smoothhead sculpins (*Artedius* spp.)



As many as seven species in the genus *Artedius* may occur in Monterey Bay, 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, specimens were only identified to the genus level and are referred to collectively as "smoothhead sculpins", the common name for *Artedius lateralis*, one of the more abundant species that occurs in Central California.

3.3.4.5.1 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.

3.3.4.5.2 Population Trends and Fishery

Smoothhead sculpins have neither commercial nor recreational fishery value, and there is little information on population trends in the Monterey area.

3.3.4.5.3 Sampling Results

Smoothhead sculpins (*Artedius* spp.) were the seventh most abundant taxon collected from the intake station and fifth most abundant from the source water stations. They comprised about 2.3% and 3.0% of the mean concentration of larval fishes collected at the intake and source water stations, respectively (**Tables 3.3-2** and **3.3-4**). At the intake station (SWE) smoothhead sculpin larvae were collected during all 13 surveys, with peak concentration (48/1,000 m^3) occurring in January 2010 (**Figure 3.3-25**). At the source water stations (SW1–SW3) smoothhead sculpin larvae were collected during 12 of the 13 surveys, with peak concentration (32/1,000 m^3) occurring in April 2009 (**Figure 3.3-26**). No smoothhead sculpin larvae were collected at the source water stations during the May 2009 survey. Larvae tended to be more abundant during nighttime samples although several surveys had equal or greater concentrations during the daytime samples (**Figure 3.3-27**). The concentrations observed in January 2010 did not include data collected during the night because no nighttime samples could be collected at either the intake station or the source water stations due to unsafe sea conditions.

A total of 59 smoothhead sculpins was measured. The smallest larva measured was 2.3 mm (0.09 in.) and the largest was 4.0 mm (0.16 in.). Statistical analysis of the bootstrap sample of 200 proportionally drawn from the 59 measured smoothhead sculpin larvae was used to estimate a mean length of 2.89 mm (0.11 in.) (**Figure 3.3-28**). Reported hatch size for *Artedius lateralis* ranges from 3.9–4.5 mm (0.15–0.18 in.) (Moser 1996). The fact that some 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 1,000 proportionally drawn bootstrap samples measurements resulted in averages of 2.9 mm (0.11 in.) for the mean and 2.8 mm (0.11 in.) for the median. The average estimated hatch size computed from the bootstrap samples was 2.5 mm (0.10 in.).

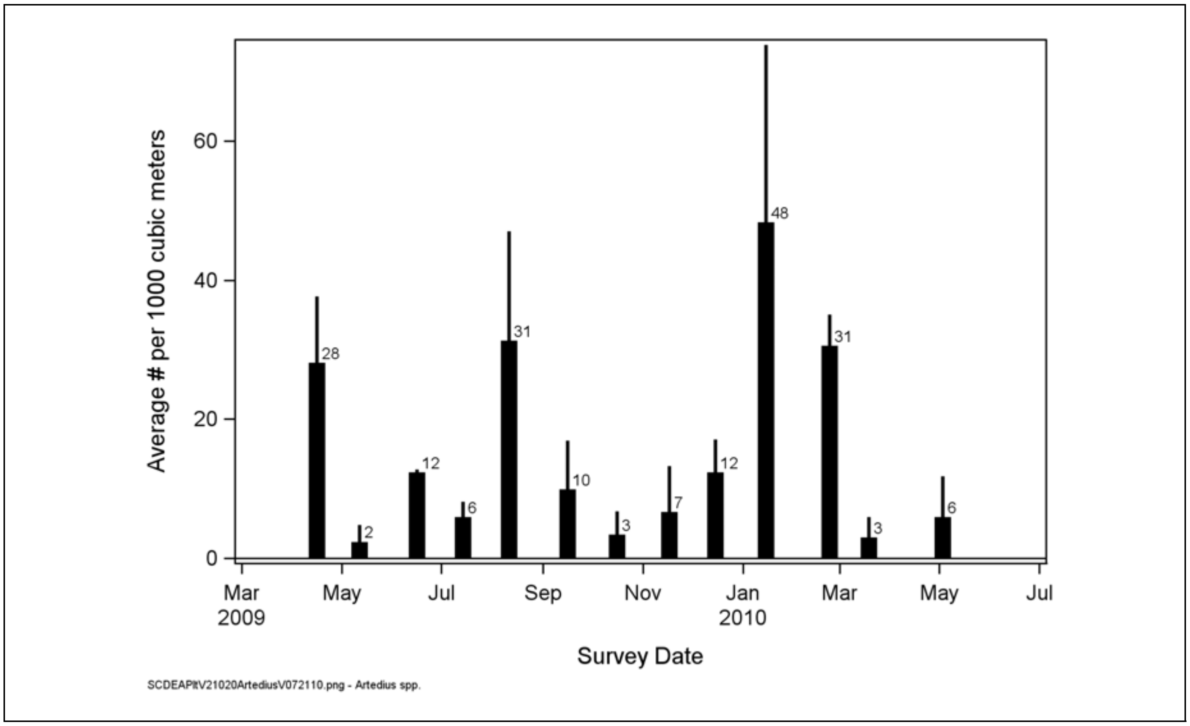


Figure 3.3-25. Survey mean concentration (#/1,000 m^3) of smoothhead sculpin larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

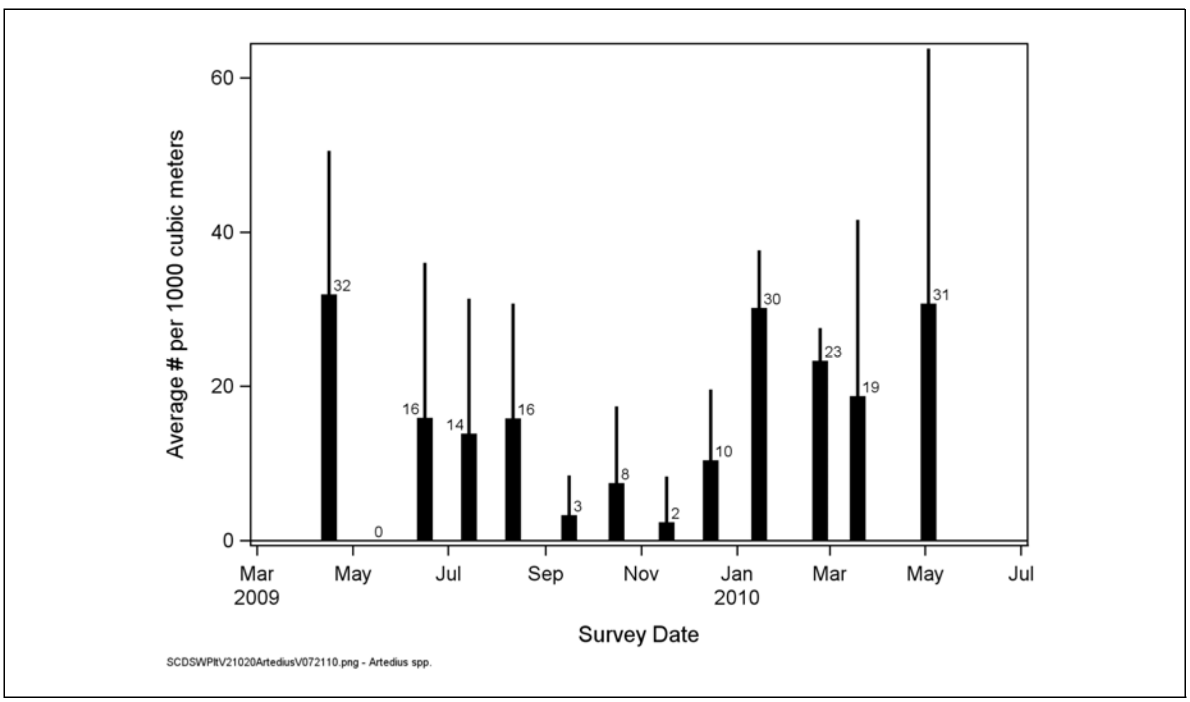


Figure 3.3-26. Survey mean concentration (#/1,000 m^3) of smoothhead sculpin larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

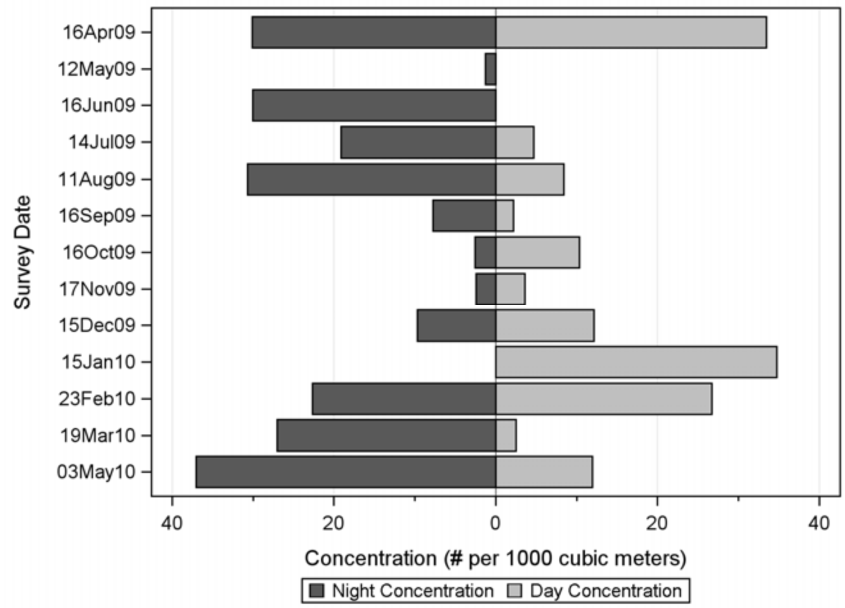


Figure 3.3-27. Mean concentration (#/1,000 m^3) in night and day samples for smoothhead sculpin larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.
Note: No nighttime samples were collected during the January 2010 survey.

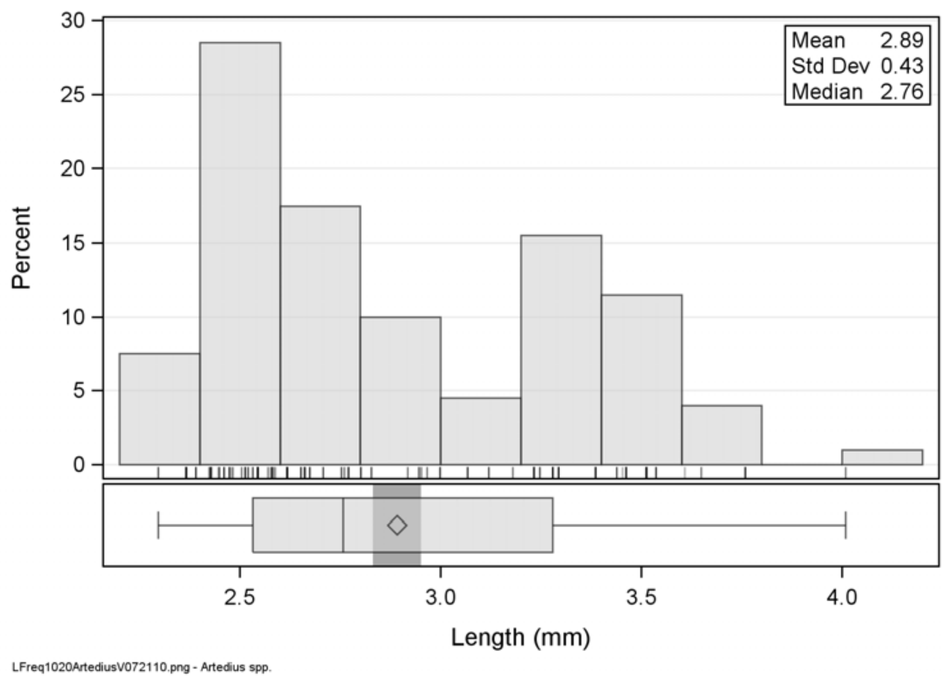


Figure 3.3-28. Length frequency histogram (NL) and statistics for smoothhead sculpin larvae at all stations based on a sample of 200 larvae proportionally sampled with replacement from the 59 smoothhead sculpin larvae measured.

3.3.4.5.4 Impact Assessment

An estimated 141,000 smoothhead sculpin larvae would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake.

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 these data to compute a larval growth rate of 0.14 mm/d (9.5 mm–2.67 mm/48 d [0.37-0.11 in./48 d]). The estimated period of entrainment exposure of 7.5 d was calculated by dividing the difference between the estimated hatch length of 2.5 mm (0.10 in.) and the size of the 95th percentile value of 3.6 mm (0.14 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 the abundances in the source water were greatest during the January and February 2010 surveys (**Table 3.3-15**). Although no *Artedius* larvae were collected from the source water stations during the May 2009 survey, they were collected at the intake station which is included as part of the source water calculations in the *ETM*. The average alongshore displacement for the source water population was 41.3 km (25.7 mi). The low intake volumes result in P_M estimates for the 7.5 d period of exposure which range from 0.00012 (0.012%) to 0.00046 (0.046%) (**Table 3.3-16**).

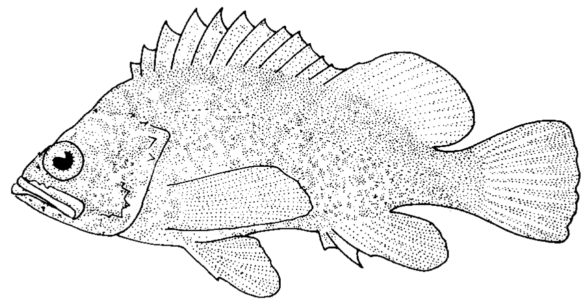
Table 3.3-15. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for sculpin (*Artedius* spp.) larvae using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000082	0.000016	0.000192	0.000037	0.000301	0.000059	0.0990	39.93	0.1127
5/12/09	0.000338	0.000326	0.000788	0.000761	0.001238	0.001195	0.0033	66.12	0.0681
6/16/09	0.000071	0.000033	0.000165	0.000076	0.000259	0.000120	0.0823	43.94	0.1024
7/14/09	0.000039	0.000017	0.000090	0.000039	0.000142	0.000062	0.0651	69.09	0.0651
8/11/09	0.000148	0.000060	0.000346	0.000141	0.000544	0.000222	0.1026	27.55	0.1634
9/16/09	0.000200	0.000092	0.000466	0.000214	0.000732	0.000337	0.0247	53.47	0.0842
10/16/09	0.000054	0.000033	0.000127	0.000076	0.000199	0.000120	0.0292	76.71	0.0587
11/17/09	0.000240	0.000189	0.000559	0.000441	0.000879	0.000693	0.0125	14.08	0.3195
12/15/09	0.000094	0.000024	0.000220	0.000056	0.000346	0.000088	0.0596	38.13	0.1180
1/15/10	0.000124	0.000046	0.000288	0.000107	0.000453	0.000169	0.2079	16.73	0.2690
2/23/10	0.000112	0.000011	0.000261	0.000027	0.000411	0.000042	0.1287	24.89	0.1808
3/19/10	0.000019	0.000013	0.000045	0.000030	0.000071	0.000047	0.0807	28.22	0.1595
5/3/10	0.000026	0.000016	0.000060	0.000037	0.000094	0.000058	0.1043	37.63	0.1196
Average >0	0.000119		0.000277		0.000436			41.27	
Average	0.000119		0.000277		0.000436			41.27	

Table 3.3-16. *ETM* estimates for sculpin (*Artedius* spp.) larvae calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00012	0.00025	0.00038	0.00000
7 mgd (26,498 m^3)	0.00029	0.00059	0.00088	0.00000
11 mgd (41,640 m^3)	0.00046	0.00093	0.00138	0.00000

3.3.4.6 KGB rockfish Complex (*Sebastes* spp. V_)



The rockfishes that comprise the KGB complex (kelp, gopher, and black-and-yellow rockfishes) can be considered a guild of nearshore, benthic, or epibenthic rockfishes sharing similar morphology and ecological roles. They are common to Monterey Bay and Santa Cruz nearshore habitats and are described in the following section.

3.3.4.6.1 Reproduction, Age, and Growth

Kelp rockfish fecundity ranges from 344 to 403 eggs/g female weight, and spawning occurs once during late winter to spring (MacGregor 1970, Love et al. 1990, Moser 1996). The reproductive period lasts about seven 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). Moser and Smith (1993) reported that the majority of rockfish larvae from the 1951–1984 CalCOFI samples were found from January–April with the majority collected in January. Moser et al. (2000) stated that the abundance of rockfish larvae that could be identified to species varied seasonally. In many eastern Pacific ichthyoplankton studies, rockfish larvae are identified to *Sebastes* spp. due to the difficulty in visually identifying most of the younger, smaller larvae (Yoklavich et al. 1996, Nishimoto 1996, Moser and Smith 1993, Moser et al. 2000). 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 (10 in.) TL at 4 yr, and the largest immature male was 338 mm (13 in.) TL (not aged; Lea et al. 1999). The smallest sexually mature female was 160 mm (6 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). The majority of the larval rockfishes collected in southern California were less than or equal to 5.5 mm (0.2 in.) in length (Moser and Pommeranz 1999). 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 20–40 mm (0.8–1.6 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 [12 in.] 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 [11 in.] 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 in.) TL at 10 yr, and the largest immature male was 237 mm (9 in.) TL at 10 yr (Lea et al. 1999). The smallest sexually mature female was 207 mm (8 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 approximately 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 (12 in.) TL at 9 yr (Lea et al. 1999). The smallest sexually mature female was 243 mm (10 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).

3.3.4.6.2 Population Trends and Fishery

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 California Department of Fish and Game (CDFG) for the years 2004–2008 showed that combined landings of kelp, gopher, black-and-yellow, brown, copper, quillback, china, greenspotted, and grass rockfishes in Monterey Region averaged 15,138 lb (6,866 kg) per year with an annual average ex-vessel value of $104,607 (**Table 3.3-17**). Starr et al. (1998) notes 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 northern California during the 2004–2009 time period averaged nearly 256,000 fishes per year.

Table 3.3-17. KGB rockfish complex* recreational fishing catch in northern California, and commercial fishing landings and ex-vessel value in Monterey region, 2005-2009. Data from RecFIN (2010) and CDFG (2005–2010).

	Recreational Fishery		Commercial Fishery	
Year	Estimated Catch (No.)	Estimated Weight (MT)	Landings (lb)	Ex-vessel Value ($)
2004	188,000	100	16,935	$92,716
2005	281,000	174	12,852	$90,090
2006	282,000	175	13,775	$104,244
2007	241,000	155	16,469	$120,523
2008	227,000	137	15,659	$115,463
2009	315,000	195	Not available	Not available
Average	**255,667**	**156.0**	**15,138**	**$104,607**

* includes data for kelp, gopher, black and yellow, brown, copper, quillback, china, greenspotted, and grass rockfish species.

3.3.4.6.3 Sampling Results

Rockfish larvae from the KGB complex (*Sebastes* spp. V_) were the twelfth most abundant taxon collected from the intake station and the ninth most abundant from the source water stations, comprising about 1.0% of all of the mean concentration of larvae at the intake station and 1.7% at source water stations (**Tables 3.3-2** and **3.3-4**). At the intake station (SWE), KGB rockfish larvae were collected during four of 13 surveys, with peak concentration (32/1,000 m^3) occurring in May 2009 (**Figure 3.3-29**). Larvae were only collected at the intake station from April and May 2009 and March and May 2010. At the source water stations (SW1–SW3), KGB rockfish larvae were collected during five of the 13 surveys, with peak concentration (53/1,000 m^3) in February 2010 (**Figure 3.3-30**). They were collected at the source water stations during the April and May 2009 and February, March, and May 2010 surveys. The larvae were more abundant in nighttime samples than in daytime samples (**Figure 3.3-31**).

A total of 30 KGB rockfishes was measured. The smallest of the 30 measured larvae was 3.2 mm (0.13 in.) and the largest was 4.4 mm (0.17 in.). Statistical analysis of the bootstrap sample of 200 proportionally drawn from the 30 measured KGB rockfish larvae was used to estimate a mean length of 3.67 mm (0.14 in.) (**Figure 3.3-32**). Reported length at birth for gopher rockfish, *Sebastes carnatus*, is approximately 4.3 mm (0.2 in.) (Moser 1996), indicating that most of the larvae were recently extruded. The 1,000 bootstrap samples of 100 proportionally drawn from the measurements resulted in averages of 3.7 mm (0.15 in.) for the mean length and 3.6 mm (0.14 in.) for the median. The computed hatch length was 3.4 mm (0.13 in.) which is less than the value reported by Moser (1996).

DNA analysis was performed on all larval *Sebastes* that were collected during the first two surveys and preserved in 95% non-denatured ethanol. Fishes preserved in formaldehyde cannot be used for DNA analysis. In the laboratory during identification these individuals were visually identified and recorded as being either *Sebastes* V_ (13 individuals) or *Sebastes* spp. (2 individuals). The two *Sebastes* spp larvae were slightly damaged and could not easily be placed into one of the two main rockfish pigment groupings (those having either a long ot short series of ventral pigment). Based on this analysis the majority of these larvae were determined to be black-and-yellow/gopher rockfishes (**Table 3.3-18**). These two species cannot be separated based on the DNA analysis that was performed. The other two larvae were determined to be one kelp and one brown rockfish larvae. The larvae of these three species plus others cannot visually be separated form each other.

Table 3.3-18. Results of DNA analysis of larval *Sebastes* collected during April and May 2009 at all stations combined.

Taxa name based on DNA	Common name based on DNA	Count
S. chrysomelas/S. carnatus	black-and- yellow/gopher rockfish	13
S. atrovirens	kelp rockfish	1
S. auriculatus	brown rockfish	1

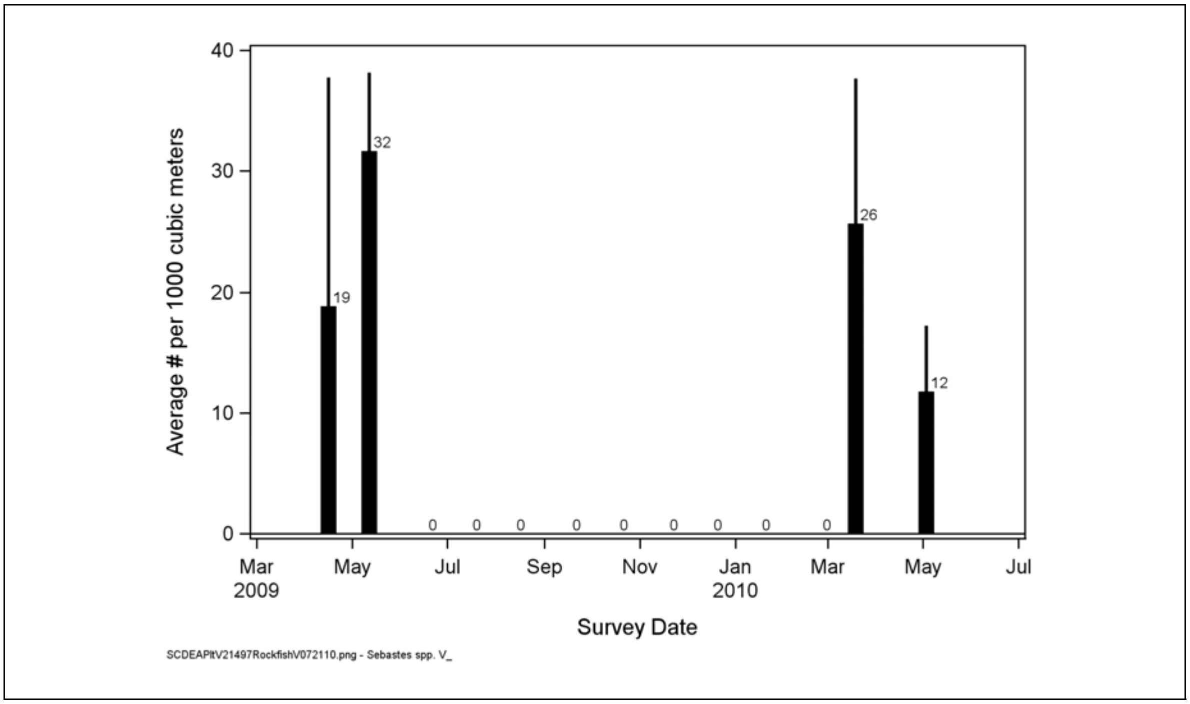


Figure 3.3-29. Survey mean concentration (#/1,000 m^3) of KGB rockfish complex larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

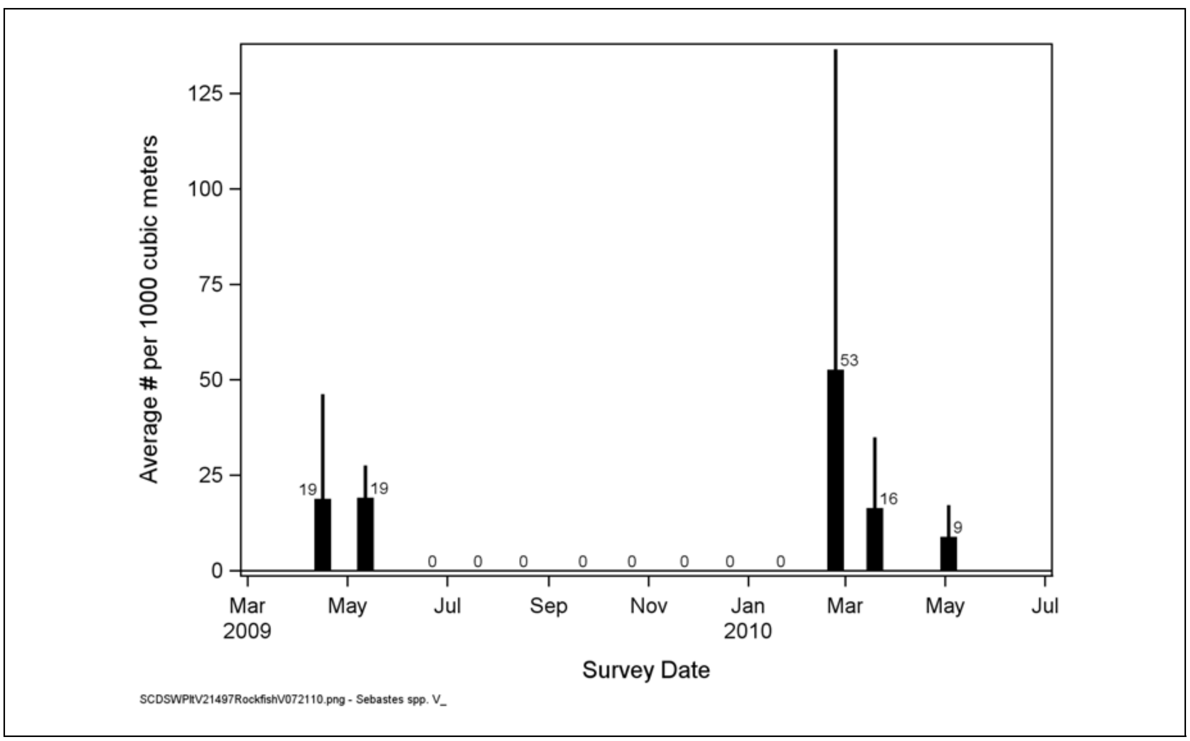


Figure 3.3-30. Survey mean concentration (#/1,000 m^3) of KGB rockfish complex larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

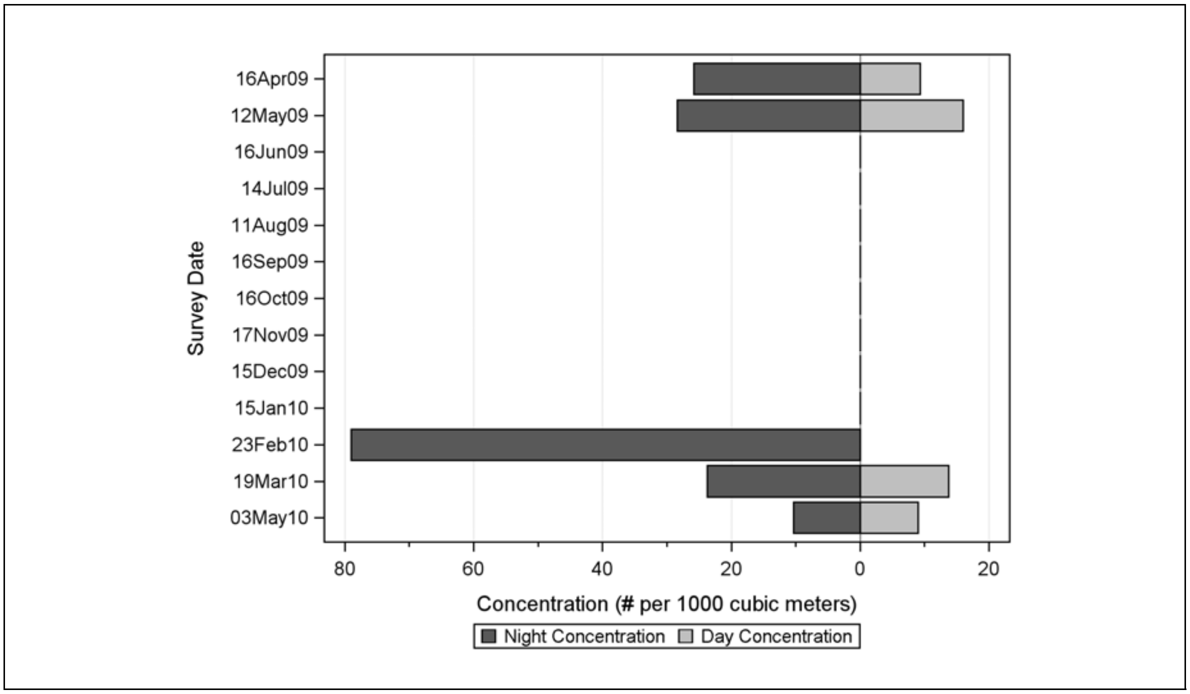


Figure 3.3-31. Mean concentration (#/1,000 m^3) in night and day samples for KGB rockfish complex larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.
Note: No night samples were collected during the January 2010 survey.

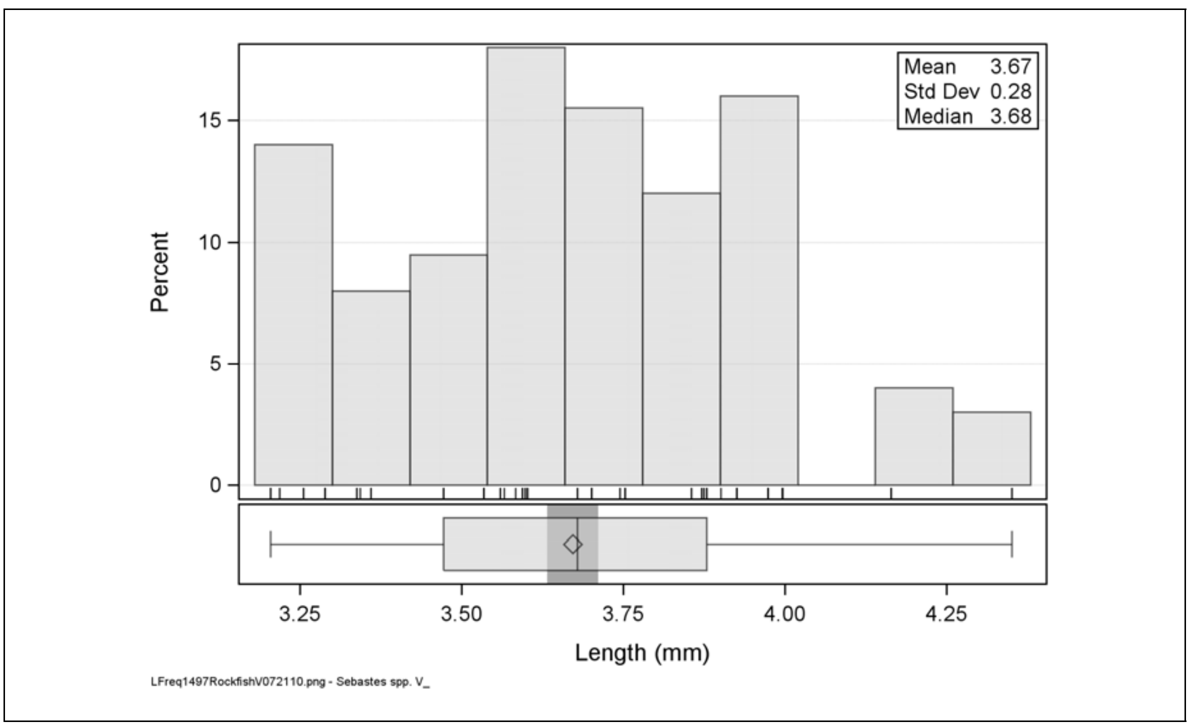


Figure 3.3-32. Length frequency histogram (NL) and statistics for KGB rockfish complex larvae at all stations based on a sample of 200 larvae proportionally sampled with replacement from the 30 KGB rockfish complex larvae measured.

3.3.4.6.4 Impact Assessment

An estimated 52,000 KGB rockfish larvae would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake.

Empirical Transport Model (*ETM*)

The estimated larval growth rate for KGB rockfish 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). The estimated period of entrainment exposure of 3.2 d used in the *ETM* calculations was calculated by dividing the difference between the estimated hatch length of 3.4 mm (0.13 in.) and the size of the 95^{th} percentile value of 4.1 mm (0.16 in.) 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 only collected during the February through May surveys (**Table 3.3-19**). The average alongshore displacement during these surveys for the short period of larval exposure was 26.4 km (16.4 mi). The low intake volumes and short period of exposure to entrainment result in P_M estimates which range from 0.00004 (0.004%) to 0.00015 (0.015%) (**Table 3.3-20**).

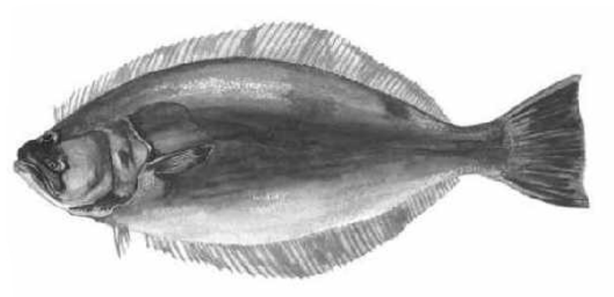
Table 3.3-19. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for KGB rockfish complex larvae using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000056	0.000029	0.000131	0.000068	0.000205	0.000107	0.1759	14.32	0.3143
5/12/09	0.000127	0.000041	0.000296	0.000097	0.000465	0.000152	0.2125	39.57	0.1137
6/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	20.65	0.2179
7/14/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	40.42	0.1113
8/11/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	17.90	0.2514
9/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	30.24	0.1488
10/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	43.68	0.1030
11/17/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	4.71	0.9551
12/15/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	17.19	0.2618
1/15/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	9.13	0.4928
2/23/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.3628	10.59	0.4249
3/19/10	0.000146	0.000049	0.000340	0.000114	0.000534	0.000180	0.1699	21.30	0.2113
5/3/10	0.000123	0.000038	0.000287	0.000089	0.000451	0.000140	0.0790	30.41	0.1480
Average >0	0.000113		0.000263		0.000414			26.40	
Average	0.000035		0.000081		0.000127			23.09	

Table 3.3-20. *ETM* estimates for KGB rockfish complex larvae calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00004	0.00018	0.00022	0.00000
7 mgd (26,498 m^3)	0.00010	0.00042	0.00051	0.00000
11 mgd (41,640 m^3)	0.00015	0.00065	0.00081	0.00000

3.3.4.7 California Halibut (*Paralichthys californicus*)



California halibut (*Paralichthys californicus*) is an important part of California's commercial and recreational fisheries (Starr et al. 1998, Kramer and Sunada 2001). It ranges from northern Washington to Bahia Magdalena, southern Baja California and is found from very shallow nearshore waters in bay nursery grounds to depths of at least 185 m (607 ft) (Miller and Lea 1972, Haaker 1975). Juveniles and adults typically occur on sandy sediments at depths less than 30 m (98.5 ft) but sometimes concentrate near rocks, algae, or Pacific sand dollar (*Dendraster excentricus*) beds (Feder et al. 1974). As with other flatfishes, they frequently lie buried or partially buried in the sediment. Newly settled and juvenile halibut often occur in unvegetated shallow embayments and occasionally on the outer coast, suggesting that bays are an important nursery habitat for this species (Kramer and Sunada 2001).

3.3.4.7.1 Reproduction, Age, and Growth

California halibut is a broadcast spawner with eggs being fertilized externally. The spawning season is generally thought to extend from February to August with most spawning occurring in May (Frey 1971), although some fall spawning may also occur. The average number of eggs per spawn is 313,000–589,000 with an average reproductive output of approximately 5.5 million eggs per spawning season (Caddell et al. 1990). During spawning season females may release eggs every seven days and the largest individuals may produce in excess of 50 million eggs per year (Caddell et al. 1990). Captive specimens were observed to spawn at least 13 times per season (Caddell et al. 1990). Halibut eggs are 0.7–0.8 mm (0.027–0.031 in.) in diameter (Ahlstrom et al. 1984) and are most abundant in the water column at depths less than 75 m (246 ft) and within 6.5 km (4.0 mi) from shore (Kramer and Sunada 2001).

Upon hatching, the larvae (1.6–2.1 mm [0.06–0.08 in.]) NL [Moser 1996]) are pelagic (Frey 1971), and most abundant between Santa Barbara, California, and Punta Eugenia, Baja California Sur (Ahlstrom and Moser 1975) from January through April and June through August (Moser 1996). A summary of the 1951–1984 CalCOFI data showed that halibut larvae were in the water column from February–March and July–August with the peaks in abundance occurring in February and August (Moser and Smith 1993). Moser and Pommeranz (1999) found the majority of the halibut larvae that they caught were in the 2.3 mm (0.09 in.) size class. California halibut has a relatively short pelagic larval stage, from 20–29 days (Gadomski et al. 1990). Larval transformation occurs at a length of about 7.5–9.4 mm (0.3–0.4 in.) SL (Moser 1996) at which time the young fish settle to the bottom, generally in bays but also occasionally in shallow substrates along the open coast (Haugen 1990). Kramer (1991) found that 6–10 mm (0.2–0.4 in.) California halibut larvae grew <0.3 mm/day (0.012 in./day), while larger 70–120 mm (2.8–4.7 in.) halibut grew about 1.0 mm/day (0.04 in./day). In a laboratory study, California halibut held at 16°C (60.8°F) grew to a length of 11.1 mm ± 2.61 (0.44 in ± 0.1) (SD) in two months from an initial hatch length of 1.9 mm (0.07 in.) (Gadomski et al. 1990). After settling in the bays, the juveniles may remain there for about two years until they emigrate to the outer coast. Males mature at 2–3 years and 20–23 cm (7.9–9.0 in.) SL; females mature at 4–5 years and 38–43 cm (14.9–16.9 in.) SL (Fitch and Lavenberg 1971, Haaker 1975). Males emigrate out of the bays when they mature (i.e. at 20 cm [7.9 in.]) but females migrate out as subadults at a length of about 25 cm (9.8 in.) (Haugen 1990). Subadults remain nearshore at depths of 6–20 m (19.7–65.6 ft) (Clark 1930, Haaker 1975). California halibut may reach 152 cm (60 in.) and 33 kg (73 lb) (Eschmeyer et al. 1983). Individuals may live as long as 30 years (Frey 1971).

3.3.4.7.2 Population Trends and Fishery

California halibut have a high commercial and recreational fishery value. The fishery for California halibut was reviewed by Kramer and Sunada (2001) and recent catch statistics are available through the PSMFC PacFIN (commercial) and RecFIN (recreational) databases. Historically, halibut have been commercially harvested by three principal gear types: otter trawl, set gill and trammel nets, and hook and line. Presently there are numerous gear, area, and seasonal restrictions that have been imposed on the commercial halibut fishery for management purposes. In northern California the average annual recreational catch during 2004–2009 was 115.8 metric tons (MT) (**Table 3.3-21**) while 2004–2008 commercial landings in the Monterey Region alone averaged approximately 51,407 lb. During this time period, the largest commercial landings were in 2004 (100,618 lb), declining by approximately 90% by 2009.

Table 3.3-21. California halibut recreational fishing catch in Northern California, and commercial fishing landings and ex-vessel value in Monterey County, 2004-2008. Data from RecFIN (2010) and CDFG (2005–2010).

Year	Estimated Recreational Catch (MT)	Estimated Recreational Catch (No.)	Commercial Landings (lb)	Ex-vessel Revenue ($)	Revenue per pound ($)
2004	91	17,000	100,618	$289,563	$2.88
2005	135	22,000	67,992	$221,253	$3.25
2006	81	16,000	70,868	$233,128	$3.29
2007	62	15,000	8,032	$28,345	$3.35
2008	172	55,000	9,525	$43,349	$4.55
2009	154	43,000	Not available	Not available	Not available
Average	**115.8**	**28,000**	**51,407**	**$163,128**	**$3.17**

3.3.4.7.3 Sampling Results

California halibut larvae were the sixteenth most abundant taxon collected from the intake station and the twentieth most abundant from the source water stations, comprising about 0.7% of the mean concentration of larvae at the intake station and 0.7% at source water stations (**Tables 3.3-2** and **3.3-4**). At the intake station (SWE) California halibut larvae were collected during four of 13 surveys, with peak concentration (46/1,000 m^3) occurring in June 2009 (**Figure 3.3-33**). They were only collected at the intake station during the April, June and July 2009 and February 2010 surveys. At the source water stations (SW1–SW3) California halibut larvae were collected during four of the 13 surveys, with peak concentration (31/1,000 m^3) occurring in June 2009 (**Figure 3.3-34**). They were collected at the source water stations during the June and July 2009 and February and May 2010 surveys. There was no consistent trend in day-night abundance (**Figure 3.3-35**).

A total of 19 California halibut was measured. The smallest of the 19 measured larvae was 1.4 mm (0.09 in.) and the largest was 7.3 mm (0.28 in.). Statistical analysis of the bootstrap sample of 200 proportionally drawn from the 19 measured California halibut larvae was used to estimate a mean length of 2.4 mm (0.09 in.) (**Figure 3.3-36**). The 1,000 bootstrap samples of 100 proportionally drawn from the measurements resulted in averages of 2.3 mm (0.09 in.) for the mean length and 2.2 mm (0.08 in.) for the median. The computed hatch length was 1.8 mm (0.07 in.) which is within the range of values reported by Moser (1996).

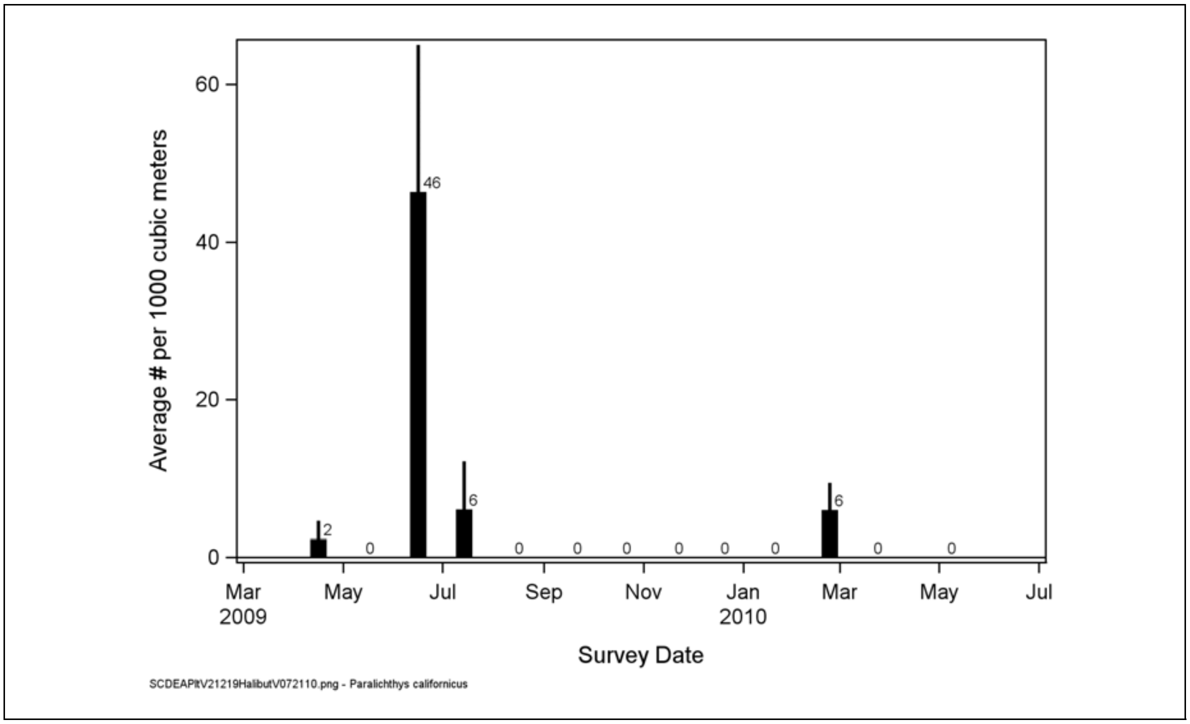


Figure 3.3-33. Survey mean concentration (#/1,000 m^3) of California halibut larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

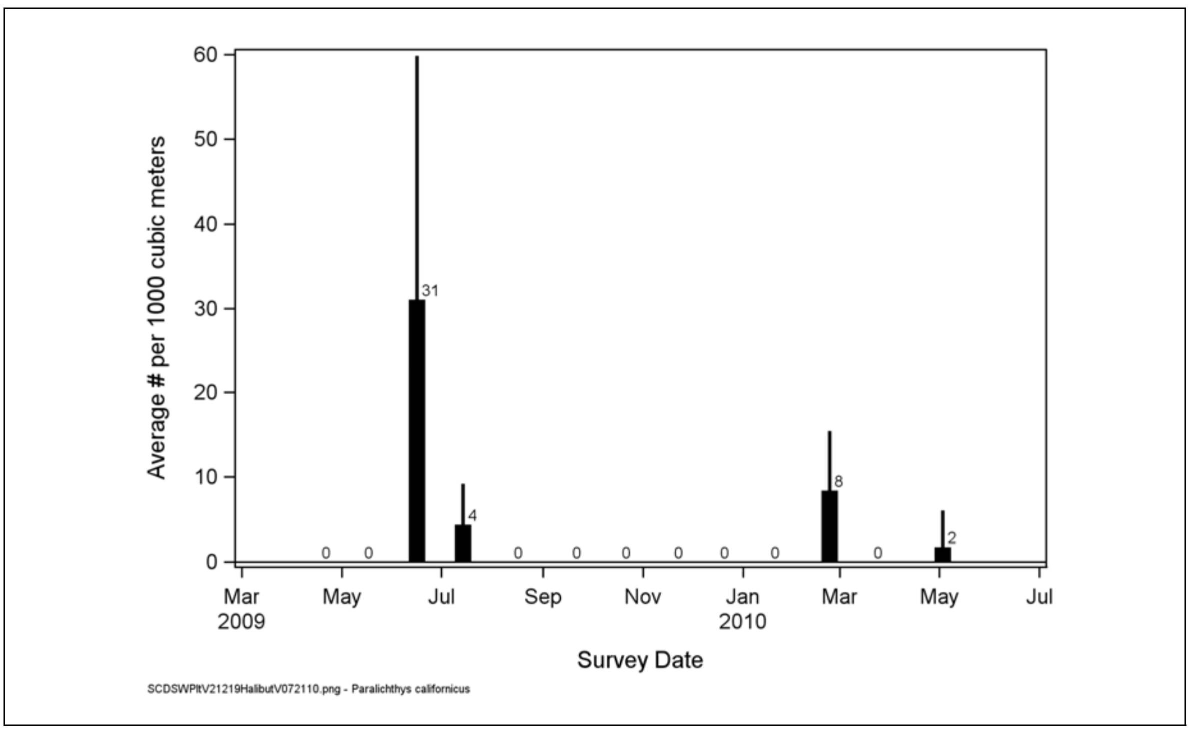


Figure 3.3-34. Survey mean concentration (#/1,000 m^3) of California halibut larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

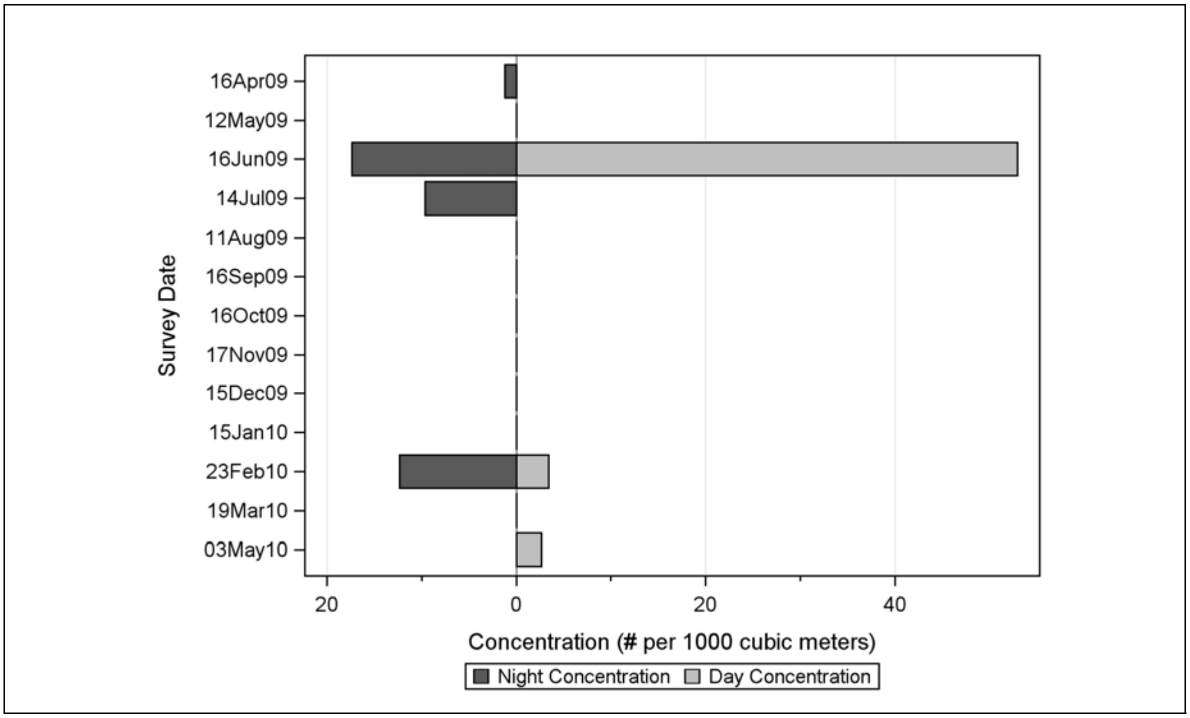


Figure 3.3-35. Mean concentration (#/1,000 m^3) in night and day samples for California halibut larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010. *Note: No nighttime samples were collected during the January 2010 survey.*

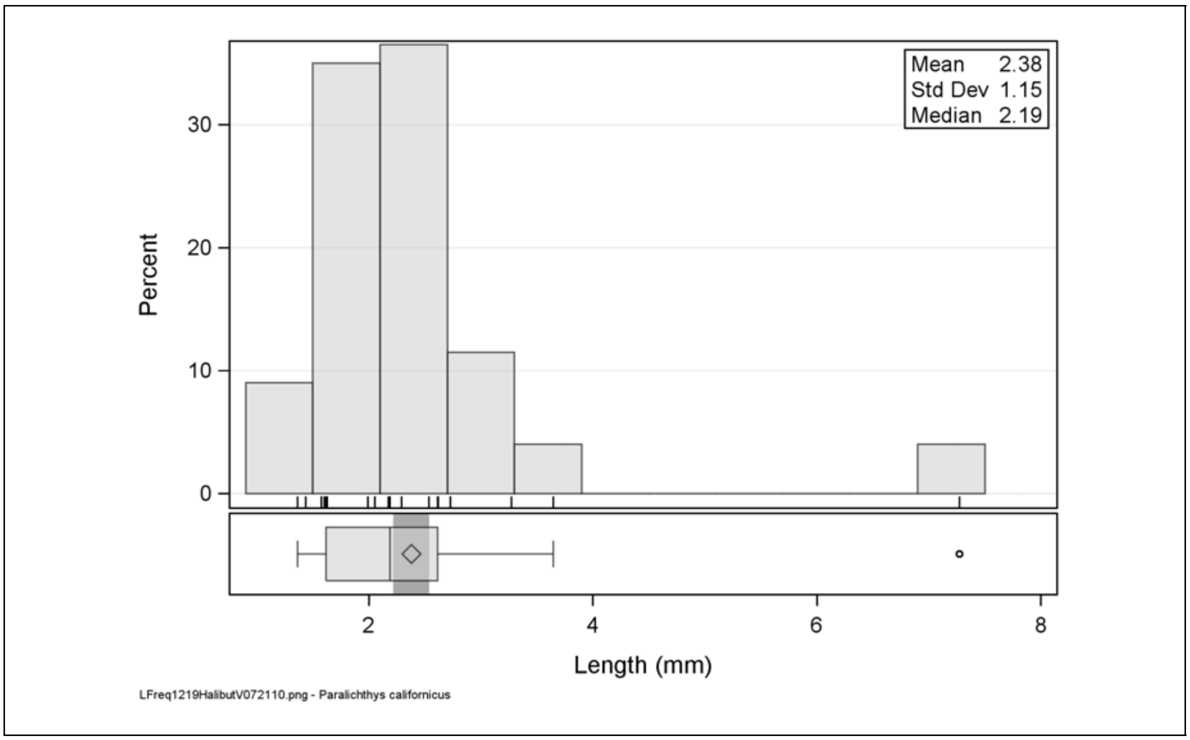


Figure 3.3-36. Length frequency histogram (NL) and statistics for California halibut larvae at all stations based on a sample of 200 larvae proportionally sampled with replacement from the 19 California halibut larvae measured.

3.3.4.7.4 Impact Assessment

An estimated 44,000 California halibut larvae would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake.

Empirical Transport Model (*ETM*)

A growth rate 0.1857 mm/d for California halibut larvae was derived from data in (Gadomski and Peterson 1988, Gadomski et al. 1990). This was used with the estimated hatch length of 1.8 mm (0.07 in.) and the length at the 95th percentile of 3.6 (0.14 in.) to estimate that the larvae were exposed to entrainment for a period of 10.1 d. This was added to the estimated planktonic duration for the eggs of 2.2 d to calculate a total exposure period of 12.3 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 California halibut show that the larvae were most abundant in the source water during the June 2009 survey (**Table 3.3-22**). The average alongshore displacement for the 12 d period of larval exposure during the surveys when the larvae were present was 57.9 km (35.6 mi). The low intake volumes and short period of exposure to entrainment result in P_M estimates which range from 0.00011 (0.011%) to 0.00042 (0.042%) (**Table 3.3-23**).

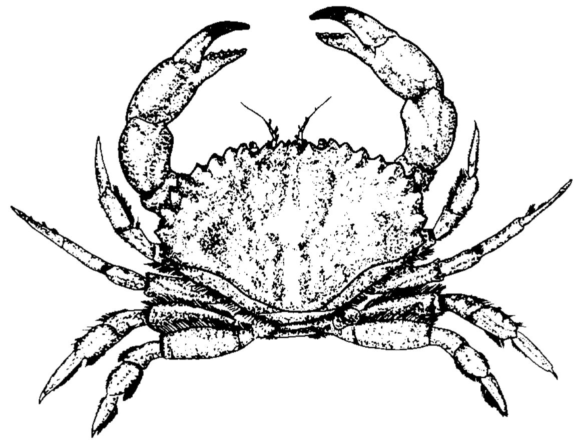
Table 3.3-22. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for California halibut larvae using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000349	0.000337	0.000814	0.000786	0.001279	0.001235	0.0079	69.67	0.0646
5/12/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	105.65	0.0426
6/16/09	0.000130	0.000039	0.000304	0.000090	0.000477	0.000142	0.6947	53.63	0.0839
7/14/09	0.000114	0.000075	0.000266	0.000175	0.000417	0.000276	0.0939	77.88	0.0578
8/11/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	48.43	0.0929
9/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	72.79	0.0618
10/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	92.75	0.0485
11/17/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	14.09	0.3194
12/15/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	49.20	0.0915
1/15/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	22.02	0.2043
2/23/10	0.000071	0.000034	0.000165	0.000079	0.000259	0.000124	0.1653	30.20	0.1490
3/19/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	35.30	0.1275
5/3/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0383	49.58	0.0908
Average >0	0.000166		0.000387		0.000608			57.85	
Average	0.000051		0.000119		0.000187			55.48	

Table 3.3-23. *ETM* estimates for California halibut larvae calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00011	0.00062	0.00074	0.00000
7 mgd (26,498 m^3)	0.00027	0.00145	0.00172	0.00000
11 mgd (41,640 m^3)	0.00042	0.00229	0.00270	0.00000

3.3.4.8 Cancer Crabs (Cancridae)



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 crabs are known to occur in Monterey Bay, but due to overlapping ranges in sizes and similarities in morphology, the megalops larvae could not be reliably identified to the level of species, except for Dungeness crab.

Common name(s)	Scientific Name
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 live 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.

3.3.4.8.1 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 (1989) study 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).

3.3.4.8.2 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. 2001). 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 Monterey Bay and northern areas of California where the fishery targets the more desirable Dungeness crab. Recreational crabbing is popular in many areas and is often conducted in conjunction with other fishing activities. The commercial harvest of rock crab 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 from five ports combined within or near the Monterey Bay National Marine Sanctuary averaged 200,000 lb/yr from 1980–1995 (Starr et al. 1998), but recent statistics show no landings at all in Santa Cruz County since 2005 (**Table 3.3–24**). Dungeness crab landings form the major crab fishery, with an average of over 100,000 lb caught annually and an average ex-vessel revenue of $283,866.

Table 3.3-24. Rock crab and Dungeness crab commercial fishing landings and ex-vessel value in Santa Cruz County, 2005-2009. Data from PacFIN (2010).

	Rock crab		Dungeness crab	
Year	**Landings (lb)**	**Ex-vessel Value ($)**	**Landings (lb)**	**Ex-vessel Value ($)**
2005	5,036	$3,379	238,279	$478,221
2006	0	$0	95,699	$223,829
2007	0	$0	85,301	$262,983
2008	0	$0	70,317	$239,412
2009	0	$0	71,407	$214,883
Average	**1,007**	**$676**	**112,201**	**$283,866**

3.3.4.8.3 Sampling Results

Cancrid crab megalops were collected at both the intake and source water stations during all surveys, except for the January 2010 survey. Peak concentrations at both the intake station (203/1,000 m^3) and the source water stations (320/1,000 m^3) occurred during the April 2009 survey (**Figures 3.3-37** and **3.3-38**). Over 80% of the cancrid crab megalops at both the intake and source water stations were classified in the *R. antennarius/M. gracilis* complex (Pacific rock crab/slender crab complex) (**Tables 3.3-2** and **3.3-4**). Only one Dungeness crab megalops specimen was collected during the study at the source water stations, and none was collected at the intake station. There were substantially greater numbers of cancrid crab megalops collected in night samples than in daytime samples in all surveys (**Figure 3.3-39**) The absence of cancrid crab megalops during the January 2010 survey could have occurred because no nighttime samples could be collected at either the intake station or the source water stations due to unsafe sea conditions.

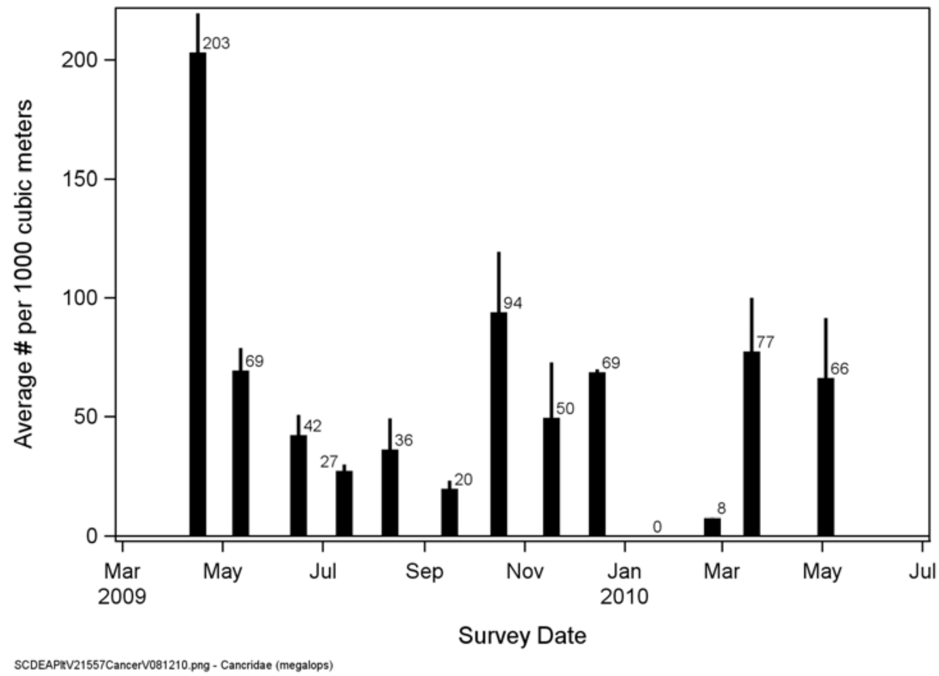


Figure 3.3-37. Survey mean concentration (#/1,000 m^3) of cancrid crab megalops collected at the intake station (SWE) with standard error indicated (+1 SE).

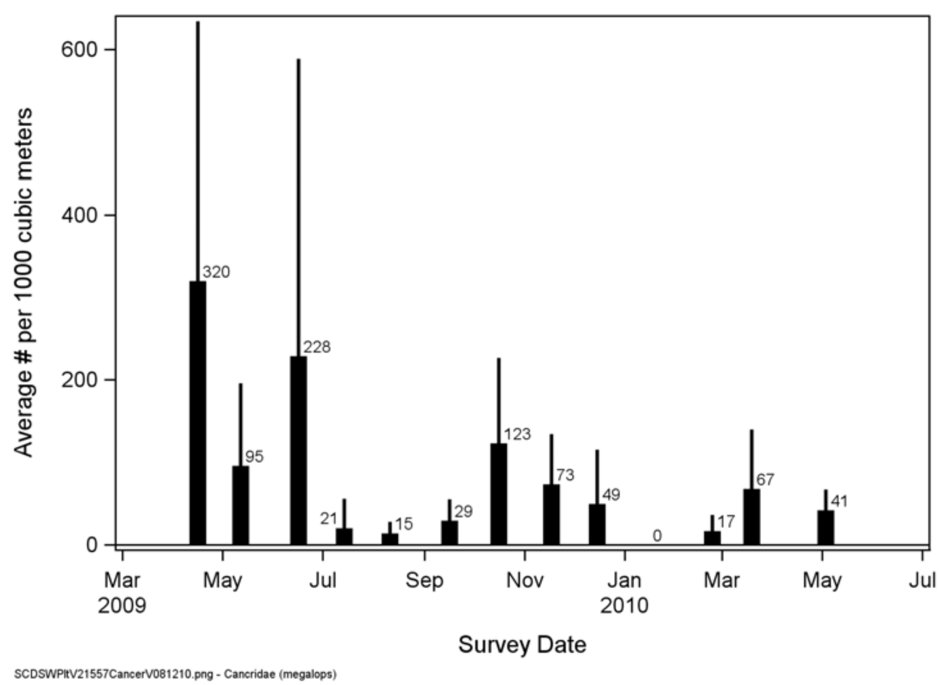


Figure 3.3-38. Survey mean concentration (#/1,000 m^3) of cancrid crab megalops collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

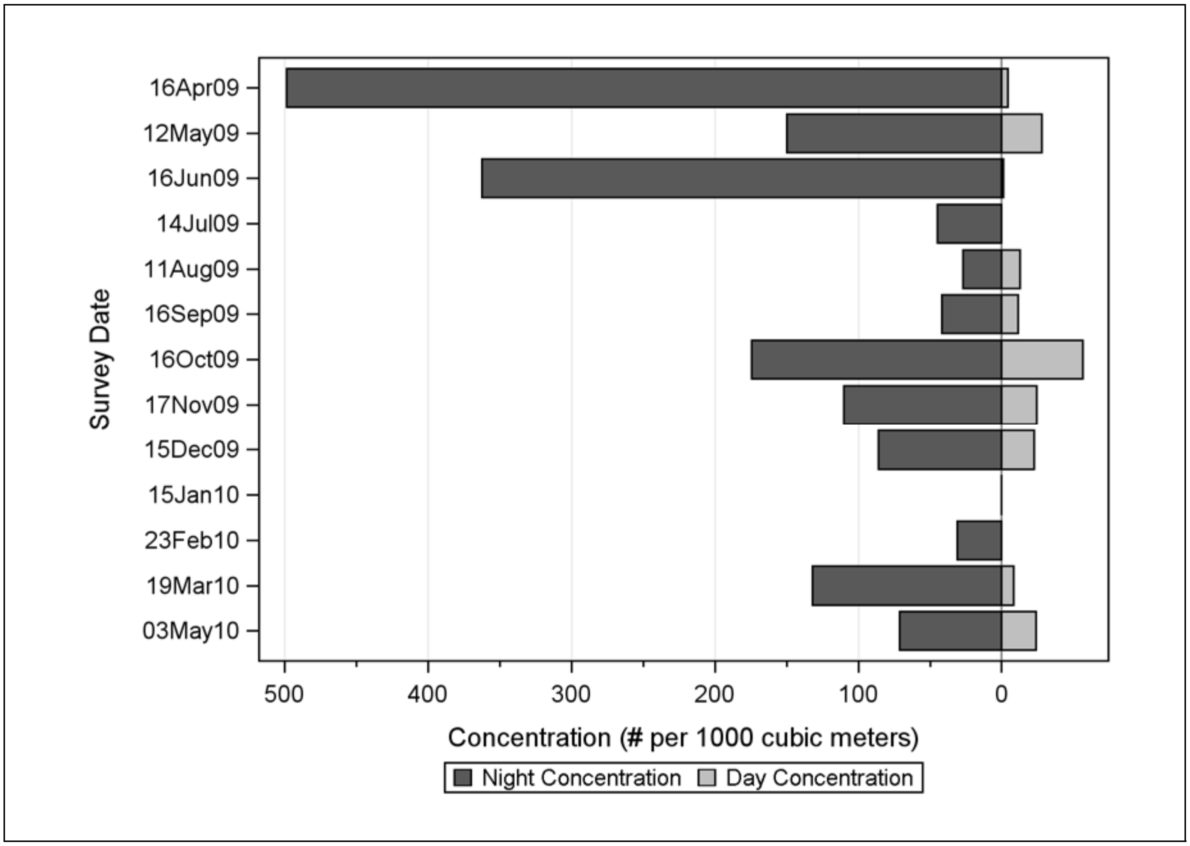


Figure 3.3-39. Mean concentration (#/1,000 m^3) in night and day samples for cancrid crab megalops collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.

Note: No night samples were collected during the January 2010 survey.

3.3.4.8.4 Impact Assessment

An estimated 473,500 cancrid crab megalops, which includes all four of the taxa groups identified, would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake.

Empirical Transport Model (*ETM*)

Cancrid crab larvae go through several different developmental stages prior to the megalops sampled for this study. No attempt was made to determine the age of the megalops larvae. A reasonable estimate on the duration of the megalops stage can be derived from studies of slender crab by Ally (1975), who found an average duration of 14.6 days. For the purposes of the *ETM* modeling the larval duration for cancrid 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 for cancrid crab megalops show that the megalops were most abundant in the source water during the April through June 2009 surveys (**Table 3.3-**

25). The average alongshore displacement for the 45 d period of megalopal exposure during the surveys when the megalops were present was 200.3 km (124.5 mi). The low intake volumes result in P_M estimates which range from 0.00009 (0.009%) to 0.00034 (0.034%) (**Table 3.3-26**).

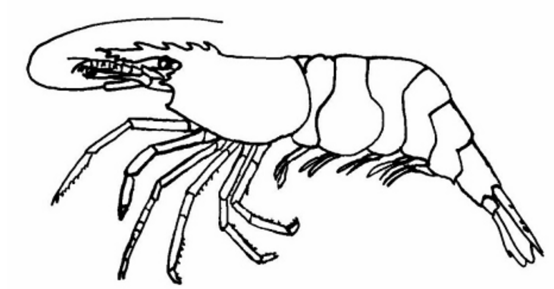
Table 3.3-25. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for cancrid crab megalops using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000061	0.000019	0.000143	0.000044	0.000225	0.000069	0.2133	210.81	0.0213
5/12/09	0.000074	0.000025	0.000173	0.000058	0.000272	0.000091	0.0983	290.05	0.0155
6/16/09	0.000025	0.000015	0.000057	0.000035	0.000090	0.000055	0.1809	341.59	0.0132
7/14/09	0.000120	0.000063	0.000280	0.000147	0.000440	0.000230	0.0215	204.93	0.0220
8/11/09	0.000163	0.000040	0.000380	0.000093	0.000597	0.000146	0.0242	246.11	0.0183
9/16/09	0.000074	0.000022	0.000174	0.000050	0.000273	0.000079	0.0298	260.63	0.0173
10/16/09	0.000077	0.000024	0.000180	0.000056	0.000283	0.000089	0.1282	286.26	0.0157
11/17/09	0.000068	0.000026	0.000158	0.000062	0.000248	0.000097	0.0745	188.23	0.0239
12/15/09	0.000102	0.000040	0.000238	0.000092	0.000374	0.000145	0.0687	69.47	0.0648
1/15/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	94.66	0.0475
2/23/10	0.000044	0.000019	0.000102	0.000045	0.000160	0.000071	0.0185	96.99	0.0464
3/19/10	0.000102	0.000042	0.000237	0.000098	0.000372	0.000154	0.0906	105.73	0.0426
5/3/10	0.000131	0.000048	0.000306	0.000112	0.000481	0.000175	0.0515	103.32	0.0436
Average >0	0.000087		0.000202		0.000318			200.34	
Average	0.000080		0.000187		0.000294			192.21	

Table 3.3-26. *ETM* estimates for cancrid crab megalops calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00009	0.00038	0.00048	0.00000
7 mgd (26,498 m^3)	0.00022	0.00090	0.00112	0.00000
11 mgd (41,640 m^3)	0.00034	0.00141	0.00175	0.00000

3.3.4.9 Shrimps (Caridea)



Caridean shrimps include several species of common tidepool shrimps (*Heptacarpus* and *Hippolyte*), bay shrimps (*Crangon*), snapping shrimps (*Alphaeus*), and dock shrimp (*Pandalus danae*). Thirty-seven species of caridean shrimps are listed as occurring in shallow subtidal and intertidal habitats in California (Carlton 2007). Shrimps of the family Crangonidae commonly live in protected sandy areas, often near sea grass beds, or subtidal sandy areas beyond the surf zone (Wicksten 2008). Although many common nearshore decapods range into beds of eelgrass (*Zostera* sp.), only one species, *Hippolyte californiensis*, usually is confined to this habitat. Species of *Heptacarpus*, especially *H. paludicola* and *H. sitchensis*, often live in sea grass beds or on mixed gravel and sand with algae (Jensen 1995). Commensal species of the shrimp *Betaeus* may live in the burrows of ghost shrimp (*Neotrypaea* spp.). Recent references place the genera *Heptacarpus, Lebbeus, Spirontocaris,* and *Hippolyte* variously in the family Hippolytidae (Carlton 2007) or the family Thoridae (Wicksten 2008), while re-assigning species of *Hippolyte* to *Heptacarpus*. Clearly the taxonomic relationships among many of the species are still under consideration.

Caridean shrimps form an important dietary component of many fish species that feed on benthic invertebrates in rocky reef habitats, kelp beds, and bays (Horn and Ferry-Graham 2006). Surfperches, greenlings, and several species of flatfishes are all known to utilize shrimps and other small crustaceans as part of their diets. Quast (1968) compiled a food utilization index of kelp bed fishes and found that shrimps comprised the fourth most important prey group among the 38 items assessed. Crangonids, and other carideans, are opportunistic predators that feed on the most abundant small epibenthic and benthic fauna and thus serve as an important step in the transfer of energy from the primary consumers and detritivores to the top predators of estuarine food webs (Siegfried 1989).

Morphologically, shrimps have a small carapace that encloses the head and the thorax, a muscular abdomen for swimming, and a thin exoskeleton to maintain a light weight. These general characters are common to all members of the class Malacostraca, which contains about half of all crustaceans. True caridean shrimps are differentiated from prawns by having the second segment of the abdomen overlapping the second and third segment, only having the first two leg pairs chelate, and having a more complex larval form.

3.3.4.9.1 Reproduction, Age, and Growth

Reproduction in caridean shrimps involves the extrusion of eggs by the adult female, which are then held with the pleopods beneath the abdomen. Fertilization occurs externally shortly after mating (Jensen 1995). Ovigerous crangonids can be found year-round along the California coast (Siegfried 1989), but are usually most abundant in the spring and summer in coastal embayments

(CDFG 1987). A bi-modal frequency in the occurrence of ovigerous females indicates that there are at least two spawning periods per year in San Francisco Bay populations of *Crangon*. The brood sizes of crangonid shrimp are related to shrimp size and species. Siegfried (1980) determined that brood size ranged from about 1,200 eggs for shrimp 48 mm (1.9 in.) long to about 7,000 eggs for shrimp 65 mm (2.6 in.) long. In another study, brood size was found to range from 2,499–8,840 eggs for shrimp from 55–71 mm (2.2–2.8 in.) long (Kinnetic Laboratories 1987). Photoperiod has been found to possibly affect reproductive output in *Heptacarpus pictus* (Custer 1986).

After a development period of several weeks to months, the eggs hatch and a 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 stages of successive increases in size: several zoeal stages are followed by megalops stage, which in *Crangon franciscorum* takes a total of 30–40 days (Hatfield 1985). Postlarval molts follow as the shrimp gradually changes into the adult form. It is during this time that they make the transition from a planktonic to a benthic life history phase. Siegfried (1989) reported that early stage larvae were more abundant in surface waters and late-stage larvae more abundant near the bottom.

There is little information on the longevity of Pacific Coast nearshore caridean shrimps. In a tropical seagrass caridean population, Bauer (1992) found that as a brood of previously spawned embryos was being incubated, the ovary of most females matured so that a new spawn took place soon after hatching of the embryos, female molting, and mating. Periods between spawns varied from 1–2 weeks in these species. Reproduction in these small seagrass carideans was characterized as both continuous and intense, both at the level of the population and the individual. Cohort analysis of some of the species indicated that female life span on the seagrass meadows was a matter of months, and certainly much less than a year, probably due to the intense fish predation that occurs on small macroinvertebrates in seagrass meadows (Heck and Orth 1980). A similar situation may apply to the species of *Heptacarpus* that were common in the present study.

3.3.4.9.2 Population Trends and Fishery

There is little information available on population trends of caridean species that are not harvested commercially, and locally this is restricted mainly to *C. franciscorum* in the San Francisco Bay area fisheries. Mortality due to predation is undoubtedly high and may explain geographic patterns of abundance within embayments (Kinnetic Laboratories 1987). Recruitment to bay populations in any one year, however, appears to depend on environmental conditions.

The annual shrimp catch in San Francisco Bay exceeded 720 MT for much of the 1920s and 1930s; the peak catch of more than 1,591 MT was made in 1935 (CDFG 1987). The annual catch did not exceed 455 MT during the 1940s and had declined to less than 45 MT by the late 1950s, it did not exceed 114 MT except in 1978 when 216 MT were landed (CDFG 1987). The catch of crangonid shrimp continued to be used for fresh or dried food until the 1960s. However, the demand declined steadily after the 1930s and the fishery became a bait fishery, supplying sport fishermen. Crangonid shrimps are too small to shell and market economically. The bait fishery relies entirely on trawls to capture shrimp. There is no fishery for caridean shrimps in the Monterey Bay area.

3.3.4.9.3 Sampling Results

Thoridae/Hippolytidae shrimps were present at the intake and source water stations but were particularly abundant in April 2009. At both the intake station and source water stations, they were collected in 11 of 13 surveys. They were not collected at any stations in January and February 2010. At the intake station, peak concentration (229/1,000 m^3) occurred in April 2009 (**Figure 3.3-40**) At source water stations, peak concentration (398/1,000 m^3) also occurred in April 2009 (**Figure 3.3-41**). The lowest concentrations occurred during winter months. Approximately 50–60% of the caridean megalops and post-larvae collected at both the intake and source water stations were classified as Thoridae/Hippolytidae shrimps (**Tables 3.3-2** and **3.3-4**), with most probably belonging to the genus *Heptacarpus* based on developmental series observed within the samples. They were collected almost exclusively in nighttime samples during all surveys (**Figure 3.3-42**). The absence of Thoridae/Hippolytidae shrimps during the January 2010 survey may have been a result of the lack of nighttime sampling due to unsafe sea conditions.

Crangonid shrimps were most abundant at the intake and source water stations in April 2009, reaching peak concentrations of 308/1,000 m^3 and 190/1,000 m^3, respectively (**Figures 3.3-43** and **3.3-44**). At the intake station (SWE) they were collected during eight of 13 surveys; they were not collected during August and September 2009 and January, February, and May 2010. At the source water stations (SW1–SW3) they were collected during nine of 13 surveys; they were not collected during August and September 2009 and January and February 2010. Approximately 40–50% of the caridean megalops and post-larvae collected at both the intake and source water stations were classified as crangonid shrimps (**Tables 3.3-2** and **3.3-4**). They were only collected in nighttime samples during all surveys except October 2009 (**Figure 3.3-45**), suggesting a behavioral trait of burying themselves in sand during the day and emerging at night into the water column to feed. The absence of crangonid shrimps during the January 2010 survey may have been a result of the lack of nighttime sampling due to unsafe sea conditions.

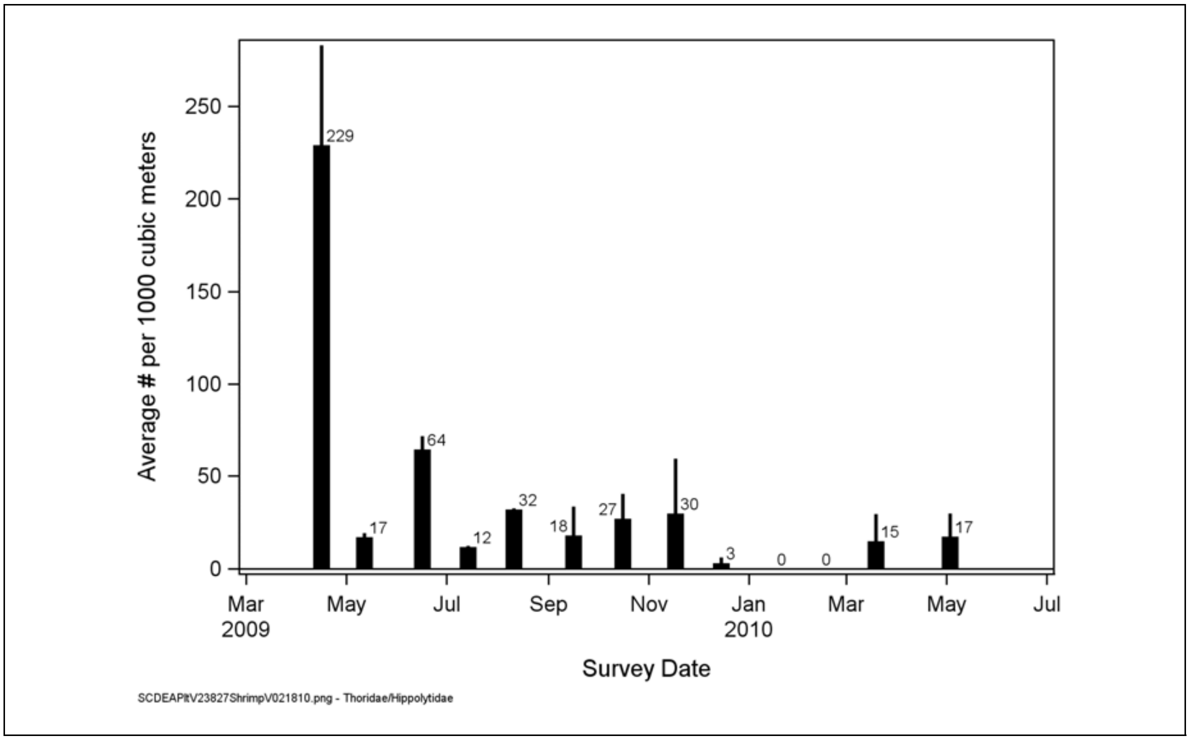


Figure 3.3-40. Survey mean concentration (#/1,000 m^3) of Thoridae/Hippolytidae shrimp larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

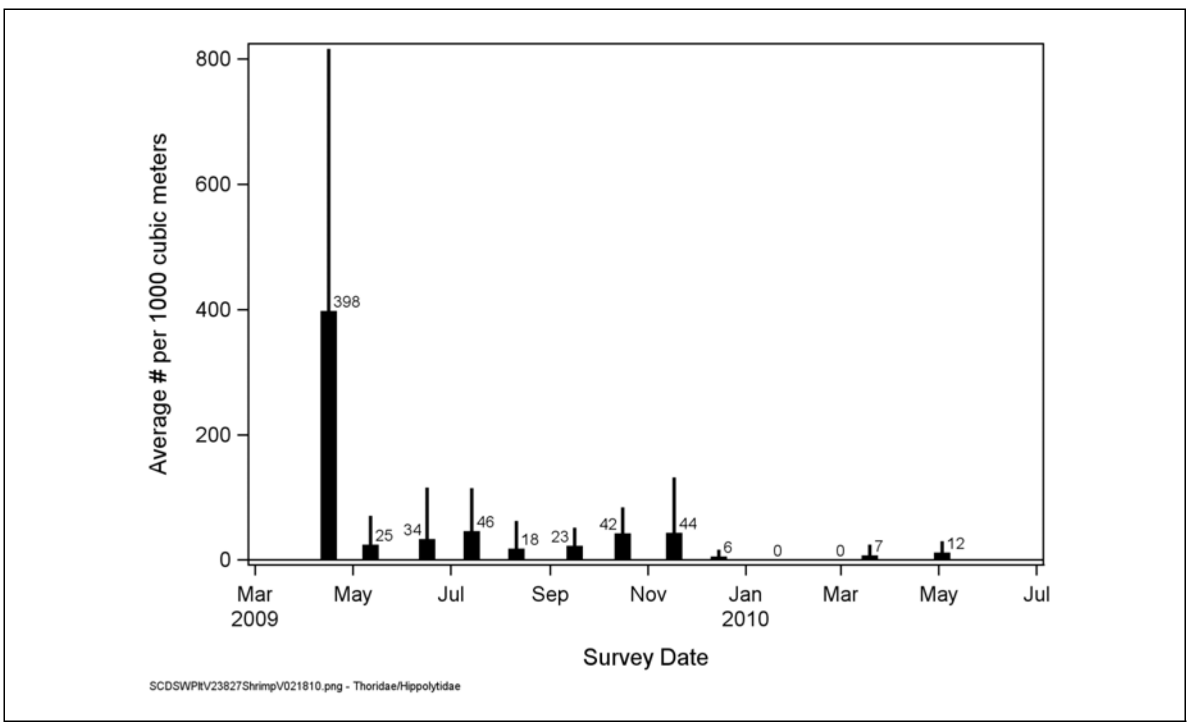


Figure 3.3-41. Survey mean concentration (#/1,000 m^3) of Thoridae/Hippolytidae shrimp larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

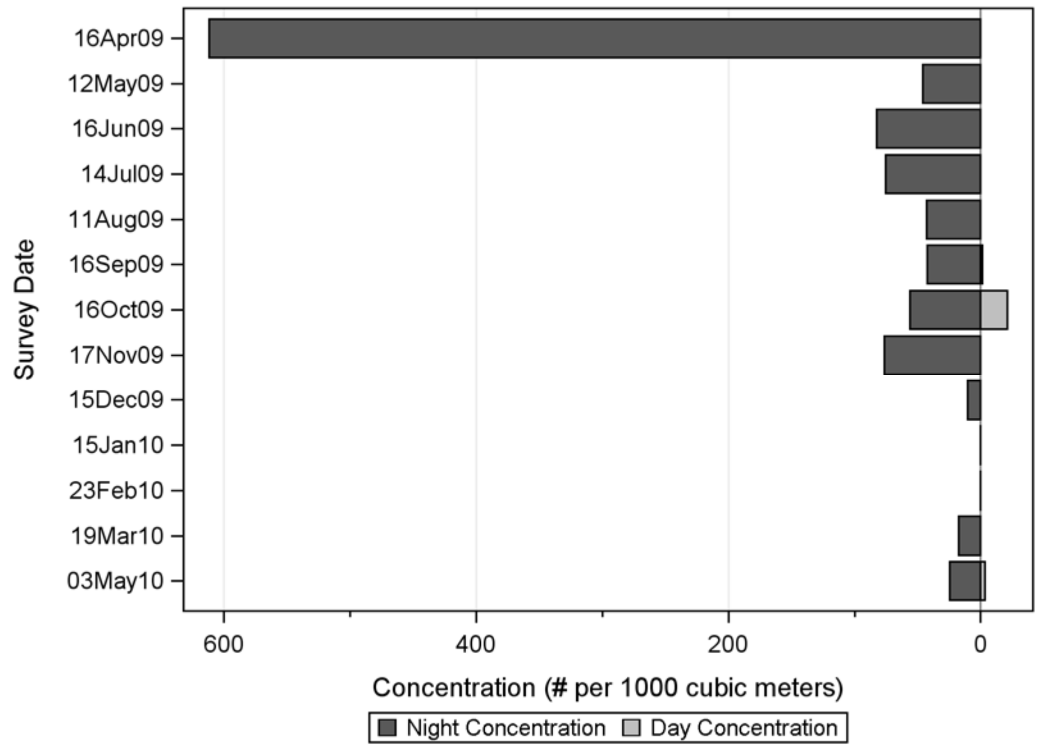


Figure 3.3-42. Mean concentration (#/1,000 m^3) in night and day samples for Thoridae/Hippolytidae shrimp larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.

Note: No night samples were collected during the January 2010 survey.

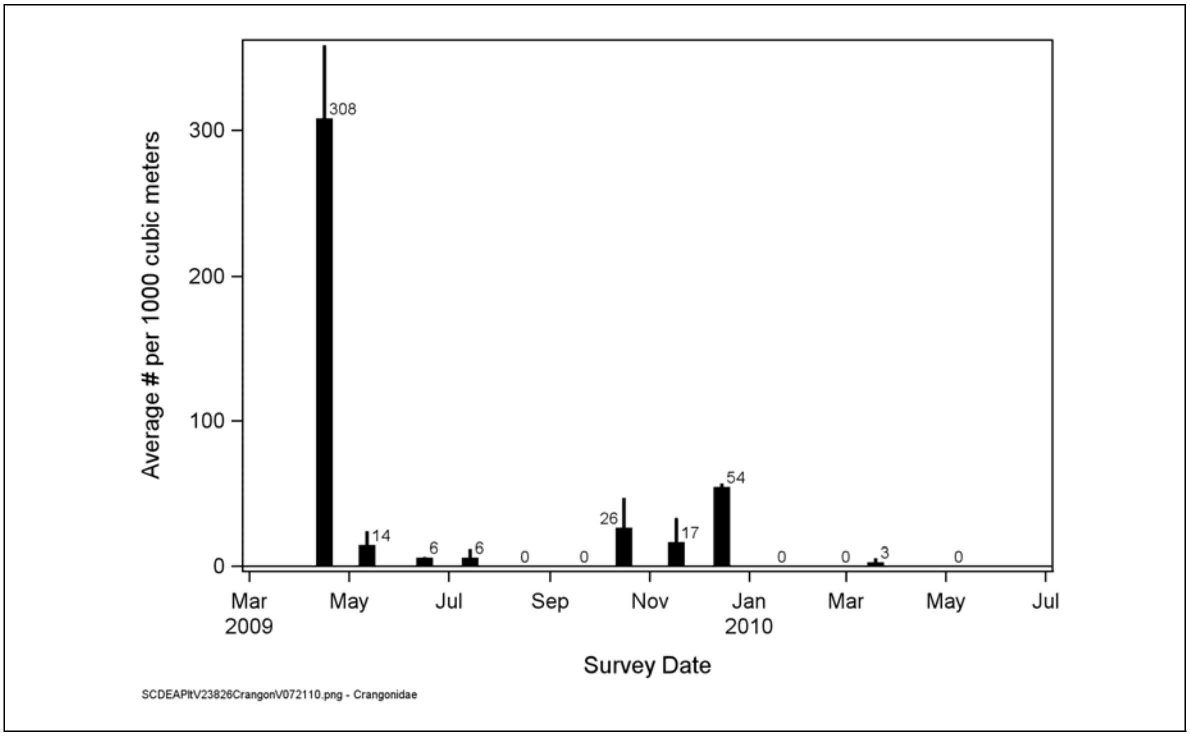


Figure 3.3-43. Survey mean concentration (#/1,000 m^3) of Crangonidae shrimp larvae collected at the intake station (SWE) with standard error indicated (+1 SE).

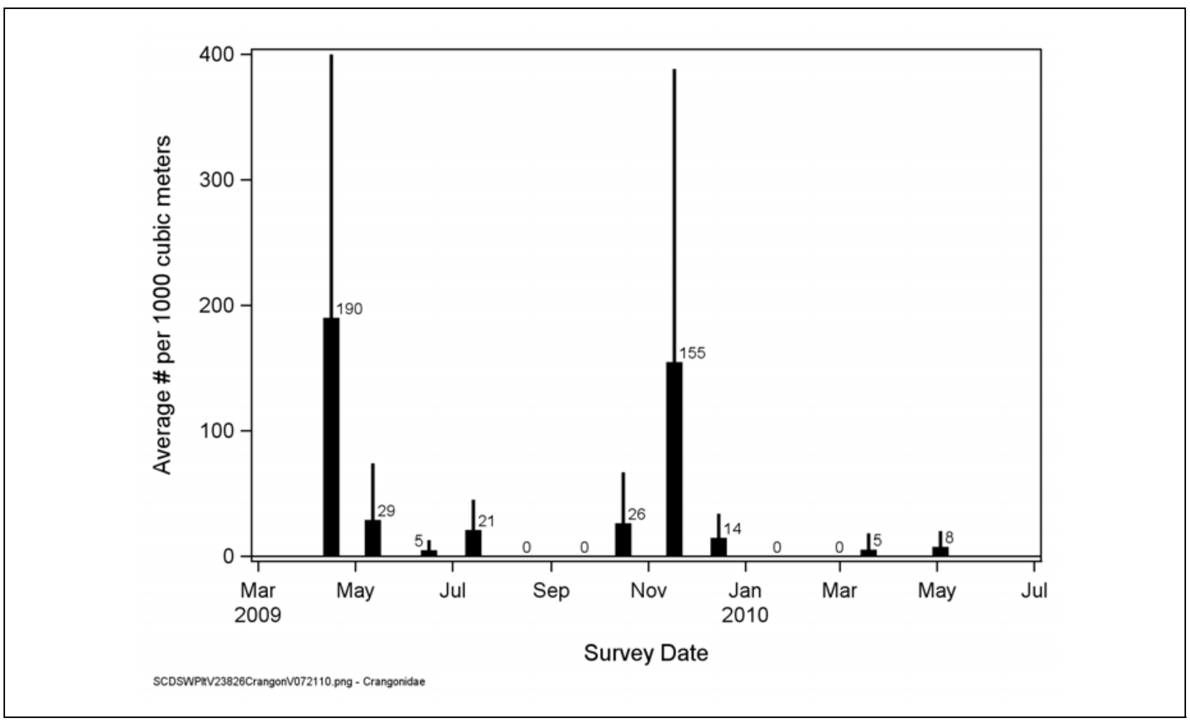


Figure 3.3-44. Survey mean concentration (#/1,000 m^3) of Crangonidae shrimp larvae collected at the source water stations (SW1–SW3) with standard error indicated (+1 SE).

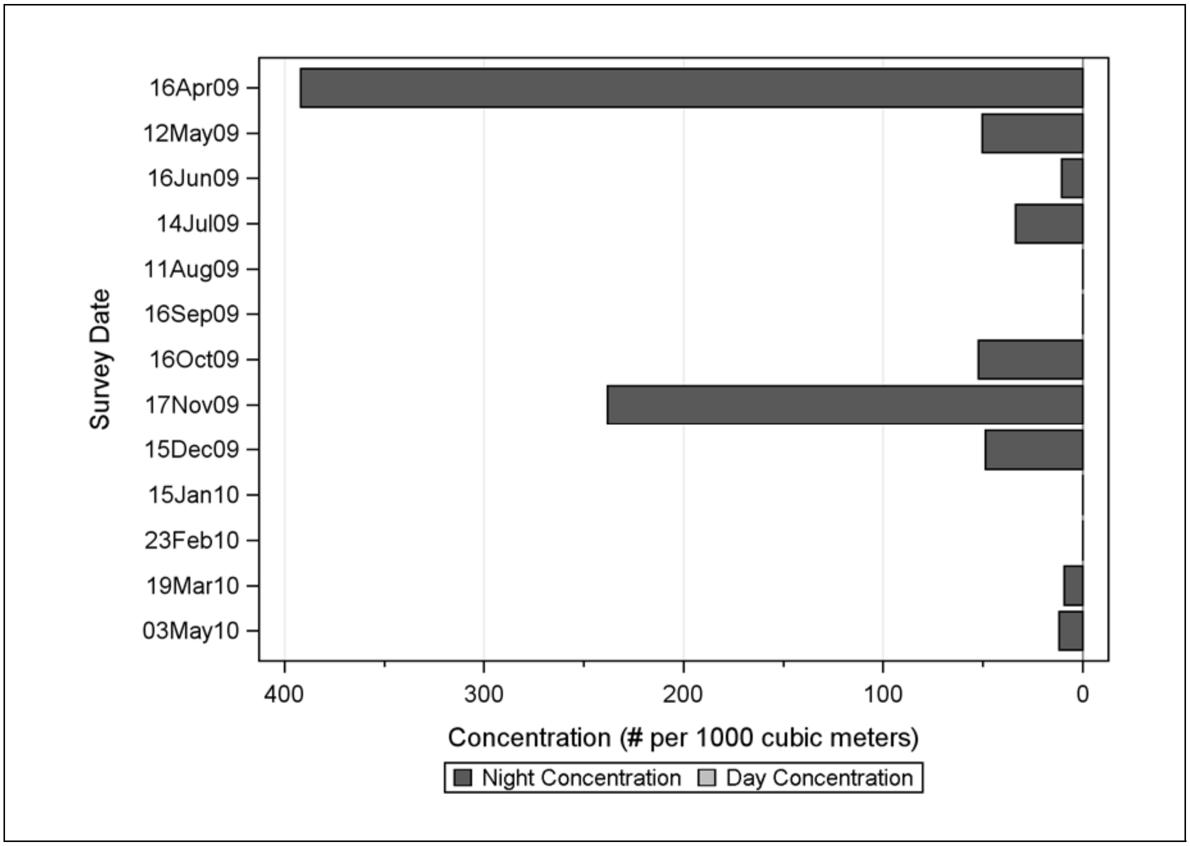


Figure 3.3-45. Mean concentration (#/1,000 m^3) in night and day samples for Crangonidae shrimp larvae collected at all stations (SW1, SW2, SW3, SWE) from April 2009 through May 2010.

Note: No night samples were collected during the January 2010 survey.

3.3.4.9.4 Impact Assessment

An estimated 432,500 advanced larval and post-larval caridean shrimps would be entrained during a one-year operation of the proposed project based on the 2009–2010 data and a pumping rate of 7 mgd (**Table 3.3-3**). Of these approximately 175,000 were Crangonidae which are larger and have some commercial value as bait, especially in the San Francisco Bay Area. The following section presents the results for the empirical transport modeling of the effects of the proposed desalination water intake on crangonid shrimp larvae.

Empirical Transport Model (*ETM*)

The larval duration for crangonid shrimp larvae collected during this study was assumed to be similar to the larval development in *Crangon franciscorum*, which takes a total of 30–40 days (Hatfield 1985). The data used to calculate the *ETM* estimates show that Crangonidae larvae were collected during nine of the 13 surveys and were most abundant during the April 2009 surveys (**Table 3.3-27**, and **Figures 3.3-43** and **3.3-44**). The average alongshore displacement for the 35 d period of larval exposure during the surveys when the larvae were present was

166.3 km (103.3 mi). The low intake volumes result in P_M estimates which range from 0.00009 (0.009%) to 0.00035 (0.035%) (**Table 3.3-28**).

Table 3.3-27. *PE* estimates and other estimates used in calculating *ETM* estimates of P_M for Crangonidae larvae using three daily intake flow volumes. Standard errors for the *PE* estimates are presented as well as the weight (f_i) applied to each survey estimate of *PE*, the alongshore current displacement for the larval period of exposure prior to the survey date, and the estimate of P_S used in extrapolating the *PE* to the extrapolated source water population. Averages calculated using the estimates from all of the surveys and also for surveys with *PE* estimates greater than zero (Average >0).

	Intake = 3 mgd		Intake = 7 mgd		Intake = 11 mgd				
Survey Date	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	PE Estimate	PE Std. Error	Survey Weight (f_i)	Alongshore Displacement (km)	P_s Estimate
4/16/09	0.000127	0.000047	0.000296	0.000109	0.000465	0.000172	0.4063	183.22	0.0246
5/12/09	0.000059	0.000038	0.000137	0.000088	0.000216	0.000138	0.0670	227.04	0.0198
6/16/09	0.000122	0.000062	0.000284	0.000146	0.000447	0.000229	0.0138	245.67	0.0183
7/14/09	0.000030	0.000021	0.000071	0.000050	0.000112	0.000078	0.0491	156.88	0.0287
8/11/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	221.71	0.0203
9/16/09	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	224.00	0.0201
10/16/09	0.000082	0.000052	0.000191	0.000121	0.000300	0.000190	0.0871	223.53	0.0201
11/17/09	0.000016	0.000012	0.000037	0.000028	0.000058	0.000045	0.2761	120.92	0.0372
12/15/09	0.000214	0.000115	0.000498	0.000269	0.000783	0.000423	0.0671	68.52	0.0657
1/15/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	64.23	0.0701
2/23/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	71.71	0.0628
3/19/10	0.000061	0.000055	0.000141	0.000129	0.000222	0.000203	0.0141	104.71	0.0430
5/3/10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0195	87.18	0.0516
Average >0	0.000089		0.000207		0.000325			166.31	
Average	0.000055		0.000127		0.000200			153.79	

Table 3.3-28. *ETM* estimates for Crangonidae larvae calculated using three intake volumes. The standard errors for the estimates of P_M included only the variance component associated with the *PE* estimates.

Intake Flow	*ETM* Estimate (P_M)	*ETM* Std. Err.	*ETM* + Std. Err.	*ETM* - Std. Err.
3 mgd (11,356 m^3)	0.00009	0.00063	0.00072	0.00000
7 mgd (26,498 m^3)	0.00022	0.00147	0.00169	0.00000
11 mgd (41,640 m^3)	0.00035	0.00231	0.00265	0.00000

4.0 Wedgewire Screen Efficiency Study

4.1 Introduction

This section provides information on *in situ* tests that were conducted to examine the operational characteristics of the proposed narrow-slot cylindrical wedgewire screen intake relative to entrainment, impingement, hydrodynamics of the screen during pumping, and screen corrosion and biofouling.

4.2 Screened vs. Unscreened Intake Study

4.2.1 Methods

4.2.1.1 Field Collection

A total of 13 entrainment surveys was conducted during the intake screen efficiency study (**Table 4.2-1**). During 12 of the 13 surveys, a total of eight samples was collected, four from the screened intake and four from the unscreened (**Table 4.2-1**). Half of the samples were collected during the day and half at night. During the May 3, 2010 survey, a total of six samples was collected, two during the day and four at night. Start and end times of the samples were recorded on field data sheets. The following water quality measurements were recorded vertically at two-meter intervals once per survey using a calibrated instrument: temperature, pH, salinity, dissolved oxygen, and turbidity.

Lights were used to illuminate the wedgewire screen module for video imaging done for the screen impingement study (Section 4.3) during the first six surveys (April 16, 2009 through September 16, 2009). It was determined that the lights used for nighttime videography could bias the results of the screen efficiency survey by attracting fishes and other organisms, and therefore, the data collected from these samples were not used in the intake screen efficiency analysis (**Table 4.2-1**)

Sampling was conducted from a stationary platform on the Santa Cruz Wharf. A Wacker PT4 pump was installed on the platform to collect the samples. A system of 10.2 cm (4-in.) (ID) PVC pipe connected the pump to both the screened and unscreened intakes, and two large ball valves were used to switch between the two intakes. Both intakes were attached to pier pilings at a depth of roughly 4.6–6.1 m (15–20 ft) of water (depending on tide).

The wedgewire screen intake module had a 2.0 mm (0.08 in.) slot opening and was sized to ensure a maximum through-screen velocity of 0.1 m/sec (0.33 ft/sec). The T-section screen was constructed of copper-nickel alloy. The diameter of the screen was 21.9 cm (8-5/8 in.), the overall length was 88.9 cm (35 in.), and the outlet flange was 16.8 cm (6-5/8 in.) diameter. The screen weighed approximately 34 kg (75 lb).

The unscreened intake consisted of a 71.1 cm (28-in.) section of 10.2 cm (4-in.) (ID) PVC pipe with several square sections cut out on either side. Originally this section was covered with 1.3 cm (½-in.) mesh plastic fencing material to keep out kelp and other large objects. The material was removed after it became heavily fouled prior to the September 16, 2009 survey. After September 16, 2009 the unscreened intake was switched out and cleaned prior to every survey.

The pumped water from both intakes was filtered through a 335-µm mesh plankton net and codend which was suspended in water to lessen the chances of damage to the larvae. Approximately 40 m^3 (10,567 gal) of water was pumped at a rate of approximately 1 m^3 (264 gal) per minute for each sample. Calibrated flowmeters were used to calculate the volume of water filtered by each net.

At the completion of each sample collection, the net was retrieved from the water and all of the collected material was rinsed into the codend. The contents of the net were then placed into a labeled jar and preserved in a 5–10% buffered formalin-seawater solution. Each sample was assigned a serial number based on the pump number, intake screen slot size, date, time, cycle number, and depth to the bottom. This information was logged onto a sequentially-numbered data sheet. The sample's serial number was used to track it through laboratory processing, data analysis, and reporting.

4.2.1.2 Laboratory Processing

Laboratory processing procedures were the same as those described in detail in Section 3.2.2. Some of the fishes were measured for notochord length and head capsule depth and width using the same system used in measuring the notochord lengths for fishes collected during the intake and source water surveys. After the length of each specimen was recorded, the widest dimensions of the head depth and head width were measured. The actual position of each of these measurements varied among taxa based on their morphology. Larvae with damaged heads were not measured.

Fish eggs were only enumerated and identified from the screen efficiency test samples collected from the April through November 2009 surveys because the overwhelming majority (over 87%) could only be classified as “undeveloped/unfertilized eggs.” Information regarding the fish eggs that were identified and enumerated from the first six surveys is provided in Appendix D.

Table 4.2-1. Summary of the number of pumped samples collected and processed during the screen efficiency study.

Survey Number	Date	Samples Collected and Processed				Samples used in Analysis			
		Screened		Unscreened		Screened		Unscreened	
		Day	Night	Day	Night	Day	Night	Day	Night
1	4/16/09	2	2	2	2	2	0[1]	2[2]	0[1]
2	5/12/09	2	2	2	2	2	0[1]	2[2]	0[1]
3	6/16/09	2	2	2	2	2	0[1]	2[2]	0[1]
4	7/14/09	2	2	2	2	2	0[1]	2[2]	0[1]
5	8/11/09	2	2	2	2	2	0[1]	2[2]	0[1]
6	9/16/09	2	2	2	2	2	0[1]	2	0[1]
7	10/16/09	2	2	2	2	2	2	2	2
8	11/17/09	2	2	2	2	2	2	2	2
9	12/15/09	2	2	2	2	2	2	2	2
10	1/15/10	2	2	2	2	2	2	2	2
11	2/23/10	2	2	2	2	2	2	2	2
12	3/19/10	2	2	2	2	2	2	2	2
13	5/3/10	1	1	2	2	1	1	2	2
	Total	**25**	**25**	**26**	**26**	**25**	**13**	**26**	**14**

[1] Lights used for nighttime filming may have attracted fishes and other organisms, and therefore the data from these samples were not used in the intake screen efficiency analysis.

[2] Half-inch mesh fencing material was used on the unscreened intake during these surveys.

4.2.1.3 Data Analysis

Entrainment estimates were calculated using the daily average larval concentrations from the field samples and the proposed flow of 26,498 m^3 per day (7 mgd) for the desalination intake. The estimates of the daily average concentrations and associated variance were calculated based on a stratified random design with two cycles (day and night) and two replicates per cycle. The estimates of larval entrainment for each of the two intakes were based on monthly sampling where E_T is the estimate of total entrainment for the study period and E_i is the monthly entrainment estimate calculated from the average concentration calculated for the day sampled within each survey period. The average concentration and variance calculated for the day was extrapolated across the days within each sampling period.

The data from the pump samples were analyzed to determine if any differences could be detected between concentrations of fish and target shrimp and crab larvae from the screened and unscreened intakes. Fish egg data were not analyzed because eggs were only processed from samples collected through the November 2009 survey. The analysis also did not include data collected at night through the first six surveys (April–September) because lights used for the video system may have attracted fishes and other organisms, potentially biasing the results. The numbers of fish larvae collected were relatively low. As a result, only white croaker was analyzed, which was the most abundant taxon of fish larvae in the screened vs. unscreened samples. White croaker was also the most abundant taxon collected during the intake and source water study (see Section 3.3.2). An analysis combining all of the larval fishes collected was done using taxa counts for each sample. Target invertebrate larvae were more abundant than fish larvae. Three taxa groups of invertebrates were analyzed: cancrid crab megalops and the later-stage larvae of Crangonidae and Thoridae/Hippolytidae shrimps.

The screen test data were first analyzed to determine if the variances were statistically similar among the treatment groups used in the study. Homogeneity of variance is an assumption of the t-test and other analysis of variance models used to test for differences in concentrations of entrained larvae between the screened and unscreened intakes. The Brown-Forsythe test was used for testing the equality of the variances among groups (Winer et al. 1991). Tests were run for the entire set of data as two groups—screened and unscreened—as well as the screened and unscreened data grouped by survey. The analyses were run on the untransformed data as well as data transformed as $\log(x+c)$, $\sqrt{(x+c)}$, $\sqrt{\sqrt{(x+c)}}$, where c represents constant values of 0.01, 0.1, 0.5, and 1.0. The transformation and constant that best equalized the variances was used in analyzing the data for differences between the screened and unscreened intakes. For data sets that did not meet the assumption of equality of variances for the data grouped by survey, an option in the Proc Mixed procedure in SAS for using adjusted degrees of freedom in the f-test was used to correct differences in variances among groups (Littell et al. 1996).

During each survey, samples were collected from the screened and unscreened intakes during day and night periods. As the data were not collected from the two intakes at the same time, the data were blocked by the survey and cycle periods for analysis. Two analyses were done on each data set following the transformation selected from the results of the Brown-Forsythe test. The first analysis was a simple paired t-test using the average of the two samples collected from each of the two intakes during each cycle, resulting in a total of 20 paired samples. The paired t-test was used to compare the average difference between the screened and unscreened intake paired samples to determine if it was significantly different from zero (null hypothesis $\bar{x} = 0$). The second analysis was an analysis of variance (ANOVA) using a blocked design with the screened and unscreened samples defined as the two treatment groups within survey and day-night cycle blocks. All analyses were done using SAS/Stat Version 9.2 (SAS Institute 2008).

4.2.2 Results

A summary of the mean concentrations of all fish larvae and target shrimps and crabs for the screened and unscreened samples is provided in **Table 4.2-2**. The highest overall mean concentrations of larval fishes occurred in February, March, and May 2010 while the lowest were seen from April 2009 through January 2010 (**Table 4.2-2**). During the time period when fish eggs were removed from the samples (April–September), peak mean concentrations (screened samples=13,701/m^3; unscreened samples=16,332/m^3) occurred in June 2009. Peak mean concentration of target invertebrates from the screened samples (12,144/m^3) occurred in May 2010 and peak mean concentration of target invertebrates from the unscreened samples (5,431/m^3) occurred in November 2009.

Table 4.2-2. Summary of the mean concentrations (#/1,000 m^3) of fish larvae, fish eggs, and target shrimp and crab larvae collected during intake screen efficiency study surveys from April 2009 through May 2010.* See Appendix D for individual survey results.

		Screened			Unscreened		
Survey #	Date	Fish Larvae	Fish Eggs	Target Shrimps and Crabs	Fish Larvae	Fish Eggs	Target Shrimps and Crabs
1	04/16/09	0.0	1,422.3	782.0	0.0	1,534.5	1,231.4
2	05/12/09	30.1	1,761.8	10,867.0	44.6	1,967.3	1,528.3
3	06/16/09	72.4	13,701.7	1,799.3	14.2	16,332.1	398.1
4	07/14/09	0.0	1,811.8	1,278.9	0.0	2,930.4	71.1
5	08/11/09	0.0	468.7	342.6	0.0	396.4	128.8
6	09/16/09	0.0	1,084.1	3,522.3	35.2	1,685.6	39.8
7	10/16/09	16.4	5,583.9	376.2	31.4	5,254.5	385.1
8	11/17/09	0.0	951.3	1,908.6	16.8	955.1	5,431.4
9	12/15/09	87.5	-	328.7	47.2	-	367.7
10	01/15/10	6.6	-	32.4	0.0	-	32.5
11	02/23/10	206.0	-	22.3	229.1	-	61.8
12	03/19/10	31.2	-	316.4	157.8	-	1,662.3
13	05/03/10	194.1	-	12,144.4	106.7	-	5,412.1

* Does not include data collected at night through the first six surveys (April–September) when lights used for the video system may have attracted fishes and other organisms potentially biasing the results. No survey was conducted in April 2010 due to unsafe conditions. Fish eggs were only identified from the April through November 2009 samples.

A summary of the notochord length and head capsule measurements from the larval fishes collected during the pump sampling through the screened and unscreened intakes at the Santa Cruz Wharf is presented in **Table 4.2-3**. The head dimensions (depth and width) of some of the fishes are similar in size (tubesnout and pricklebacks) because they have more or less rounded heads when viewed straight on from the front of the fish. A few of the fishes' heads are laterally compressed (sculpins and white croaker) while others have heads that are dorsoventrally compressed (clingfishes). It can be seen that for most taxa that were collected from screened intake that one or both of the head capsule measurements are less than the 2-mm slot size of the wedgewire screen, with a few exceptions. One snailfish and three clingfishes with head depths and widths greater than 2 mm (0.08 in.) were found in screened intake samples.

Length measurements of the juvenile and adult fishes collected during the wharf pump sampling are presented in **Table 4.2-4**. All of these fishes were collected from the unscreened intake. Head capsule measurements were not recorded for these individuals due to their large size. It should be noted that surfperch are released from females as juveniles and are not small enough to be entrained through the 2-mm openings of the wedgewire intake screen.

Table 4.2-3. Summary of notochord lengths and head capsule depths and widths of larval fishes collected from the unscreened and screened intakes at the Santa Cruz wharf pump sampling. Data includes samples collected during nighttime sampling when lights were on for videography.

		Notochord Length (mm)			Head Capsule Depth (mm)		Head Capsule Width (mm)	
	N	mean	max	min	max	min	max	min
***Aulorhynchus flavidus* (tubesnout)**								
screened	25	6.02	9.36	4.72	1.16	0.75	1.16	0.65
unscreened	19	6.05	8.46	5.13	1.12	0.73	1.16	0.81
CIQ gobies (unidentified gobies)								
screened	4	3.58	4.03	3.03	0.58	0.46	0.50	0.34
unscreened	4	3.67	4.34	3.42	0.58	0.45	0.39	0.34
Cottidae (sculpins)								
screened	2	2.06	2.15	1.96	0.43	0.38	0.38	0.33
unscreened	4	3.17	4.49	1.78	0.68	0.35	0.49	0.35
Cyclopteridae (snailfishes)*								
screened	1	7.30	–	–	2.19	–	2.05	–
unscreened	7	10.76	14.16	8.39	3.72	2.23	3.96	1.94
***Genyonemus lineatus* (white croaker)**								
screened	26	3.59	7.64	1.75	1.81	0.19	1.34	0.16
unscreened	19	2.74	8.74	1.74	2.65	0.24	1.71	0.18
Gobiesocidae (clingfishes)**								
screened	6	9.01	15.72	3.43	2.97	0.59	5.86	0.63
unscreened	3	4.38	5.14	3.44	0.94	0.65	0.90	0.69
Pholidae (gunnels)								
screened	1	11.55	–	–	0.97	–	1.11	–
unscreened	9	10.44	12.30	7.53	1.11	0.94	1.18	0.97
Stichaeidae (pricklebacks)								
screened	1	10.56			1.04		0.94	
unscreened	6	6.80	7.34	6.22	0.85	0.81	0.87	0.77

*Includes *Liparis* spp.
**Includes *Gobiesox* spp.

Table 4.2-4. Larger juvenile and adult fishes collected in the unscreened intake at the Santa Cruz Wharf.

			Standard length (mm)		
Taxon	Common name	count	mean	maximum	minimum
Artedius harringtoni	scalyhead sculpin	1	45		
Aulorhynchus flavidus	tubesnout	2	145	175	115
Cymatogaster aggregata	shiner surfperch	1	75		
Sebastes spp.	rockfishes	1	37		
*Sebastes caurinus**	copper rockfish	6	20	*	*
Sebastes mystinus	blue rockfish	3	74	90	60

* Identification based on DNA analysis. All fish were damaged and length is best estimate for this group.

4.2.2.1 Screened Samples

A total of 72 fish larvae in 15 taxonomic groups (plus seven unidentified and 12 damaged larvae) was collected in the screened samples from the 13 surveys conducted during the April 2009–May 2010 study period (**Table 4.2-5**). The estimated total number of fish larvae that would be entrained annually through a 2-mm wedgewire screen based on an intake volume of 7 mgd and the 2009-2010 data from the screened intake was 417,819 (**Table 4.2-5**).

Seven taxa comprised 86% of the total mean concentration of fish larvae during the study period: white croaker, tubesnout (*Aulorhynchus flavidus*), damaged larval fishes, clingfishes (family Gobiesocidae), unidentified yolk sac larvae, sculpins, and Pacific staghorn sculpin (*Leptocottus armatus*) (**Table 4.2-5**). White croaker comprised nearly 26% of the total mean concentration of larval fishes collected in the screened samples.

Four taxa of cancrid crab megalops were identified from the screened samples from the 13 surveys conducted during the April 2009–May 2010 study period. They comprised 36% of the total mean concentration of target invertebrates. The remainder of the target invertebrate larvae was from four different shrimp families (**Table 4.2-5**). Most of the shrimp specimens, although in advanced stages of larval development, could only be reliably identified to the family level. The estimated total number of target invertebrate larvae that would be entrained annually through a 2-mm wedgewire screen based on an intake volume of 7 mgd and the 2009-2010 data from the screened intake was 20,236,208 (**Table 4.2-5**).

The highest mean concentration of larval fishes collected in the screened samples occurred in February 2010 at 206.0/1,000 m^3. No larval fishes were collected in April, July, August, September and November 2009 (**Table 4.2-2**). The highest mean concentration of target invertebrates (12,144.4/1,000 m^3) occurred in May 2010. The lowest mean concentration of target invertebrates (22.3/1,000 m^3) occurred in February 2010 (**Table 4.2-2**).

Table 4.2-5. Counts and concentrations (#/1,000 m^3) of larval fishes and target shrimps and crabs collected in the screened samples during the intake screen efficiency study from April 2009 through May 2010* along with estimated annual entrainment based on an intake flow of 7 mgd and the 2009–2010 screened sample data.

Taxon	Common Name	Number Collected (screened samples)	Mean Conc. (#/1,000 m^3)	Percent of Total Mean Conc.	Screened Annual Entrainment Estimate**
Fishes					
Genyonemus lineatus	white croaker	28	12.7	25.5%	124,532
Aulorhynchus flavidus	tubesnout	16	10.0	20.1%	38,245
larval fish – damaged	damaged larval fishes	12	6.3	12.7%	65,957
unid. larvae, yolksac	yolksac larvae	7	3.0	6.1%	33,049
Gobiesocidae	clingfishes	6	4.8	9.7%	46,271
Cottidae	sculpins	5	3.5	7.1%	27,917
Leptocottus armatus	Pacific staghorn sculpin	5	2.6	5.1%	22,797
Stichaeidae	pricklebacks	2	1.1	2.3%	7,606
Engraulis mordax	northern anchovy	2	0.9	1.7%	9,108
Pholidae	gunnels	1	0.5	0.9%	5,555
CIQ goby complex	gobies	1	0.5	1.0%	6,121
Sebastes spp.	rockfishes	1	0.7	1.3%	2,051
Gibbonsia spp.	kelpfishes	1	0.7	1.3%	2,051
Cebidichthys violaceus	monkeyface prickleback	1	1.2	2.3%	12,440
Citharichthys spp.	sanddabs	1	0.5	0.9%	4,900
Gobiidae	gobies	1	0.4	0.9%	4,610
Neoclinus spp.	fringeheads	1	0.4	0.9%	4,610
	Total	**91**	**49.8**	**100.0%**	**417,819**
Target Shrimps and Crabs					
Thoridae/Hippolytidae	shrimps	1,485	1,504.6	58.0%	15,469,280
Romaleon antennarius/ Metacarcinus gracilis	Cancer crabs	1,305	849.3	32.7%	2,860,984
Crangonidae	sand shrimps	318	141.6	5.5%	1,412,174
Metacarcinus anthonyi	yellow crab megalops	71	44.8	1.7%	190,556
Cancridae	Cancer crabs megalops	51	34.3	1.3%	164,454
Alpheidae	shrimps	22	10.3	0.4%	110,430
Cancer productus/ Romaleon spp.	rock crab megalops	14	9.1	0.4%	28,331
	Total	**3,266**	**2,594.0**	**100.0%**	**20,236,208**

* Does not include data collected at night through the first six surveys (April–September) when lights used for the video system may have attracted fishes and other organisms potentially biasing the results. No survey was conducted in April 2010 due to unsafe conditions.

**Estimate based on each survey's concentration multiplied by the intake volume (# days x 26,498 m^3/day) between surveys.

4.2.2.2 Unscreened Samples

A total of 88 fish larvae in 17 taxonomic groups (plus six unidentified and 10 damaged larvae) was collected during the 13 surveys in the unscreened samples during the April 2009–May 2010 study period (**Table 4.2-6**). The total estimated number of fish larvae that would be entrained annually, based on an intake volume of 7 mgd and the 2009–2010 data from the unscreened samples, was 515,837 (**Table 4.2-6**).

Eight taxa comprised over 80% of the total mean concentration of fish larvae collected at the unscreened intake during the study period: white croaker, tubesnout, damaged larval fishes, gunnels (family Pholidae), unidentified yolk sac larvae, pricklebacks, sculpins and snailfishes (family Cyclopteridae). White croaker comprised 21% of the total mean concentration of larval fishes collected in the unscreened samples

Four taxa of cancrid crab megalops were identified from the samples collected from the unscreened intake. They comprised 36.1% of the total mean concentration of target invertebrates. The remainder of the target invertebrate larvae was from four shrimp families (**Table 4.2-6**). Many of the shrimp specimens, although in advanced stages of larval development, could only be reliably identified to the family level. Based on the proposed pumping rate of 7 mgd, it was estimated that the total annual entrainment of these target invertebrates would be 9,912,617 individuals (**Table 4.2-6**).

The peak mean concentration of larval fishes (229.1/1,000 m^3) occurred in February 2010. No larval fishes were collected in April, July, and August 2009 and January 2010 (**Table 4.2-2**). The peak mean concentration of target invertebrates (5,431.4/1,000 m^3) occurred in November 2009. The lowest mean concentration of target invertebrates (32.5/1,000 m^3) occurred in January 2010 (**Table 4.2-2**).

Table 4.2-6. Counts and concentrations (#/1,000 m^3) of larval fishes and target shrimps and crabs collected in the unscreened samples during the intake screen efficiency study from April 2009 through May 2010* along with estimated annual entrainment based on an intake flow of 7 mgd and the 2009–2010 unscreened sample data.

Taxon	Common Name	Number Collected (unscreened samples)	Mean Conc. (#/1,000 m^3)	Percent of Total Mean Conc.	Unscreened Annual Entrainment Estimate**
Fishes					
Genyonemus lineatus	white croaker	25	11.2	21.4%	111,451
Aulorhynchus flavidus	tubesnout	20	11.4	21.7%	82,921
larval fish – damaged	damaged larval fishes	10	5.2	9.9%	51,324
Pholidae	gunnels	9	4.2	8.0%	50,607
unid. larvae, yolksac	yolksac larvae	6	2.6	4.9%	27,705
Stichaeidae	pricklebacks	6	2.8	5.4%	34,055
Cottidae	sculpins	5	2.2	4.2%	23,034
CIQ goby complex	gobies	4	1.8	3.3%	18,181
Gobiesocidae	clingfishes	3	1.3	2.4%	14,303
Cyclopteridae	snailfishes	3	2.7	5.1%	28,454
Sebastes spp.	rockfishes	2	1.4	2.7%	10,926
Engraulis mordax	northern anchovy	2	0.9	1.7%	9,298
Gibbonsia spp.	kelpfishes	2	0.9	1.7%	10,061
Artedius spp.	sculpins	2	1.2	2.3%	13,491
Rhinogobiops nicholsi	blackeye goby	1	1.1	2.1%	11,681
Citharichthys spp.	sanddabs	1	0.4	0.8%	4,449
Cymatogaster aggregata	shiner surfperch	1	0.5	0.9%	4,801
Agonidae	poachers	1	0.4	0.8%	4,654
Sebastes mystinus	blue rockfish	1	0.4	0.8%	4,441
	Total	**104**	**52.6**	**100.0%**	**515,837**
Target Shrimps and Crabs					
Crangonidae	sand shrimps	966	404.3	31.4%	4,147,986
Romaleon antennarius/ Metacarcinus gracilis	Cancer crabs	669	420.2	32.6%	1,743,650
Thoridae/Hippolytidae	shrimps	574	402.3	31.2%	3,593,092
Metacarcinus anthonyi	yellow crab	43	24.8	1.9%	143,950
Alpheidae	shrimps	34	15.0	1.2%	169,104
Cancer productus/ Romaleon spp.	rock crab	19	12.2	0.9%	53,543
Cancridae	Cancer crabs	15	9.7	0.7%	61,292
	Total	**2,320**	**1288.5**	**100.0%**	**9,912,617**

* Does not include data collected at night through the first six surveys (April–September) when lights used for the video system may have attracted fishes and other organisms potentially biasing the results. No survey was conducted in April 2010 due to unsafe conditions.

**Estimate based on each survey's concentration multiplied by the intake volume (# days x 26,498 m^3/day) between surveys.

4.2.2.3 Analysis

4.2.2.3.1 All Fishes

Fish larvae were collected in the screened samples in eight of the 13 surveys. Peak mean concentration (206/1,000 m^3) of fishes in the screened samples occurred during the February 2010 survey (**Figure 4.2-1**). No fish larvae were collected in the screened samples during the April, July, August, September or November 2009 surveys.

Fish larvae were collected in the unscreened samples in nine of the 13 surveys. Peak mean concentration (229/1,000 m^3) of fishes in the unscreened samples occurred during the February 2010 (**Figure 4.2-1**). No fish larvae were collected in the unscreened samples during the April, July, August 2009 or January 2010 surveys. Daytime and nighttime concentrations of all fishes collected from the screened and unscreened samples are provided in **Figure 4.2-2.**

The Brown-Forsythe test for equality of variances was not significant for the two groups representing the screened and unscreened samples, but when the screened and unscreened sample data were grouped by survey, significant differences among group variances were detected in all of the data sets except for the data transformed as $log(x + 0.01)$. As a result, further analyses of the data were done using the $log(x + 0.01)$ transformed data.

No significant difference was detected between zero and the average of the differences between the screened–unscreened data using the paired t-test (n=19, T-value=-0.02, p=0.984). The results reflect the similarity of the average concentrations of larval fishes for the screened and unscreened groups which were 0.056 and 0.058, respectively. The results of the t-test were consistent with the results of the ANOVA which did not detect a significant difference between the screened and unscreened treatment groups (F-value=0.09, p=0.767).

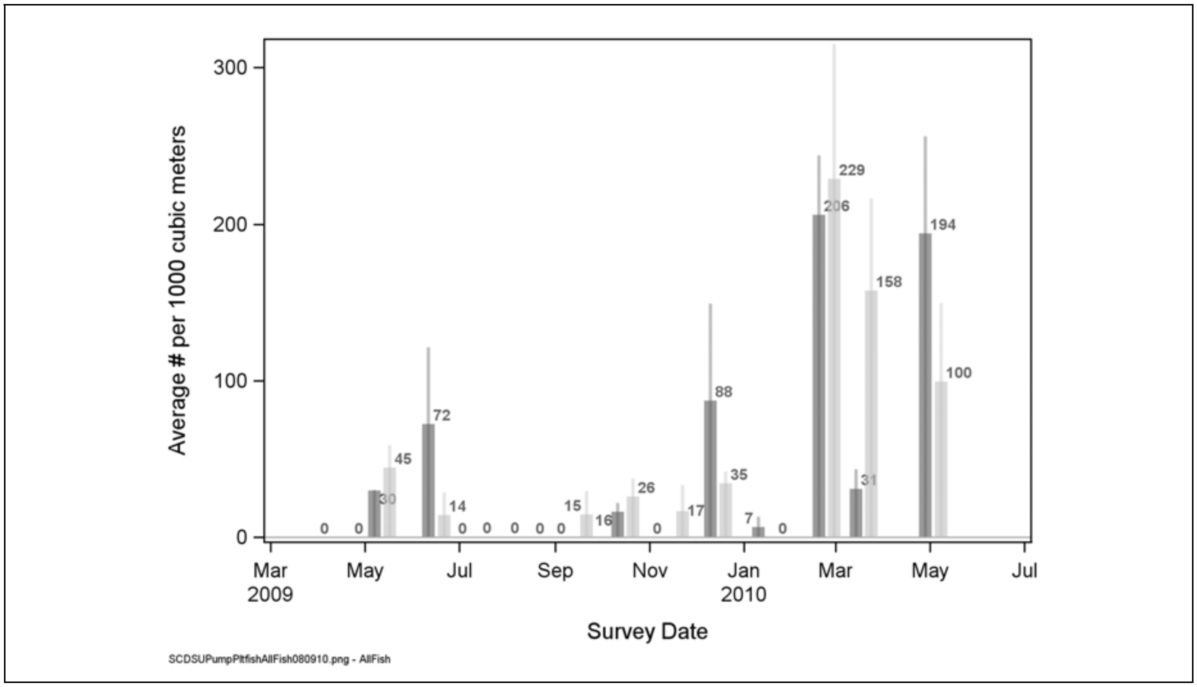


Figure 4.2-1. Mean concentration (#/1,000 m^3) in screened (dark bars) and unscreened (light bars) samples for all fishes collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation).

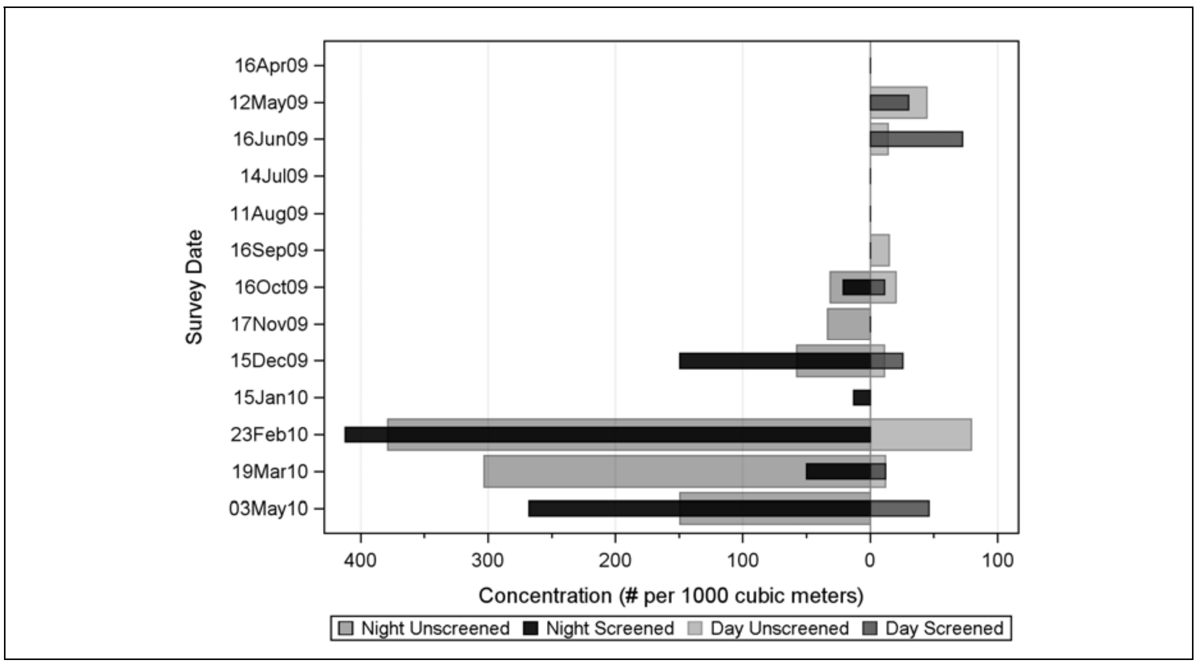


Figure 4.2-2. Mean concentration (#/1,000 m^3) in day and night samples for all fishes collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation). No survey was conducted in April 2010 due to unsafe sampling conditions.

4.2.2.3.2 White Croaker

White croaker was the most abundant fish taxon collected from the screened samples. It comprised 25.5% of the total mean concentration of larvae in the screened samples (**Table 4.2-5)**. White croaker larvae were collected in the screened samples in three of the 13 surveys. Peak mean concentration (123/1,000 m^3) of white croaker in the screened samples occurred during the February 2010 (**Figure 4.2-3**). No white croaker larvae were collected in the screened samples during the April through November 2009 surveys and in the January and March 2010 surveys.

White croaker was the most abundant fish taxon collected from the unscreened samples. It comprised 21.4% of the total mean concentration of larvae in the unscreened samples (**Table 4.2-6**). White croaker larvae were collected in the screened samples in three of the 13 surveys. Peak mean concentration (117/1,000 m^3) of white croaker in the unscreened samples occurred during the February 2010 (**Figure 4.2-3**). No white croaker larvae were collected in the unscreened samples during the April 2009 through January 2010 surveys. Daytime and nighttime concentrations of white croaker collected from the screened and unscreened samples are provided in **Figure 4.2-4.**

The Brown-Forsythe test for equality of variances was not significant for the two groups representing the screened and unscreened samples, but when the screened and unscreened sample data were grouped by survey, significant differences among group variances were detected in all of the data sets. The $log(x + 0.01)$ transformation resulted in the greatest reduction in the differences among group variances. As a result, further analyses of the data were done using the $log(x + 0.01)$ transformed data and the option for adjusted degrees of freedom was used in the Proc Mixed procedure for the analysis of variance.

No significant difference was detected between zero and the average of the differences between the screened–unscreened data using the paired t-test (n=19, T-value=-0.32, p=0.750). The results reflect the similarity of the average concentrations of larval fishes for the screened and unscreened groups which were 0.016 and 0.014, respectively. The results of the t-test were consistent with the results of the ANOVA which did not detect a significant difference between the screened and unscreened treatment groups (F-value=0.10, p=0.753).

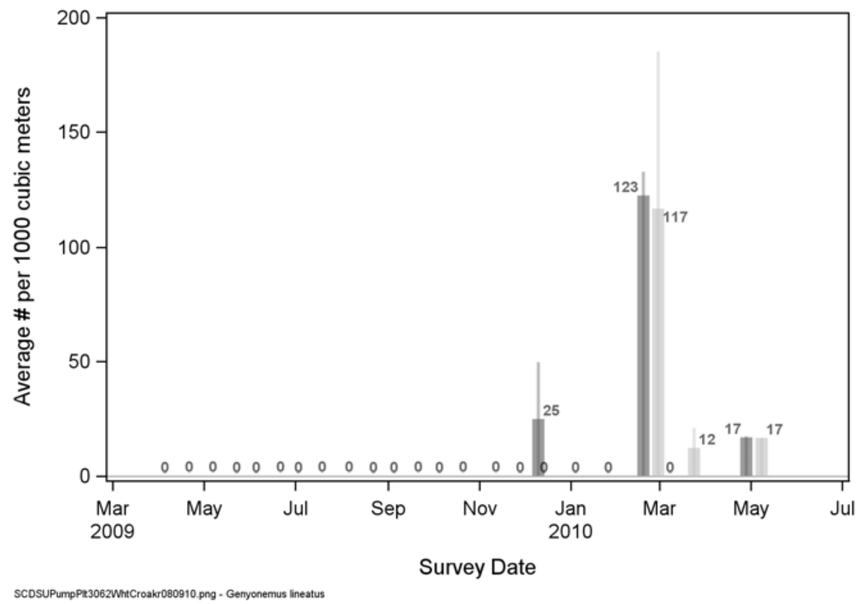


Figure 4.2-3. Mean concentration (#/1,000 m^3) in screened (dark bars) and unscreened (light bars) samples for white croaker collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation).

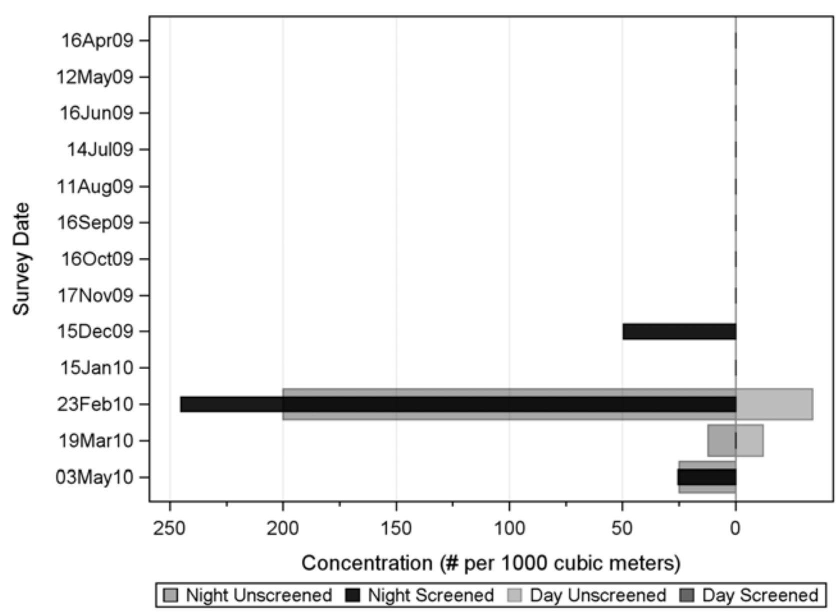


Figure 4.2-4. Mean concentration (#/1,000 m^3) in day and night samples for white croaker larvae collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation). No survey was conducted in April 2010 due to unsafe sampling conditions.

4.2.2.3.3 Cancrid Crabs

Cancrid crab megalops were the second most abundant invertebrate taxon collected from the screened samples. They comprised 36.1% of the total mean concentration of target invertebrates in the screened samples (**Table 4.2-5)**. Cancrid crab megalops were collected in the screened samples in 12 of the 13 surveys. Peak mean concentration (11,653/1,000 m^3) of cancrid crab megalops in the screened samples occurred during the May 2010 survey (**Figure 4.2-5**). No cancrid crab megalops were collected in the screened samples during the January 2010 survey.

Cancrid crab megalops were the second most abundant invertebrate taxon collected from the unscreened samples. They comprised 36.1% of the total mean concentration of target invertebrates in the unscreened samples (**Table 4.2-6)**. Cancrid crab megalops were collected in the unscreened samples in 11 of the 13 surveys. Peak mean concentration (5,109/1,000 m^3) of cancrid crab megalops in the unscreened samples occurred during the May 2010 (**Figure 4.2-5**). No cancrid crab megalops were collected in the unscreened samples during the July and September 2009 surveys.

Daytime and nighttime concentrations of cancrid crab megalops collected from the screened and unscreened samples are provided in **Figure 4.2-6.**

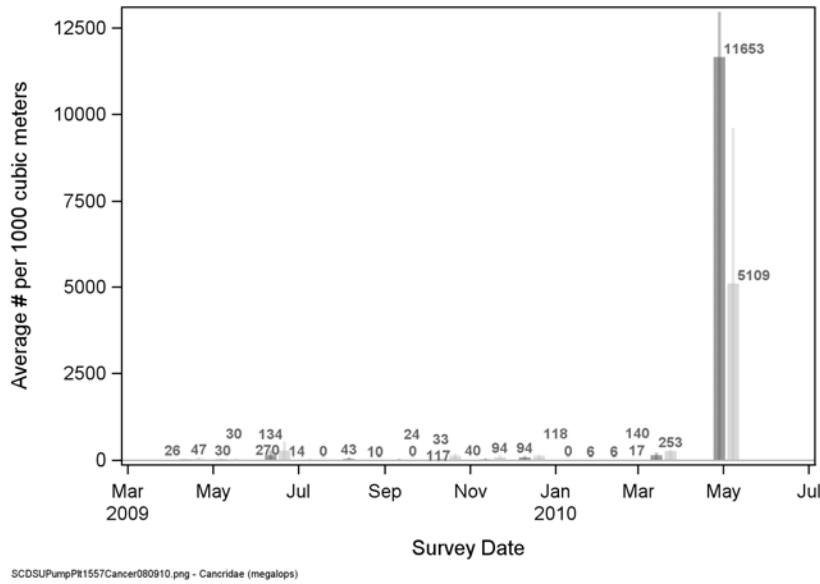


Figure 4.2-5. Mean concentration (#/1,000 m^3) in screened (dark bars) and unscreened (light bars) samples for cancrid crab megalops collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation).

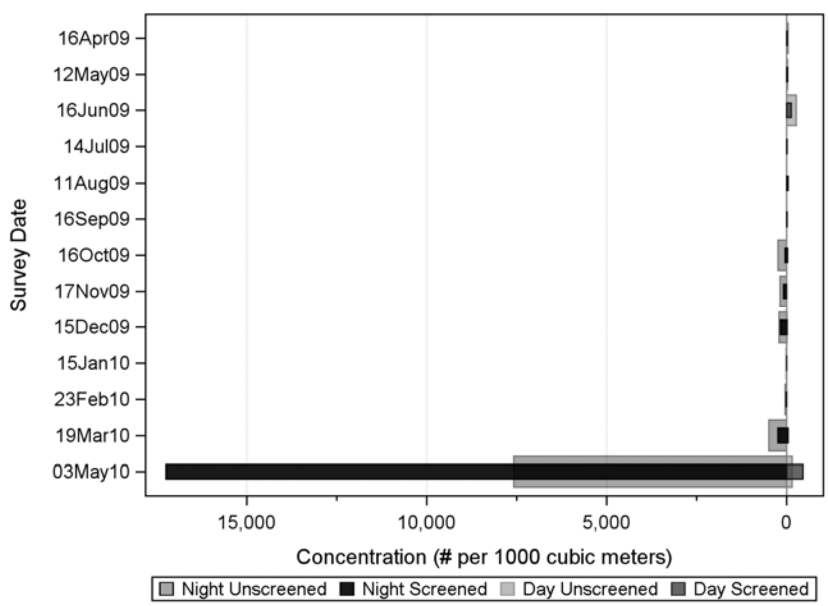


Figure 4.2-6. Mean concentration (#/1,000 m^3) in day and night samples for cancrid crab megalops collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation). No survey was conducted in April 2010 due to unsafe sampling conditions.

4.2.2.3.4 Crangon Shrimps

Crangon shrimps were the third most abundant invertebrate taxon collected from the screened samples. They comprised 5.5% of the total mean concentration of target invertebrates in the screened samples (**Table 4.2-5)**. Crangon shrimps were collected in the screened samples in four of the 13 surveys. Peak concentration (1,696/1,000 m^3) of crangon shrimps in the screen samples occurred during the November 2009 survey (**Figure 4.2-7**). No crangon shrimps were collected in the screened samples during the April through September 2009 and January through March 2010 surveys.

Crangon shrimps were the most numerically abundant invertebrate taxon collected from the unscreened samples. They comprised 31.4% of the total mean concentration of target invertebrates in the unscreened samples (**Table 4.2-6)**. Crangon shrimps were collected in the unscreened samples in six of the 13 surveys. Peak mean concentration (5,076/1,000 m^3) of crangon shrimps in the screened samples occurred during the November 2009 survey (**Figure 4.2-7**). No crangon shrimps were collected in the unscreened samples during the April, May, July, August and September 2009 surveys and during January and February 2010 surveys. Daytime and nighttime concentrations of crangon shrimps collected from the screened and unscreened samples are provided in **Figure 4.2-8.**

The Brown-Forsythe test for equality of variances was not significant for the two groups representing the screened and unscreened samples, but when the screened and unscreened sample data were grouped by survey, significant differences among group variances were detected in all of the data sets except for the data transformed as $\sqrt{\sqrt{(x + 0.01)}}$. As a result, further analyses of the data were done using the $\sqrt{\sqrt{(x + 0.01)}}$ transformed data.

No significant difference was detected between zero and the average of the differences between the screened–unscreened data using the paired t-test (n=19, T-value=0.62, p=0.543), despite the differences between the average concentrations for the screened (0.930) and unscreened samples (0.466). This result was consistent with the results of the ANOVA which did not detect a significant difference between the screened and unscreened treatment groups (F-value=0.27, p=0.606).

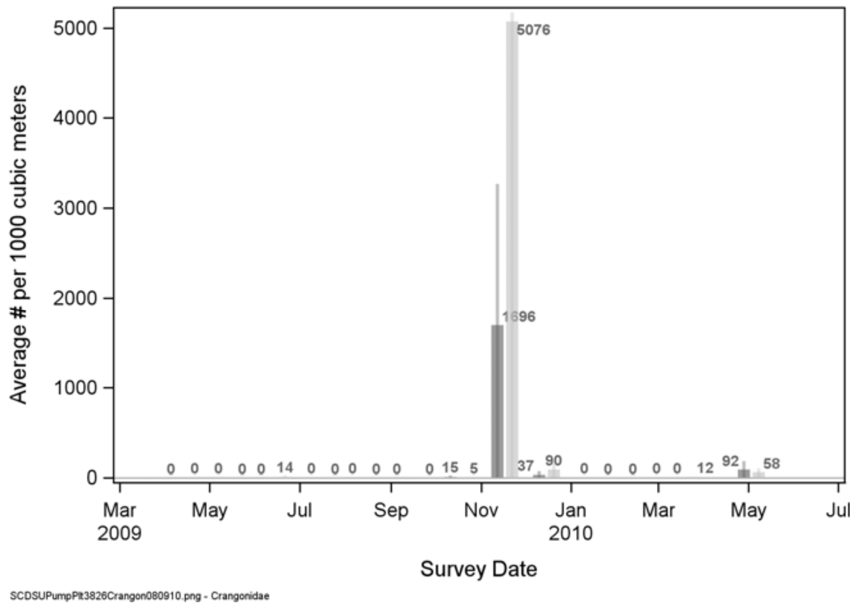


Figure 4.2-7. Mean concentration (#/1,000 m^3) in screened (dark bars) and unscreened (light bars) samples for crangon shrimps collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation).

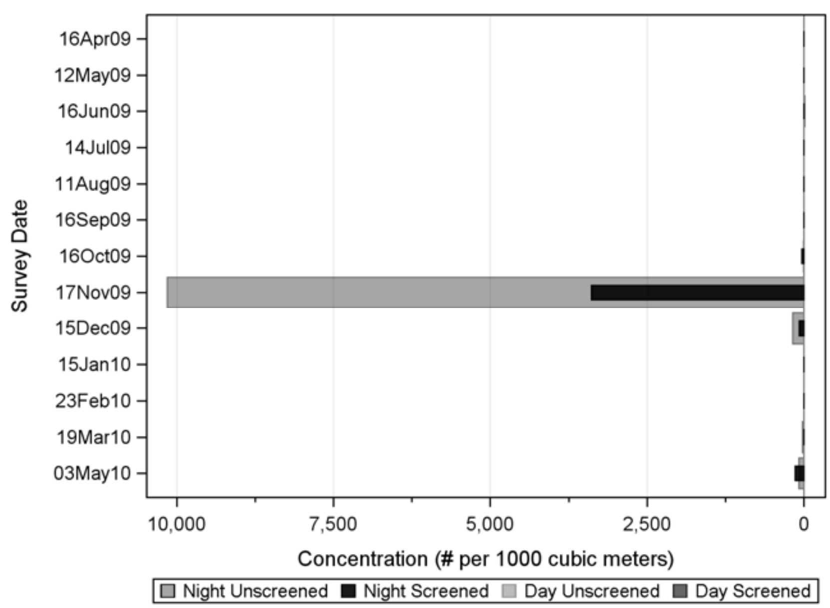


Figure 4.2-8. Mean concentration (#/1,000 m^3) in day and night samples for crangon shrimps collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation). No survey was conducted in April 2010 due to unsafe sampling conditions.

4.2.2.3.5 Thoridae/Hippolytidae

Thoridae/Hippolytidae shrimps were the most abundant target invertebrate taxon collected from the screened samples. They comprised 58.0% of the total mean concentration of target invertebrates in the screened samples (**Table 4.2-5)**. Thoridae/Hippolytidae shrimps were collected in the screened samples in all 13 surveys. Peak mean concentration (10,837/1,000 m^3) of Thoridae/Hippolytidae shrimps in the screened samples occurred during May 2009 (**Figure 4.2-9**).

Thoridae/Hippolytidae shrimps were the third most abundant target invertebrate taxon collected from the unscreened samples. They comprised 31.2% of the total mean concentration of target invertebrates in the unscreened samples (**Table 4.2-6)**. Thoridae/Hippolytidae shrimps were collected in the unscreened samples during all the surveys. Peak concentration (1,499/1,000 m^3) of Thoridae/Hippolytidae shrimps in the unscreened samples occurred during May 2009 (**Figure 4.2-9**).

Daytime and nighttime concentrations of Thoridae/Hippolytidae shrimps collected from the screened and unscreened samples are provided in **Figure 4.2-10.**

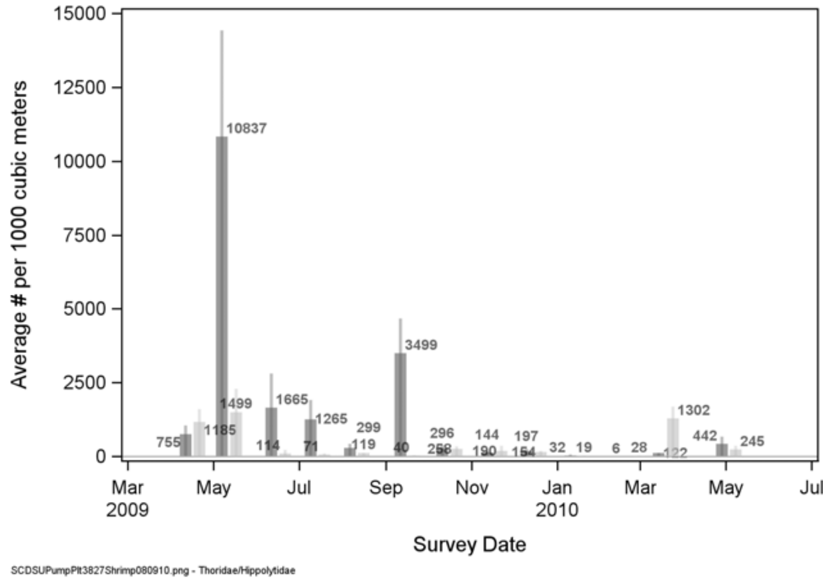


Figure 4.2-9. Mean concentration (#/1,000 m^3) in screened (dark bars) and unscreened (light bars) samples for Thoridae/Hippolytidae shrimps collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation).

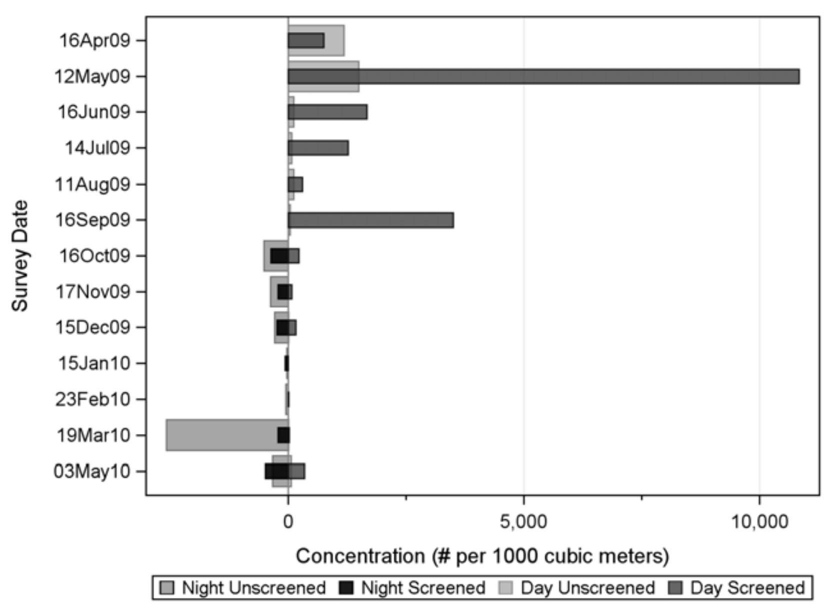


Figure 4.2-10. Mean concentration (#/1,000 m^3) in day and night samples for Thoridae/Hippolytidae shrimps collected during the intake screen efficiency study from April 2009 through May 2010.
Note: Does not include data collected at night through the first six surveys (see Section 4.2.1.3–Data Analysis, for explanation). No survey was conducted in April 2010 due to unsafe sampling conditions.

The Brown-Forsythe test for equality of variances was not significant for the two groups representing the screened and unscreened samples, but when the screened and unscreened sample data were grouped by survey, significant differences among group variances were detected in all of the data sets. The $log(x + 0.01)$ transformation resulted in the greatest reduction in the differences among group variances. As a result, further analyses of the data were done using the $log(x + 0.01)$ transformed data and the option for adjusted degrees of freedom was used in the Proc Mixed procedure for the analysis of variance.

A significant difference was detected between zero and the average of the differences between the screened–unscreened data using the paired t-test (n=19, T-value=2.41, p=0.026). The results reflect the higher average concentrations of shrimp larvae collected at the screened intake (1.038) when compared to the unscreened intake (0.367). The results of the t-test were consistent with the results of the ANOVA which also detected a significant difference between the screened and unscreened treatment groups (F-value=10.68, p=0.002).

4.3 *In Situ* Wedgewire Screen Impingement Study

4.3.1 Methods

To study the possibility of fishes being pulled and held (impinged) on the wedgewire screen, two video cameras were installed on the wedgewire screen module. The cameras were positioned to the side and above the intake screen at a distance of approximately 16 cm (6.3 in.) in order to image objects approximately 2 mm (0.08 in.) in size. One of the cameras (the transverse camera) was oriented to videograph a lengthwise view of the screen's surface (**Figure 4.3-1a**), and the second camera (the direct camera) was oriented directly at the screen to videograph a top view of the screen's surface (**Figure 4.3-1b**). The transverse camera provided a view of not only the screen's surface but also of fishes and invertebrates that were swimming near the screen (**Figure 4.3-1c**). The direct camera provided a close-up top-down view of the screen's surface so that objects that came into contact with the screen could be observed in detail (**Figure 4.3-1d**).

Underwater lights were deployed on movable arms and were positioned to minimize particle backscatter interference with video images. Both the cameras and lights were hardwired to the entrainment sampling deck above, with underwater cables running through conduit tie-wrapped to the piling. Prior to each impingement filming, divers inspected each camera and light while clearing algae and replacing the removable lens protectors. Videos were displayed and recorded to DVR when the pump was operated. Data were transferred to a DVD from the DVR for review.

Impingement recordings were reviewed and observations were logged on pre-printed filming datasheets. Quantitative observations such as the number of times fishes, invertebrates, or debris were seen on camera or came in contact with the wedgewire screen, and qualitative observations such as when a fish appeared to resist the flow, were recorded. Recordings were either watched in their entirety or subsampled. If subsampling occurred, a random number was generated corresponding to a 10-minute section of film, which was then reviewed.

Prior to watching the impingement films, all biologists observations were standardized by having them watch and record observations of the same film. This procedure was repeated until they all recorded similar level of observations.

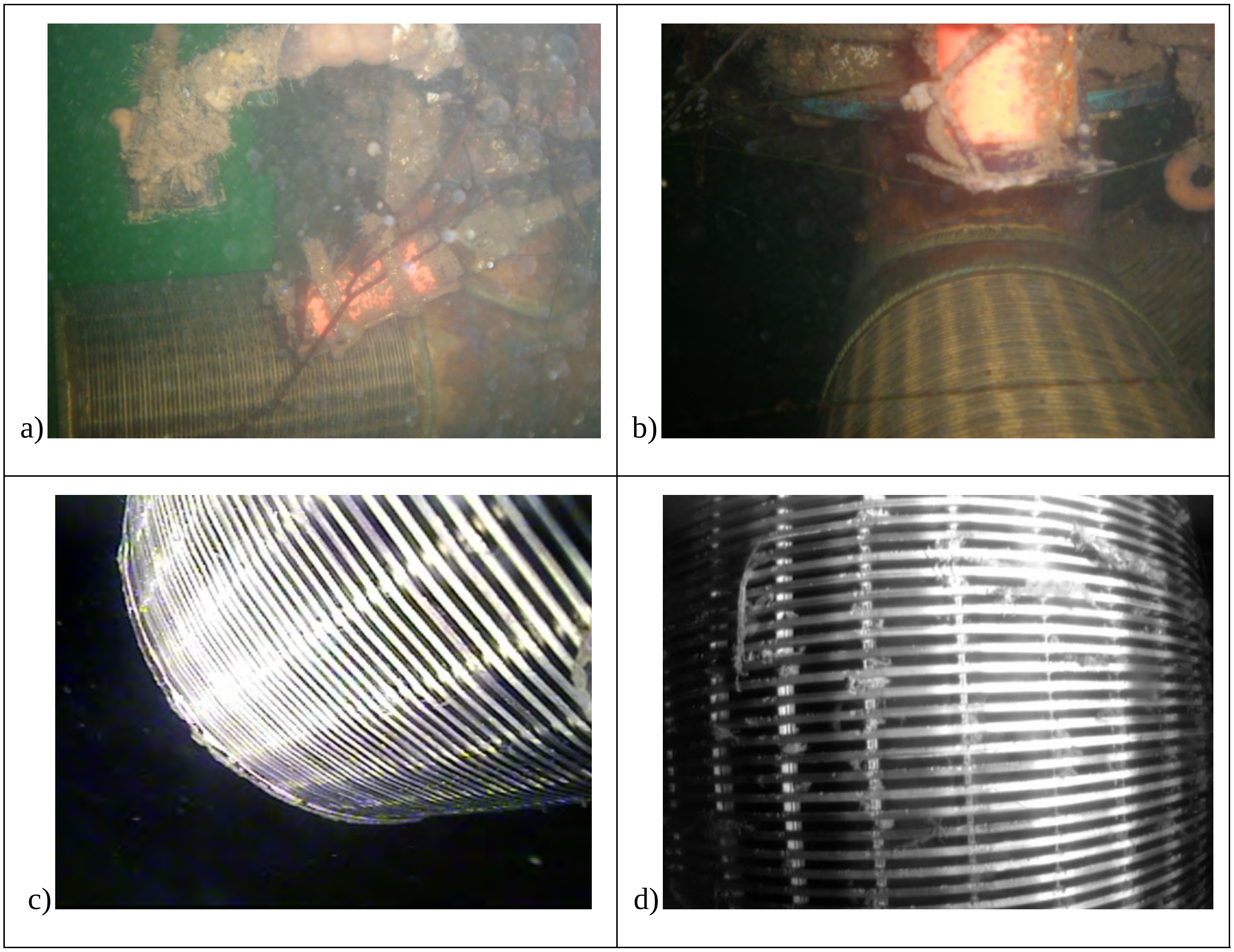


Figure 4.3-1. Photographs of: a) transverse camera (center) and light (upper left) in filming position, b) direct camera (top center) in filming position, c) screenshot from transverse camera, and d) screenshot from direct camera.

4.3.2 Results

A total of 15 wedgewire screen impingement surveys was conducted (**Table 4.3-1**). All of the daytime surveys were conducted concurrently with the screen efficiency surveys. The nighttime surveys from April 16, 2009 through September 16, 2009 were conducted concurrently with the screen efficiency surveys. However, it was determined that the lights used for the video system may have attracted fishes and other organisms potentially biasing the results. From October 16, 2009 through May 3, 2010 nighttime sampling was conducted within 24 hours of the screen efficiency surveys. Additionally, two supplemental nighttime surveys were conducted, one on April 27, 2010 and one on June 17, 2010 (**Table 4.3-1**).

A total of 53 hours and 20 minutes of recordings was made during the wedgewire screen impingement study (**Table 4.3-1**). Of these, 27 hours and 20 minutes were recorded during the day and 26 hours were recorded at night. A total of 24 hours and 40 minutes was recorded with the transverse camera (**Figure 4.3-1a**), and a total of 28 hours and 40 minutes was recorded with the direct camera (**Figure 4.3-1b**). On several occasions (most notably with the transverse camera from September 16, 2009 through February 23, 2010) recordings could not be made due to malfunctions with either the underwater lights or the camera.

A total of 22 hours and 10 minutes (roughly 42%) of the 53 hours and 20 minutes of recordings made during the wedgewire screen impingement study was reviewed (**Table 4.3-2**). A total of 1,321 events was observed and recorded on to filming log sheets. **Figure 4.3-2** provides photographs of some of the events captured by the video cameras. During some surveys, the numbers of fishes or shrimps swimming near the screen were so great that these events were not recorded individually (**Figure 4.3-2h**). All direct interactions with the screen were recorded. Of these observations, 880 were of invertebrates, 262 were of fishes, 144 were of debris and the remaining 35 were other events such as sea lions swimming by or organisms crawling on the camera lens (**Table 4.3-2**). A description of each event was recorded on filming log sheets and events were tallied by the type of object (fish, invertebrate or debris) and whether they came in contact with the screen or were seen in the vicinity of the screen.

Of the 262 interactions with fishes recorded during the logging of the wedgewire screen impingement study, 191 times fishes were observed near the screen but did not come in contact with it, while the other 71 times fishes contacted the screen. Contact behaviors were classified according to the duration and speed of contact, or interaction activities such as picking food items off of the screen surface (**Table 4.3-3**). During the April 27, 2010 survey, there were dozens of fishes observed near the screen throughout the survey (**Figure 4.3-2h**). The fishes were so numerous that they were not recorded individually so the actual number of fishes observed near the screen was greater than 191. The majority of fish interaction events occurred during the surveys conducted from April–August 2009 and April–June 2010. Of the 71 events in which a fish was observed to contact the screen, the majority were “bumps” in which the fish’s body briefly contacted the screen, followed by “sweeps” of the tail fin as a fish swam past the screen (**Table 4.3-4**). The majority of fishes observed were rockfishes. At no time was a fish observed that could not free itself after being held on the screen.

The 880 invertebrate interactions observed during the logging of the wedgewire screen impingement study videos included caprellids and smaller amphipods crawling on the screen (**Figure 4.3-2e and f**), squid swimming near the screen, and smaller shrimps being pulled into the screen (entrained). The 314 observations of invertebrates in the vicinity of the screen consisted almost entirely of shrimps swimming near the screen (**Figure 4.3-2g**). The 566 observations that were made of invertebrates coming in contact with the screen consisted primarily of caprellids and other amphipods crawling on the screen, and shrimps bumping into it.

The 144 interactions of debris contacting the screen primarily consisted of small pieces of kelp or other organic matter being pulled onto the screen, where it was either held on the screen or pushed off by wave action after a short while, sometimes after sliding around on the screen’s surface.

Table 4.3-1. Summary of the filming activities during the wedgewire screen impingement surveys from April 16, 2009 through June 17, 2010.

Screen Efficiency Survey	Date	Day Transverse Camera	Day Direct Camera	Night Transverse Camera	Night Direct Camera	Total
1	April 16, 2009	80 min	80 min	80 min	80 min	5 hrs:20 min
2	May 12, 2009	80 min	80 min	80 min	80 min	5 hrs:20 min
3	June 16, 2009	80 min	80 min	80 min	80 min	5 hrs:20 min
4	July 14, 2009	80 min	40 min	80 min	80 min	5 hrs:20 min
5	August 11, 2009	80 min	80 min	80 min	80 min	5 hrs:20 min
6	September 16, 2009	80 min	80 min	–	40 min	3 hrs:20 min
7	October 16, 2009	–	40 min	–	–	0 hrs 40 min
8	November 17, 2009	80 min	80 min	–	120 min	4 hrs:40 min
9	December 16, 2009	40 min	40 min	–	120 min	3 hrs:20 min
10	January 15, 2010	40 min	40 min	–	–	2 hrs:40 min
11	February 23, 2010	80 min	40 min	–	–	2 hrs:00 min
12	March 18, 2010	80 min	80 min	60 min	60 min	4 hrs:40 min
Supplemental	April 27, 2010	–	–	120 min	120 min	4 hrs:00 min
13	May 3, 2010	40 min	40 min	–	–	1 hrs:20 min
Supplemental	June 17, 2010	–	–	60 min	60 min	2 hrs:00 min
	Total	**14 hrs**	**13 hrs:20 min**	**10 hrs:40 min**	**15 hrs:20 min**	**53 hrs:20 min**

Table 4.3-2. Summary of information collected during the wedgewire screen impingement study from April 16, 2009 through June 17, 2010.

Date	Cycle	Sample Length (min)	Amount Reviewed (min)	Percent Reviewed	Fishes		Invertebrates		Debris		Other Event
					Near	Contact	Near	Contact	Near	Contact	
04/16/09	Day	160	160	100	2	0	2	15	1	3	3
	Night	160	130	81	1	0	11	13	1	12	5
05/12/09	Day	160	130	81	0	1	1	283	0	9	6
	Night	160	160	100	46	13	169	104	0	6	12
06/16/09	Day	160	100	63	52	1	0	16	1	5	1
	Night	160	70	44	17	12	68	25	3	1	2
07/14/09	Day	160	90	56	6	6	1	4	1	19	4
	Night	160	40	25	8	4	0	0	2	4	0
08/11/09	Day	200	40	20	1	3	1	0	0	10	0
	Night	360	60	17	14	16	8	19	0	4	0
09/16/09	Day	160	40	25	1	0	0	9	1	3	0
	Night	40	10	25	0	0	0	0	2	2	1
10/16/09	Day	40	10	25	1	0	1	0	1	6	0
11/16/09	Night	120	20	17	3	0	21	5	0	3	1
11/17/09	Day	160	40	25	1	0	1	8	1	8	0
12/15/09	Day	80	20	25	0	0	0	2	0	3	0
12/16/09	Night	120	20	17	0	0	3	2	0	2	0
01/15/10	Day	160	30	19	0	0	2	6	0	2	0
02/23/10	Day	120	30	25	2	0	0	3	0	3	0
03/18/10	Night	180	30	17	0	0	2	2	0	0	0
03/19/10	Day	160	40	25	1	0	0	10	0	4	0
04/27/10	Night	240	40	17	20	14	19	31	0	2	0
05/03/10	Day	80	20	25	1	0	4	9	1	4	0
06/17/10	Night	120	20	17	14	1	0	0	1	13	0
	Totals	**53 hrs:20 min**	**22 hrs:10 min**	**37**	**191**	**71**	**314**	**566**	**16**	**128**	**35**

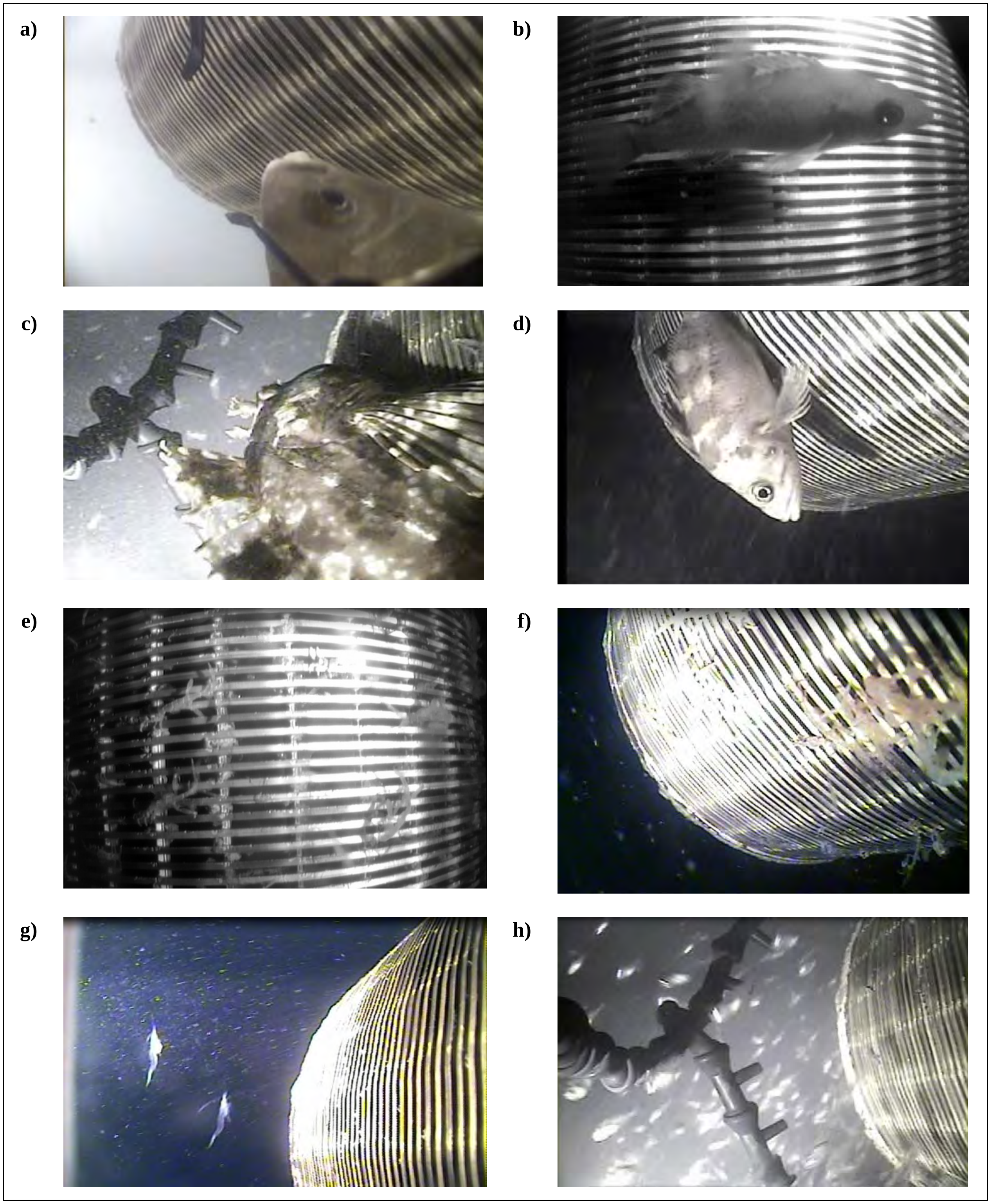


Figure 4.3-2. Video frame grabs taken during wedgewire screen efficiency study with pump operating: a) pile perch feeding on invertebrates on screen; b) rockfish swimming close to screen; c) cabezon resting on screen; d) rockfish resting on screen; e) and f) amphipods on screen; g) mysid shrimps swimming near screen; and h) school of juvenile rockfish swimming near screen.

Table 4.3-3. Description of behavior categories used to classify fish interactions with wedgewire screen during operational flow periods.

Behavior Category	Description
bump	Anterior or lateral parts of the body briefly (<1 sec) contact the screen; usually induced by wave surge
sweep	Tail only brushes against screen as fish swims by once
scrape	Fish contacts screen and is drawn transversely across screen
contact	Controlled contact with screen, then active swimming movements away
eat	Fish picks food item off of screen (e.g., polychaete, amphipod)
sit	Resting in place on screen
swim	Fish swimming near screen with several brief periods of contact

Table 4.3-4. Summary of recorded fish contacts with the wedgewire screen during video surveys conducted from April 16, 2009 through June 17, 2010.

Behavior	Rockfishes		Black surfperch		Kelp surfperch		Unid. surfperch		Cabezon		Pipefish		Unid. fishes		Total No. of Inter-actions
	n	avg. sec.	n	avg. sec.	n	avg. sec.	n	avg. sec.	n	avg. sec.	n	avg. sec.	n	avg. sec.	
bump	19	<1.0			1	<1.0	2	<1.0	1	<1.0			2	<1.0	**25**
sweep	11	1.0					1	1.0			2	1.5	4	1.0	**18**
scrape	8	2.3			1	3.0					1	2.0	3	2.3	**13**
contact	3	5.0			1	16.0	2	6.5					1	4.0	**7**
eat	1	7.0	1	1.0											**2**
sit	2	18.5							3	14.3					**5**
swim	1	3.0													**1**
	45		**1**		**3**		**5**		**4**		**3**		**10**		**71**

4.4 Dye Test Study

4.4.1 Methods

A dye study apparatus was installed on the screen to study the interactions between water flow through the screen and wave action. The dye study apparatus consisted of flexible ¼-in. LocLine arms with nozzles that were positioned near the screens (**Figure 4.4-1**). Plastic tubing carried the dye from a holding container on the surface to the dye study apparatus. A small pond pump was used to pump the dye out of the container, down the plastic tubing, and out through the nozzles in the dye study apparatus. A brass valve was fitted into the tubing on the surface so that the flow could be adjusted. The dye was a mixture of Rose Bengal and saltwater.

The videographic equipment used in the wedgewire screen impingement study was used to monitor and record these operations. During dye study operations water was pumped at a rate of 1 m^3/minute to obtain the target through-screen velocity of 0.1 m/sec (0.33 ft/sec). Field observations on pump speed, wave intensity, and direction were recorded in field notebooks. All dye study recordings were reviewed in their entirety. Observations made were qualitative in nature.

a) b)

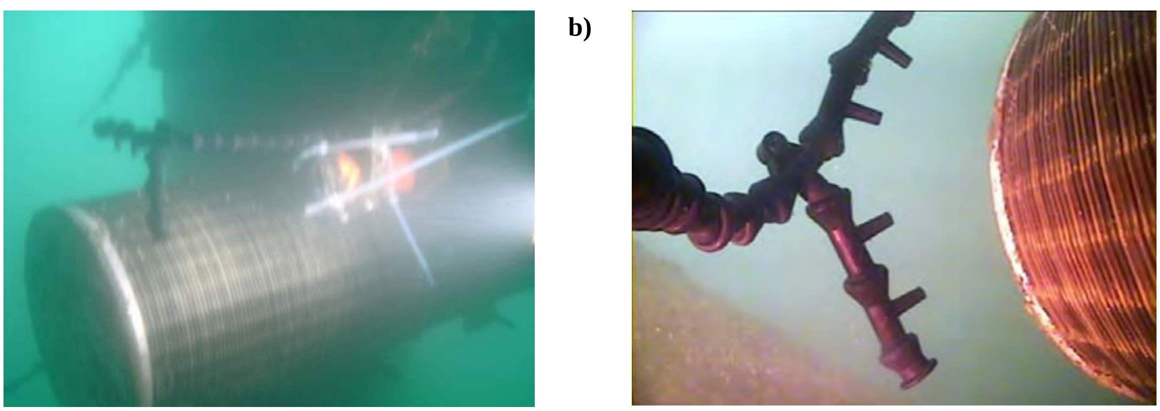


Figure 4.4-1. Photograph showing: a) WWS module, with camera (right) and dye study apparatus (left) and b) screenshot from camera showing WWS and dye study apparatus with four nozzles.

4.4.2 Results

The dye test was conducted on two occasions, April 27, 2010 and June 17, 2010, so that hydrodynamic information under different ocean conditions could be obtained. The April 27 recording was 46 minutes long, and the June 17 recording was 17 minutes long. A total of 1 hour and 3 minutes of dye study testing was recorded. During the April 27 survey, the wave height was 3–4 ft and came out of the south, approaching the wharf head-on and moving directly down the length of the wharf. During the June 17 survey, the wave height was 1–2 ft and came out of the west, approaching the wharf from the side and moving across it. A summary of information regarding the dye study surveys is shown in **Table 4.4-1.**

Table 4.4-1. Summary of occurrence and conditions of the dye study surveys.

Date	Length of Recording	Wave Height	Wave Direction
April 27, 2010	46 minutes	3–4 feet	South
June 17, 2010	17 minutes	1–2 feet	West

Figure 4.4-2 shows an example of a dye study time series (2-second intervals) in which a) dye flows into the screen during a lull period between waves; b) dye is pushed up and over the top of the wedgewire screen during the outgoing surge; c) dye flows in several directions during a period towards the end of the outgoing surge; d) dye flows into the screen during a second lull; e) dye flows back and down during an incoming surge and e) dye again flows into the screen during a lull, completing the wave cycle sequence.

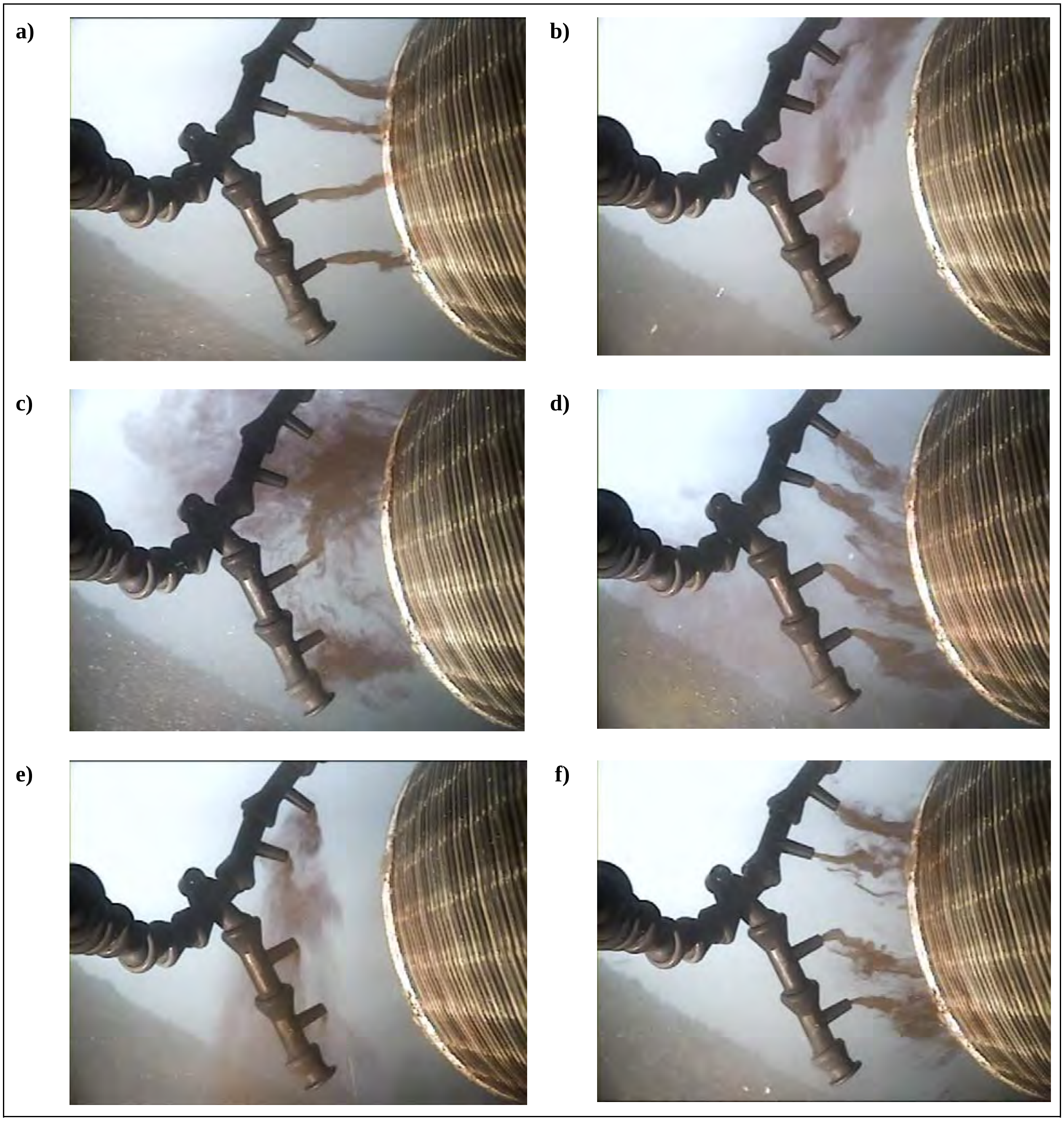


Figure 4.4-2. Example of dye study video from April 27, 2010. These images were taken from the video at two-second intervals.

4.5 Corrosion/Biofouling Study

4.5.1 Methods

The corrosion and biofouling study was comprised of two components. The first component consisted of visual observations made by divers each month as they cleaned the wedgewire screen prior to the screen efficiency surveys. Observations of biofouling along with the tools used during cleaning were recorded on pre-printed datasheets. On some occasions, photographs were taken of the wedgewire screen before and after cleaning, and on other occasions the entire cleaning operation was recorded using videographic equipment.

The second component of the study examined the biofouling rates of four different metals: 1) stainless steel, 2) a duplex alloy, 3) titanium, and 4) the copper-nickel "Z-alloy" used in the wedgewire screen that was in the other components of this study. Two small, approximately 10 cm (4 in.) square, pieces of screens (referred to as "coupons") made out of each metal were tested. Prior to deployment, the coupons were weighed to the nearest 0.001 g. The coupons were then mounted on PVC planks and deployed at the beneath the wharf at the same depth as the wedgewire screen intake.

During each survey, the coupons were brought to the surface where they were photographed, and observations were made on the quantity and composition of the biofouling. To prevent organisms present on the PVC from interfering with the biofouling of the metals, the coupons were placed on clean PVC planks before they were returned to the water.

The coupons were permanently removed from the water on June 17, 2010. To obtain a value for the level of biofouling present, the coupons were weighed before being cleaned, then to obtain a value for the amount of metal that was lost (due to electrolysis or other factors) the coupons were then cleaned and weighed again. Some organic material, consisting primarily of barnacle base material and encrusting bryozoans, was present on the coupons (except for the Z-alloy coupons). This organic material could not be removed and therefore, its weight was included in the final weight. The initial and final weights were obtained with a Mettler P1210 balance with 0.01 g precision. All weights, except the initial and final weights, were obtained with an Ohaus ScoutPro balance with a 0.01 g precision except for the 316 stainless steel coupon which weighed above the range of the Ohaus ScoutPro, so a Pesola 1,000 g balance with a 1.0 g precision was used.

4.5.2 Results

4.5.2.1 Diver Observations of Wedgewire Intake Screen

Divers cleaned the wedgewire intake screen and made observations of biofouling in conjunction with the 13 screen efficiency surveys (**Table 4.5-1**). Qualitative observations ranged from the "the screen was clean" to "there was a large amount of detritus on the screen." At no point during the 13-month study was anything observed growing on the wedgewire screen. Throughout the study, the bright clean screen was in sharp contrast to the PVC pipes, cameras, cables, and all other equipment which became completely covered in growth within three months of being deployed (see **Figure 4.3-1a, b**).

Detritus and other organic matter would collect on the screen as evidenced by direct observation. Before each screen efficiency survey, divers observed detritus and other organic material on the surface of the screen. For approximately 30 seconds after the pump was operated, the pumped water contained large amounts of organic material, as evidenced by the black color of the water. After about 30 seconds the pumped water was clear. This organic material was easily brushed away and might not have collected on the screen if the pump ran continuously. A soft nylon brush was used to clean the screens during six of the 13 surveys; no cleaning was required during the other seven surveys. Nothing more abrasive than the soft nylon brush was ever required to clean the screen.

Table 4.5-1. Diver observations during manual cleaning of wedgewire intake screen from April 2009 through May 2010.

Survey	Date	Observations
1	04/16/09	No growth on screen.
2	05/12/09	Light “fuzz” on screen, nothing appeared to be collecting/growing on inside.
3	06/16/09	Screen relatively clean.
4	07/14/09	Screen was very clean and did not need any brushing. Camera, wires, lines and all other equipment was covered in growth.
5	08/11/09	Light layer of “fuzz” collected on screen, all other equipment covered in growth.
6	09/16/09	Screen was clean.
7	10/16/09	Screen was clean.
8	11/17/09	Screen looked clean, although there was some organic material on outside and between mesh, but it was easily brushed away.
9	12/15/09	Screen was clean.
10	01/15/10	An above-average amount of material was present on screen, though still a small amount.
11	02/23/10	Screen had a lot of detritus in and on it.
12	03/19/10	Screen fairly clean.
13	05/03/10	Screen was clean.

4.5.2.2 Coupon Corrosion and Biofouling Results

The test coupons were deployed at the survey site on October 16, 2009 and were in place for a total of 244 days. During this time period, the coupons were photographed a total of eight times at approximately monthly intervals. All of the coupons, except the Z-Alloy, had substantial biofouling from the first time they were observed and photographed on November 16, 2009, 31 days after they were deployed (**Figures 4.5-1–4)**. As the study progressed, biofouling organisms included barnacles, bryozoans, tunicates, and mussels. Very light biofouling on the Z-alloy coupons was observed one month after deployment but not at anytime thereafter (**Figure 4.5-4**).

The amount of biofouling present on the coupons at the end of the study was measured as the percent increase in the weight of the coupons attributed to biofouling (**Table 4.5-2**). The percentage of additional weight attributed to biofouling material ranged from 186.2% for the Duplex #1 coupon to 0.4% for the Z-alloy #1 coupon. The Duplex #1 and Duplex #2 coupons had the highest percent increase in weight due to biofouling, 186.2% and 150.1%, respectively. The Titanium #1 and Titanium #2 coupons had the second highest percent increase in weight due to biofouling, 134.0% and 111.3%, respectively. The 316 stainless steel coupon had the third highest percent increase in weight (99.0%) due to biofouling. The Z-alloy #1 and Z-alloy #2 coupons had virtually no biofouling, 0.4% and 0.6% respectively (**Table 4.5-2**).

Table 4.5-2. Changes in weight of the coupons tested during the biofouling and corrosion study conducted from October 2009 through June 2010.

Coupon Type and Replicate	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Change in Weight Attributed to Biofouling		Change in Weight Attributed to Corrosion	
	(W_i)	(W_b)	(W_f)	(W_b - W_f)		(W_f - W_i)	
	9/29/2009	7/17/2010	7/23/2010	(g)	% increase	(g)	% increase
316 Stainless Steel	291.11	578.00	290.45	288.00	99.0%	-0.66	-0.23%
2205 Duplex (#1)	107.86	310.30	108.42	201.88	186.2%	0.56	0.52%
2205 Duplex (#2)	105.31	265.61	106.19	159.42	150.1%	0.88	0.83%
Z-Alloy (#1)	167.99	158.95	158.38	0.57	0.4%	-9.61	-6.07%
Z-Alloy (#2)	170.31	161.84	160.80	1.04	0.6%	-9.51	-5.91%
Titanium (#1)	82.47	193.81	82.83	110.98	134.0%	0.36	0.43%
Titanium (#2)	78.40	166.36	78.73	87.63	111.3%	0.33	0.42%

The change in weight of the coupons between the beginning of the study and their retrieval 211 days later varied by the type of metal. All of the coupons except the Z-alloy experienced heavy biofouling, which was thoroughly cleaned before weighing. However, a small amount of the organic material, primarily the base material of barnacles and encrusting bryozoans, could not be removed and contributed to the final weight of the coupons. Both the duplex and titanium coupons underwent a small (<1.0 g, <1%) increase in weight, though this is most likely due to the small amount of remaining biofouling material. The stainless steel coupon experienced a small (0.66 g, 0.23%) decrease in weight. The two Z-alloy coupons experienced a decrease in weight of 9.61 and 9.51 grams or 6.07 and 5.91%.

Figure 4.5-1. Biofouling of stainless steel (316) coupon from November 16, 2009 to June 17, 2010.

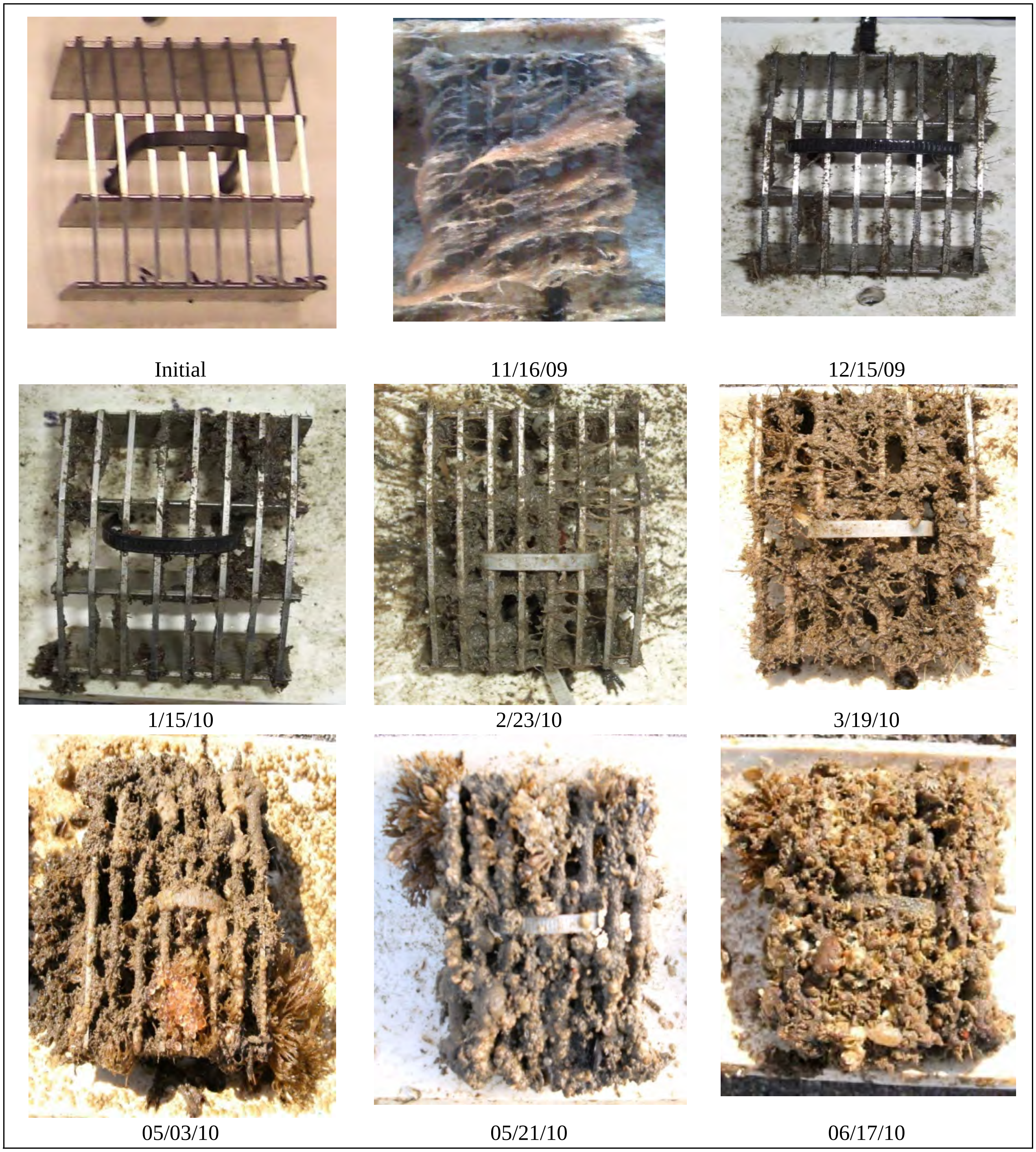
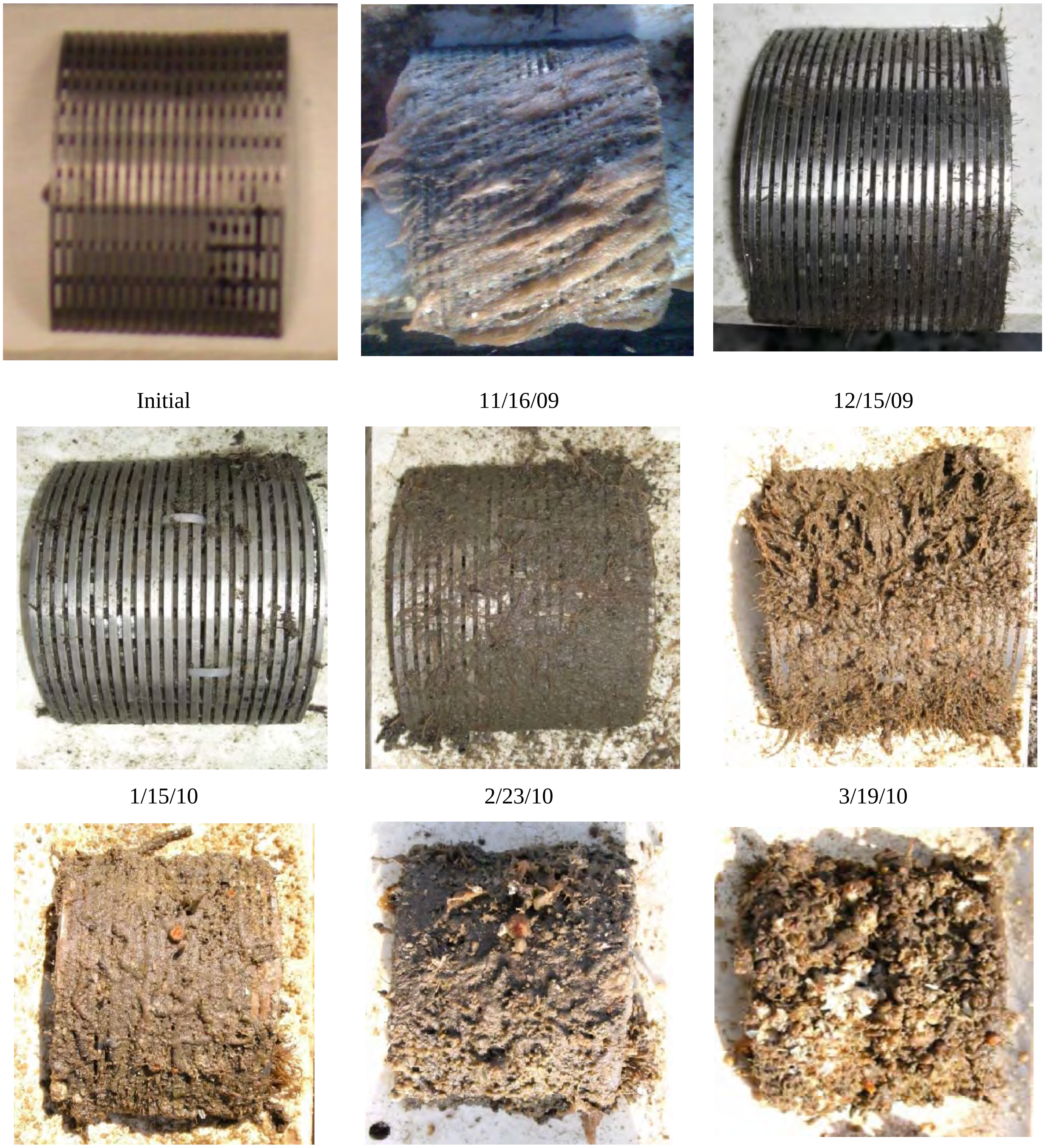


Figure 4.5-2. Biofouling of duplex coupon (#1) from November 16, 2009 to June 17, 2010.



Initial | 11/16/09 | 12/15/09

1/15/10 | 2/23/10 | 3/19/10

05/03/10 | 05/21/10 | 06/17/10

Figure 4.5-3. Biofouling of titanium coupon (# 1) from November 16, 2009 to June 17, 2010.

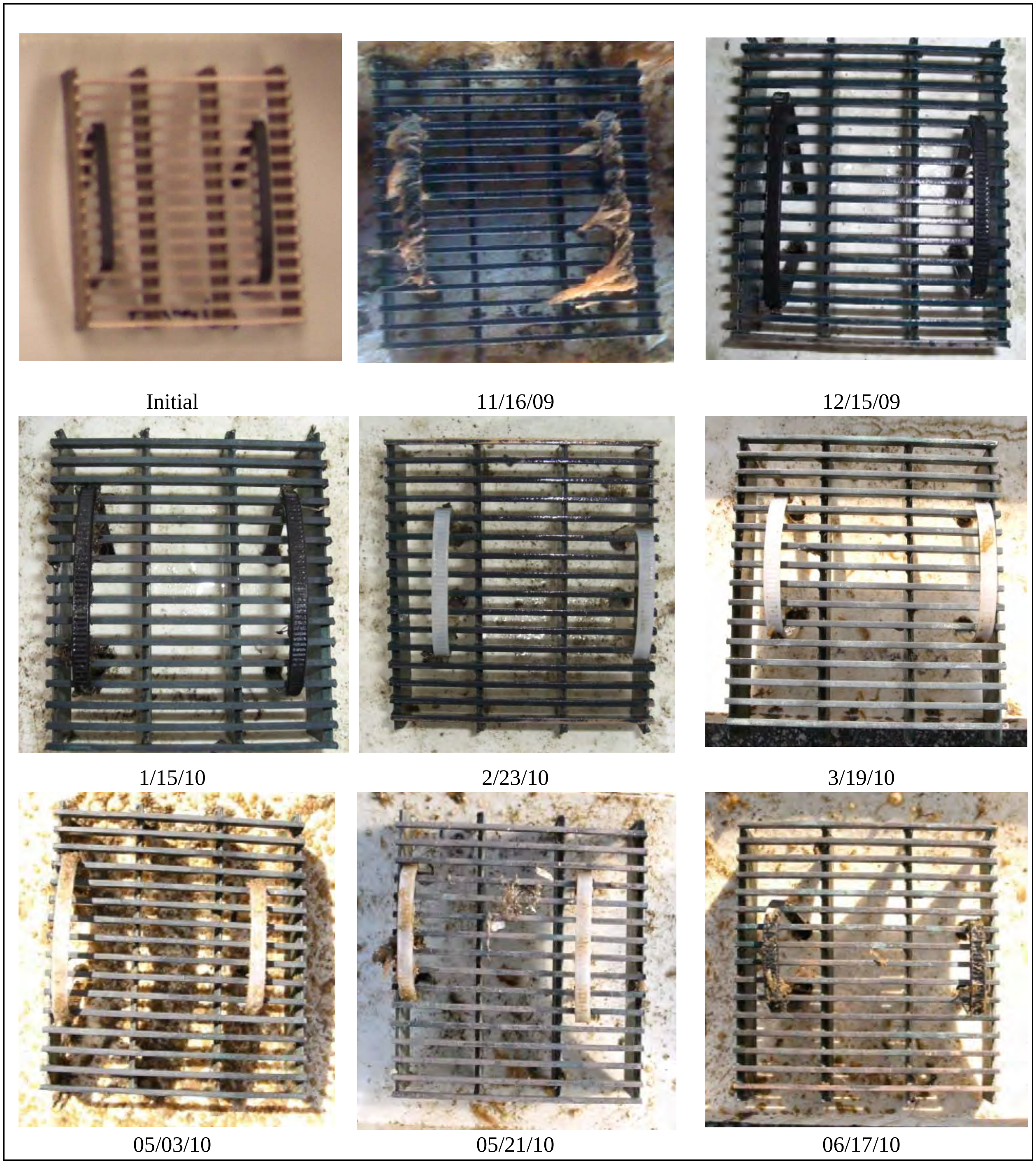


Figure 4.5-4. Biofouling of Z-alloy coupon # 1 from November 16, 2009 to June 17, 2010.

4.6 Discussion

Passive, narrow-slot screens used on intakes in rivers and estuaries have been proven to be effective at excluding most life stages of fishes. The efficiency of these intake screening devices varies with the physical size of the screen slot, life stage of the fishes, and the difference between ambient current velocity and through-screen velocity. The relationship between these three variables and narrow-slot screen efficiency has been reported from laboratory tests using hydrodynamic flumes to control aspects of intake and sweeping flows (EPRI 2003). Striped bass eggs and larvae were generally the investigators' test specimens of choice (EPRI 2003). The combination of laboratory test conditions and the choice of striped bass eggs makes it difficult to use the test results to predict narrow-slot screen performance in alternative, non-riverine settings with their associated entrainable fish species. The effectiveness of narrow-slot intake screens to reduce entrainment of planktonic larvae has not been demonstrated in the open ocean, particularly in the complex hydrodynamic environment of waves and currents typical of nearshore conditions. In addition, the screening efficiencies of various slot sizes and intake velocities have not been tested for marine species of fish larvae, which tend to be smaller than the larvae of freshwater fish species.

The completed **scwd^2** *in situ* investigations of the efficacy of a passive, narrow-slot intake screen to reduce entrainment and impingement have provided an initial *in situ* test relevant to the actual performance of these screens for a California open-ocean intake. State and federal resource and regulatory agencies approved the use of narrow-slot intake screens in the San Francisco Bay Estuary to minimize the impingement and entrainment of San Francisco Bay-Delta larval and juvenile fishes, including several protected species. The screens were designed based on published information on screen efficiency, slot size, and the expected intake and sweeping velocities (EPRI 2003, Dye 2003). At another facility in Central San Francisco Bay, a 30-mgd narrow-slot screen intake has operated successfully for nearly seven years—initial fouling of the stainless steel screens has been partially controlled by an applied coating. The University California at Santa Cruz (UCSC) operates a seawater intake for the Long Marine Laboratory that is fitted with 2.0-mm narrow-slot intake screens similar to **scwd^2's** narrow-slot test screens. The UCSC intake has operated successfully for a number of years but the screening efficiency has not been tested.

The potential for the use of wedgewire screens on the California coast has not been previously studied and one of the goals of these studies was to investigate the potential of a 2.0-mm slot screen to reduce entrainment. As the study progressed and preliminary results were made available to the review team, additional tests were incorporated into the study in order to investigate impingement, biofouling, corrosion, and hydrodynamics of the test screen. The questions to be addressed by the studies included the following:

- What species and life stages of fishes and selected shrimps and crabs are <u>entrained</u> through a 2.0-mm narrow-slot intake screen with intake flows of ~0.33 fps?

- What species and life stages of fishes and invertebrates are impinged on a 2.0-mm narrow-slot intake screen with intake flows of ~0.33 fps?
- To what extent do screens constructed of copper-nickel alloy (Z-alloy), stainless steel, or titanium resist settlement and growth of marine fouling organisms?
- What kind of sweeping and entrainment patterns of flow are created in the interaction of ocean swell and a stationary, narrow-slot intake screen, with intake flows of ~0.33 fps?

Results of the screen efficacy tests of the 2.0-mm slot screen with intake flows of ~0.33 fps demonstrate a reduction in entrainment as a function of slot size and size of organisms and elimination of impingement. The experimental variability associated with testing the screens *in situ* beneath the Santa Cruz Wharf as opposed to Mitchell's Cove made the study's findings both uniquely representative of **scwd²**'s test screen site, but also made it more difficult to determine the screen's ability to reduce entrainment.

4.6.1 Biofouling and Corrosion

The study findings on the corrosion and resistance of selected screen materials were unambiguous. Z-alloy proved to be resistant to biofouling over the 13-month continuous deployment of the intake screen during the entrainment and impingement performance testing. Stainless steel bolts and nuts and the PVC pipe flanges, and the PVC piping were heavily fouled with encrusting organisms during this same period of time. Z-alloy was observed to be similarly resistant to biofouling during Marin Municipal Water District's deployment of narrow-slot intake screens constructed of similar materials and plumbing. The results of biofouling tests using test coupons of stainless steel, titanium, and Z-alloy confirmed that Z-alloy was the most highly resistant of all the materials to the settlement and growth of biofouling organisms.

The results of our preliminary corrosion tests of Z-alloy deployed beneath the Santa Cruz Wharf indicate that the alloy corrodes at a relatively high rate in seawater. Two identical coupons of Z-alloy each lost nearly 6% of their initial weight during the test period compared with zero losses in weight for similar stainless steel and titanium coupons. However, since it was only possible to weigh the Z-alloy coupons at the beginning and end of the test period, it is not certain whether the weight loss represents an instantaneous loss or corrosion over the entire period of deployment. In addition, since the coupons were installed in an area of active wave energy and sand transport, it cannot be ruled out the weight loss was caused, in part or wholly, by sand scouring. Even though the stainless steel and titanium coupons did not lose weight when exposed to the same conditions, the copper-nickel composition of Z-alloy is reasoned to be a softer metal than stainless steel, rendering it more susceptible to abrasion loss.

Although the use of narrow-slot screens in the marine environment are made feasible by high resistivity of Z-alloy to biofouling, as demonstrated by the **scwd²** test results, the design and engineering of Z-alloy screens for use in open ocean conditions will need to take the potential corrosion of Z-alloy into consideration.

4.6.2 Entrainment

The **scwd²** 2.0-mm slot intake screens with 0.3 fps through-screen velocity effectively reduced the total estimated annual number of all entrained ichthyoplankton combined by nearly 20% based on the results of the screened versus unscreened tests. However, the tests results also indicate that though the screens affect a positive reduction in entrainment of larvae of some fishes occurring in the nearshore area of Santa Cruz, the reduction is not significant compared to entrainment of an unscreened intake. Results of screen efficiency test closely approximate a result that would be expected based simply on a comparison of the screen's 2.0-mm slot size to the size of larval fishes found in the entrainment samples. From these limited results of our screen efficiency tests, based on 195 specimens of larval fishes, it would appear that the hydrodynamic properties attributed to wedgewire screen material did not contribute to a significant reduction in entrainment of larval fishes. The "sweeping" current created by wave surge under the Santa Cruz Wharf during the screen tests may not have been of sufficient velocity or orientation to create the appropriate sweeping currents that are reportedly required to produce the hydrodynamic screening effects of wedgewire screen. However, it is premature to conclude that altering the elevation and orientation of the wedgewire screen surface to wave forces cannot produce the appropriate "sweeping" currents to achieve the full potential of an open ocean narrow-slot wedgewire screen to reduce entrainment.

The average head capsule size of the larval fishes entrained during the **scwd²** narrow-slot screen test was significantly smaller than the 2.0-mm slots of the screens (see **Table 4.2-3**). Using the same reasoning, slot sizes of 1.0 mm or less would be required to significantly reduce the entrainment of larval fishes that were found in the Santa Cruz nearshore water. However, in using the smallest dimension of a larval fish to predict entrainment, one has to assume that all fishes are in a head-on orientation to the screen's slot. Whether or not this set of conditions occurred during the **scwd²** test is not known. However, it is reasonable to assume that a significant fraction of larval fishes arrive at the screen in a side-wise orientation particularly given the highly variable directions of currents produced by wave interaction with the screen.

Laboratory studies of narrow-slot screen entrainment have found that the orientation of the screen with respect to ambient flow had no significant effect on the rate of larval fish entrainment (EPRI 2003). The tests, using striped bass larvae, measured a slight reduction in entrainment when the screen's slotted openings were oriented perpendicularly to unidirectional ambient currents. The **scwd²** screen was exposed to constantly changing directions of ocean waves and interference currents created by the interaction of waves and tidal flows with the wharf's pilings. The videographic results of the study's impingement tests demonstrated the complexity of these ambient flows and the stationary test screen. The complexity of the screen and wave hydrodynamics was also observed in the videographic results of the series of dye releases immediately in front of the screen's surface. These preliminary observations of the hydrodynamics of passive narrow-slot screens in open ocean settings further demonstrate the potential problems in extrapolating the results of laboratory flume and entrainment tests to the field, and demonstrate the need for further investigation into the effect of screen orientation on screen efficiency and entrainment reduction.

4.6.3 Impingement

Results of the **scwd^2** impingement tests demonstrate that use of a passive cylindrical narrow-slot screen of similar design, construction, and flow rate to that of the 2.0-mm narrow-slot intake screen tested will effectively eliminate impingement of sea life of any kind at the **scwd^2** desalination seawater intake. A new approach and methodology was required to measure impingement on a freestanding, passive screen. With very few exceptions, all of California's industrial-scale, seawater intake screens are located in shoreline intake facilities; the City of Santa Barbara's desalination facility's offshore intake is one of the exceptions. Impingement studies of California's large seawater intakes at most steam electric generating facilities typically involve the collection of samples from impinged materials that are rinsed off 3/8-inch mesh traveling screens. The traveling screens are typically housed in forebays protected by widely spaced, vertical bar racks. Through-screen intake velocities nearly always exceed 0.5 fps and are generally greater than 1 fps. Sea life and detritus that are drawn into the forebay are at risk to entrapment and impingement; the likelihood of impingement has been shown to increase with increasing distance between the screen and the entrance to the forebay, as in the case of offshore intakes 305 m (1,000 ft) or more offshore. The buildup of detritus in the forebay is commonly associated with higher impingement rates of fishes and invertebrates, possibly due to an entanglement effect. The use of a free-standing, passive open-ocean intake screen will completely eliminate the potential for the kind of impingement losses that occur at California's large ocean intakes with flat surface screens located at the blind-end intake forebays for either offshore and shoreline intakes.

The measurement of impingement, or demonstrating its absence at a free-standing, open-ocean intake screen without a forebay or a screen wash device to sample impingement, required new sampling methods to observe and measure impingement. Members of the Technical Working Group (TWG) suggested that the use of smaller mesh (slots) screens to reduce entrainment might lead to an increase in impingement of the organisms that would have otherwise been entrained through larger slots. Videographic techniques were proposed and adopted by the TWG as a method to document the nature and frequency of impingement on the **scwd^2** narrow-slot test screen's surface. Data collected from underwater video cameras and lights installed above the screen's surface also required new data processing and analysis methods to treat the videographic results.

The observation of the video tape images and results from the analysis of the videographic data demonstrate that desalination intake impingement of sea life can be effectively eliminated by **scwd^2**'s use of a passive cylindrical narrow-slot screen of a design, construction, and flow rates similar to the 2.0-mm narrow-slot intake screen tested at through screen velocities of 0.3 fps. The video recording provided unambiguous evidence of marine fishes and invertebrates as small as a few millimeters that are able to encounter the surface of the screen and move away at will. Qualitative impressions from watching video recordings of these encounters suggest that the ability of these small organisms to move off of the screen's surface is aided by the continually changing directions and velocities of currents on the surface of the screen that are created by its interaction with the nearly constant to and fro of wave surge. Although it was not a part of our tests, it would be feasible to measure the effect of wave surge as a change in hydrostatic head at the pump. It is possible that the interaction of the pump's suction with the wave-induced oscillations in hydrostatic head to form a pulse current in the screen's through-slot velocities might also facilitate the movement of smaller organisms away the screen's surface. In any case, in viewing the video recordings, we found no clear example of an organism encountering the screen that was held on or appeared to struggle to move away from the screen's surface. Even in the case of a flat blade of green algae that was pulled against the screen and held by intake flow, the combination of pulsing currents induced by wave surge and the cylindrical shape of the screen cleared the inert algae from the screen surface in less than a minute.

The performance of a cylindrical narrow-slot screen in an open ocean setting is affected by specific-site ocean conditions, particularly the strength and frequency of ambient wave surge and the depth of the intake screen and possibly by the orientation of the screen. At the present time, these factors, in combination with the size and behavior of entrainable species at the site, can only be assessed deterministically through site-specific studies. It is reasonable to expect that some organisms might remain on the surface of the screen for longer periods of time when wave surge is of low strength and frequency. Screen transit time would also be affected by the length and diameter of the intake screen. In the **scwd²** tests, the screen transit times were a matter of seconds owing to the small size of the test screens used in the study.

4.7 Conclusion

The results of **scwd²** tests of a cylindrical, 2.0-mm wedgewire screen successfully demonstrated that the use of the passive screen at intake velocities of 0.3 fps could completely eliminate impingement at the test-size. It is highly likely that the screen's ability to reduce or eliminate impingement at full scale would be equally effective. The screen test results also demonstrated that constructing the screens of Z-alloy, a copper-nickel alloy, could effectively control the settlement and growth of fouling organisms. The preliminary estimates of alloy loss, either from corrosion or electrolysis, must be considered in the design and maintenance of Z-alloy screens, as well as the potential mass emissions of these materials in a process stream discharge.

Results of the screen tests also demonstrated an effective reduction in larval fish entrainment for fishes with the largest head capsule dimension similar to or greater than the test screen's 2.0-mm slot size. Based on the results of these preliminary screen tests, the use of 2.0-mm slot screens could be expected to reduce **scwd²** desalination intake fish entrainment by nearly 20%. Actual day-to-day reductions in entrainment using a 2.0-mm slot size screen will depend on the real time size of larval fishes present at the point of intake. The size of larval fishes will vary seasonally with the magnitude and timing of spawning, dispersion, and growth rates of the area's fish species. The greater the abundance of larger-sized larval fish species and the faster the growth of all larval fishes would result in greater day-to-day reductions in entrainment using narrow-slot intake screens. The relative abundance of larger-sized larval fishes and, probably to a much lesser extent, growth rates, will vary with intake location. Locating a 2.0-mm screened intake at **scwd^2**'s proposed offshore intake location with its greater relative abundance of larger-sized white croaker larvae would theoretically reduce entrainment compared, for example, to the study's screen testing location under the Santa Cruz Wharf. However, any such reduction in entrainment losses would be weighed against other environmental effects and considerations of alternative intake locations.

5.0 Impact Assessment

This study was designed to assess the effects of a **scwd^2** desalination project offshore screened intake on populations of marine fishes and selected shrimps and crabs. Effects from the offshore feedwater screened intake can result from impingement of organisms on the intake wedgewire screen and entrainment into the feedwater system. Towed plankton samples were collected near the vicinity of the proposed offshore intake, and in the surrounding source water, to quantify fish eggs, larval fishes, and selected larval shrimps and crabs. Nine target taxa were chosen for the detailed assessment, including seven types of fishes, cancrid crabs, and caridean shrimps. The decision to narrow the list to these taxa was based on their abundances at the intake station, the availability of suitable life-history information to meet assessment model requirements, and criteria outlined in USEPA Draft Guidelines (USEPA 1977).

5.1 Overview of Assessment Approach

The data collected from the intake and source water sampling were used to assess the potential for adverse environmental impacts (AEI) to fish and target shrimp and crab 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 KGB rockfishes and California halibut that were not among the most abundant but had local fishery importance. The assessment involved the calculation of entrainment estimates for individual taxa based on three proposed flow volumes, and then used these results to model the losses to adult and larval source populations using the *ETM* modeling approach. The *ETM* 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. Project-caused larval mortality is calculated after *PE* is weighted by the estimated fraction of the total population affected and compounded by the time larvae are susceptible to entrainment.

Another approach that is sometimes used to assess impacts is a demographic model that estimates the equivalent number of adult females' lifetime reproductive output (fecundity hindcasting [*FH*]) lost due to entrainment. 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. 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. Therefore, only the *ETM* analysis was conducted, although the magnitude of larval losses can be compared to lifetime fecundity estimates for target species as a way of putting potential entrainment losses into perspective.

5.1.1 Larval Duration

Larval lengths at entrainment were used to estimate the age at which larvae were entrained, using growth rates reported or derived from available scientific literature. This method has many assumptions with implications for the results of the present study. Primary among these is the assumption that the point estimates for larval growth reported in the literature, often from areas geographically removed from the central coast of California, are representative of growth rates for larvae in the area in northern Monterey Bay near Santa Cruz. Dividing all larval lengths by the same growth rate to obtain estimated ages assumes that growth is constant for the different larval stages and the durations estimated. Variation in growth rates, more probable for larger individuals, could lead to some inaccuracy in the estimates of the ages of the entrained larvae.

Examination of length-frequency histograms for the larvae of various taxa treated in this study and comparison with reported hatch lengths indicates that there is much wider variation in hatch lengths of these fishes than is presently reflected in the literature. This follows from the observation that many of the larvae collected and measured in this study were smaller than the reported hatch lengths. In many cases, the average lengths of larvae entrained were less than reported hatch lengths. Although this may be partially due to larval shrinkage resulting from preservation (Theilacker 1980), the large variation could also represent natural variation that is much greater than previously reported (Matarese et al. 1989, Moser 1996). If the actual larval ages at entrainment were younger than our estimates, then the source water areas estimated for the affected population would be smaller than those estimated using the present methods because they would be at risk of entrainment for a shorter time period. If the affected populations are actually smaller than the current estimates used in the *ETM*, then P_M may also be underestimated.

5.2 Summary of Entrainment Results

Composition and abundance of ichthyoplankton and selected shrimp and crab larvae potentially entrained by an offshore intake were determined by sampling in the proximity of the intake once per month from April 2009 through May 2010.[6] A total of 2,887 entrainable fish larvae from 45 separate taxonomic categories (including unidentified and damaged larval fishes) was collected from 100 samples at the intake station. Eight taxa comprised the top 82% of the average mean concentration of larval fishes collected at the intake station. The most abundant taxa were white croaker (51.6%), unidentified yolk sac larvae (9.3%), northern anchovy (5.8%), CIQ gobies (5.1%), sanddabs (2.7%), unidentified smelts (2.6%), unidentified ronquils (2.3%), and smoothhead sculpins (2.3%). Most of the commonly entrained taxa were from species with shallow nearshore distributions, but larvae from some deepwater species (e.g., lanternfishes [Myctophidae]) were also collected in smaller numbers. The estimated total annual entrainment based on the 2009–2010 sampling and a feedwater intake flow of 7 mgd was 6.55 million fish larvae (**Table 5.2-1**).

[6] No survey was conducted during April 2010 due to dangerous sea conditions.

A total of 658 target shrimp and crab larvae (cancrid crabs and caridean shrimps) was identified from the monthly intake samples. Caridean shrimps comprised approximately 55% of the total mean concentration of target invertebrates collected at the intake station. Total annual entrainment of target shrimp and crab larvae based on a feedwater intake flow of 7 mgd and the 2009–2010 data was estimated to be 432,524 later-stage caridean shrimp larvae and 473,475 cancrid crab megalops (**Table 5.2-1**).

Table 5.2-1. Summary of **scwd²** sampling results and model output for fishes and target shrimps and crabs based on 7 mgd flows and 2009–2010 intake survey data.

Species	Common Name	Est. Annual Larval Ent. (7 mgd flow)	*ETM* P_M (%) (7 mgd flow)
Fish Larvae			
Genyonemus lineatus	white croaker	3,596,272	0.053
Engraulis mordax	northern anchovy	380,146	0.047
CIQ goby complex	gobies	320,160	0.063
Citharichthys spp.	sanddabs	183,575	0.033
Artedius spp.	sculpins	140,946	0.029
Sebastes spp. V_	KGB rockfishes	51,579	0.010
Paralichthys californicus	California halibut	43,738	0.027
	38 other taxa	1,837,087	
	Total larval fishes	**6,553,503**	
Target Shrimp and Crab Larvae			
Caridean shrimps (post-larval)	caridean shrimps	432,524	0.022
Cancridae (megalops)	cancrid crab megalops	473,475	0.022
	Total target larval shrimps and crabs	**905,999**	

5.3 Assessment of Entrainment Effects

The following criteria are applicable to assessing potential environmental impacts on marine organisms caused by entrainment into the **scwd²** intake system:

- Magnitude of effects,
- Population distributions,
- Life history strategies (e.g., longevity and fecundity),
- Abundance trends of target species, and
- Environmental trends (climatological or oceanographic).

These criteria are discussed in the sections that follow. The criteria were considered on a taxon-specific basis when trying to determine the extent of entrainment effects on local populations. This provides 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*."

5.3.1 Magnitude of Effects and Population Distributions

Because the proposed desalination water intake is situated off of a rocky shoreline that is adjacent to sand substrate habitat at deeper depths, it follows that the greatest magnitude of effects is likely to occur to species that produce larvae from these types of habitats. However, the dominance of white croaker larvae in the samples is consistent with the general oceanographic conditions in northern Monterey Bay that typically produce a counter-clockwise gyre transporting larvae produced from species inhabiting the more sheltered sand bottom habitats south and east of the intake location. This predominant flow pattern was confirmed by current data showing that movement was generally upcoast in the alongshore direction (see **Figure 3.3-2**).

The *ETM* approach applied to all target taxa required an estimate of a population that was defined by extrapolating larval concentration over an area delimited by estimated larval duration combined with current speed and direction in the study period. The expansions of the abundances were based on measurements of current speed and direction from the ADCP current data and were constrained by larval ages at entrainment. The greatest proportional effects of larval entrainment were on gobies and sanddabs, which are directly associated with soft substrate habitats, white croaker which is an epibenthic or open water species also associated with sand bottoms, and northern anchovy, which is a widely distributed pelagic species. However, even those species with the highest proportional entrainment, based on the *ETM* modeling, would have less than approximately six one-hundredths of one percent of their populations within the source water at risk of entrainment at a projected intake flow rate of 7 mgd (**Table 5.2-1**). Larvae of sculpins and KGB rockfishes, which are characteristic of nearshore rock and kelp bed habitats, were less abundant than the species associated with sand-bottom or open water habitats. The proportional entrainment for these rocky shoreline species was calculated as less than three one-hundredths of one percent of their populations within the source water area. The target invertebrate groups (caridean shrimps and cancrid crabs) sampled during the study had similarly low values of modeled proportional entrainment. The low P_m values represent an insignificant source of mortality on these populations considering other anthropogenic and natural mortality sources that can also affect these species, and considering the high temporal variation that these populations typically experience due to a range of environmental conditions.

If the absolute numbers of larvae projected to be annually entrained at a 7 mgd rate are compared to fecundity estimates of an individual species such as white croaker, it is evident that the potential larval losses (3.6 million white croaker larvae) obviously are a very small fraction of the reproductive output of the source populations, and are comparable to the total lifetime fecundity of a single female fish. For example, batch fecundities of white croaker are known to range 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), and some older fish may spawn for seven months. 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). Combining this information on fecundity, age, growth, mortality rates, and reproduction yields an estimate a total lifetime fecundity of 2.3 million eggs for a female white croaker with an average longevity of 5.75 years. Applying these same types of calculations to the other fish and invertebrate species described in this study would show that it would be highly unlikely that the projected larval losses from an intake in the proposed range of 7 mgd would have any significant effect on source water populations.

5.3.2 Life History Strategies

Differing life history strategies among the various taxa should be considered when assessing the magnitude of entrainment effects. For example, for pelagic species that release planktonic eggs, such as white croaker and northern anchovy, the estimates of exposure to risk of entrainment were increased to account for the planktonic egg phase. This is in contrast to nearshore species with demersal egg masses, such as sculpins, or rockfishes that extrude developed larvae directly into open water.

Based on the length frequency information collected during the study, average lengths of most larvae were skewed toward the small end of their developmental range, demonstrating that they were recently hatched and would therefore be exposed to entrainment for only a brief period during their larval development. Very few flexion or post-flexion larvae were entrained. Flexion and post-flexion stages have more highly-developed swimming abilities than younger individuals and could be avoiding the nets and therefore potential entrainment. The lack of these later developmental stages in the samples may also indicate that these taxa demonstrate larval behavior that removes them from risk of entrainment as they develop (e.g., settlement to benthic habitats or migration into deeper areas).

A complicating factor in projecting equivalent adults from larval mortality estimates is the uncertain but often large mortality rate associated with predation on newly-settled individuals. Field experiments have shown that there is strong density-dependent mortality in juvenile gobies caused by predation, and to some extent competition (Steele 1997, Steele and Forester 2002), implying that adult populations may often be regulated by post-settlement processes rather than the input of settlers. Cohorts of blue rockfish have been shown to be affected by density-dependent post-settlement predation (Adams and Howard 1996), but increased habitat complexity may be associated with a reduction in both density-independent and density-dependent mortality (Johnson 2007). It was found that low levels of habitat complexity had relatively little influence on population size but as habitat complexity increased recruitment intensity became a more important determinant of adult population size. Therefore, local conditions can play an important role in the link between larval supply and cohort strength.

Although the present study focused on species potentially affected by entrainment, it is important to note that several of the most common fish species in the vicinity of the proposed **scwd²** intake have life stages that are not susceptible to entrainment. For example, live-bearers, such as surfperches, and elasmobranchs (sharks and rays) produce young that are fully developed and too large to be affected by entrainment. These species can comprise a significant fraction of the numbers, and especially biomass in the case of sharks and rays, of species in kelp forest and nearshore sand bottom habitats (Allan and Pondella 2006).

5.3.3 Environmental Trends

Changes in the distribution and dispersal patterns of pelagic larvae are influenced by changes in ocean climate regime and can be expected to occur during either anomalously warm oceanographic events such as El Niño (Bailey and Incze 1985, Brodeur et al. 1985) or during periods of strong upwelling (Parrish et al. 1981). Variation in upwelling intensity from year to year is one factor affecting spawning and recruitment success in fish populations, along with variation in spawning stock size, distribution, mortality rates, among other factors. Upwelling is correlated with cooler coastal water temperatures, higher nutrient concentrations (nitrates, phosphates and silicates) in surface waters, increased primary production, and stronger offshore transport, while the opposite conditions prevail during periods of weak or no upwelling. The monthly upwelling index anomaly (developed by the Pacific Fisheries Environmental Laboratory) off Monterey is an indicator of the general oceanographic conditions that were present in Monterey Bay during the study period in comparison to long-term average conditions. The May–August period in 2009 at the beginning of the study had a weaker upwelling signal compared to the long-term mean, while spring months in 2010 were about average but with a slight positive anomaly (**Figure 5.3-1**).

Within the northern Monterey Bay and the vicinity of the proposed intake, upwelling "shadows" strongly influence patterns of water mass distributions, fronts, and circulation, and thereby determine distributions of nutrients and plankton (Graham and Largier 1997). One influence is a cyclonic circulation that develops during upwelling that was found to entrain and rapidly spread part of a northeastern Monterey Bay algal bloom (Ryan et al. 2009). Another influence of the upwelling shadow on planktonic distributions can be retention. Despite strong cyclonic flow transporting part of the bloom seaward and southward, a large patch of the bloom remained in the NE corner of the Bay. This is the same area where drifter studies have indicated a strong retention zone.

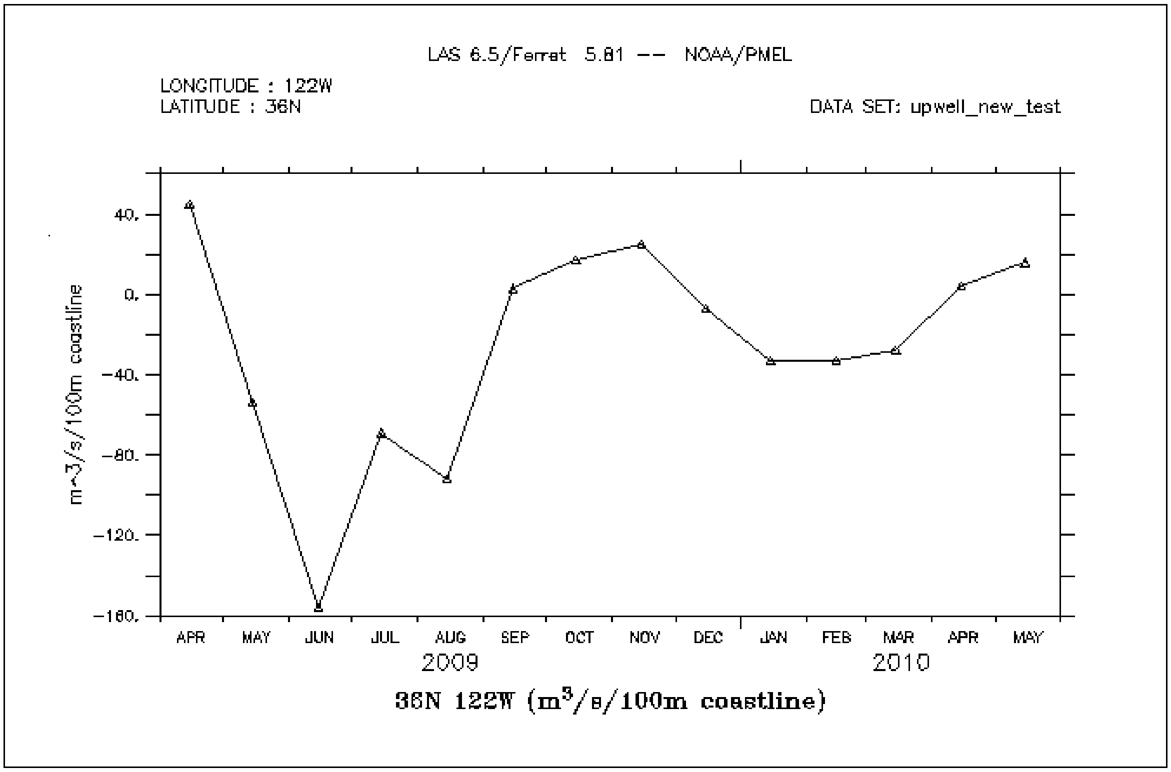


Figure 5.3-1. Monthly upwelling index anomalies for Monterey, California coastline during the 2009–2010 study period (source: Pacific Fisheries Environmental Laboratory; http://www.pfeg.noaa.gov).

5.3.4 Abundance Trends

The most abundant species of fish larvae entrained was white croaker. Abundance trends of adult populations of this species have not been recently assessed in Monterey Bay, although some information is available from catch statistics of the commercial and recreational fisheries. The commercial landings for white croaker in Monterey Bay were low during 2005–2009 with no reported landings from Santa Cruz County during these years and 29.8 metric tons (65,794 lb) reported from Monterey County in 2009 (PacFIN 2010). In the previous five-year period from 2000–2004, there were landings recorded in Monterey Bay during all years with an average of 4.3 metric tons (9,512 lb) per year from Santa Cruz County and 1.8 metric tons (3,996 lb) per year from Monterey County. Recreational catches of white croaker in central California are taken from piers, breakwaters, private boats, and commercial passenger fishing vessels (Love 1996). Annual recreational landings in central California, including Santa Cruz, Monterey, and San Luis Obispo counties, have averaged 28,565 fish per year since 2005, but recently declined to an estimated low of only 3,511 fish in 2009 from a high of 51,129 fish in 2005 (RecFIN 2010; see **Table 3.3-5**). Fishing effort is not constant among years, but these numbers indicate that the population probably varies substantially over time depending on factors such as recruitment success and natural mortality.

The next most abundant species at the entrainment station was northern anchovy. Again, the best metric for changes in population abundance comes from commercial fishery statistics as there are no fishery-independent, long-term sampling data available from Monterey Bay, such as the CalCOFI program conducted for larval fishes in the Southern California Bight. The stock is thought to be stable, and the size of the anchovy resource is largely dependent on natural influences such as ocean temperature and upwelling strength. Annual landings in the Monterey region since 2005 have varied from a high of over 12,000 MT (27 million lb) in 2008 to a low the following year of 978 MT (2.1 million lb) in 2009 (see **Table 3.3-8**), with an average of 15.3 million pounds annually. There are no commercial landings of northern anchovy listed for Santa Cruz County in the PacFIN database.

For all species with some fishery importance, the magnitude of the recreational or commercial catches in the source water greatly exceeds the potential for adverse effects caused by the proposed desalination intake. For species with no fisheries, such as the various species of sculpins and gobies, their populations fluctuate annually depending on recruitment success and local oceanographic conditions, and any incremental mortality incurred from entrainment would be insignificant compared to these natural population changes.

5.4 Assessment Summary and Conclusions

In summary, none of the populations of fishes or target shrimps and crabs analyzed with the proportional entrainment (*ETM*) modeling would be significantly affected by entrainment from the proposed desalination intake. The analyzed taxa had a wide range of habitat, depth, and onshore-offshore distributions. Larvae from fish and target shrimp and crab species that are typically found in the shallow rock reef, kelp bed habitat in proximity to the proposed intake actually had the least potential effects based on the *ETM* analysis results. The species with the greatest potential entrainment, based on the 2009–2010 sampling results, was white croaker, a species with a wide geographical distribution that typically occurs over shallow sandy bottoms. White croaker spawn pelagic eggs generally from November through May, and prevailing current patterns in the source water tended to transport the eggs and larvae into the vicinity of the proposed intake. Measurements of larvae indicate that white croaker and most of the target taxa are exposed to entrainment for a relatively short period of time during their larval development and thus were produced locally. These results indicate that any entrainment effects would be limited to localized effects on nearshore species. Therefore, the potential for damage due to entrainment on the biological value of the source water body is very low.

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Appendix A

Formulation of Entrainment Analysis Models

A1. Calculating Total Entrainment

A2. Estimating Proportional Entrainment and the Empirical Transport Model Calculations

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A1. Calculating Total Entrainment

The following section describes calculations used for estimating entrainment for the proposed **scwd²** desalination plant offshore intake. The entrainment estimate for a selected taxon is built on estimates of larval concentration for each survey period, which was determined by sampling approximately monthly at a location near the proposed intake. Two plankton samples were collected at the station during two sampling cycles within a day. The within-day sampling was based on a stratified random design with two temporal cycles (night and day) and two replicates per cycle. The associated statistics based on the stratified sampling were based on Gilbert (1987). For the calculations let

i = survey period $\left(i = 1, \ldots, N\right)$;

j = day within survey period $\left(j = 1, \ldots, N_i\right)$;

k = cycle within day $\left(k = 1, \ldots, N_{ij}\right)$; and

l = number of replicate tows $\left(l = 1, \ldots, N_{ijk}\right)$.

The average concentration $\overline{\rho}_{ijk}$ for cycle k within day j within survey period i was calculated as follows:

$$\overline{\rho}_{ijk} = \frac{1}{n_l}\sum_{l=1}^{N_{ijk}} \rho_{ijkl} \text{, where } n_l = 2 \text{, the number of replicate tows,} \qquad \text{(A1-1)}$$

with associated variance of

$$Var(\overline{\rho}_{ijk}) = \frac{1}{n_l(n_l - 1)}\sum_{l=1}^{N_{ijk}} (\rho_{ijkl} - \overline{\rho}_{ijk})^2 . \qquad \text{(A1-2)}$$

The average concentration $\overline{\rho}_{ij}$ for day j within survey period i was calculated as follows:

$$\overline{\rho}_{ij} = \sum_{k=1}^{N_{ij}} \frac{n_l}{n_{kl}} \overline{\rho}_{ijk} \text{, where } n_{kl} = 4 \text{, the total samples over 2 cycles,} \qquad \text{(A1-3)}$$

with associated variance of

$$Var(\hat{\rho}_{ij}) = \sum_{l=1}^{N_{ij}} \left(\frac{n_l}{n_{kl}}\right)^2 Var\left(\overline{\rho}_{ijk}\right). \qquad \text{(A1-4)}$$

where

$\overline{\rho}_{ij}$ = the average concentration of larvae on the jth day in the ith survey period.

The estimates of average daily concentration and their associated variances were used in many of the data presentations in the report, as well as in calculating estimates of daily entrainment that were used in proportional entrainment (*PE*) calculations for the empirical transport model (*ETM*). The estimate of daily entrainment, E_{ij} , was calculated as:

$$E_{ij} = \bar{\rho}_{is} V_{ij}, \qquad \text{(A1-5)}$$

where

V_{ij} is the volume of water entrained by the plant on day *j* of survey period *i*.

In addition, for any period *i*, daily entrainment is estimated by using the average survey density from the one sampling day times the daily entrainment volume. Similarly, the survey period's variance of density is estimated using the variance of the survey day. The variance of daily entrainment was calculated as:

$$\widehat{Var}(E_{ij}) = \widehat{Var}(\bar{\rho}_{ij}) V_{ij}^{\,2}\,. \qquad \text{(A1-6)}$$

Estimates of entrainment for a survey period were calculated by using the estimate of the daily average concentration, $\bar{\rho}_{ij}$, and calculating an estimate of daily entrainment and the associated variance using Equations A1-5 and A1-6, respectively, after substituting the appropriate volume for the days in each period, V_{ij} , into the equations. The start and end dates of a survey period were defined as the midpoint between successive sampling dates. Data collected on the sampling date between the midpoints was assumed to be representative of the entire survey period. Total larval entrainment was calculated as follows:

$$E_T = \sum_{i=1}^{N} \sum_{j=1}^{N_i} E_{ij}, \qquad \text{(A1-7)}$$

The associated variance was calculated as:

$$\widehat{Var}(E_T) = \sum_{i=1}^{N} \sum_{j=1}^{N_i} \widehat{Var}(E_{ij}).\,. \qquad \text{(A1-8)}$$

Estimates of total entrainment for the yearlong study period were calculated by summing the estimates from the individual survey periods.

A2. Estimating Proportional Entrainment and the Empirical Transport Model Calculations

The empirical transport model (*ETM*) is used to estimate the probability of mortality due to desalination facility entrainment. The estimate is based on periodic estimates of the probability of entrainment based on daily sampling. Generally, sampling takes place over the course of a year so that larval mortality of various species is estimated, and the estimate is for the period of one year.

The daily probability of entrainment during survey period *i* can be defined as

$$PE_i = \frac{\text{abundance of entrained larvae}_\text{i}}{\text{abundance of larvae in source population}_\text{i}}$$
$$= \text{probability of entrainment in } i\text{th survey period } \left(i = 1, \ldots, N\right).$$

where the daily probability can be estimated and expressed as

$$PE_i = \frac{\widehat{E_i}}{\widehat{R_i}} \qquad \text{(A2-1)}$$

where

E_i = estimated abundance of larvae entrained in the i^{th} survey period $\left(i = 1, \ldots, N\right)$ calculated per Equation A1-5; and

R_i = estimated abundance of larvae at risk of entrainment from the source population in the i^{th} survey period $\left(i = 1, \ldots, N\right)$.

Estimating Numbers of Larvae at Risk

The daily abundance of larvae in the sampled source water (*S*) stations at risk can be estimated by

$$\widehat{R_i} = \sum_{l=1}^{N_l} V_{S_l} \cdot \bar{\rho}_{S_{il}}, \qquad \text{(A2-2)}$$

where V_{S_l} denotes the static volume for each of the *l* sampled source water stations , and $\bar{\rho}_{S_{il}}$ denotes the average concentration in each of the *l* sampled source water stations during survey period *i*. The variance of Expression A2-2 can be written as

$$Var\left(\widehat{R_i} \mid R_i\right) = \sum_{i=1}^{N_l} V_{S_l}^2 \cdot Var\left(\widehat{\bar{\rho}_{S_{il}}} \mid \bar{\rho}_{S_{il}}\right) \qquad \text{(A2-3)}$$

Formula A2-3 describes the temporal-spatial variance in the sampled source water population during the day of sampling. Three source water locations were sampled in the vicinity of the proposed offshore intake, in addition to samples taken at the proposed intake location. Ideally, tow samples would be collected randomly through time and space during a sampling day over a potential source water population. However, practical limitations due to sampling a large area required a directed and fixed time and location sampling scheme. Source water estimates of population and variance were made for each period using only one day, i.e. $\widehat{R_i} = \widehat{R_{ij}}$ and $\widehat{Var}\left(\widehat{R_i}\right) = Var\left(\widehat{R_{ij}} \mid R_{ij}\right)$.

A total sum over all survey periods used in calculating the fraction (f_i) of the source water population present during survey *i* was calculated as follows:

$$\hat{R}_T = \sum_{i=1}^{N} \sum_{j=1}^{N_i} \hat{R}_i, \tag{A2-4}$$

The associated variance was calculated as:

$$\widehat{Var}(\hat{R}_T) = \sum_{i=1}^{N} \sum_{j=1}^{N_i} \widehat{Var}(\hat{R}_i). \tag{A2-5}$$

Period Entrainment and *ETM* Calculations

The sampled source water represents some proportion of the total source water population which was estimated in this study using current data collected during each i^{th} survey period. The ratio C_{S_i} described the fraction sampled to extrapolated source water for each survey period. C_{S_i} was used to adjust the estimate of the source water population, $\hat{R}_i$, to allow the direct calculation of $\widehat{PE}_i$ by dividing estimated period entrainment (A1-5) by the corresponding source population (A2-2) as

$$\widehat{PE}_i = \frac{\widehat{E}_i}{\hat{R}_{i-Adj.}} = \frac{\widehat{E}_i}{\widehat{R}_i \bullet \widehat{C}_{S_i}} \tag{A2-6}$$

Variance for the Estimate of PE_i

The variance for the period estimate of $\widehat{PE}_i$ can be expressed as

$$Var\left(\widehat{PE}_i \middle| PE_i\right) = Var\left(\frac{\widehat{E}_i}{\widehat{R_{i-Adj}}} \middle| E_i, R_{i-Adj}\right).$$

Assuming zero covariance between the entrainment and source and using the delta method (Seber 1982), the variance of an estimator formed from a quotient (like $\widehat{PE_i}$) can be effectively approximated by

$$Var\left(\frac{A}{B}\right) \approx Var(A)\left(\frac{\partial\left[\frac{A}{B}\right]}{\partial A}\right)^2 + Var(B)\left(\frac{\partial\left[\frac{A}{B}\right]}{\partial B}\right)^2 .$$

The delta method approximation of $Var(\widehat{PE_i})$ is shown as

$$Var\left(\widehat{PE_i}\right) = Var\left(\frac{\widehat{E_i}}{C_{S_i} \cdot V_S \cdot \widehat{\overline{\rho}_{S_i}}}\right)$$

which by the Delta method can be approximated by

$$\widehat{Var}\left(\widehat{PE_i}\right) \approx \widehat{Var}\left(\widehat{E_i}\right)\left(\frac{1}{C_{S_i} \cdot V_S \cdot \widehat{\overline{\rho}_{S_i}}}\right)^2 + \widehat{Var}\left(C_{S_i} \cdot V_S \cdot \overline{\rho}_{S_i}\right)\left(\frac{-\widehat{E_i}}{C_{S_i} \cdot V_S \cdot \left(\widehat{\overline{\rho}_{S_i}}\right)^2}\right)^2 \quad \text{(A2-7)}$$

and is equivalent to

$$= PE_i^2\left[CV\left(\widehat{E_i}\right)^2 + CV\left(C_{S_i} \cdot V_S \cdot \widehat{\overline{\rho}_{S_i}}\right)^2\right]$$

where

$$\widehat{R_{i-Adj}} = C_{S_i} \cdot V_S \cdot \widehat{\overline{\rho}_{S_{ij}}} \text{ and}$$

$$CV\left(\hat{\theta}\middle|\theta\right) = \frac{\widehat{Var}\left(\hat{\theta}\middle|\theta\right)}{\widehat{\theta^2}}.$$

Regardless of whether a species has a single spawning period per year or multiple overlapping spawnings the estimate of total larval entrainment mortality can be expressed by

$$\widehat{P_M} = 1 - \sum_{i=1}^{N} \widehat{f_i}\left(1 - \widehat{PE_i}\right)^q \quad \text{(A2-8)}$$

where

q = number of days of larval life, and

$\hat{f}_i$ = estimated annual fraction of total larvae hatched during the *i*th survey period.

Formula A2-8 is based on the total probability law where

$$P(A) = \sum_{i=1}^{N} P(A|B_i) \cdot P(B_i).$$

In the above example, the event A is larval survival and event B is hatching with $P(B)$ estimated by $\widehat{f_i}$ where

$$\widehat{f_i} = \frac{\widehat{R_i}}{\widehat{R_T}},$$

where $\widehat{R_i}$ = static source population at risk in the *i*th survey period, and R_T = total source population at risk for all survey periods. Then based on the Delta method

$$\begin{aligned}
\widehat{Var}(\hat{f}_i) &= \widehat{Var}\left[\frac{\widehat{R_i}}{\widehat{R_T}}\right] \\
&= \widehat{Var}\left[\frac{\widehat{R_i}}{\widehat{R_i} + \sum_{j \neq i}^{N} \widehat{R_j}}\right] \\
&= \hat{f}_i^{\,2}(1 - \hat{f}_i)^2 \left[\frac{\widehat{Var}(\widehat{R_i})}{\widehat{R_i}^{\,2}} + \frac{\widehat{Var}(\widehat{R_T})}{\widehat{R_T}^{\,2}}\right].
\end{aligned}$$

The estimates of PE_i and f_i and their respective variance estimates can be combined in an estimate of the variance for $\widehat{P_M}$ following the Delta method (Seber 1982) for variance and covariance as follows:

$$\begin{aligned}
\widehat{Var}(\widehat{P_M}) &= \widehat{Var}\left(1 - \sum_{i=1}^{N} \hat{f}_i (1 - \widehat{PE_i})^q\right) \\
&= \widehat{Var}\left(\sum_{i=1}^{N} \hat{f}_i (1 - \widehat{PE_i})^q\right) \\
&= \sum_{i=1}^{N}\left[Var(\hat{f}_i)(1 - \widehat{PE_i})^{2q}\right] \\
&\quad + \sum_{i=1}^{N}\left[Var(\widehat{PE}_i)(\hat{f}_i q (1 - \widehat{PE_i})^{q-1})^2\right].
\end{aligned}$$

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Appendix B

Ocean Surface Currents: April 2009 – May 2010

B1. Current Vectors: Hourly Averages

B2. Current Trajectories: 24-hour Composites

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Surface currents are measured hourly over the entire coastline of California using high frequency (HF) radar by a network of CODAR Ocean Sensors, Ltd. SeaSondes® operated by the member institutions of the Central & Northern California Ocean Observing System (CeNCOOS) and Southern California Coastal Ocean Observing System (SCCOOS) consortia of the Coastal Ocean Currents Monitoring Program (COCMP) with funding provided by California voters through Propositions 40 & 50 and administered by the State Coastal Conservancy. The following figures show hourly averages (Appendix B1) and 24-hour trajectories (Appendix B2) in the vicinity of Monterey Bay and are from the CeNCOOS website.* Plots are presented for the 13 days during which entrainment and source water sampling occurred.

**http://www.cencoos.org/sections/conditions/currents/index.shtml.*

B1. Current Vectors: Hourly averages

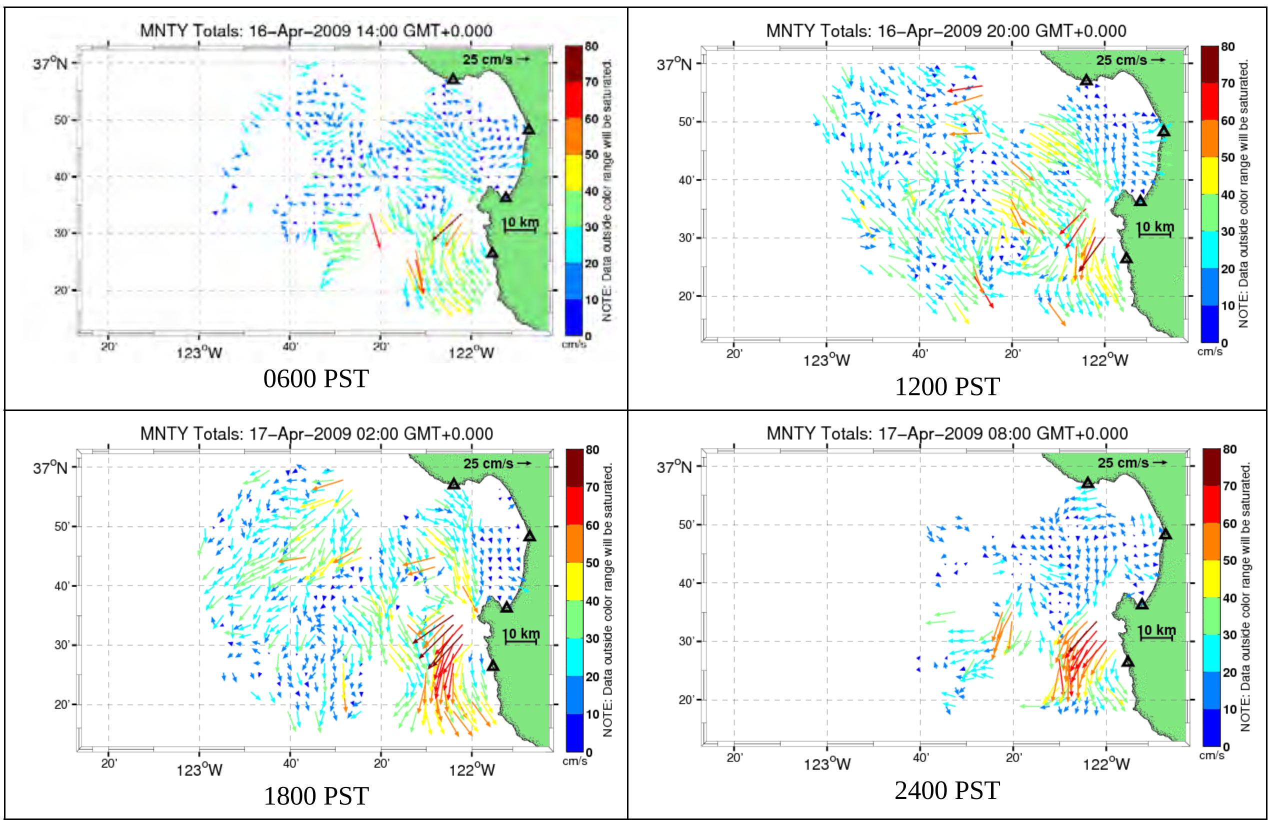

Figure B1-1. Hourly mean ocean surface currents at four times on April 16, 2009. Colors indicate current speed bins in cm/s with longer arrows indicating faster speeds.

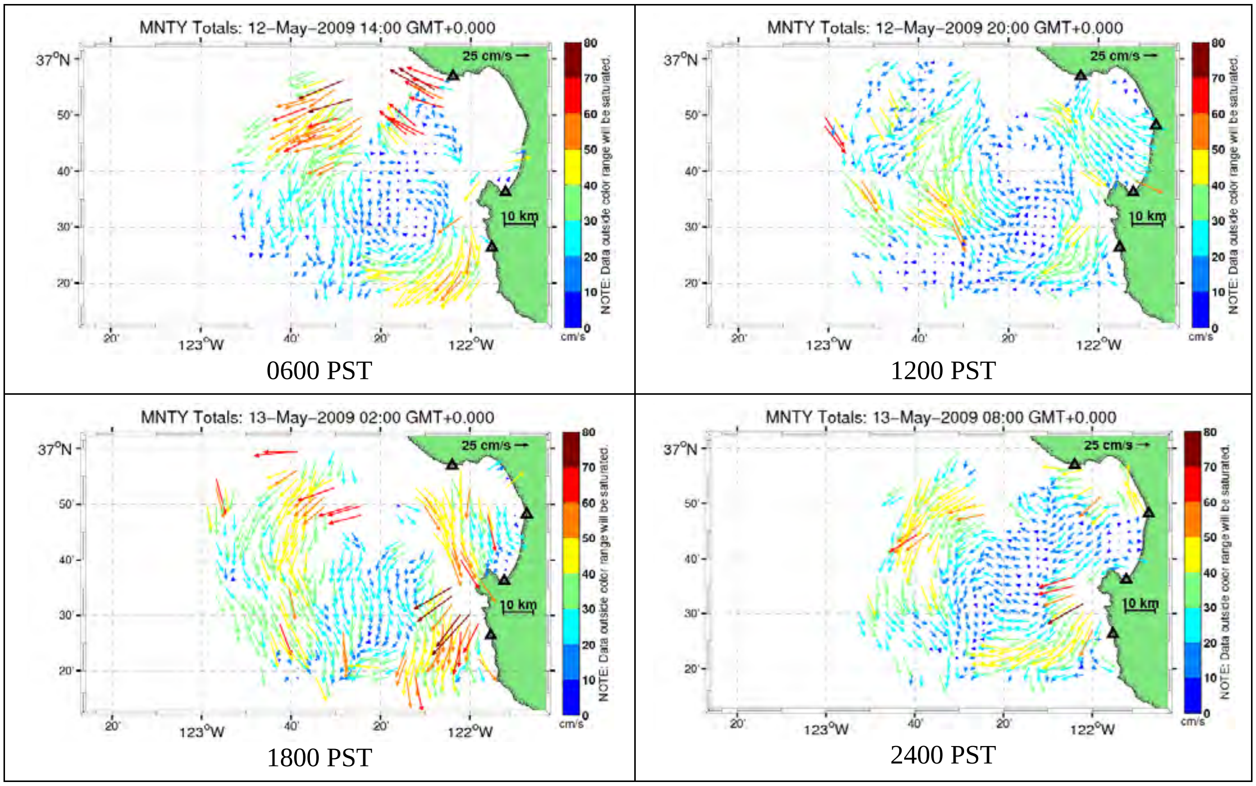

Figure B1-2. Hourly mean ocean surface currents at four times on May 12, 2009. Colors indicate current speed bins in cm/s with longer arrows indicating faster speeds.

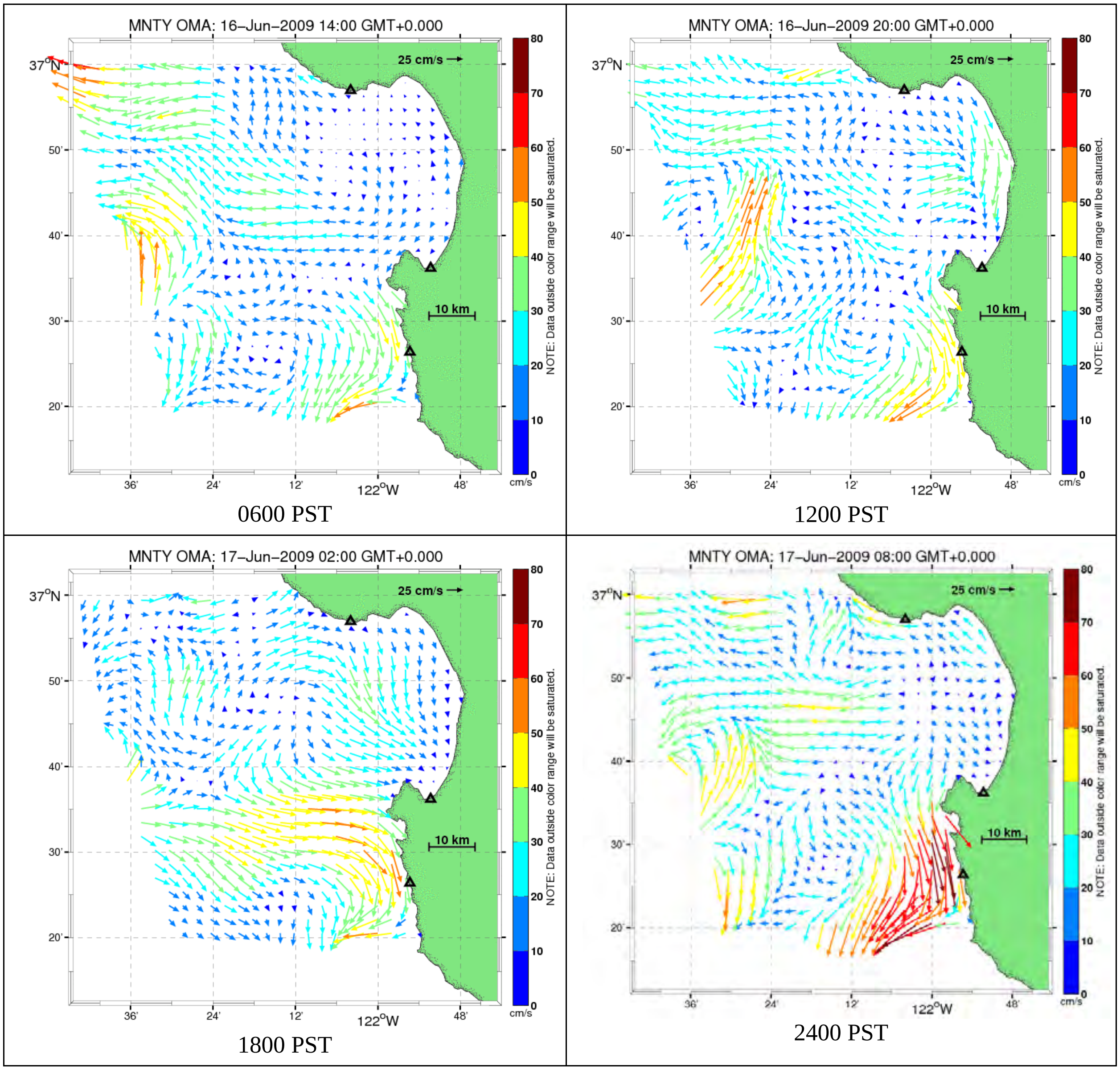

Figure B1-3. Hourly mean ocean surface currents at four times on June 16, 2009. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

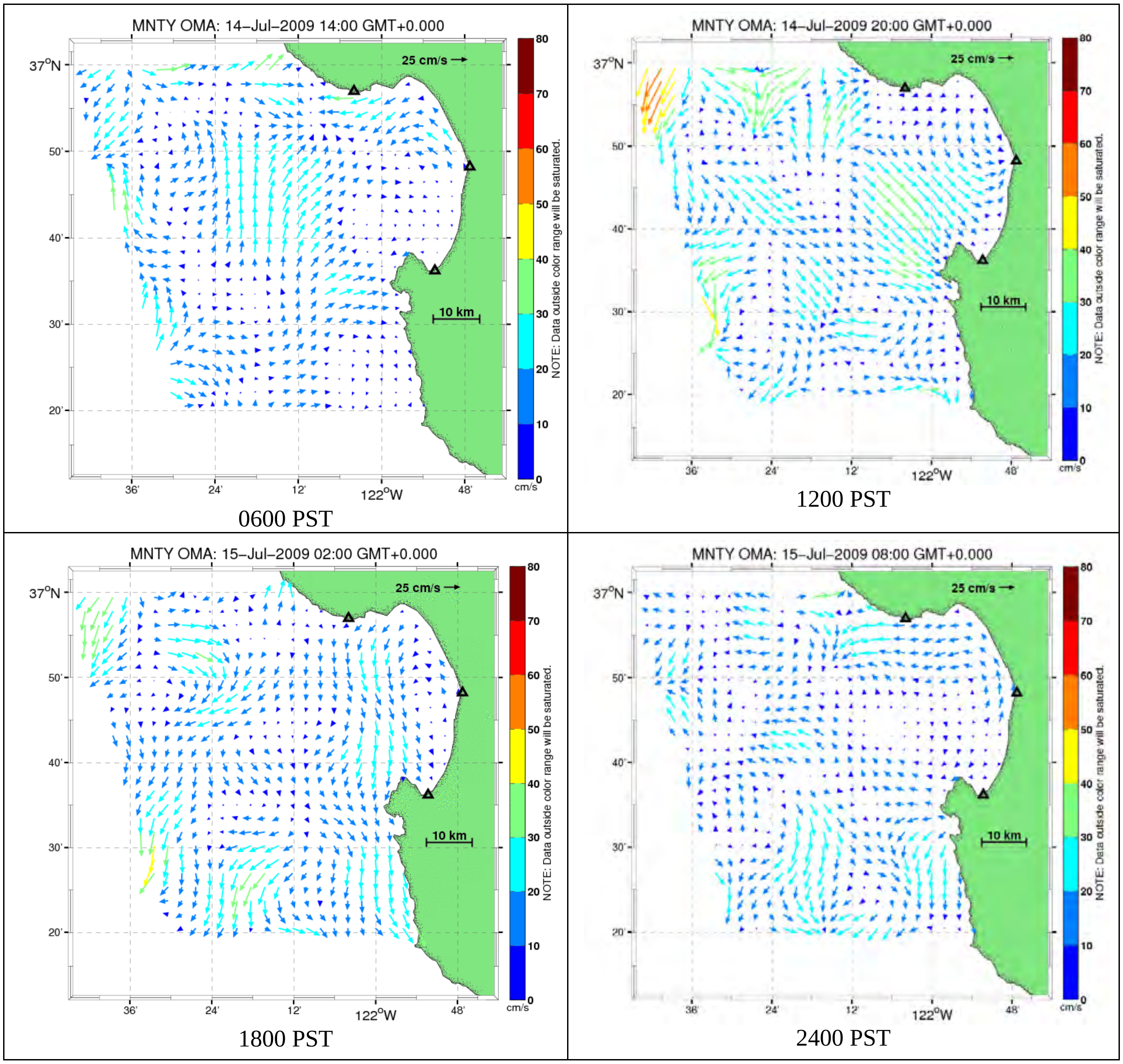

Figure B1-4. Hourly mean ocean surface currents at four times on July 14, 2009. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

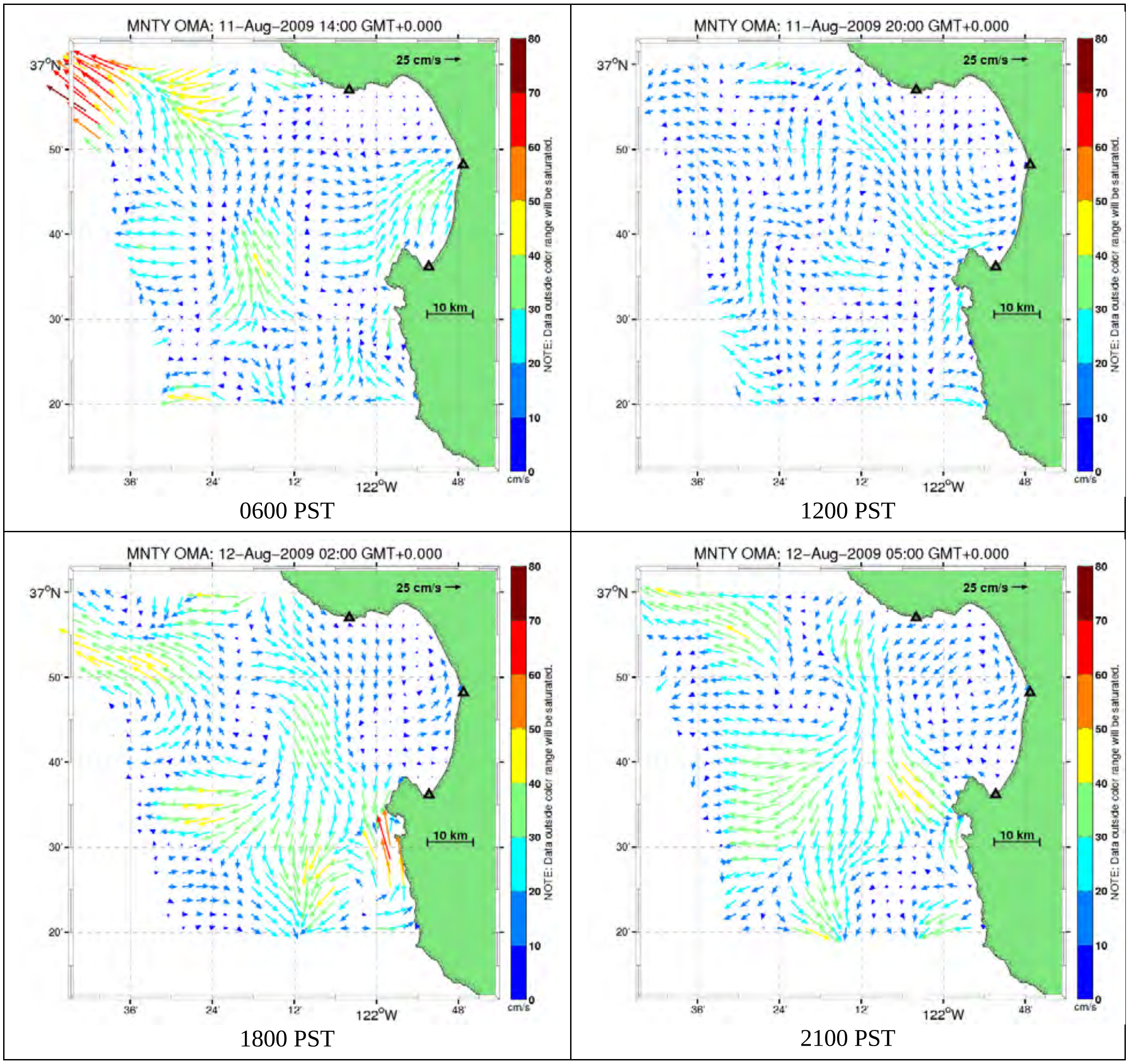

Figure B1-5. Hourly mean ocean surface currents at four times on August 11, 2009. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

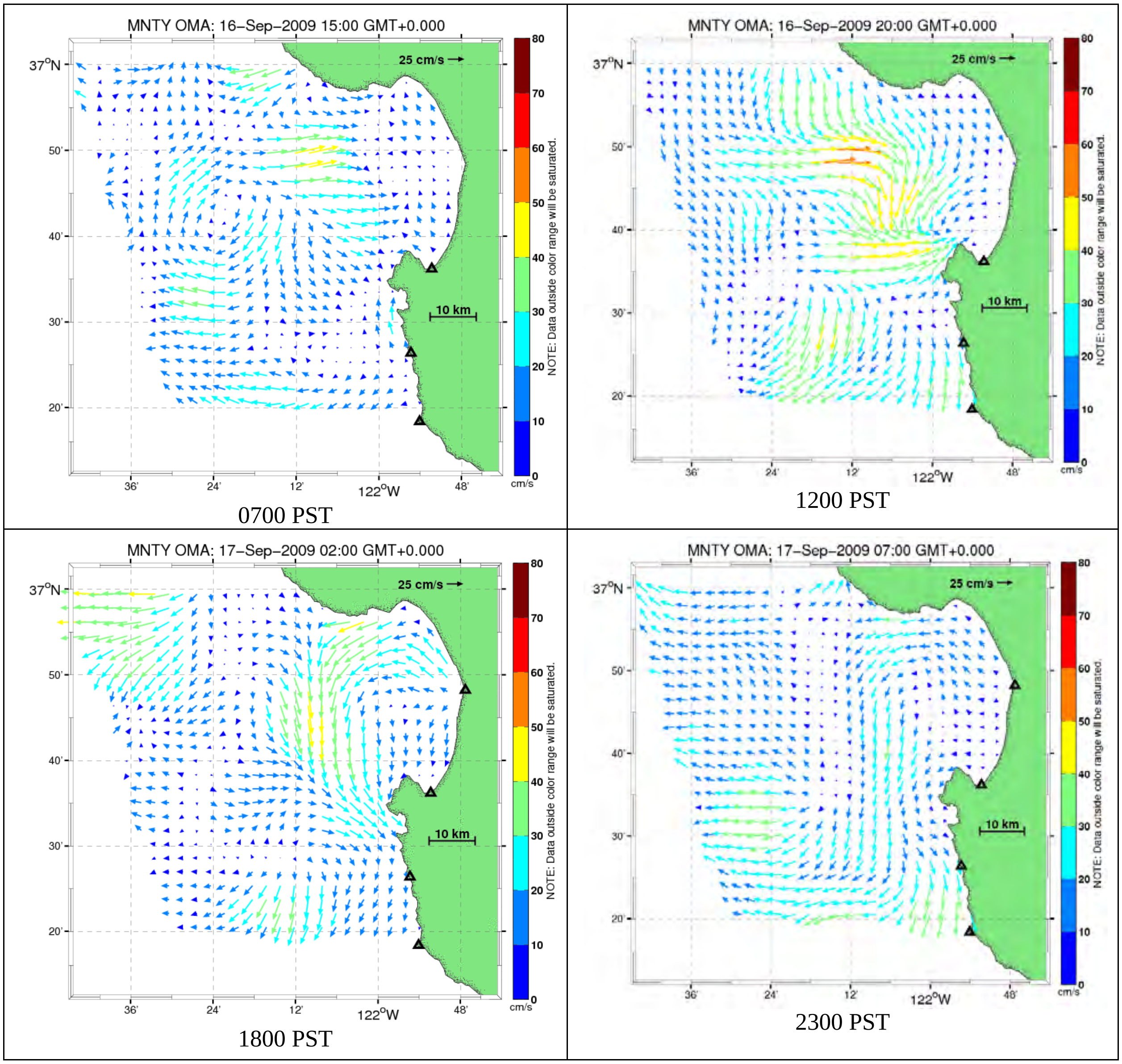

Figure B1-6. Hourly mean ocean surface currents at four times on September 16, 2009. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

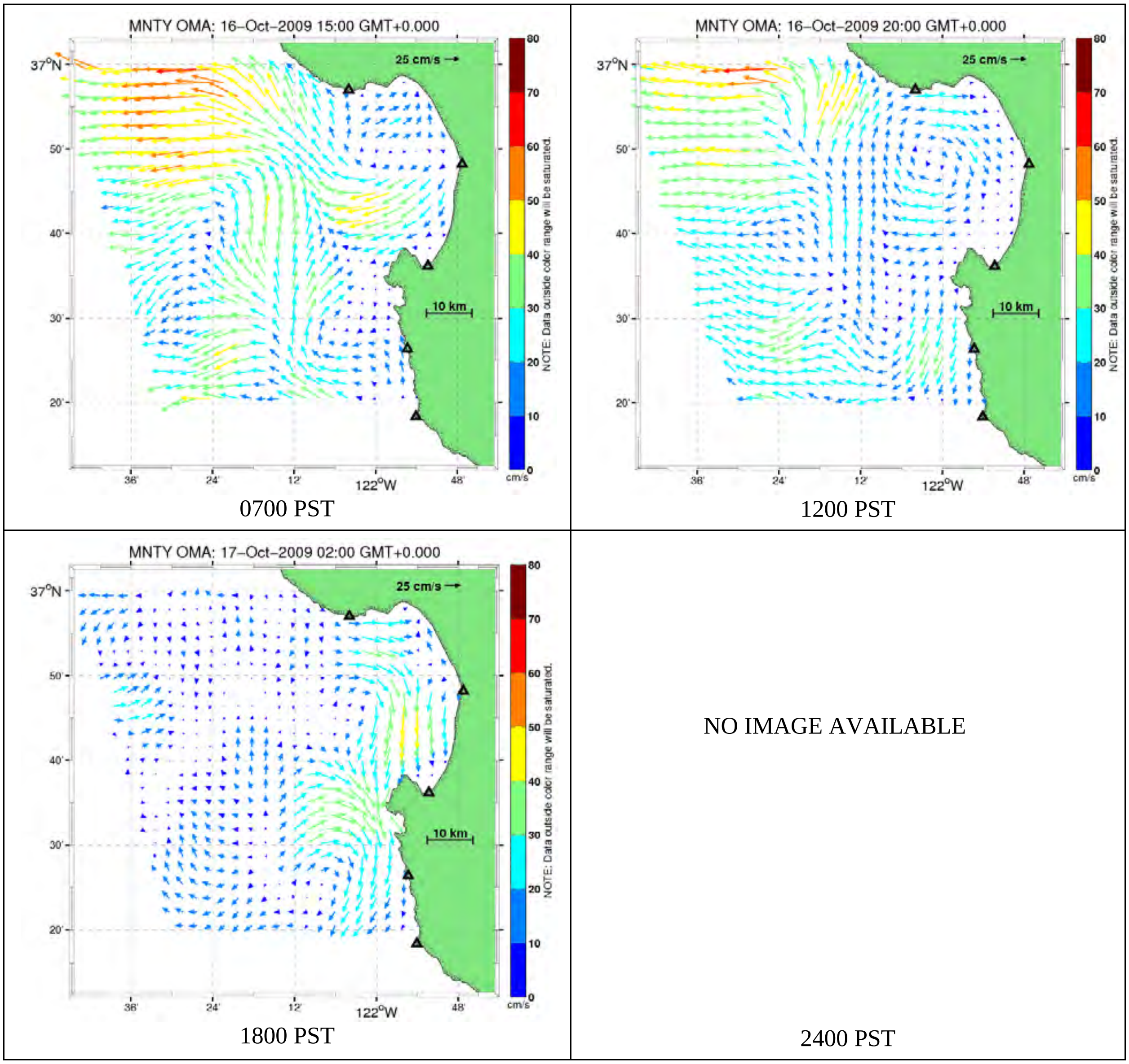

Figure B1-7. Hourly mean ocean surface currents at four times on October 16, 2009. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

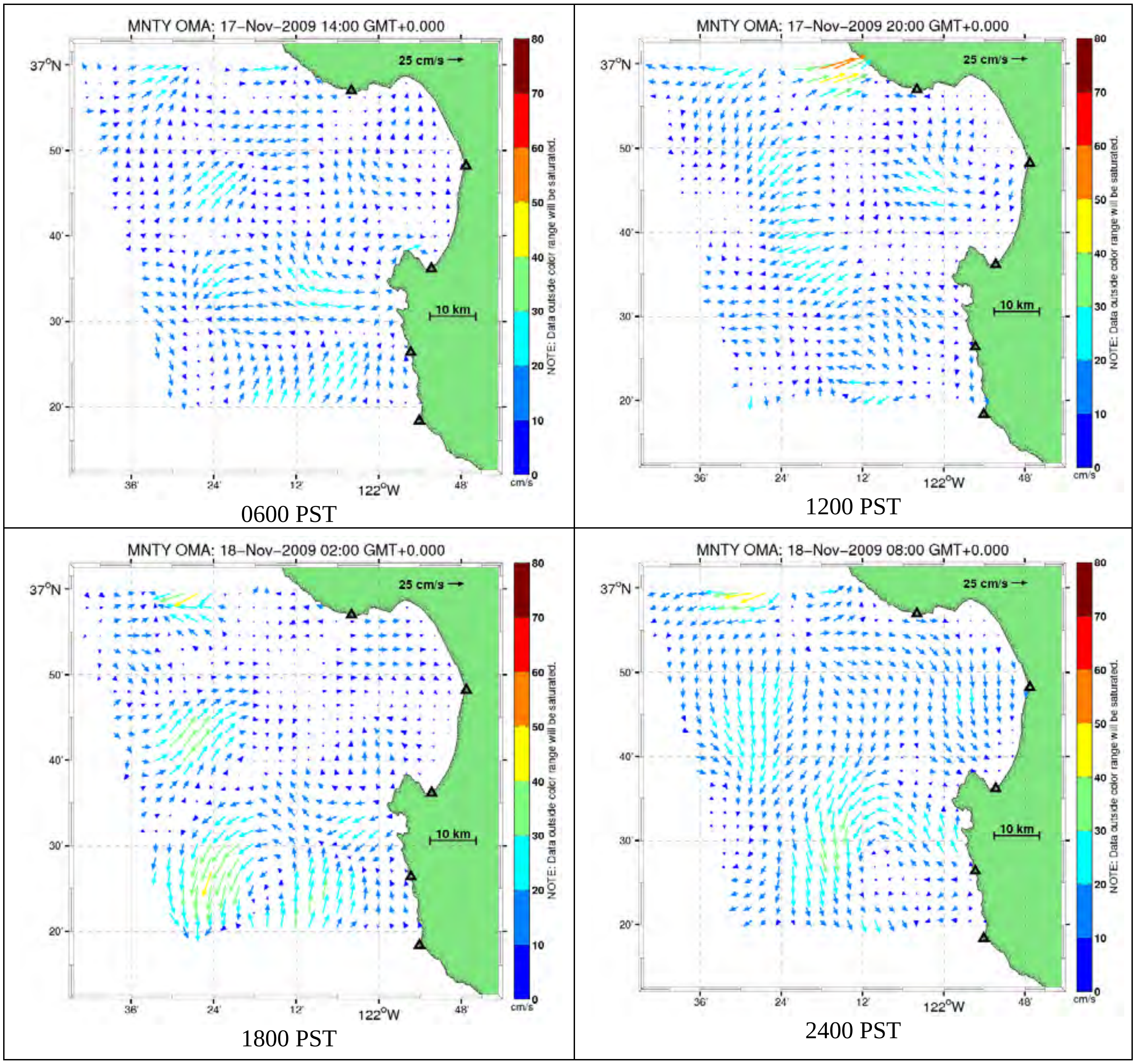

Figure B1-8. Hourly mean ocean surface currents at four times on November 17, 2009. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

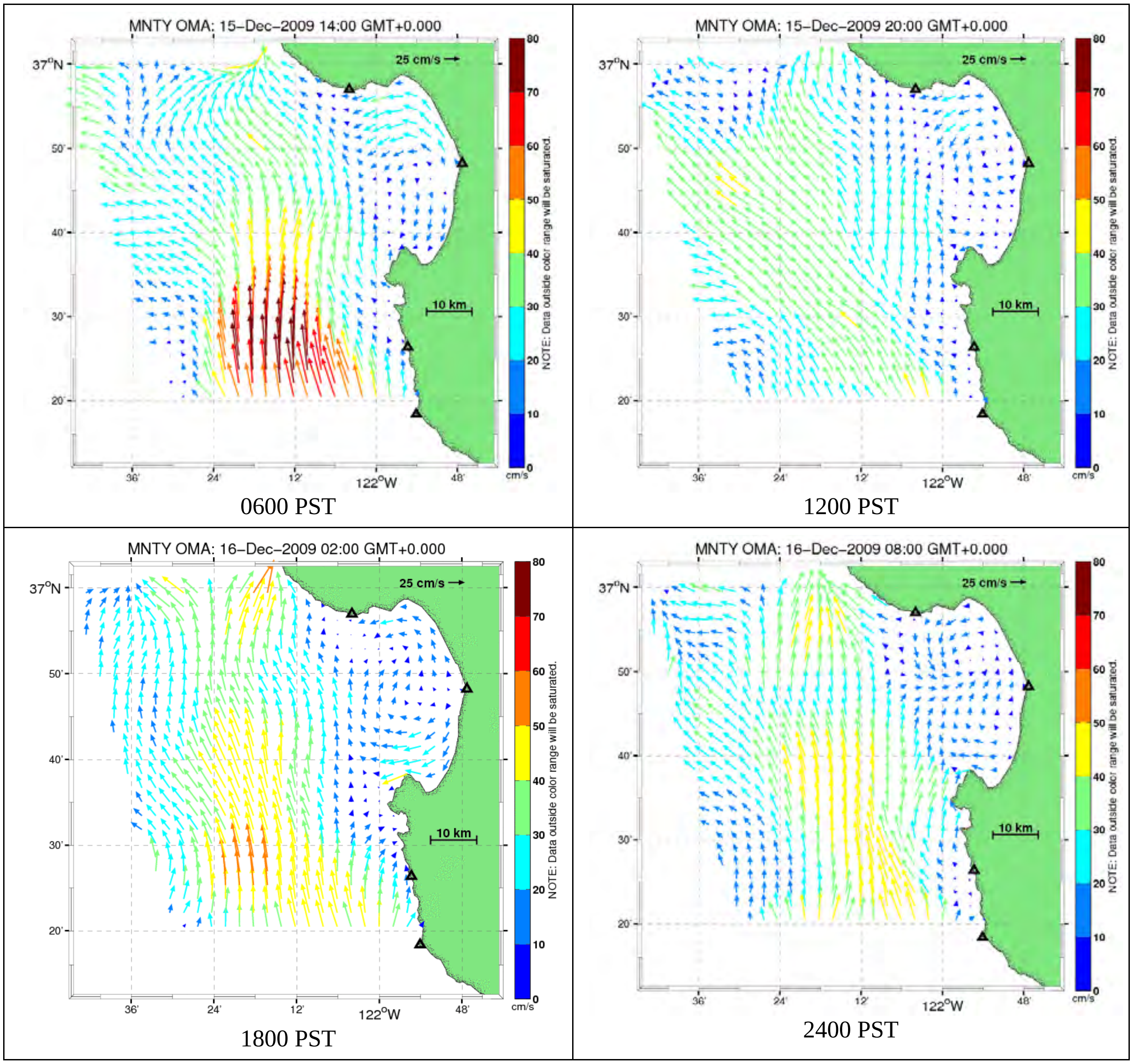

Figure B1-9. Hourly mean ocean surface currents at four times on December 15, 2009. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

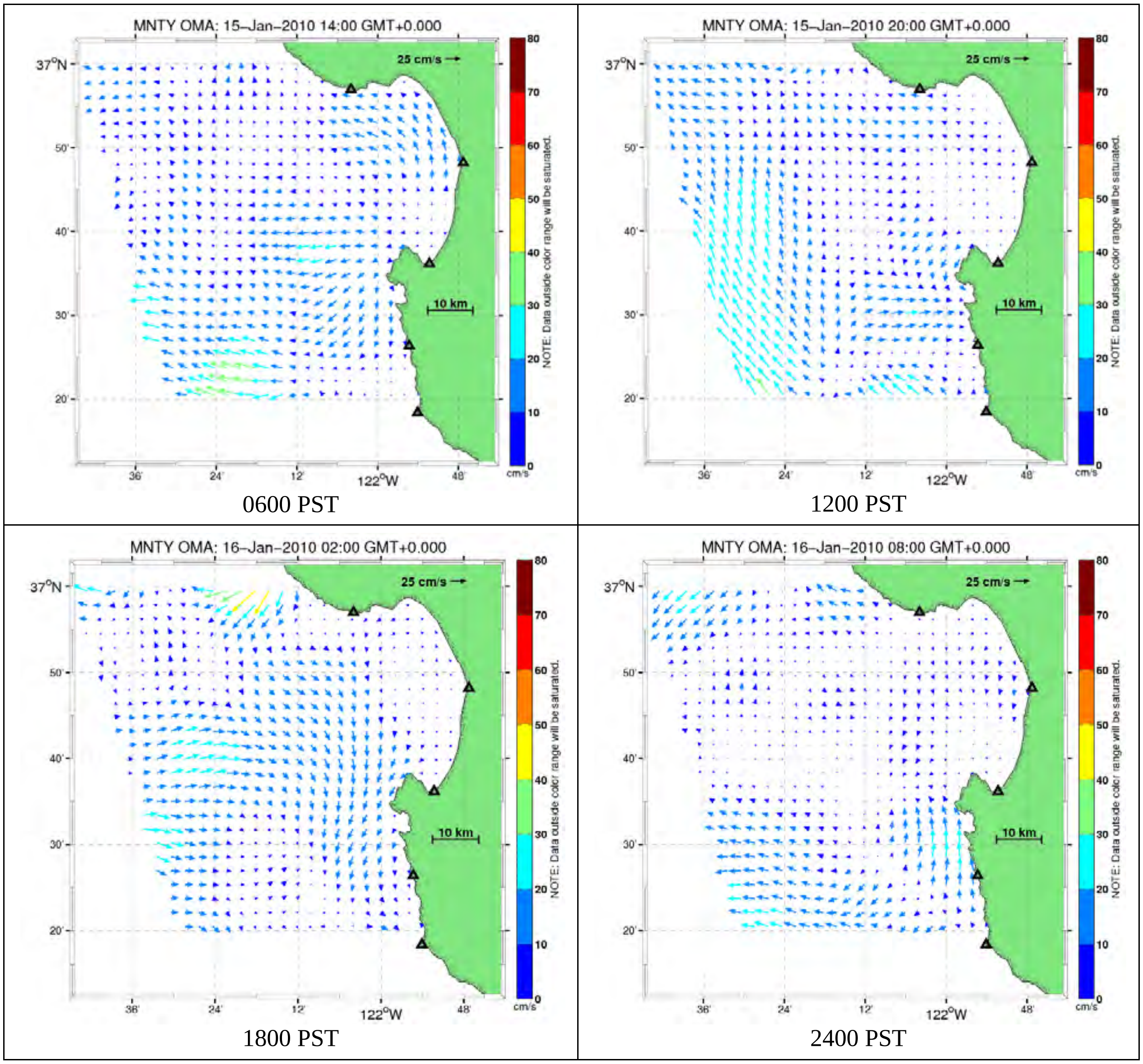

Figure B1-10. Hourly mean ocean surface currents at four times on January 15, 2010. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

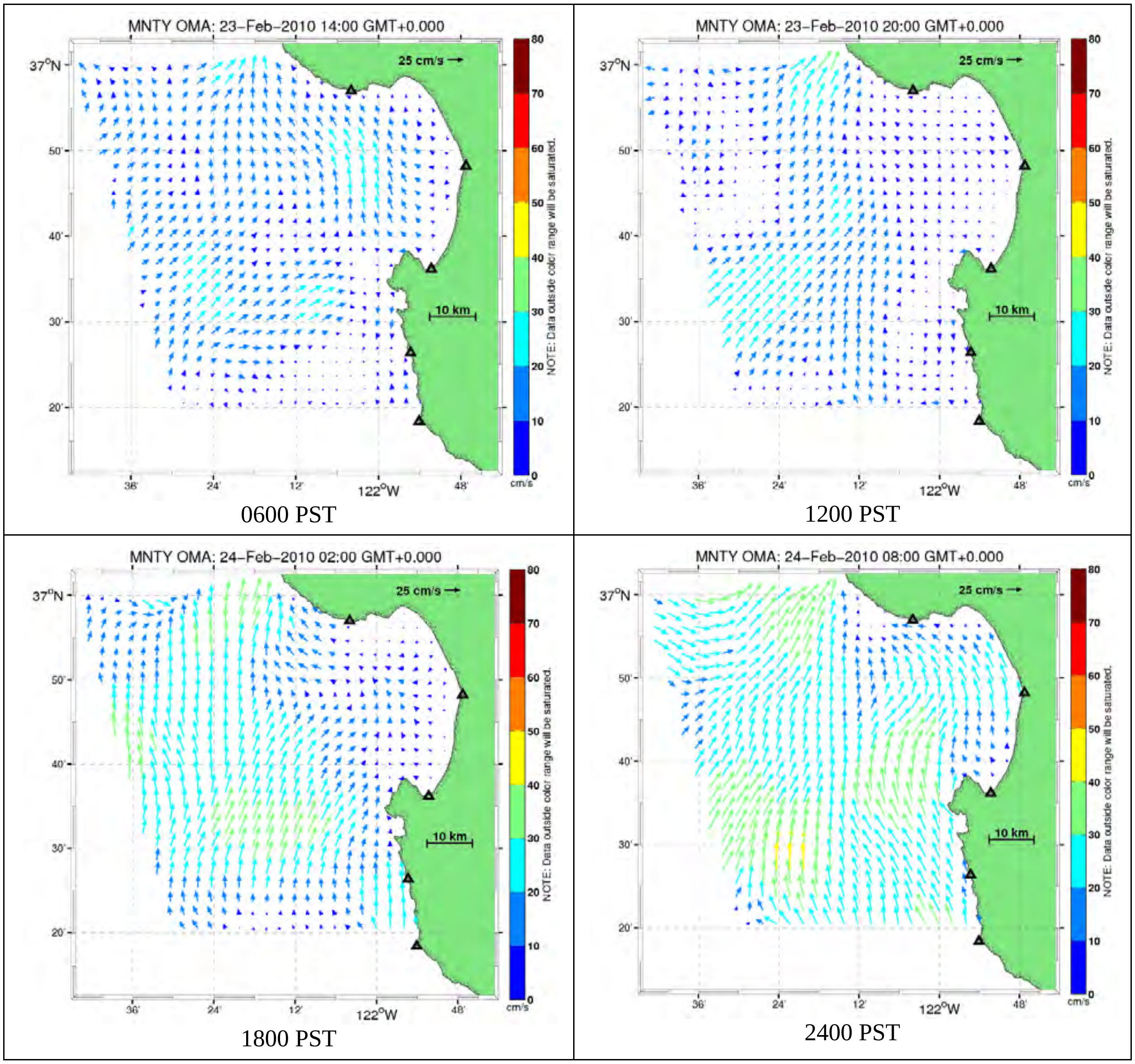

Figure B1-11. Hourly mean ocean surface currents at four times on February 23, 2010. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

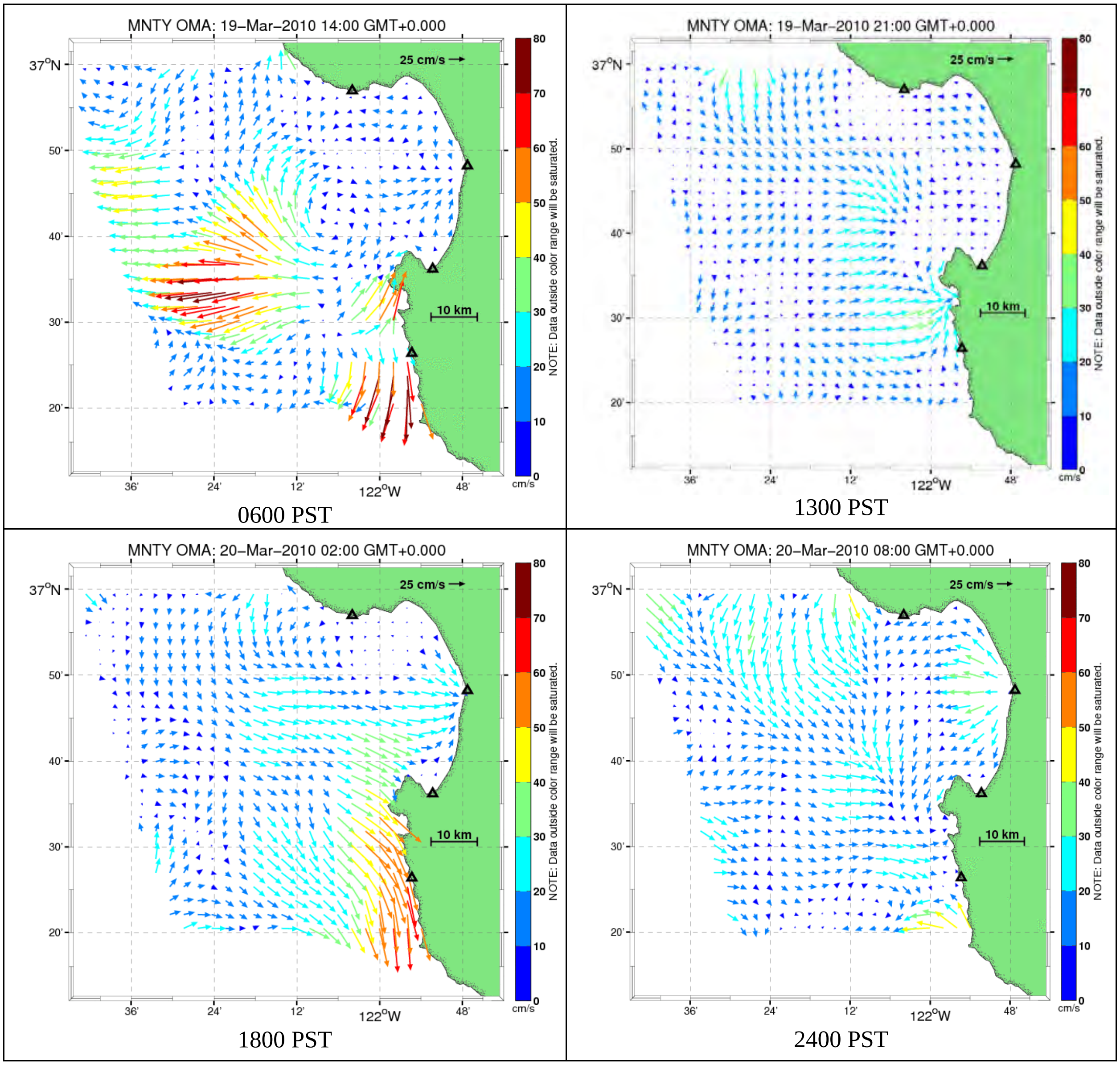

Figure B1-12. Hourly mean ocean surface currents at four times on March 19, 2010. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

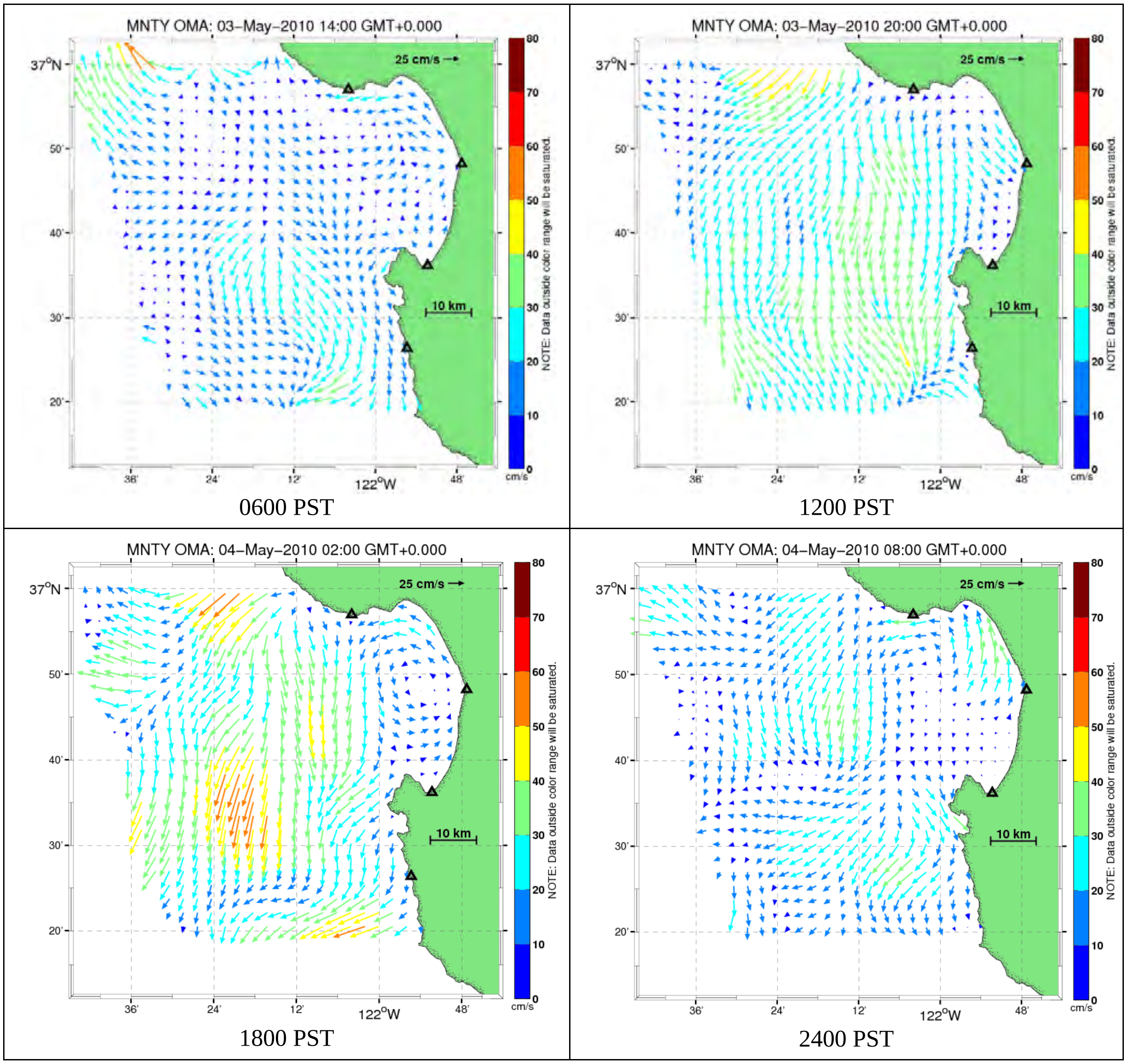

Figure B1-13. Hourly mean ocean surface currents at four times on May 03, 2010. Surface current vectors are mapped with colors corresponding to current speeds in cm/s and longer arrows indicating faster speeds using Open Normal Mode Analysis (OMA) modeling, which combines surface currents with predicted tides.

B2. Current Trajectories: 24-hour Composites

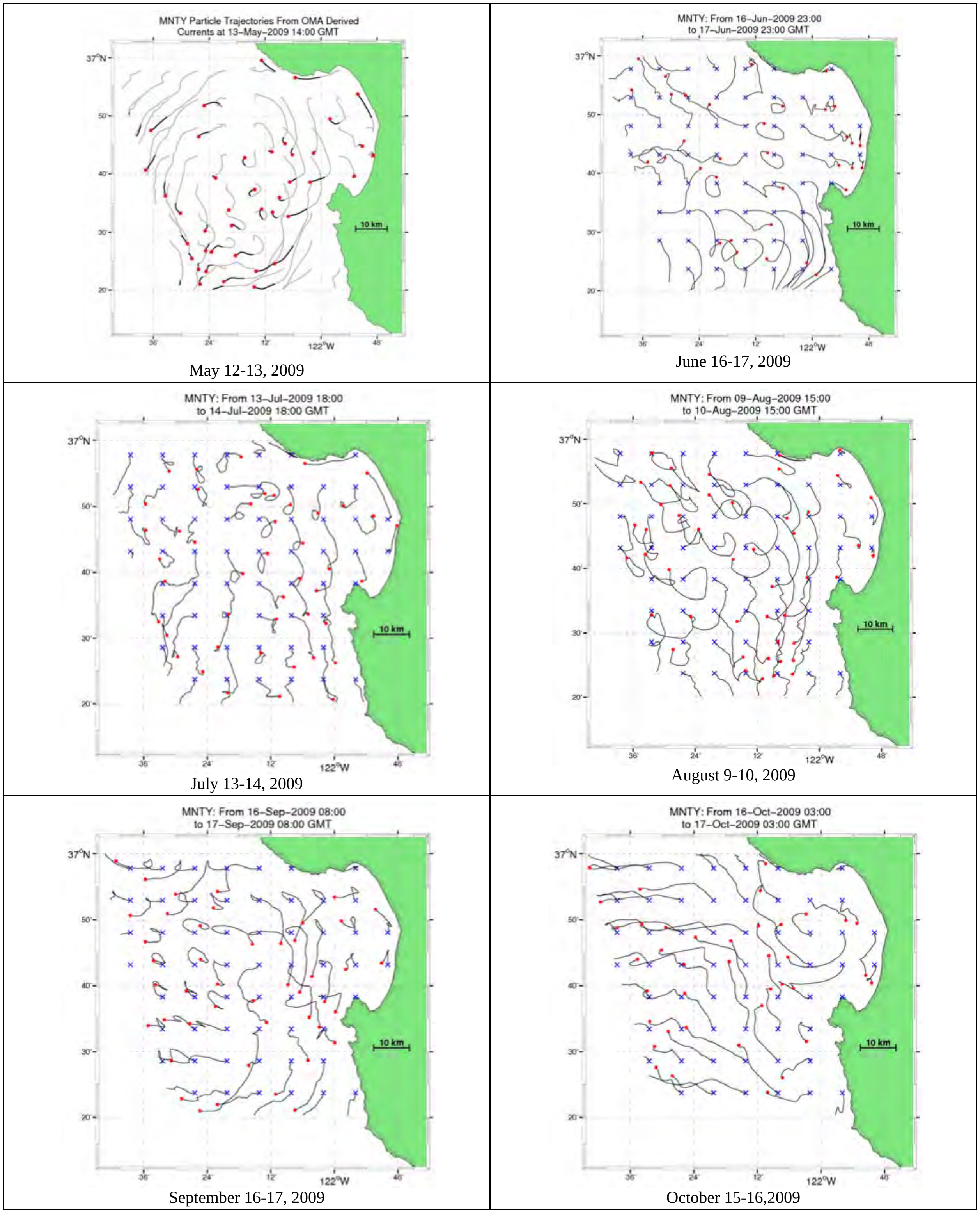

Figure B2-1. 24-hour water current trajectories corresponding to source water and entrainment sampling days from May 2009 through October 2009. *Note: Trajectory plot was unavailable for the April 16–17, 2009 (Survey 01) time period.*

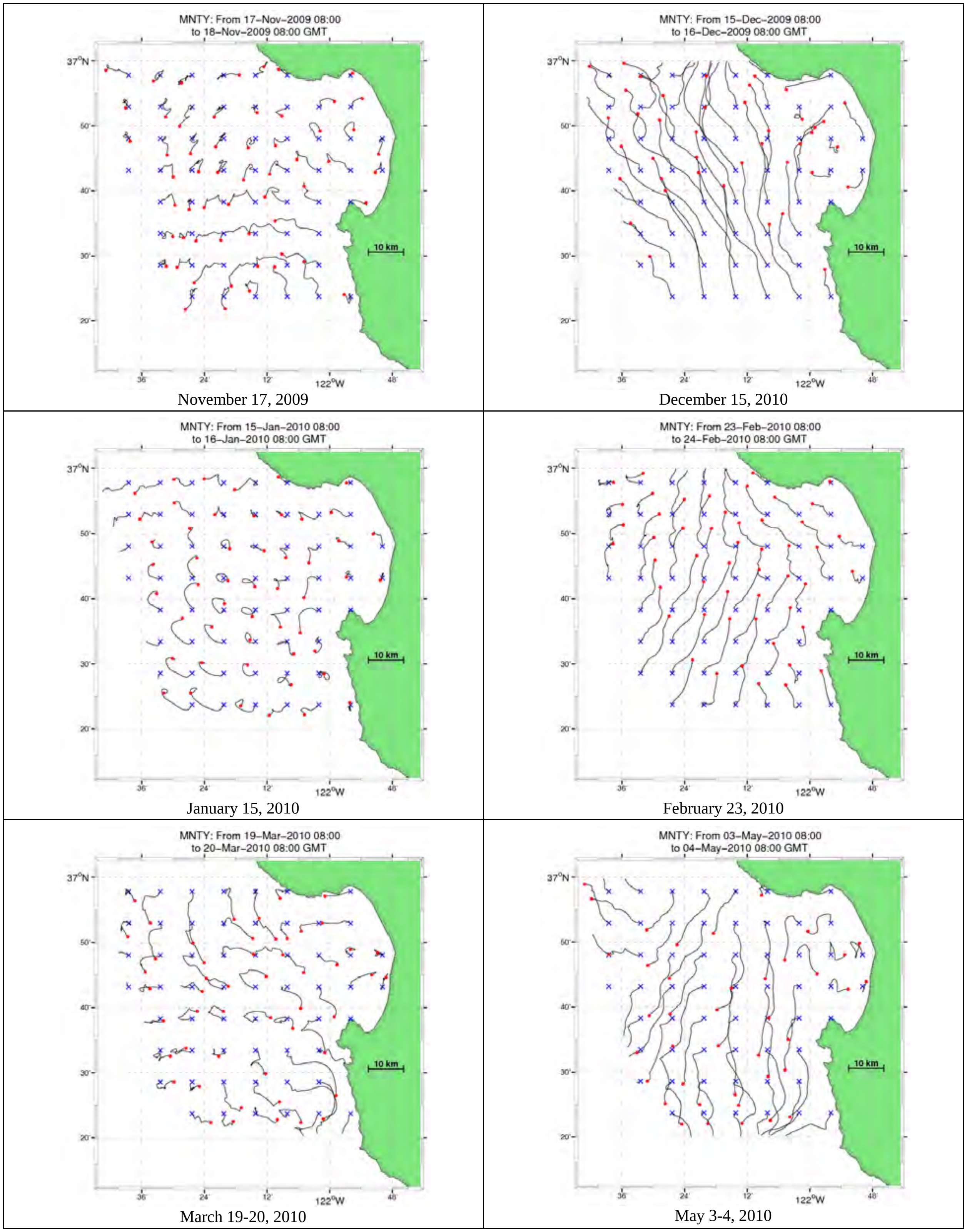

Figure B2-2. Water current trajectories over 24-hours corresponding to source water and entrainment sampling days from November 2009 through May 2010.

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Appendix C

Intake and Source Water Sampling Results by Survey

C1. Intake Station Larval Counts and Mean Concentrations

C2. Source Water Stations Larval Counts and Mean Concentrations

C3. Intake Station Larval Fish Lengths

C4. Source Water Station Water Quality Measurements

C1. Intake Station (SWE) Larval Concentrations

Table C1-1. Intake station (SWE) larval counts and mean concentrations (#/1,000 m^3), SCEN01.

Survey: **SCEN01**
Survey Date: **04/16/09**

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Genyonemus lineatus	white croaker	26	61.01
Cottidae	sculpins	22	53.31
CIQ goby complex	gobies	18	46.10
Oligocottus/Clinocottus spp.	sculpins	13	34.31
Artedius spp.	sculpins	12	28.20
Sebastes spp. V_	rockfishes	8	18.88
Bathymasteridae	ronquils	6	14.18
Myctophidae	lanternfishes	6	15.87
larval fish - damaged	damaged larval fishes	5	11.72
Osmeridae	smelts	5	11.64
Lepidopsetta bilineata	rock sole	4	9.39
Cebidichthys violaceus	monkeyface prickleback	3	7.10
Pleuronectoidei	flatfishes	3	6.92
Gibbonsia spp.	kelpfishes	2	5.32
Rhinogobiops nicholsi	blackeye goby	2	4.61
Stichaeidae	pricklebacks	2	4.69
Agonidae	poachers	1	2.38
Cottus asper	prickly sculpin	1	2.36
Neoclinus spp.	fringeheads	1	2.96
Orthonopias triacis	snubnose sculpin	1	2.36
Paralichthys californicus	California halibut	1	2.31
unidentified larvae, yolksac	yolksac larvae	1	2.96
	Total Fish Larvae:	**143**	
Fish Eggs			
fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	726	1,859.98
Citharichthys spp. (eggs)	sanddab eggs	60	146.17
Pleuronectidae (eggs)	righteye flounder eggs	8	18.45
Parophrys vetulus (eggs)	English sole eggs	4	10.70
Genyonemus lineatus (eggs)	white croaker eggs	3	7.65
Pleuronectoidei (eggs)	flatfish eggs	3	7.58
fish eggs (damaged)	damaged fish eggs unid.	2	4.72
poss. Bathylagidae (eggs)	poss. Blacksmelt eggs	1	2.36
	Total Fish Eggs:	**807**	
Target Invertebrate Larvae			
Crangonidae	sand shrimps	132	308.50
Thoridae/Hippolytidae	shrimps	98	229.23
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	70	163.77
Cancridae (megalops)	cancer crabs megalops	11	25.53
Metacarcinus anthonyi (megalops)	yellow crab megalops	6	13.89
Alpheidae	shrimps	1	2.36
Pandalidae	shrimps	1	2.31
	Total Invertebrate Larvae:	**319**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C1-2. Intake station (SWE) larval counts and mean concentrations (#/1,000 m^3), SCEN02.

Survey: SCEN02
Survey Date: 05/12/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Sebastes spp. V_	rockfishes	13	31.68
Oxylebius pictus	painted greenling	4	9.67
Cottidae	sculpins	3	7.29
Brosmophycis marginata	red brotula	2	4.77
Cebidichthys violaceus	monkeyface prickleback	2	4.91
CIQ goby complex	gobies	2	5.04
Cyclopteridae	snailfishes	2	5.33
larval fish - damaged	damaged larval fishes	2	5.47
Neoclinus spp.	fringeheads	2	5.33
Agonidae	poachers	1	2.94
Artedius spp.	sculpins	1	2.38
Cottus asper	prickly sculpin	1	2.52
Oligocottus/Clinocottus spp.	sculpins	1	2.52
Pleuronectidae	righteye flounders	1	2.52
Sebastes spp.	rockfishes	1	2.57
	Total Fish Larvae:	**38**	
Fish Eggs			
fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	698	1,842.20
Citharichthys spp. (eggs)	sanddab eggs	55	144.11
Pleuronectidae (eggs)	righteye flounder eggs	4	10.28
Genyonemus lineatus (eggs)	white croaker eggs	3	8.08
Paralichthyidae (eggs)	sand flounder eggs	1	2.38
Pleuronectoidei (eggs)	flatfish eggs	1	2.94
Sciaenidae/Paralichthyidae (eggs)	fish eggs	1	2.94
	Total Fish Eggs:	**763**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	24	59.14
Thoridae/Hippolytidae	shrimps	8	19.62
Crangonidae	sand shrimps	6	14.44
Cancridae (megalops)	cancer crabs megalops	4	10.23
	Total Invertebrate Larvae:	**42**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C1-3. Intake station (SWE) larval counts and mean concentrations (#/1,000 m³), SCEN03.

Survey: SCEN03
Survey Date: 06/16/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m³)
Fish Larvae			
Paralichthys californicus	California halibut	17	46.33
Oxylebius pictus	painted greenling	13	40.60
unidentified larvae, yolksac	yolksac larvae	13	35.02
Citharichthys spp.	sanddabs	12	31.69
CIQ goby complex	gobies	10	27.84
Cottidae	sculpins	8	23.76
Oligocottus/Clinocottus spp.	sculpins	7	21.49
Artedius spp.	sculpins	4	12.34
Cebidichthys violaceus	monkeyface prickleback	4	12.34
Gobiesocidae	clingfishes	4	11.18
Rhinogobiops nicholsi	blackeye goby	4	11.82
Cyclopteridae	snailfishes	3	9.16
Blennioidei	blennies	2	5.51
Engraulis mordax	northern anchovy	2	5.51
Gibbonsia spp.	kelpfishes	2	6.37
Myctophidae	lanternfishes	2	5.19
Orthonopias triacis	snubnose sculpin	2	6.37
Pleuronectoidei	flatfishes	2	5.65
Genyonemus lineatus	white croaker	1	3.18
Osmeridae	smelts	1	3.18
unidetified larval/post-larval fish	larval fishes	1	2.66
	Total Fish Larvae:	**114**	
Fish Eggs			
fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	3,344	9,343.62
Citharichthys spp. (eggs)	sanddab eggs	2,484	6,742.68
Paralichthys californicus (eggs)	California halibut eggs	183	480.94
Sciaenidae/Paralichthyidae (eggs)	fish eggs	174	527.42
Engraulidae (eggs)	anchovy eggs	30	93.54
unidentified fish eggs	fish eggs	30	75.69
Pleuronectidae (eggs)	righteye flounder eggs	20	51.87
fish eggs (damaged)	damaged fish eggs unid.	11	28.22
Genyonemus lineatus (eggs)	white croaker eggs	10	26.64
	Total Fish Eggs:	**6,286**	
Target Invertebrate Larvae			
Thoridae/Hippolytidae	shrimps	21	64.48
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	10	30.65
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	3	9.16
Crangonidae	sand shrimps	2	6.17
Metacarcinus anthonyi (megalops)	yellow crab megalops	1	2.52
	Total Invertebrate Larvae:	**37**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C1-4. Intake station (SWE) larval counts and mean concentrations (#/1,000 m³), SCEN04.

Survey: SCEN04
Survey Date: 07/14/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Citharichthys spp.	sanddabs	5	10.29
Artedius spp.	sculpins	3	5.92
CIQ goby complex	gobies	3	6.44
Paralichthys californicus	California halibut	3	6.06
Cottidae	sculpins	2	4.27
Cyclopteridae	snailfishes	2	4.27
Engraulis mordax	northern anchovy	1	1.88
Gobiesocidae	clingfishes	1	2.40
Oxylebius pictus	painted greenling	1	1.88
Syngnathus spp.	pipefishes	1	1.88
	Total Fish Larvae:	**22**	
Fish Eggs			
fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	2,488	5,422.51
Citharichthys spp. (eggs)	sanddab eggs	305	636.86
Sciaenidae/Paralichthyidae (eggs)	fish eggs	74	151.49
Paralichthys californicus (eggs)	California halibut eggs	27	56.69
Pleuronichthys spp. (eggs)	turbot eggs	6	12.54
Pleuronectidae (eggs)	righteye flounder eggs	1	2.40
	Total Fish Eggs:	**2,901**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	8	15.73
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	6	11.40
Thoridae/Hippolytidae	shrimps	6	11.69
Crangonidae	sand shrimps	3	6.06
	Total Invertebrate Larvae:	**23**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C1-5. Intake station (SWE) larval counts and mean concentrations (#/1,000 m³), SCEN05.

Survey: SCEN05
Survey Date: 08/11/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Artedius spp.	sculpins	10	31.36
Rhinogobiops nicholsi	blackeye goby	4	11.57
Cottidae	sculpins	3	8.30
Agonidae	poachers	2	6.42
Ruscarius creaseri	roughcheek sculpin	2	6.42
CIQ goby complex	gobies	1	3.27
Genyonemus lineatus	white croaker	1	3.27
Gibbonsia spp.	kelpfishes	1	2.80
larval fish - damaged	damaged larval fishes	1	3.27
Neoclinus spp.	fringeheads	1	3.27
Pleuronichthys verticalis	hornyhead turbot	1	3.27
	Total Fish Larvae:	**27**	
Fish Eggs			
fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	932	2,652.22
Citharichthys spp. (eggs)	sanddab eggs	362	1,021.24
Sciaenidae/Paralichthyidae (eggs)	fish eggs	10	29.36
Pleuronichthys spp. (eggs)	turbot eggs	1	3.15
	Total Fish Eggs:	**1,305**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	14	36.19
Thoridae/Hippolytidae	shrimps	10	32.08
Alpheidae	shrimps	1	3.15
	Total Invertebrate Larvae:	**25**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C1-6. Intake station (SWE) larval counts and mean concentrations (#/1,000 m³), SCEN06.

Survey: SCEN06
Survey Date: 09/16/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Neoclinus spp.	fringeheads	9	23.13
CIQ goby complex	gobies	7	16.65
Rhinogobiops nicholsi	blackeye goby	7	15.83
Artedius spp.	sculpins	4	9.87
Orthonopias triacis	snubnose sculpin	3	7.46
Cottidae	sculpins	2	5.37
Cyclopteridae	snailfishes	2	5.52
Engraulis mordax	northern anchovy	2	4.26
Gibbonsia spp.	kelpfishes	1	2.18
Gobiesocidae	clingfishes	1	2.76
Oxylebius pictus	painted greenling	1	2.61
unidentified larvae, yolksac	yolksac larvae	1	2.18
	Total Fish Larvae:	**40**	
Fish Eggs			
fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	1,909	4,303.84
Citharichthys spp. (eggs)	sanddab eggs	879	2,061.81
Engraulidae (eggs)	anchovy eggs	72	154.99
Sciaenidae/Paralichthyidae (eggs)	fish eggs	26	58.14
unidentified fish eggs	fish eggs	10	21.75
Paralichthys californicus (eggs)	California halibut eggs	1	2.61
	Total Fish Eggs:	**2,897**	
Target Invertebrate Larvae			
Metacarcinus anthonyi (megalops)	yellow crab megalops	8	19.78
Thoridae/Hippolytidae	shrimps	7	17.84
	Total Invertebrate Larvae:	**15**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C1-7. Intake station (SWE) larval counts and mean concentrations (#/1,000 m^3), SCEN07.

Survey: SCEN07
Survey Date: 10/16/09

Taxon	**Common Name**	**Count**	**Mean Concentration (#/1,000 m^3)**
<u>Fish Larvae</u>			
CIQ goby complex	gobies	10	27.08
Leptocottus armatus	Pacific staghorn sculpin	6	17.83
Myctophidae	lanternfishes	5	13.88
Engraulis mordax	northern anchovy	3	7.86
unidentified larvae, yolksac	yolksac larvae	3	7.90
Cottidae	sculpins	2	6.01
Lepidogobius lepidus	bay goby	2	5.22
Neoclinus spp.	fringeheads	2	5.97
Agonidae	poachers	1	2.65
Artedius spp.	sculpins	1	3.36
Chilara taylori	spotted cusk-eel	1	2.65
Citharichthys spp.	sanddabs	1	2.61
Cyclopteridae	snailfishes	1	2.61
Syngnathus spp.	pipefishes	1	2.65
	Total Fish Larvae:	**39**	
<u>Fish Eggs</u>			
fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	2,274	6,523.19
Citharichthys spp. (eggs)	sanddab eggs	183	533.19
Genyonemus lineatus (eggs)	white croaker eggs	80	243.35
Paralichthyidae (eggs)	sand flounder eggs	33	88.14
Sciaenidae/Paralichthyidae (eggs)	fish eggs	31	88.04
Engraulidae (eggs)	anchovy eggs	1	2.61
fish eggs (damaged)	damaged fish eggs unid.	1	3.36
Pleuronectidae (eggs)	righteye flounder eggs	1	2.65
	Total Fish Eggs:	**2,604**	
<u>Target Invertebrate Larvae</u>			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	32	88.67
Crangonidae	sand shrimps	10	26.12
Thoridae/Hippolytidae	shrimps	10	26.92
Alpheidae	shrimps	2	5.22
Metacarcinus anthonyi (megalops)	yellow crab megalops	2	5.22
	Total Invertebrate Larvae:	**56**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C1-8. Intake station (SWE) larval counts and mean concentrations (#/1,000 m^3), SCEN08.

Survey: SCEN08
Survey Date: 11/17/09

Taxon	**Common Name**	**Count**	**Mean Concentration (#/1,000 m^3)**
Fish Larvae			
Genyonemus lineatus	white croaker	288	862.85
unidentified larvae, yolksac	yolksac larvae	76	223.40
larval fish - damaged	damaged larval fishes	46	129.44
Engraulis mordax	northern anchovy	39	113.76
Citharichthys spp.	sanddabs	19	61.38
Pleuronectoidei	flatfishes	17	45.42
Leptocottus armatus	Pacific staghorn sculpin	16	45.06
Pleuronectidae	righteye flounders	12	39.62
Artedius spp.	sculpins	2	6.60
CIQ goby complex	gobies	2	5.73
Cottidae	sculpins	2	5.25
Cyclopteridae	snailfishes	2	6.15
Myctophidae	lanternfishes	2	5.67
Agonidae	poachers	1	3.30
Blennioidei	blennies	1	2.42
Neoclinus spp.	fringeheads	1	2.82
	Total Fish Larvae:	**526**	
Fish Eggs*			
fish eggs (undeveloped/unfertilized)	undeveloped/unfertilized fish eggs	400	1,134.71
Citharichthys spp. (eggs)	sanddab eggs	105	297.81
Genyonemus lineatus (eggs)	white croaker eggs	14	39.73
fish eggs (damaged)	damaged fish eggs unid.	2	5.70
Engraulidae (eggs)	anchovy eggs	1	2.85
Pleuronectidae (eggs)	righteye flounder eggs	1	2.82
Pleuronectoidei (eggs)	flatfish eggs	1	2.82
Sciaenidae/Paralichthyidae (eggs)	fish eggs	1	2.85
	Total Fish Eggs:	**525**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	18	47.16
Thoridae/Hippolytidae	shrimps	9	29.72
Crangonidae	sand shrimps	5	16.51
Alpheidae	shrimps	2	6.60
Metacarcinus anthonyi (megalops)	yellow crab megalops	1	2.42
	Total Invertebrate Larvae:	**35**	

Samples may have been split. Count and concentration are based on adjusted split count.
***** Fish eggs not sorted from all samples.

Table C1-9. Intake station (SWE) larval counts and mean concentrations (#/1,000 m³), SCEN09.

Survey: SCEN09
Survey Date: 12/15/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Genyonemus lineatus	white croaker	202	629.42
unidentified larvae, yolksac	yolksac larvae	55	170.89
CIQ goby complex	gobies	39	122.97
Citharichthys spp.	sanddabs	35	109.91
Engraulis mordax	northern anchovy	30	95.23
Leptocottus armatus	Pacific staghorn sculpin	18	55.30
larval fish - damaged	damaged larval fishes	10	30.73
Myctophidae	lanternfishes	8	25.48
Pleuronectoidei	flatfishes	8	24.26
Artedius spp.	sculpins	4	12.37
Cottidae	sculpins	2	6.01
Agonidae	poachers	1	3.24
Gillichthys mirabilis	longjaw mudsucker	1	3.24
Isopsetta isolepis	butter sole	1	3.15
Lepidogobius lepidus	bay goby	1	2.89
Oxylebius pictus	painted greenling	1	3.15
Pleuronichthys verticalis	hornyhead turbot	1	3.24
Scorpaenichthys marmoratus	cabezon	1	3.15
Sebastes spp. V	rockfishes	1	3.15
	Total Fish Larvae:	**419**	
Target Invertebrate Larvae			
Crangonidae	sand shrimps	17	54.29
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	17	52.90
Metacarcinus anthonyi (megalops)	yellow crab megalops	5	15.87
Thoridae/Hippolytidae	shrimps	1	3.15
	Total Invertebrate Larvae:	**40**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table C1-10. Intake station (SWE) larval counts and mean concentrations (#/1,000 m³), SCEN10.

Survey: SCEN10
Survey Date: 01/15/10

Taxon	Common Name	Count	Mean Concentration (#/1,000 m³)
Fish Larvae			
Bathymasteridae	ronquils	17	100.72
CIQ goby complex	gobies	17	101.59
Artedius spp.	sculpins	8	48.37
Genyonemus lineatus	white croaker	8	47.94
unidentified larvae, yolksac	yolksac larvae	8	47.07
Gibbonsia spp.	kelpfishes	2	11.44
Oligocottus/Clinocottus spp.	sculpins	2	11.88
Citharichthys spp.	sanddabs	1	5.72
Cottidae	sculpins	1	5.72
Engraulis mordax	northern anchovy	1	5.72
Leptocottus armatus	Pacific staghorn sculpin	1	6.15
Myctophidae	lanternfishes	1	6.15
Orthonopias triacis	snubnose sculpin	1	5.72
	Total Fish Larvae:	**68**	
Target Invertebrate Larvae			
No Target Invertebrate		0	
	Total Invertebrate Larvae:	**0**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table C1-11. Intake station (SWE) larval counts and mean concentrations (#/1,000 m³), SCEN11.

Survey: SCEN11
Survey Date: 02/23/10

Taxon	Common Name	Count	Mean Concentration (#/1,000 m³)
Fish Larvae			
Genyonemus lineatus	white croaker	225	658.45
unidentified larvae, yolksac	yolksac larvae	105	308.46
Engraulis mordax	northern anchovy	47	140.00
Bathymasteridae	ronquils	16	49.18
Artedius spp.	sculpins	10	30.65
CIQ goby complex	gobies	5	14.72
Ammodytes hexapterus	Pacific sand lance	4	10.76
Citharichthys spp.	sanddabs	3	7.67
Pleuronectoidei	flatfishes	3	7.67
Atherinopsidae	silversides	2	6.86
Lepidopsetta bilineata	rock sole	2	5.98
Leptocottus armatus	Pacific staghorn sculpin	2	6.86
Paralichthys californicus	California halibut	2	5.98
Cebidichthys violaceus	monkeyface prickleback	1	3.43
Cottus asper	prickly sculpin	1	2.56
Cyclopteridae	snailfishes	1	3.43
Gibbonsia spp.	kelpfishes	1	3.09
Oligocottus/Clinocottus spp.	sculpins	1	2.56
Osmeridae	smelts	1	3.09
Oxylebius pictus	painted greenling	1	2.56
Scorpaenichthys marmoratus	cabezon	1	2.56
Sebastes spp. V	rockfishes	1	2.56
	Total Fish Larvae:	**435**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	3	7.67
	Total Invertebrate Larvae:	**3**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table C1-12. Intake station (SWE) larval counts and mean concentrations (#/1,000 m^3), SCEN12.

Survey: SCEN12
Survey Date: 03/19/10

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Genyonemus lineatus	white croaker	649	1,870.39
Engraulis mordax	northern anchovy	24	69.04
Osmeridae	smelts	14	40.26
Bathymasteridae	ronquils	11	30.69
Sebastes spp. V_	rockfishes	9	25.73
CIQ goby complex	gobies	7	20.21
Cottidae	sculpins	4	11.41
Neoclinus spp.	fringeheads	3	8.48
Gibbonsia spp.	kelpfishes	2	5.64
Artedius spp.	sculpins	1	2.93
Pholidae	gunnels	1	2.86
Stichaeidae	pricklebacks	1	2.93
	Total Fish Larvae:	**726**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	27	77.43
Thoridae/Hippolytidae	shrimps	5	14.66
Alpheidae	shrimps	1	2.93
Crangonidae	sand shrimps	1	2.77
	Total Invertebrate Larvae:	**34**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table C1-13. Intake station (SWE) larval counts and mean concentrations (#/1,000 m³), SCEN13.

Survey: SCEN13
Survey Date: 05/03/10

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Genyonemus lineatus	white croaker	101	293.86
Cottus asper	prickly sculpin	61	178.86
Osmeridae	smelts	55	161.47
Engraulis mordax	northern anchovy	20	56.89
CIQ goby complex	gobies	15	43.76
Cottidae	sculpins	9	26.77
larval fish - damaged	damaged larval fishes	5	14.97
Sebastes spp. V_	rockfishes	4	11.78
Lepidogobius lepidus	bay goby	3	8.83
Oxylebius pictus	painted greenling	3	8.39
Artedius spp.	sculpins	2	5.88
Bathymasteridae	ronquils	2	5.88
Leptocottus armatus	Pacific staghorn sculpin	2	5.67
Rhinogobiops nicholsi	blackeye goby	2	5.88
Ruscarius creaseri	roughcheek sculpin	2	5.67
Agonidae	poachers	1	3.18
Cyclopteridae	snailfishes	1	2.73
Neoclinus spp.	fringeheads	1	2.73
Orthonopias triacis	snubnose sculpin	1	2.94
	Total Fish Larvae:	**290**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	21	60.72
Thoridae/Hippolytidae	shrimps	6	17.21
Cancridae (megalops)	cancer crabs megalops	1	2.94
Metacarcinus anthonyi (megalops)	yellow crab megalops	1	2.73
	Total Fish Eggs:	**29**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

C2. Source Water Stations (SW1–SW3) Larval Counts and Mean Concentrations

Table C2-1. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN01.

Survey: SCEN01
Survey Date: 04/16/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Genyonemus lineatus	white croaker	53	97.90
Cottidae	sculpins	31	58.50
Bathymasteridae	ronquils	14	25.50
Artedius spp.	sculpins	12	21.70
Stenobrachius leucopsarus	northern lampfish	12	22.10
Sebastes spp. V_	rockfishes	10	18.70
Rhinogobiops nicholsi	blackeye goby	8	14.50
CIQ goby complex	gobies	7	13.30
Lepidogobius lepidus	bay goby	6	11.50
Ruscarius meanyi	Puget Sound sculpin	6	11.20
Artedius lateralis	smoothhead sculpin	5	10.20
Clinocottus analis	woolly sculpin	5	10.00
Oligocottus/Clinocottus spp.	sculpins	5	10.00
Oligocottus snyderi	fluffy sculpin	4	8.00
Osmeridae	smelts	4	7.50
Lepidopsetta bilineata	rock sole	3	5.60
Blennioidei	blennies	2	4.00
Odontopyxis trispinosa	pygmy poacher	2	3.70
Orthonopias triacis	snubnose sculpin	2	4.10
Oxylebius pictus	painted greenling	2	3.60
Ruscarius creaseri	roughcheek sculpin	2	3.70
Agonidae	poachers	1	1.70
Cebidichthys violaceus	monkeyface prickleback	1	1.90
Cottus asper	prickly sculpin	1	1.70
larval fish - damaged	damaged larval fishes	1	2.00
Leptocottus armatus	Pacific staghorn sculpin	1	2.00
Lyopsetta exilis	slender sole	1	1.70
Parophrys vetulus	English sole	1	1.90
Sciaenidae	croakers	1	1.90
Sebastes spp.	rockfishes	1	2.10
	Total Fish Larvae:	**204**	
Fish Eggs			
fish eggs (undeveloped)	undeveloped fish eggs	968	1,686.70
Citharichthys spp. (eggs)	sanddab eggs	61	110.50
Pleuronectidae (eggs)	righteye flounder eggs	13	20.60
Genyonemus lineatus (eggs)	white croaker eggs	10	19.80
Paralichthyidae (eggs)	sand flounder eggs	2	3.80
fish eggs (damaged)	damaged fish eggs unid.	1	2.00
Pleuronectoidei (eggs)	flatfish eggs	1	1.90
poss. Bathylagidae (eggs)	poss. blacksmelt eggs	1	2.00
Sciaenidae/Paralichthyidae (eggs)	fish eggs	1	1.50
	Total Fish Eggs:	**1,058**	

Samples may have been split. Count and concentration are based on adjusted split count. *(continued)*

Table C2-1 (continued). Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN01.

Survey: SCEN01
Survey Date: 04/16/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Target Invertebrate Larvae			
Thoridae/Hippolytidae	shrimps	200	380.40
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	139	256.90
Crangonidae	sand shrimps	100	190.20
Cancridae (megalops)	cancer crabs megalops	27	49.80
Heptacarpus spp.	tidepool shrimps	9	17.30
Metacarcinus anthonyi (megalops)	yellow crab megalops	6	11.50
Alpheidae	shrimps	5	9.20
Metacarcinus magister (megalops)	dungeness crab megalops	1	1.70
	Total Target_Invertebrate Larvae:	**487**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C2-2. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN02.

Survey: SCEN02
Survey Date: 05/12/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Sebastes spp. V_	rockfishes	11	19.00
Odontopyxis trispinosa	pygmy poacher	5	8.20
Cottidae	sculpins	3	5.10
larval fish - damaged	damaged larval fishes	3	5.60
Bathymasteridae	ronquils	2	4.10
Liparis spp.	snailfishes	1	1.60
Myctophidae	lanternfishes	1	1.60
Osmeridae	smelts	1	1.40
Rhinogobiops nicholsi	blackeye goby	1	2.00
Ruscarius meanyi	Puget Sound sculpin	1	2.00
	Total Fish Larvae:	**29**	
Fish Eggs			
fish eggs (undeveloped)	undeveloped fish eggs	1,240	2,337.20
Citharichthys spp. (eggs)	sanddab eggs	70	131.50
poss. *Microstomus pacificus* (eggs)	poss. Dover sole eggs	3	5.10
Genyonemus lineatus (eggs)	white croaker eggs	2	3.80
Sciaenidae/Paralichthyidae (eggs)	fish eggs	2	4.00
Paralichthyidae (eggs)	sand flounder eggs	1	1.60
Pleuronectidae (eggs)	righteye flounder eggs	1	1.60
Pleuronichthys spp. (eggs)	turbot eggs	1	2.00
	Total Fish Eggs:	**1,320**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	49	82.80
Crangonidae	sand shrimps	18	28.80
Thoridae/Hippolytidae	shrimps	15	23.40
Cancridae (megalops)	cancer crabs megalops	5	7.20
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	3	5.50
Heptacarpus spp.	tidepool shrimps	1	1.40
	Total Target Invertebrate Larvae:	**91**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C2-3. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN03.

Survey: SCEN03
Survey Date: 06/16/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
larvae, yolksac	yolksac larvae	38	68.20
Cottidae	sculpins	29	48.30
Citharichthys stigmaeus	speckled sanddab	19	35.80
Paralichthys californicus	California halibut	17	31.10
Rhinogobiops nicholsi	blackeye goby	13	21.40
Artedius spp.	sculpins	10	15.90
CIQ goby complex	gobies	10	15.40
Cebidichthys violaceus	monkeyface prickleback	9	18.50
Clinocottus analis	woolly sculpin	5	7.80
Gibbonsia spp.	kelpfishes	5	7.00
Oxylebius pictus	painted greenling	5	8.10
larval fish - damaged	damaged larval fishes	4	6.80
Bathymasteridae	ronquils	3	6.00
Osmeridae	smelts	3	4.20
Pleuronectoidei	flatfishes	3	5.20
Genyonemus lineatus	white croaker	2	3.40
Neoclinus spp.	fringeheads	2	3.40
Oligocottus/Clinocottus spp.	sculpins	2	2.80
Blennioidei	blennies	1	2.10
Brosmophycis marginata	red brotula	1	1.70
Citharichthys sordidus	Pacific sanddab	1	1.70
Citharichthys spp.	sanddabs	1	2.10
Engraulis mordax	northern anchovy	1	1.70
larval/post-larval fish	larval fishes	1	1.70
Lepidogobius lepidus	bay goby	1	1.40
Liparis spp.	snailfishes	1	1.70
Myctophidae	lanternfishes	1	1.70
Odontopyxis trispinosa	pygmy poacher	1	2.10
Orthonopias triacis	snubnose sculpin	1	1.70
Paralichthyidae	sand flounders	1	2.30
Pleuronectidae	righteye flounders	1	2.10
Pleuronichthys spp.	turbots	1	1.70
Pleuronichthys verticalis	hornyhead turbot	1	2.30
Ruscarius creaseri	roughcheek sculpin	1	1.70
Ruscarius meanyi	Puget Sound sculpin	1	1.40
Stellerina xyosterna	pricklebreast poacher	1	1.40
	Total Fish Larvae:	**197**	
Fish Eggs			
fish eggs (undeveloped)	undeveloped fish eggs	5,582	10,338.40
Citharichthys spp. (eggs)	sanddab eggs	1,851	3,578.80
Paralichthyidae (eggs)	sand flounder eggs	230	429.10
Paralichthys californicus (eggs)	California halibut eggs	76	134.10

Samples may have been split. Count and concentration are based on adjusted split count. *(continued)*

Table C2-3 (continued). Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN03.

Survey: SCEN03
Survey Date: 06/16/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Eggs (continued)			
Sciaenidae/Paralichthyidae (eggs)	fish eggs	64	137.80
Genyonemus lineatus (eggs)	white croaker eggs	60	128.10
Engraulis mordax (eggs)	northern anchovy eggs	20	39.50
Pleuronectidae (eggs)	righteye flounder eggs	20	34.30
Pleuronectoidei (eggs)	flatfish eggs	20	42.70
Pleuronichthys spp. (eggs)	turbot eggs	20	42.70
fish eggs	fish eggs	10	17.10
fish eggs (damaged)	damaged fish eggs unid.	1	1.70
	Total Fish Eggs:	**7,954**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	129	205.00
Thoridae/Hippolytidae	shrimps	23	32.10
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	10	16.00
Cancridae (megalops)	cancer crabs megalops	4	7.40
Crangonidae	sand shrimps	3	5.10
Heptacarpus spp.	tidepool shrimps	1	1.40
	Total Target Invertebrate Larvae:	**170**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C2-4. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN04.

Survey: SCEN04
Survey Date: 07/14/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Artedius spp.	sculpins	9	13.90
Rhinogobiops nicholsi	blackeye goby	8	12.40
Oxylebius pictus	painted greenling	4	6.00
Citharichthys stigmaeus	speckled sanddab	3	4.50
Gibbonsia spp.	kelpfishes	3	4.90
Lepidogobius lepidus	bay goby	3	4.70
Liparis spp.	snailfishes	3	4.90
Paralichthys californicus	California halibut	3	4.40
larvae, yolksac	yolksac larvae	2	2.90
Neoclinus spp.	fringeheads	2	3.20
Bathymasteridae	ronquils	1	1.50
Chilara taylori	spotted cusk-eel	1	1.60
CIQ goby complex	gobies	1	1.50
Clupeiformes	herrings and anchovies	1	1.60
Cottidae	sculpins	1	1.60
Genyonemus lineatus	white croaker	1	1.60
Gillichthys mirabilis	longjaw mudsucker	1	1.60
Gobiesox spp.	clingfishes	1	1.60
Hypsoblennius spp.	combtooth blennies	1	1.80
Pleuronichthys verticalis	hornyhead turbot	1	1.50
	Total Fish Larvae:	**50**	
Fish Eggs			
fish eggs (undeveloped)	undeveloped fish eggs	2,352	3,703.60
Citharichthys spp. (eggs)	sanddab eggs	327	537.30
Sciaenidae/Paralichthyidae (eggs)	fish eggs	78	116.20
Paralichthys californicus (eggs)	California halibut eggs	19	33.60
Paralichthyidae (eggs)	sand flounder eggs	3	4.70
Pleuronichthys spp. (eggs)	turbot eggs	3	4.70
	Total Fish Eggs:	**2,782**	
Target Invertebrate Larvae			
Thoridae/Hippolytidae	shrimps	33	46.30
Crangonidae	sand shrimps	14	20.50
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	9	12.30
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	5	7.10
Metacarcinus anthonyi (megalops)	yellow crab megalops	1	1.30
	Total Target Invertebrate Larvae:	**62**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C2-5. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN05.

Survey: SCEN05
Survey Date: 08/11/09

Taxon	**Common Name**	**Count**	**Mean Concentration (#/1,000 m^3)**
Fish Larvae			
Rhinogobiops nicholsi	blackeye goby	23	48.90
Artedius spp.	sculpins	8	15.90
Neoclinus spp.	fringeheads	8	14.70
Lepidogobius lepidus	bay goby	4	8.90
CIQ goby complex	gobies	3	4.90
Cottidae	sculpins	3	4.40
Liparis spp.	snailfishes	2	4.50
Odontopyxis trispinosa	pygmy poacher	2	3.70
Pleuronichthys verticalis	hornyhead turbot	2	5.10
Blennioidei/Zoarcoidei	blennies/zoarcoids	1	2.00
Gibbonsia spp.	kelpfishes	1	1.20
Gobiesox spp.	clingfishes	1	1.30
Oligocottus/Clinocottus spp.	sculpins	1	1.30
Porichthys notatus	plainfin midshipman	1	1.20
Ruscarius meanyi	Puget Sound sculpin	1	1.20
	Total Fish Larvae:	**61**	
Fish Eggs			
fish eggs (undeveloped)	undeveloped fish eggs	4,120	7,277.70
Citharichthys spp. (eggs)	sanddab eggs	1,039	1,692.80
Sciaenidae/Paralichthyidae (eggs)	fish eggs	117	229.20
Paralichthyidae (eggs)	sand flounder eggs	16	32.90
Pleuronectoidei (eggs)	flatfish eggs	12	15.40
Pleuronichthys spp. (eggs)	turbot eggs	1	1.30
	Total Fish Eggs:	**5,305**	
Target Invertebrate Larvae			
Thoridae/Hippolytidae	shrimps	10	18.00
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	7	12.70
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	1	1.80
	Total Target Invertebrate Larvae:	**18**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C2-6. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN06.

Survey: SCEN06
Survey Date: 09/16/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Neoclinus spp.	fringeheads	12	16.10
Lepidogobius lepidus	bay goby	8	11.90
CIQ goby complex	gobies	4	6.30
Rhinogobiops nicholsi	blackeye goby	4	5.60
Artedius spp.	sculpins	2	3.30
Blennioidei	blennies	2	3.10
Citharichthys stigmaeus	speckled sanddab	2	2.90
Cottidae	sculpins	2	3.00
Engraulis mordax	northern anchovy	2	2.70
Gobiesox spp.	clingfishes	2	2.60
larvae, yolksac	yolksac larvae	2	2.40
Brosmophycis marginata	red brotula	1	1.50
Citharichthys sordidus	Pacific sanddab	1	1.50
Hypsoblennius spp.	combtooth blennies	1	1.50
Liparis spp.	snailfishes	1	1.50
Oxylebius pictus	painted greenling	1	1.20
	Total Fish Larvae:	**47**	
Fish Eggs			
fish eggs (undeveloped)	undeveloped fish eggs	5,687	8,600.30
Citharichthys spp. (eggs)	sanddab eggs	1,431	2,180.90
Engraulidae (eggs)	anchovy eggs	164	248.20
Sciaenidae/Paralichthyidae (eggs)	fish eggs	61	87.70
Paralichthyidae (eggs)	sand flounder eggs	14	20.10
Pleuronichthys spp. (eggs)	turbot eggs	2	3.20
Genyonemus lineatus (eggs)	white croaker eggs	1	1.50
	Total Fish Eggs:	**7,360**	
Target Invertebrate Larvae			
Metacarcinus anthonyi (megalops)	yellow crab megalops	15	22.30
Thoridae/Hippolytidae	shrimps	10	16.50
Heptacarpus spp.	tidepool shrimps	4	6.00
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	3	5.10
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	1	1.50
	Total Target Invertebrate Larvae:	**33**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C2-7. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN07.

Survey: SCEN07
Survey Date: 10/16/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
CIQ goby complex	gobies	31	62.20
Tarletonbeania crenularis	blue lanternfish	7	11.70
Rhinogobiops nicholsi	blackeye goby	5	8.50
Artedius spp.	sculpins	4	7.50
Citharichthys sordidus	Pacific sanddab	4	7.30
Citharichthys stigmaeus	speckled sanddab	4	7.30
Gobiesox spp.	clingfishes	4	8.30
Orthonopias triacis	snubnose sculpin	4	6.80
Lepidogobius lepidus	bay goby	3	5.00
Sebastes spp. V	rockfishes	3	5.40
Agonidae	poachers	2	3.70
larvae, yolksac	yolksac larvae	2	3.80
Odontopyxis trispinosa	pygmy poacher	2	3.60
Porichthys notatus	plainfin midshipman	2	3.60
Scorpaenichthys marmoratus	cabezon	2	3.10
Chilara taylori	spotted cusk-eel	1	2.00
Cottidae	sculpins	1	1.70
Genyonemus lineatus	white croaker	1	1.90
Gibbonsia spp.	kelpfishes	1	1.60
Gobiidae	gobies	1	1.50
Neoclinus spp.	fringeheads	1	1.50
Stenobrachius leucopsarus	northern lampfish	1	1.50
Triphoturus mexicanus	Mexican lampfish	1	2.00
	Total Fish Larvae:	**87**	
Fish Eggs			
fish eggs (undeveloped)	undeveloped fish eggs	1,969	3,468.30
Citharichthys spp. (eggs)	sanddab eggs	418	737.00
Genyonemus lineatus (eggs)	white croaker eggs	240	423.60
Sciaenidae/Paralichthyidae (eggs)	fish eggs	179	316.30
Engraulidae (eggs)	anchovy eggs	5	8.90
Pleuronichthys spp. (eggs)	turbot eggs	2	3.30
	Total Fish Eggs:	**2,813**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	54	93.00
Thoridae/Hippolytidae	shrimps	17	29.50
Crangonidae	sand shrimps	16	26.20
Metacarcinus anthonyi (megalops)	yellow crab megalops	12	21.00
Hippolyte californiensis	California green shrimp	8	13.00
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	4	7.30
Cancridae (megalops)	cancer crabs megalops	1	1.50
	Total Target Invertebrate Larvae:	**112**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table C2-8. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN08.

Survey: SCEN08
Survey Date: 11/17/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Genyonemus lineatus	white croaker	362	820.20
larvae, yolksac	yolksac larvae	139	320.30
Engraulis mordax	northern anchovy	40	90.20
Scorpaenichthys marmoratus	cabezon	39	71.60
Pleuronectoidei	flatfishes	24	54.70
CIQ goby complex	gobies	22	40.40
Citharichthys stigmaeus	speckled sanddab	20	43.60
Pleuronectidae	righteye flounders	13	31.50
larval fish - damaged	damaged larval fishes	11	25.40
Citharichthys sordidus	Pacific sanddab	5	11.60
Leptocottus armatus	Pacific staghorn sculpin	5	10.60
Lepidogobius lepidus	bay goby	4	8.40
Oxylebius pictus	painted greenling	2	4.10
Agonidae	poachers	1	1.80
Artedius spp.	sculpins	1	2.40
Chilara taylori	spotted cusk-eel	1	1.80
Cottidae	sculpins	1	2.30
Lampadena urophaos	lanternfish	1	1.90
Lyopsetta exilis	slender sole	1	2.10
Orthonopias triacis	snubnose sculpin	1	2.30
Pleuronichthys spp.	turbots	1	2.30
Stenobrachius leucopsarus	northern lampfish	1	2.30
Syngnathus spp.	pipefishes	1	2.40
	Total Fish Larvae:	**696**	
Fish Eggs*			
fish eggs (undeveloped)	undeveloped fish eggs	308	709.30
Citharichthys spp. (eggs)	sanddab eggs	64	147.40
Genyonemus lineatus (eggs)	white croaker eggs	50	115.10
fish eggs	fish eggs	14	32.20
Pleuronectoidei (eggs)	flatfish eggs	12	27.60
Engraulis mordax (eggs)	northern anchovy eggs	3	6.90
Pleuronectidae (eggs)	righteye flounder eggs	1	2.30
	Total Fish Eggs:	**452**	
Target Invertebrate Larvae			
Crangonidae	sand shrimps	77	154.80
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	29	61.10
Thoridae/Hippolytidae	shrimps	22	41.80
Alpheidae	shrimps	6	12.90
Metacarcinus anthonyi (megalops)	yellow crab megalops	5	10.10
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	1	1.80
Hippolyte californiensis	California green shrimp	1	1.80
	Total Target Invertebrate Larvae:	**141**	

Samples may have been split. Count and concentration are based on adjusted split count.
***** Fish eggs not sorted from all samples.

Table C2-9. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN09.

Survey: SCEN09
Survey Date: 12/15/09

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Genyonemus lineatus	white croaker	336	668.70
larvae, yolksac	yolksac larvae	92	186.40
Engraulis mordax	northern anchovy	34	62.40
CIQ goby complex	gobies	26	47.80
Citharichthys sordidus	Pacific sanddab	26	47.20
Citharichthys stigmaeus	speckled sanddab	18	31.70
Leptocottus armatus	Pacific staghorn sculpin	14	24.50
Pleuronectoidei	flatfishes	12	22.70
Sebastes spp. V	rockfishes	12	19.60
Stenobrachius leucopsarus	northern lampfish	11	20.90
larval fish - damaged	damaged larval fishes	9	18.20
Artedius spp.	sculpins	6	10.50
Cottidae	sculpins	5	9.60
Lepidogobius lepidus	bay goby	5	8.60
Bathymasteridae	ronquils	4	6.70
Pleuronectidae	righteye flounders	4	7.80
Scorpaenichthys marmoratus	cabezon	2	3.30
Sebastes spp.	rockfishes	2	3.20
Stellerina xyosterna	pricklebreast poacher	2	3.20
Agonidae	poachers	1	1.60
Gillichthys mirabilis	longjaw mudsucker	1	1.70
Hexagrammidae	greenlings	1	1.90
	Total Fish Larvae:	**623**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	21	36.20
Crangonidae	sand shrimps	7	14.50
Metacarcinus anthonyi (megalops)	yellow crab megalops	7	13.20
Thoridae/Hippolytidae	shrimps	3	5.90
	Total Target Invertebrate Larvae:	**38**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table C2-10. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN10.

Survey: SCEN10
Survey Date: 01/15/10

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Bathymasteridae	ronquils	11	36.70
Artedius spp.	sculpins	9	30.10
Genyonemus lineatus	white croaker	9	30.00
larvae, yolksac	yolksac larvae	9	28.20
Stenobrachius leucopsarus	northern lampfish	8	27.00
CIQ goby complex	gobies	6	21.30
Engraulis mordax	northern anchovy	6	19.80
Leptocottus armatus	Pacific staghorn sculpin	6	21.10
Cottidae	sculpins	5	17.70
Atherinopsis californiensis	jacksmelt	2	6.60
Agonidae	poachers	1	3.70
Gibbonsia spp.	kelpfishes	1	3.70
Hemilepidotus spinosus	brown Irish lord	1	3.10
larval fish - damaged	damaged larval fishes	1	3.10
Liparis spp.	snailfishes	1	3.70
Oxylebius pictus	painted greenling	1	3.70
Pleuronectidae	righteye flounders	1	3.50
Sebastes spp.	rockfishes	1	3.10
	Total Fish Larvae:	**79**	
Target Invertebrate Larvae			
No Target Invertebrate		0	
	Total Target Invertebrate Larvae:	**0**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table C2-11. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN11.

Survey: SCEN11
Survey Date: 02/23/10

Taxon	Common Name	Count	Mean Concentration (#/1,000 m^3)
Fish Larvae			
Genyonemus lineatus	white croaker	168	234.20
Engraulis mordax	northern anchovy	91	125.80
larvae, yolksac	yolksac larvae	90	130.30
Sebastes spp. V_	rockfishes	34	52.70
Bathymasteridae	ronquils	26	34.30
Ammodytes hexapterus	Pacific sand lance	17	23.30
Artedius spp.	sculpins	16	22.10
Cottidae	sculpins	9	13.00
CIQ goby complex	gobies	7	11.30
Paralichthys californicus	California halibut	6	8.40
Hemilepidotus spinosus	brown Irish lord	5	6.60
Neoclinus spp.	fringeheads	4	6.60
Pleuronectoidei	flatfishes	4	5.30
Citharichthys sordidus	Pacific sanddab	3	4.30
Citharichthys stigmaeus	speckled sanddab	3	4.00
Lepidopsetta bilineata	rock sole	3	4.00
Oligocottus/Clinocottus spp.	sculpins	3	5.30
Oxylebius pictus	painted greenling	3	4.80
Scorpaenichthys marmoratus	cabezon	3	4.80
Gobiesocidae	clingfishes	2	3.00
larval fish - damaged	damaged larval fishes	2	3.00
Pleuronectidae	righteye flounders	2	2.80
Rhinogobiops nicholsi	blackeye goby	2	2.60
Agonidae	poachers	1	1.50
Artedius harringtoni	scalyhead sculpin	1	1.30
Orthonopias triacis	snubnose sculpin	1	1.30
Osmeridae	smelts	1	1.50
Paralichthyidae	sand flounders	1	1.80
Pleuronichthys spp.	turbots	1	1.30
Ruscarius meanyi	Puget Sound sculpin	1	1.30
Sebastolobus spp.	thornyheads	1	1.30
	Total Fish Larvae:	**511**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	12	16.90
Caridea	caridean shrimp	1	1.80
	Total Target Invertebrate Larvae:	**13**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table C2-12. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN12.

Survey: SCEN12
Survey Date: 03/19/10

Taxon	**Common Name**	**Count**	**Mean Concentration (#/1,000 m^3)**
Fish Larvae			
Genyonemus lineatus	white croaker	740	1,276.80
Engraulis mordax	northern anchovy	61	108.50
CIQ goby complex	gobies	15	24.80
Artedius spp.	sculpins	11	18.80
Sebastes spp. V_	rockfishes	9	16.40
Bathymasteridae	ronquils	8	13.00
Oxylebius pictus	painted greenling	8	13.00
Cottidae	sculpins	6	9.10
larval fish - damaged	damaged larval fishes	5	8.80
Osmeridae	smelts	4	7.20
Neoclinus spp.	fringeheads	2	3.40
Ruscarius creaseri	roughcheek sculpin	2	2.90
Agonidae	poachers	1	1.80
Clinocottus analis	woolly sculpin	1	1.90
Cottus asper	prickly sculpin	1	1.40
Gobiesocidae	clingfishes	1	1.90
Leptocottus armatus	Pacific staghorn sculpin	1	1.50
Liparis spp.	snailfishes	1	1.40
Myctophidae	lanternfishes	1	1.80
Oligocottus snyderi	fluffy sculpin	1	1.40
Parophrys vetulus	English sole	1	1.40
Rhinogobiops nicholsi	blackeye goby	1	1.40
Sebastes spp.	rockfishes	1	1.50
Stichaeidae	pricklebacks	1	1.80
	Total Fish Larvae:	**883**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	39	65.60
Crangonidae	sand shrimps	3	5.30
Thoridae/Hippolytidae	shrimps	3	5.30
Heptacarpus spp.	tidepool shrimps	1	1.80
Metacarcinus anthonyi (megalops)	yellow crab megalops	1	1.80
	Total Target Invertebrate Larvae:	**47**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table C2-13. Source water stations (SW1–SW3) larval counts and mean concentrations (#/1,000 m^3), SCEN13.

Survey: SCEN13
Survey Date: 05/03/10

Taxon	**Common Name**	**Count**	**Mean Concentration (#/1,000 m^3)**
Fish Larvae			
Genyonemus lineatus	white croaker	35	63.40
Engraulis mordax	northern anchovy	23	41.90
Artedius spp.	sculpins	17	30.70
CIQ goby complex	gobies	16	25.60
Osmeridae	smelts	16	30.10
Cottidae	sculpins	9	16.20
Sebastes spp. V_	rockfishes	5	8.80
Bathymasteridae	ronquils	2	3.70
Lepidogobius lepidus	bay goby	2	3.20
Oxylebius pictus	painted greenling	2	3.30
Bathylagus spp.	blacksmelts	1	1.80
Cottus asper	prickly sculpin	1	1.30
Cyclopteridae	snailfishes	1	1.90
Gillichthys mirabilis	longjaw mudsucker	1	1.80
Leptocottus armatus	Pacific staghorn sculpin	1	1.90
Neoclinus spp.	fringeheads	1	1.80
Paralichthys californicus	California halibut	1	1.80
Scorpaenichthys marmoratus	cabezon	1	1.80
Stenobrachius leucopsarus	northern lampfish	1	1.90
Syngnathidae	pipefishes	1	1.80
	Total Fish Larvae:	**137**	
Target Invertebrate Larvae			
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	19	35.00
Thoridae/Hippolytidae	shrimps	6	11.00
Crangonidae	sand shrimps	5	7.80
Cancridae (megalops)	cancer crabs megalops	2	3.70
Metacarcinus anthonyi (megalops)	yellow crab megalops	2	2.70
Heptacarpus spp.	tidepool shrimps	1	1.30
	Total Target Invertebrate Larvae:	**35**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

C3. Intake Station (SWE) Larval Fish Lengths

Table C3-1. Intake station (SWE) larval fish lengths, SCEN01.

Survey: **SCEN01**
Start Date: **April 16, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Genyonemus lineatus	white croaker	26	21	2.48-8.70	6.16
Cottidae	sculpins	22	18	2.20-7.49	3.57
CIQ goby complex	gobies	18	18	3.09-17.04	6.19
Artedius lateralis	smoothhead sculpin	8	8	2.45-3.65	3.28
Sebastes spp. V_	rockfishes	8	8	3.58-4.00	3.78
Oligocottus snyderi	fluffy sculpin	7	7	3.18-4.78	4.17
Bathymasteridae	ronquils	6	6	3.44-4.51	3.80
Stenobrachius leucopsarus	northern lampfish	6	5	2.67-4.11	3.31
larval fish - damaged	damaged larval fishes	5	0	-	-
Osmeridae	smelts	5	4	7.09-9.19	7.98
Artedius spp.	sculpins	4	3	3.51-3.76	3.60
Lepidopsetta bilineata	rock sole	4	4	1.99-19.59	10.43
Oligocottus/Clinocottus spp.	sculpins	4	4	3.91-5.17	4.52
Cebidichthys violaceus	monkeyface prickleback	3	3	6.27-6.76	6.46
Pleuronectoidei	flatfishes	3	1	2.70	2.70
Clinocottus analis	woolly sculpin	2	2	2.45-2.70	2.57
Gibbonsia spp.	kelpfishes	2	2	6.87-6.97	6.92
Rhinogobiops nicholsi	blackeye goby	2	2	2.39-3.04	2.72
Stichaeidae	pricklebacks	2	1	7.41	7.41
Cottus asper	prickly sculpin	1	1	4.66	4.66
Neoclinus spp.	fringeheads	1	0	-	-
Odontopyxis trispinosa	pygmy poacher	1	1	4.62	4.62
Orthonopias triacis	snubnose sculpin	1	1	4.27	4.27
Paralichthys californicus	California halibut	1	1	7.27	7.27
unidentified larvae, yolksac	yolksac larvae	1	0	-	-
	Total:	**143**	**122**		

Table C3-2. Intake station (SWE) larval fish lengths, SCEN02.

Survey: **SCEN02**
Start Date: **May 12, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Sebastes spp. V_	rockfishes	13	10	3.20-3.93	3.46
Oxylebius pictus	painted greenling	4	3	3.46-3.78	3.59
Cottidae	sculpins	3	2	1.89-2.47	2.18
Brosmophycis marginata	red brotula	2	1	7.86	7.86
Cebidichthys violaceus	monkeyface prickleback	2	1	5.84	5.84
CIQ goby complex	gobies	2	2	2.22-4.05	3.13
larval fish - damaged	damaged larval fishes	2	0	-	-
Liparis spp.	snailfishes	2	2	2.07-2.18	2.12
Neoclinus spp.	fringeheads	2	0	-	-
Artedius spp.	sculpins	1	1	2.58	2.58
Clinocottus analis	woolly sculpin	1	1	2.12	2.12
Cottus asper	prickly sculpin	1	1	2.53	2.53
Odontopyxis trispinosa	pygmy poacher	1	1	3.95	3.95
Pleuronectidae	righteye flounders	1	0	-	-
Sebastes spp.	rockfishes	1	0	-	-
	Total:	**38**	**25**		

Table C3-3. Intake station (SWE) larval fish lengths, SCEN03.

Survey: **SCEN03**
Start Date: **June 16, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Paralichthys californicus	California halibut	17	13	1.36-2.73	1.93
Oxylebius pictus	painted greenling	13	13	3.11-4.59	3.89
unidentified larvae, yolksac	yolksac larvae	13	0	-	-
Citharichthys stigmaeus	speckled sanddab	11	5	1.35-1.70	1.59
CIQ goby complex	gobies	10	10	3.24-4.65	3.73
Cottidae	sculpins	8	8	2.53-4.68	3.02
Clinocottus analis	woolly sculpin	6	6	2.36-2.80	2.48
Artedius spp.	sculpins	4	4	2.30-2.89	2.59
Cebidichthys violaceus	monkeyface prickleback	4	4	5.43-6.26	5.89
Gobiesox spp.	clingfishes	4	3	3.28-4.15	3.61
Rhinogobiops nicholsi	blackeye goby	4	4	2.29-8.67	4.02
Liparis spp.	snailfishes	3	3	2.13-2.40	2.25
Blennioidei	blennies	2	1	2.96	2.96
Engraulis mordax	northern anchovy	2	2	2.52-2.83	2.68
Gibbonsia spp.	kelpfishes	2	0	-	-
Orthonopias triacis	snubnose sculpin	2	2	2.94-3.58	3.26
Pleuronectoidei	flatfishes	2	2	1.89-2.65	2.27
Citharichthys sordidus	Pacific sanddab	1	1	2.34	2.34
Genyonemus lineatus	white croaker	1	0	-	-
larval/post-larval fish	larval fishes	1	0	-	-
Myctophidae	lanternfishes	1	1	3.63	3.63
Oligocottus/Clinocottus spp.	sculpins	1	1	4.39	4.39
Osmeridae	smelts	1	1	11.11	11.11
Tarletonbeania crenularis	blue lanternfish	1	1	3.89	3.89
	Total:	**114**	**85**		

Table C3-4. Intake station (SWE) larval fish lengths, SCEN04.

Survey: **SCEN04**
Start Date: **July 14, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Artedius spp.	sculpins	3	3	2.36-2.48	2.44
CIQ goby complex	gobies	3	2	3.80-3.87	3.84
Citharichthys sordidus	Pacific sanddab	3	2	2.40-2.58	2.49
Paralichthys californicus	California halibut	3	3	2.53-3.65	3.15
Citharichthys stigmaeus	speckled sanddab	2	2	1.99-2.34	2.17
Cottidae	sculpins	2	2	2.32-10.88	6.60
Liparis spp.	snailfishes	2	2	1.81-10.30	6.06
Engraulis mordax	northern anchovy	1	1	2.93	2.93
Gobiesox spp.	clingfishes	1	1	3.91	3.91
Oxylebius pictus	painted greenling	1	1	3.21	3.21
Syngnathus spp.	pipefishes	1	1	9.36	9.36
		Total: 22	**20**		

Table C3-5. Intake station (SWE) larval fish lengths, SCEN05.

Survey: **SCEN05**
Start Date: **August 11, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Artedius spp.	sculpins	10	10	2.43-2.95	2.59
Rhinogobiops nicholsi	blackeye goby	4	3	2.40-2.64	2.53
Cottidae	sculpins	3	1	2.89	2.89
Odontopyxis trispinosa	pygmy poacher	2	2	3.53-3.96	3.74
Ruscarius creaseri	roughcheek sculpin	2	2	2.52-2.67	2.59
CIQ goby complex	gobies	1	1	3.57	3.57
Genyonemus lineatus	white croaker	1	1	2.19	2.19
Gibbonsia spp.	kelpfishes	1	1	5.50	5.50
larval fish - damaged	damaged larval fishes	1	0	-	-
Neoclinus spp.	fringeheads	1	1	4.23	4.23
Pleuronichthys verticalis	hornyhead turbot	1	1	2.38	2.38
		Total: 27	**23**		

Table C3-6. Intake station (SWE) larval fish lengths, SCEN06.

Survey: **SCEN06**
Start Date: **September 16, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Neoclinus spp.	fringeheads	9	9	4.16-6.91	4.95
CIQ goby complex	gobies	7	7	3.07-25.57	6.68
Rhinogobiops nicholsi	blackeye goby	7	7	2.40-2.70	2.59
Artedius spp.	sculpins	4	4	2.37-2.62	2.51
Orthonopias triacis	snubnose sculpin	3	3	2.91-3.01	2.95
Cottidae	sculpins	2	2	2.52-2.95	2.73
Engraulis mordax	northern anchovy	2	2	2.28-2.83	2.56
Liparis spp.	snailfishes	2	2	2.07-2.17	2.12
Gibbonsia spp.	kelpfishes	1	1	5.02	5.02
Gobiesox spp.	clingfishes	1	1	3.30	3.30
Oxylebius pictus	painted greenling	1	1	3.62	3.62
unidentified larvae, yolksac	yolksac larvae	1	0	-	-
	Total:	**40**	**39**		

Table C3-7. Intake station (SWE) larval fish lengths, SCEN07.

Survey: **SCEN07**
Start Date: **October 16, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
CIQ goby complex	gobies	10	8	3.20-3.92	3.64
Leptocottus armatus	Pacific staghorn sculpin	6	5	3.56-4.05	3.78
Tarletonbeania crenularis	blue lanternfish	5	5	2.28-2.63	2.48
Engraulis mordax	northern anchovy	3	2	18.07-20.85	19.46
unidentified larvae, yolksac	yolksac larvae	3	0	-	-
Cottidae	sculpins	2	2	2.17-2.64	2.40
Lepidogobius lepidus	bay goby	2	2	3.07-3.39	3.23
Neoclinus spp.	fringeheads	2	1	3.94	3.94
Artedius spp.	sculpins	1	1	2.47	2.47
Chilara taylori	spotted cusk-eel	1	1	3.32	3.32
Citharichthys stigmaeus	speckled sanddab	1	1	2.80	2.80
Liparis spp.	snailfishes	1	1	9.79	9.79
Odontopyxis trispinosa	pygmy poacher	1	1	3.96	3.96
Syngnathus spp.	pipefishes	1	0	-	-
	Total:	**39**	**30**		

Table C3-8. Intake station (SWE) larval fish lengths, SCEN08.

Survey: **SCEN08**
Start Date: **November 17, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Genyonemus lineatus	white croaker	288	50	1.52-4.57	2.04
unidentified larvae, yolksac	yolksac larvae	76	0	-	-
larval fish - damaged	damaged larval fishes	46	0	-	-
Engraulis mordax	northern anchovy	39	18	1.84-3.09	2.42
Pleuronectoidei	flatfishes	17	13	2.02-2.80	2.51
Leptocottus armatus	Pacific staghorn sculpin	16	12	4.38-7.02	5.82
Pleuronectidae	righteye flounders	12	8	1.59-2.45	2.08
Citharichthys stigmaeus	speckled sanddab	11	10	1.79-3.44	2.23
Citharichthys sordidus	Pacific sanddab	8	5	2.22-2.68	2.47
Artedius spp.	sculpins	2	2	2.51-2.66	2.59
CIQ goby complex	gobies	2	2	5.21-7.82	6.51
Cottidae	sculpins	2	2	2.80-3.38	3.09
Liparis spp.	snailfishes	2	2	2.19-2.39	2.29
Blennioidei	blennies	1	0	-	-
Neoclinus spp.	fringeheads	1	1	6.88	6.88
Odontopyxis trispinosa	pygmy poacher	1	1	3.79	3.79
Stenobrachius leucopsarus	northern lampfish	1	1	2.55	2.55
Tarletonbeania crenularis	blue lanternfish	1	1	3.06	3.06
	Total:	**526**	**128**		

Table C3-9. Intake station (SWE) larval fish lengths, SCEN09.

Survey: **SCEN09**
Start Date: **December 15, 2009**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Genyonemus lineatus	white croaker	202	49	1.48-9.04	2.51
unidentified larvae, yolksac	yolksac larvae	55	0	-	-
CIQ goby complex	gobies	39	38	2.76-19.71	6.95
Engraulis mordax	northern anchovy	30	27	11.43-28.84	17.18
Citharichthys stigmaeus	speckled sanddab	20	11	1.78-3.06	2.54
Leptocottus armatus	Pacific staghorn sculpin	18	18	4.82-8.70	6.85
Citharichthys sordidus	Pacific sanddab	15	11	2.69-3.69	3.24
larval fish - damaged	damaged larval fishes	10	0	-	-
Pleuronectoidei	flatfishes	8	3	2.31-3.27	2.88
Stenobrachius leucopsarus	northern lampfish	8	7	2.42-4.81	3.44
Artedius spp.	sculpins	4	3	2.75-3.23	3.04
Cottidae	sculpins	2	0	-	-
Gillichthys mirabilis	longjaw mudsucker	1	1	4.22	4.22
Isopsetta isolepis	butter sole	1	0	-	-
Lepidogobius lepidus	bay goby	1	1	3.25	3.25
Oxylebius pictus	painted greenling	1	1	4.35	4.35
Pleuronichthys verticalis	hornyhead turbot	1	1	2.38	2.38
Scorpaenichthys marmoratus	cabezon	1	1	4.43	4.43
Sebastes spp. V	rockfishes	1	1	5.74	5.74
Stellerina xyosterna	pricklebreast poacher	1	1	5.17	5.17
	Total:	**419**	**174**		

Table C3-10. Intake station (SWE) larval fish lengths, SCEN10.

Survey: **SCEN10**
Start Date: **January 15, 2010**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Bathymasteridae	ronquils	17	16	3.68-4.97	4.26
CIQ goby complex	gobies	17	17	3.51-5.94	4.42
Artedius spp.	sculpins	8	7	2.67-3.39	2.99
Genyonemus lineatus	white croaker	8	7	1.67-2.80	2.38
unidentified larvae, yolksac	yolksac larvae	8	0	-	-
Gibbonsia spp.	kelpfishes	2	2	6.59-8.75	7.67
Citharichthys stigmaeus	speckled sanddab	1	1	2.47	2.47
Cottidae	sculpins	1	1	2.96	2.96
Engraulis mordax	northern anchovy	1	1	20.08	20.08
Leptocottus armatus	Pacific staghorn sculpin	1	1	5.29	5.29
Oligocottus snyderi	fluffy sculpin	1	1	3.71	3.71
Oligocottus/Clinocottus spp.	sculpins	1	1	2.83	2.83
Orthonopias triacis	snubnose sculpin	1	1	3.70	3.70
Stenobrachius leucopsarus	northern lampfish	1	1	2.94	2.94
	Total:	**68**	**57**		

Table C3-11. Intake station (SWE) larval fish lengths, SCEN11.

Survey: **SCEN11**
Start Date: **February 23, 2010**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Genyonemus lineatus	white croaker	225	52	1.44-4.50	2.42
unidentified larvae, yolksac	yolksac larvae	105	0	-	-
Engraulis mordax	northern anchovy	47	33	3.21-23.11	5.67
Bathymasteridae	ronquils	16	16	3.49-5.08	4.16
Artedius spp.	sculpins	10	10	2.39-3.44	2.91
CIQ goby complex	gobies	5	5	3.71-4.97	4.12
Ammodytes hexapterus	Pacific sand lance	4	4	3.70-4.28	4.05
Pleuronectoidei	flatfishes	3	2	1.50-2.24	1.87
Atherinopsidae	silversides	2	2	9.20-9.27	9.23
Citharichthys stigmaeus	speckled sanddab	2	1	2.72	2.72
Lepidopsetta bilineata	rock sole	2	2	2.67-2.78	2.73
Leptocottus armatus	Pacific staghorn sculpin	2	2	4.53-4.54	4.53
Paralichthys californicus	California halibut	2	2	2.29-2.62	2.45
Cebidichthys violaceus	monkeyface prickleback	1	1	7.12	7.12
Citharichthys sordidus	Pacific sanddab	1	1	2.81	2.81
Clinocottus analis	woolly sculpin	1	1	2.29	2.29
Cottus asper	prickly sculpin	1	1	4.54	4.54
Gibbonsia spp.	kelpfishes	1	1	7.58	7.58
Liparis spp.	snailfishes	1	1	2.40	2.40
Osmeridae	smelts	1	1	3.21	3.21
Oxylebius pictus	painted greenling	1	1	4.03	4.03
Scorpaenichthys marmoratus	cabezon	1	1	4.73	4.73
Sebastes spp. V	rockfishes	1	1	3.90	3.90
	Total:	**435**	**141**		

Table C3-12. Intake station (SWE) larval fish lengths, SCEN12.

Survey: **SCEN12**
Start Date: **March 19, 2010**

Taxon	Common Name	Total Count	Measured Count	Length Range (mm)	Average Length (mm)
Genyonemus lineatus	white croaker	649	50	5.29-9.23	7.00
Engraulis mordax	northern anchovy	24	22	4.42-32.37	20.55
Osmeridae	smelts	14	10	7.54-16.12	11.78
Bathymasteridae	ronquils	11	11	3.22-4.15	3.76
Sebastes spp. V_	rockfishes	9	9	3.34-4.35	3.80
CIQ goby complex	gobies	7	7	3.80-10.86	6.60
Cottidae	sculpins	4	4	2.68-5.23	3.40
Neoclinus spp.	fringeheads	3	3	5.32-6.28	5.69
Gibbonsia spp.	kelpfishes	2	2	5.32-6.38	5.85
Artedius spp.	sculpins	1	1	2.62	2.62
Pholidae	gunnels	1	1	9.72	9.72
Xiphister spp.	pricklebacks	1	0	-	-
	Total:	**726**	**120**		

Table C3-13. Intake station (SWE) larval fish lengths, SCEN13.

Survey: **SCEN13**
Start Date: **May 3, 2010**

Taxon	**Common Name**	**Total Count**	**Measured Count**	**Length Range (mm)**	**Average Length (mm)**
Genyonemus lineatus	white croaker	101	48	2.96-9.39	5.22
Cottus asper	prickly sculpin	61	50	4.24-7.13	5.86
Osmeridae	smelts	55	35	5.70-17.76	10.39
Engraulis mordax	northern anchovy	20	18	17.34-29.40	24.35
CIQ goby complex	gobies	15	14	3.68-13.60	7.82
Cottidae	sculpins	9	7	2.90-9.67	5.28
larval fish - damaged	damaged larval fishes	5	0	-	-
Sebastes spp. V_	rockfishes	4	3	3.56-3.97	3.71
Lepidogobius lepidus	bay goby	3	3	5.14-5.85	5.41
Oxylebius pictus	painted greenling	3	3	3.58-4.44	3.91
Artedius spp.	sculpins	2	2	2.54-4.01	3.28
Bathymasteridae	ronquils	2	2	3.75-3.87	3.81
Leptocottus armatus	Pacific staghorn sculpin	2	2	5.65-5.74	5.69
Rhinogobiops nicholsi	blackeye goby	2	2	2.55-2.63	2.59
Ruscarius creaseri	roughcheek sculpin	2	1	2.71	2.71
Agonidae	poachers	1	0	-	-
Liparis spp.	snailfishes	1	1	1.89	1.89
Neoclinus spp.	fringeheads	1	1	4.56	4.56
Orthonopias triacis	snubnose sculpin	1	1	2.74	2.74
	Total:	**290**	**193**		

C4. Source Water Station Water Quality Measurements

Table C4-1. Water quality data by survey from source water Station SW2, April 2009 – May 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
04/16/09	13:05	0	10.49	NS	7.79	7.81	0.8
04/16/09	13:05	1	10.55	NS	7.85	7.87	0.9
Night							
04/16/09	20:35	0	11.33	NS	8.99	8.01	0.9
04/16/09	20:35	1	11.36	NS	8.99	8.02	1.0
Day							
05/12/09	13:50	0	14.61	33.51	9.72	7.11	-1.4
05/12/09	13:50	1	13.38	33.29	12.63	7.33	-0.6
05/12/09	13:50	2	13.27	33.32	11.88	7.23	0.1
05/12/09	13:50	3	13.25	33.34	11.66	7.21	-0.3
05/12/09	13:50	4	13.21	33.34	11.56	7.22	-0.5
05/12/09	13:50	5	13.10	33.31	11.48	7.19	-0.1
05/12/09	13:50	6	12.22	33.37	11.57	7.07	0.3
05/12/09	13:50	7	12.07	33.44	11.18	7.03	0.4
05/12/09	13:50	8	12.01	33.42	10.76	7.01	0.2
05/12/09	13:50	9	11.98	33.45	10.43	6.93	0.5
05/12/09	13:50	10	11.98	33.42	10.30	6.98	0.3
05/12/09	13:50	11	11.74	33.42	10.16	7.02	0.5
05/12/09	13:50	12	11.49	33.50	9.92	6.88	1.0
05/12/09	13:50	13	11.24	33.54	9.88	6.87	1.1
Night							
05/12/09	20:00	0	14.88	33.37	8.08	7.75	-1.0
05/12/09	20:00	1	14.03	33.14	11.28	7.94	-1.0
05/12/09	20:00	2	13.49	33.36	11.62	7.89	-0.7
05/12/09	20:00	3	13.50	33.38	11.43	7.80	-0.7
05/12/09	20:00	4	13.50	33.36	11.33	7.87	-0.5
05/12/09	20:00	5	13.49	33.36	11.23	7.84	-0.7
05/12/09	20:00	6	13.36	33.39	11.28	7.87	-0.5
05/12/09	20:00	7	12.57	33.42	11.54	7.78	0.4
05/12/09	20:00	8	12.44	33.42	11.31	7.79	0.1
05/12/09	20:00	9	12.31	33.46	10.84	7.67	0.1
05/12/09	20:00	10	12.25	33.42	10.63	7.73	-0.2
05/12/09	20:00	11	11.65	33.51	10.45	7.72	0.4
05/12/09	20:00	12	11.46	33.49	10.14	7.71	0.7
05/12/09	20:00	13	11.25	33.54	9.61	7.67	0.7
05/12/09	20:00	14	11.10	33.50	9.50	7.65	1.4
05/12/09	20:00	15	10.94	33.59	9.03	7.49	1.6
05/12/09	20:00	16	10.92	33.59	8.56	7.55	2.1

NS- not sampled

Table C4-2. Water quality data by survey from source water Station SW2, June 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
06/16/09	13:10	0	16.11	34.34	11.71	8.30	0.0
06/16/09	13:10	1	16.03	34.34	11.85	8.30	0.0
06/16/09	13:10	2	16.06	34.34	11.77	8.30	0.0
06/16/09	13:10	3	16.01	34.39	11.68	8.27	0.0
06/16/09	13:10	4	15.88	34.33	11.47	8.29	0.0
06/16/09	13:10	5	15.71	34.39	11.36	8.26	0.0
06/16/09	13:10	6	15.71	34.39	11.51	8.26	0.0
06/16/09	13:10	7	15.70	34.39	11.35	8.25	0.0
06/16/09	13:10	8	15.60	34.31	10.79	8.20	0.0
06/16/09	13:10	9	15.42	34.44	9.39	8.14	0.0
06/16/09	13:10	10	15.39	34.37	9.64	8.16	0.0
06/16/09	13:10	11	15.21	34.43	10.32	8.18	0.0
06/16/09	13:10	12	15.26	34.43	10.51	8.18	0.0
06/16/09	13:10	13	15.25	34.43	10.61	8.18	0.0
06/16/09	13:10	14	15.14	34.43	10.56	8.18	0.0
06/16/09	13:10	15	14.14	34.40	7.42	8.03	0.0
06/16/09	13:10	16	13.87	34.35	8.10	7.93	2.0
06/16/09	13:10	17	13.78	34.33	7.10	7.90	6.3
Night							
06/16/09	22:16	0	16.91	34.25	11.15	8.30	0.0
06/16/09	22:16	1	16.93	34.25	11.61	8.31	0.0
06/16/09	22:16	2	16.18	34.27	11.75	8.26	0.0
06/16/09	22:16	3	15.62	34.38	11.02	8.14	0.0
06/16/09	22:16	4	14.38	34.30	9.79	8.00	0.0
06/16/09	22:16	5	13.86	34.20	9.19	7.95	0.0
06/16/09	22:16	6	13.47	34.17	8.42	7.93	0.0
06/16/09	22:16	7	13.44	34.24	8.31	7.91	0.0
06/16/09	22:16	8	13.32	34.23	7.97	7.89	0.0
06/16/09	22:16	9	13.06	34.21	7.77	7.83	0.0
06/16/09	22:16	10	12.99	34.21	7.27	7.82	0.0
06/16/09	22:16	11	12.97	34.21	7.01	7.81	0.0
06/16/09	22:16	12	12.97	34.21	6.64	7.81	5.2

Table C4-3. Water quality data by survey from source water Station SW2, July 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
07/14/09	12:43	0	16.67	34.69	8.79	7.99	-0.2
07/14/09	12:43	1	16.63	34.68	8.51	8.00	-0.3
07/14/09	12:43	2	16.57	34.71	8.11	7.98	-0.1
07/14/09	12:43	3	16.18	34.70	7.66	7.98	-0.2
07/14/09	12:43	4	15.54	34.74	7.24	7.96	-0.2
07/14/09	12:43	5	14.76	34.71	6.88	8.00	-0.2
07/14/09	12:43	6	14.43	34.69	6.49	7.97	-0.2
07/14/09	12:43	7	14.41	34.68	6.50	7.92	-0.1
07/14/09	12:43	8	13.81	34.83	6.28	7.85	-0.1
07/14/09	12:43	9	12.62	34.82	6.44	7.78	6.5
07/14/09	12:43	10	12.31	34.82	6.51	7.76	6.5
07/14/09	12:43	11	11.92	34.76	6.66	7.68	6.5
07/14/09	12:43	12	11.65	34.84	6.90	7.67	6.5
07/14/09	12:42	13	11.04	34.84	7.03	7.61	6.4
07/14/09	12:42	14	10.92	34.77	7.33	7.62	6.4
07/14/09	12:42	15	10.79	34.79	7.36	7.58	6.4
07/14/09	12:42	16	10.81	34.75	7.63	7.61	6.4
Night							
07/14/09	20:14	0	16.10	34.75	8.92	8.02	0.0
07/14/09	20:13	1	15.64	34.81	8.31	7.99	-0.2
07/14/09	20:13	2	15.42	34.79	8.04	8.02	0.0
07/14/09	20:13	3	15.33	34.81	7.57	8.01	-0.3
07/14/09	20:13	4	14.97	34.94	7.18	7.99	-0.1
07/14/09	20:13	5	14.06	34.96	6.88	7.97	0.1
07/14/09	20:13	6	13.89	34.79	6.40	7.96	0.6
07/14/09	20:13	7	13.83	34.80	6.01	7.93	0.6
07/14/09	20:13	8	13.74	34.83	5.89	7.89	0.6
07/14/09	20:13	9	13.39	35.01	6.10	7.80	0.6
07/14/09	20:13	10	12.48	34.90	6.28	7.69	0.6
07/14/09	20:13	11	11.87	35.03	6.65	7.62	0.6
07/14/09	20:13	12	10.58	35.09	7.35	7.53	0.3
07/14/09	20:13	13	10.48	34.92	7.38	7.55	0.2
07/14/09	20:13	14	10.50	34.96	9.73	7.61	2.0

Table C4-4. Water quality data by survey from source water Station SW2, August 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
08/11/09	13:43	0	16.51	33.17	8.44	7.80	-2.6
08/11/09	13:43	1	16.47	33.18	8.03	7.79	-2.9
08/11/09	13:43	2	16.29	33.18	7.53	7.78	-2.9
08/11/09	13:42	3	15.92	33.19	7.62	7.76	-2.8
08/11/09	13:42	4	15.50	33.20	7.21	7.76	-2.8
08/11/09	13:42	5	15.29	33.24	6.75	7.66	-2.8
08/11/09	13:42	6	15.01	33.23	6.34	7.71	-2.8
08/11/09	13:42	7	14.94	33.18	6.35	7.69	-2.8
08/11/09	13:42	8	14.60	33.34	6.17	7.57	-2.8
08/11/09	13:42	9	13.68	33.18	6.16	7.61	-2.5
08/11/09	13:42	10	13.14	33.29	6.15	7.48	-1.7
08/11/09	13:42	11	12.74	33.22	6.23	7.47	-2.3
08/11/09	13:42	12	12.61	33.19	6.36	7.48	-2.1
08/11/09	13:42	13	12.29	33.17	6.61	7.48	-2.4
08/11/09	13:42	14	12.03	33.24	6.66	7.43	-2.5
08/11/09	13:42	15	11.90	33.13	6.94	7.42	-1.3
08/11/09	13:42	16	11.87	33.16	7.20	7.39	0.1
Night							
08/11/09	19:45	0	15.82	33.24	8.18	7.84	-2.9
08/11/09	19:45	1	15.83	33.22	7.53	7.89	-2.9
08/11/09	19:45	2	15.52	33.33	7.22	7.81	-2.6
08/11/09	19:45	3	14.37	33.34	7.16	7.77	-2.2
08/11/09	19:45	4	13.89	33.39	7.26	7.72	-2.5
08/11/09	19:45	5	13.46	33.28	7.05	7.80	-2.7
08/11/09	19:45	6	13.08	33.42	6.86	7.70	-2.7
08/11/09	19:45	7	12.82	33.27	6.69	7.69	-2.1
08/11/09	19:45	8	12.72	33.28	6.71	7.67	-2.1
08/11/09	19:45	9	12.57	33.26	6.65	7.64	-2.1
08/11/09	19:44	10	12.46	33.28	6.83	7.61	-2.1
08/11/09	19:44	11	12.27	33.29	6.87	7.54	-2.1
08/11/09	19:44	12	12.05	33.24	7.13	7.54	-1.9
08/11/09	19:44	13	12.03	33.22	7.35	7.51	-1.4
08/11/09	19:44	14	12.01	33.22	7.92	7.56	0.0

Table C4-5. Water quality data by survey from source water Station SW2, September 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
09/16/09	11:35	0	15.64	34.64	9.06	8.01	0.0
09/16/09	11:35	1	15.13	34.95	9.00	7.97	-0.1
09/16/09	11:35	2	14.68	34.62	9.01	8.07	0.0
09/16/09	11:34	3	14.53	34.64	8.96	8.01	-0.3
09/16/09	11:34	4	14.37	34.66	9.00	7.98	-0.3
09/16/09	11:34	5	14.36	34.64	8.97	7.93	-0.1
09/16/09	11:34	6	14.35	34.62	8.98	8.01	0.1
09/16/09	11:34	7	14.31	34.65	8.99	7.96	0.3
09/16/09	11:34	8	14.26	34.69	9.06	7.88	0.7
09/16/09	11:34	9	14.15	34.68	9.16	7.87	2.1
09/16/09	11:34	10	14.12	34.70	9.23	7.86	2.1
09/16/09	11:34	11	14.10	34.69	9.24	7.93	2.1
09/16/09	11:34	12	14.13	34.64	9.27	7.94	2.1
09/16/09	11:34	13	14.20	34.64	9.27	7.94	2.1
09/16/09	11:34	14	14.29	34.65	9.27	7.91	2.1
Night							
09/16/09	19:27	0	15.87	29.98	9.11	8.26	0.2
09/16/09	19:27	1	15.90	34.62	8.05	8.27	0.4
09/16/09	19:27	2	15.84	34.65	7.77	8.27	0.4
09/16/09	19:27	3	15.59	34.65	7.76	8.22	0.4
09/16/09	19:27	4	14.24	34.90	8.08	8.19	0.3
09/16/09	19:27	5	13.94	34.65	8.03	8.10	0.5
09/16/09	19:26	6	13.93	34.65	7.89	8.10	0.2
09/16/09	19:26	7	13.95	34.63	7.78	8.21	0.6
09/16/09	19:26	8	13.44	34.61	7.88	8.17	0.3
09/16/09	19:26	9	13.21	34.67	7.96	8.13	0.4
09/16/09	19:26	10	13.09	34.66	7.99	8.08	1.0
09/16/09	19:26	11	13.09	34.64	8.13	8.11	0.9
09/16/09	19:26	12	13.04	34.66	8.24	8.00	2.7
09/16/09	19:26	13	13.06	34.64	8.38	8.10	3.7
09/16/09	19:26	14	13.04	34.66	8.91	8.10	0.7

Table C4-6. Water quality data by survey from source water Station SW2, October 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
10/16/09	11:53	0	14.66	33.26	8.28	8.15	3.8
10/16/09	11:53	1	14.35	33.35	7.32	8.04	5.7
10/16/09	11:53	2	13.63	33.40	7.53	7.94	3.7
10/16/09	11:53	3	13.48	33.41	7.50	7.92	3.6
10/16/09	11:53	4	13.30	33.53	7.42	7.87	3.6
10/16/09	11:53	5	13.25	33.54	7.10	7.87	1.2
10/16/09	11:53	6	13.18	33.58	7.49	7.85	2.0
10/16/09	11:53	7	13.16	33.59	7.45	7.84	2.5
10/16/09	11:53	8	13.12	33.62	7.38	7.80	4.0
10/16/09	11:53	9	13.08	33.65	7.50	7.80	4.2
10/16/09	11:52	10	13.07	33.65	7.40	7.80	3.0
10/16/09	11:52	11	13.07	33.65	7.37	7.84	3.3
10/16/09	11:52	12	13.08	33.65	7.44	7.83	4.2
10/16/09	11:52	13	13.08	33.65	7.77	7.84	5.6
10/16/09	11:52	14	13.12	33.61	7.76	7.86	8.8
10/16/09	11:52	15	13.05	33.67	7.55	7.78	12.1
10/16/09	11:52	16	13.05	33.68	7.34	7.76	7.6
Night							
10/16/09	18:12	0	13.88	33.44	7.43	7.98	2.5
10/16/09	18:12	1	13.79	33.39	7.38	7.95	2.4
10/16/09	18:12	2	13.67	33.41	7.53	7.92	1.9
10/16/09	18:12	3	13.43	33.41	7.21	7.90	1.7
10/16/09	18:12	4	13.20	33.51	7.52	7.90	0.8
10/16/09	18:12	5	13.15	33.59	7.17	7.89	1.0
10/16/09	18:12	6	13.11	33.64	7.23	7.87	0.6
10/16/09	18:12	7	13.14	33.59	7.22	7.91	0.6
10/16/09	18:12	8	13.07	33.65	7.21	7.88	0.8
10/16/09	18:11	9	13.09	33.64	7.14	7.89	1.1
10/16/09	18:11	10	13.06	33.67	7.26	7.84	1.1
10/16/09	18:11	11	13.08	33.65	7.10	7.88	1.2
10/16/09	18:11	12	13.05	33.69	7.27	7.81	11.9
10/16/09	18:11	13	13.03	33.70	7.53	7.79	11.9
10/16/09	18:11	14	13.06	33.68	7.52	7.81	11.9
10/16/09	18:11	15	13.03	33.70	7.53	7.79	11.9

Table C4-7. Water quality data by survey from source water Station SW2, November 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
11/17/09	16:17	0	12.13	34.53	8.96	8.03	-0.8
11/17/09	16:17	1	12.15	34.52	8.86	8.05	-0.8
11/17/09	16:17	2	12.15	34.53	8.86	8.04	-0.8
11/17/09	16:17	3	12.16	34.52	8.73	8.03	-0.8
11/17/09	16:17	4	12.13	34.57	8.59	7.95	-0.8
11/17/09	16:17	5	12.16	34.51	8.39	8.04	-0.8
11/17/09	16:17	6	12.15	34.54	8.39	8.03	-0.9
11/17/09	16:17	7	12.15	34.49	8.18	8.04	-0.7
11/17/09	16:17	8	12.13	34.49	7.95	8.05	-0.9
11/17/09	16:17	9	12.05	34.51	7.86	7.98	-0.9
11/17/09	16:17	10	12.02	34.52	7.93	7.92	-0.3
11/17/09	16:17	11	12.02	34.52	7.93	7.90	-0.1
11/17/09	16:17	12	11.99	34.55	8.04	7.83	0.4
11/17/09	16:17	13	12.05	34.50	8.15	7.93	2.7
11/17/09	16:17	14	12.03	34.51	8.31	7.90	1.5
11/17/09	16:17	15	12.05	34.50	8.30	7.93	1.2
11/17/09	16:16	16	12.01	34.54	8.49	7.87	1.2
Night							
11/17/09	21:41	0	12.17	34.27	7.50	8.02	-0.1
11/17/09	21:41	1	12.13	34.31	7.51	7.95	-0.1
11/17/09	21:41	2	12.12	34.30	7.47	8.02	-0.2
11/17/09	21:40	3	12.12	34.30	7.41	8.01	-0.2
11/17/09	21:40	4	12.09	34.32	7.42	7.95	-0.2
11/17/09	21:40	5	12.08	34.31	7.39	8.02	-0.2
11/17/09	21:40	6	12.04	34.33	7.36	7.95	-0.2
11/17/09	21:40	7	12.05	34.30	7.32	7.97	0.4
11/17/09	21:40	8	12.07	34.29	7.25	8.01	-0.4
11/17/09	21:40	9	12.03	34.32	7.23	7.97	-0.2
11/17/09	21:40	10	12.00	34.31	7.21	7.96	0.4
11/17/09	21:40	11	12.02	34.30	7.20	8.00	-0.2
11/17/09	21:40	12	12.00	34.32	7.20	7.95	0.0
11/17/09	21:40	13	12.00	34.30	7.21	7.99	0.5
11/17/09	21:40	14	11.97	34.32	7.22	7.95	0.1
11/17/09	21:39	15	11.96	34.32	7.35	7.94	0.9
11/17/09	21:39	16	11.99	34.30	7.40	8.00	13.0

Table C4-8. Water quality data by survey from source water Station SW2, December 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
12/15/09	13:13	0	11.92	34.79	NS	7.80	NS
12/15/09	13:13	1	11.90	34.81	NS	7.78	NS
12/15/09	13:13	2	11.89	34.80	NS	7.81	NS
12/15/09	13:13	3	11.89	34.80	NS	7.81	NS
12/15/09	13:13	4	11.88	34.81	NS	7.75	NS
12/15/09	13:13	5	11.88	34.80	NS	7.86	NS
12/15/09	13:13	6	11.67	34.80	NS	7.84	NS
12/15/09	13:13	7	11.65	34.76	NS	7.84	NS
12/15/09	13:13	8	11.65	34.81	NS	7.78	NS
12/15/09	13:13	9	11.64	34.83	NS	7.72	NS
12/15/09	13:13	10	11.64	34.81	NS	7.71	NS
12/15/09	13:13	11	11.69	34.84	NS	7.77	NS
12/15/09	13:13	12	11.73	34.87	NS	7.76	NS
12/15/09	13:12	13	11.75	34.87	NS	7.78	NS
12/15/09	13:12	14	11.76	34.89	NS	7.77	NS
Night							
12/15/09	17:29	0	11.88	34.81	NS	7.94	NS
12/15/09	17:29	1	11.81	34.79	NS	7.83	NS
12/15/09	17:29	2	11.81	34.84	NS	7.89	NS
12/15/09	17:29	3	11.72	34.81	NS	7.92	NS
12/15/09	17:29	4	11.65	34.82	NS	7.81	NS
12/15/09	17:29	5	11.67	34.86	NS	7.87	NS
12/15/09	17:29	6	11.67	34.87	NS	7.85	NS
12/15/09	17:29	7	11.69	34.83	NS	7.89	NS
12/15/09	17:29	8	11.70	34.82	NS	7.90	NS
12/15/09	17:28	9	11.72	34.84	NS	7.89	NS
12/15/09	17:28	10	11.73	34.85	NS	7.88	NS
12/15/09	17:28	11	11.73	34.84	NS	7.88	NS
12/15/09	17:28	12	11.72	34.86	NS	7.87	NS
12/15/09	17:28	13	11.72	34.86	NS	7.79	NS

NS - not sampled

Table C4-9. Water quality data by survey from source water Station SW2, January – February 2010.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
01/15/10	12:51	0	12.49	34.46	8.59	7.74	-4.1
01/15/10		1	NS	NS	NS	NS	NS
01/15/10	12:51	2	12.39	34.46	9.38	7.87	1.9
01/15/10	12:51	3	12.47	34.57	8.82	7.90	1.5
01/15/10	12:51	4	12.42	34.53	9.08	8.02	1.4
01/15/10	12:51	5	12.46	34.57	9.16	7.94	2.3
01/15/10		6	NS	NS	NS	NS	NS
01/15/10	12:52	7	12.40	34.64	9.40	7.84	2.4
01/15/10	12:52	8	12.38	34.57	8.74	8.01	1.3
01/15/10	12:52	9	12.38	34.61	9.51	7.96	0.8
01/15/10	12:52	10	12.35	34.63	9.50	7.91	2.0
01/15/10	12:52	11	12.35	34.60	8.71	7.94	1.7
01/15/10	12:52	12	12.36	34.62	9.15	7.92	2.3
01/15/10	12:53	13	12.34	34.63	8.87	7.79	5.1
Night							
No night samples due to unsafe sampling conditions							
Day							
02/23/10	11:27	0	12.88	33.39	8.55	8.07	0.2
02/23/10	11:27	1	12.88	33.41	8.55	8.05	0.6
02/23/10	11:27	2	12.91	33.43	8.53	8.00	0.3
02/23/10	11:27	3	12.91	33.54	8.51	7.96	0.3
02/23/10	11:27	4	12.95	33.61	8.47	7.99	0.3
02/23/10	11:27	5	12.95	33.66	8.44	8.04	0.3
02/23/10	11:27	6	12.97	33.62	8.39	8.06	0.3
02/23/10	11:27	7	12.96	33.64	8.38	8.01	0.3
02/23/10	11:27	8	12.98	33.61	8.37	8.05	0.5
02/23/10	11:26	9	13.00	33.63	8.36	8.04	0.8
02/23/10	11:26	10	12.99	33.64	8.36	8.02	0.6
02/23/10	11:26	11	12.97	33.65	8.40	7.94	0.8
02/23/10	11:26	12	13.02	33.62	8.42	8.05	1.0
02/23/10	11:26	13	13.00	33.63	8.42	8.03	2.8
02/23/10	11:26	14	13.00	33.63	8.45	7.96	1.6
Night							
02/23/10	21:22	0	12.61	32.63	8.53	8.00	0.8
02/23/10	21:22	1	12.61	32.62	8.45	7.95	0.4
02/23/10	21:22	2	12.71	32.80	8.42	8.00	0.7
02/23/10	21:22	3	12.85	33.11	8.29	8.00	0.5
02/23/10	21:22	4	12.89	33.44	8.26	7.98	0.6
02/23/10	21:22	5	12.95	33.63	8.23	7.95	0.7
02/23/10	21:22	6	12.96	33.64	8.24	7.90	1.5
02/23/10	21:22	7	12.96	33.65	8.26	7.97	2.1
02/23/10	21:22	8	12.95	33.66	8.26	7.96	10.7
02/23/10	21:22	9	12.93	33.69	8.31	7.85	10.7
02/23/10	21:22	10	12.96	33.65	8.33	7.96	10.7
02/23/10	21:21	11	12.94	33.69	8.33	7.85	10.7
02/23/10	21:21	12	12.96	33.66	8.33	7.95	10.7
02/23/10	21:21	13	12.94	33.68	8.37	7.84	10.7

NS - not sampled

Table C4-10. Water quality data by survey from source water Station SW2, March 2010.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
03/19/10	12:14	0	15.05	35.03	8.82	7.97	-0.8
03/19/10	12:13	1	13.79	36.27	9.10	7.93	-0.5
03/19/10	12:13	2	13.55	36.31	9.16	7.96	-0.2
03/19/10	12:13	3	13.45	36.34	9.18	7.93	0.0
03/19/10	12:13	4	13.38	36.37	9.16	7.96	0.4
03/19/10	12:13	5	13.31	36.42	9.10	7.93	-0.6
03/19/10	12:13	6	13.30	36.44	8.97	7.97	-0.6
03/19/10	12:13	7	13.30	36.44	8.90	7.93	-0.6
03/19/10	12:13	8	13.29	36.42	8.77	7.96	-0.1
03/19/10	12:13	9	13.26	36.43	8.71	7.92	0.1
03/19/10	12:12	10	13.26	36.43	8.65	7.94	-0.3
03/19/10	12:12	11	13.24	36.44	8.64	7.90	-0.1
03/19/10	12:12	12	13.10	36.53	8.78	7.88	-0.4
03/19/10	12:12	13	12.97	36.55	8.96	7.87	0.1
03/19/10	12:12	14	12.97	36.54	9.07	7.88	-0.2
Night							
03/19/10	19:00	0	14.58	36.11	8.50	7.95	-0.6
03/19/10	18:59	1	14.37	36.25	7.97	8.04	-0.5
03/19/10	18:59	2	14.03	36.41	8.04	8.03	0.0
03/19/10	18:59	3	13.82	36.41	7.82	8.03	-0.6
03/19/10	18:59	4	13.70	36.45	7.68	7.95	-0.4
03/19/10	18:59	5	13.50	36.51	7.50	8.02	-0.1
03/19/10	18:59	6	13.32	36.51	7.28	8.01	-0.5
03/19/10	18:59	7	13.20	36.55	7.13	8.01	-0.4
03/19/10	18:59	8	13.09	36.57	7.05	8.00	-0.2
03/19/10	18:59	9	12.93	36.64	7.08	7.94	-0.2
03/19/10	18:59	10	12.92	36.62	7.03	7.96	0.0
03/19/10	18:59	11	12.87	36.64	7.04	7.89	1.7
03/19/10	18:59	12	12.85	36.68	7.07	7.91	1.7
03/19/10	18:59	13	12.64	36.76	7.11	7.89	1.7
03/19/10	18:59	14	12.58	36.78	7.18	7.80	1.7
03/19/10	18:59	15	12.58	36.77	7.23	7.80	1.7
03/19/10	18:58	16	12.61	36.73	7.60	7.89	0.1

Table C4-11. Water quality data by survey from source water Station SW2, May 2010.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Day							
05/03/10	11:44	0	12.64	35.26	8.16	7.72	-0.4
05/03/10	11:44	1	12.67	35.26	8.17	7.71	-0.4
05/03/10	11:44	2	12.64	35.24	7.38	7.72	-0.4
05/03/10	11:44	3	12.38	35.39	7.21	7.63	-0.4
05/03/10	11:44	4	12.24	35.29	7.12	7.68	-0.4
05/03/10	11:44	5	11.46	35.45	7.30	7.57	-0.3
05/03/10	11:44	6	11.42	35.36	7.25	7.53	-0.3
05/03/10	11:44	7	11.40	35.35	7.22	7.55	-0.7
05/03/10	11:44	8	11.35	35.38	7.23	7.48	-0.3
05/03/10	11:44	9	11.31	35.37	7.27	7.52	-0.2
05/03/10	11:44	10	11.26	35.37	7.28	7.51	-0.3
05/03/10	11:44	11	11.23	35.38	7.35	7.47	-0.9
05/03/10	11:44	12	11.18	35.38	7.46	7.45	-0.1
05/03/10	11:44	13	11.17	35.39	7.46	7.48	-0.4
05/03/10	11:44	14	11.14	35.40	7.60	7.42	-0.6
05/03/10	11:44	15	11.15	35.39	7.75	7.43	-0.5
05/03/10	11:44	16	11.14	35.38	7.94	7.41	1.4
Night							
05/03/10	19:31	0	14.03	34.83	9.54	8.04	-0.8
05/03/10	19:31	1	12.83	35.39	8.21	7.92	-0.3
05/03/10	19:30	2	12.53	35.27	8.15	7.88	-0.8
05/03/10	19:30	3	12.41	35.26	8.07	7.89	-0.4
05/03/10	19:30	4	12.25	35.28	8.11	7.85	-0.8
05/03/10	19:30	5	11.96	35.36	8.15	7.78	-0.5
05/03/10	19:30	6	11.76	35.31	8.20	7.78	-0.5
05/03/10	19:30	7	11.66	35.31	8.25	7.77	-0.4
05/03/10	19:30	8	11.61	35.31	8.27	7.79	-0.6
05/03/10	19:30	9	11.59	35.31	8.30	7.76	-0.4
05/03/10	19:30	10	11.58	35.32	8.39	7.76	-0.5
05/03/10	19:30	11	11.56	35.32	8.51	7.76	-0.8
05/03/10	19:30	12	11.54	35.33	8.64	7.70	-0.8
05/03/10	19:30	13	11.53	35.33	8.80	7.69	0.7

scwd[2]

Appendix D

Wharf Sampling Results by Survey

D1. Wharf Station Larval Counts and Mean Concentrations

D2. Wharf Station Larval Fish Lengths

D3. Wharf Station Water Quality Measurements

D1. Wharf Station Larval Counts and Concentrations

Table D1-1. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP01.

Survey: SCWP01
Survey Date: 04/16/09

			SCREENED		UNSCREENED	
Taxon	**Common Name**	**Total Count**	**Count**	**Mean Concentration (#/1,000 m^3)**	**Count**	**Mean Concentration (#/1,000 m^3)**
Entrainable Fish Larvae						
Genyonemus lineatus	white croaker	17	17	107.30	-	-
larval fish - damaged	damaged larval fishes	14	9	59.80	5	36.90
Cottidae	sculpins	4	2	13.40	2	14.80
Aulorhynchus flavidus	tubesnout	3	2	14.70	1	7.40
Agonidae	poachers	1	1	7.30	-	-
Artedius spp.	sculpins	1	1	7.30	-	-
CIQ goby complex	gobies	1	1	6.10	-	-
Cottus asper	prickly sculpin	1	1	7.30	-	-
Cyclopteridae	snailfishes	1	-	-	1	7.40
larval/post-larval fish	larval fishes	1	-	-	1	7.40
Leptocottus armatus	Pacific staghorn sculpin	1	1	7.30	-	-
Pholidae	gunnels	1	-	-	1	7.30
Scorpaenichthys marmoratus	cabezon	1	-	-	1	7.40
	Total Entrainable Fish Larvae:	**47**	**35**		**12**	
Fish Eggs						
fish eggs (undeveloped)	undeveloped fish eggs	425	213	1,427.70	212	1,517.80
Citharichthys spp. (eggs)	sanddab eggs	9	9	56.60	-	-
Paralichthyidae (eggs)	sand flounder eggs	7	6	44.00	1	7.40
Pleuronectoidei (eggs)	flatfish eggs	4	1	6.10	3	22.30
fish eggs	fish eggs	3	3	18.70	-	-
Genyonemus lineatus (eggs)	white croaker eggs	2	1	7.00	1	6.50
Pleuronectidae (eggs)	righteye flounder eggs	2	1	7.30	1	7.40

Samples may have been split. Count and concentration are based on adjusted split count.

(continued)

Table D1-1 (continued). Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP01.

Survey: SCWP01
Survey Date: 04/16/09

Taxon	Common Name	Total Count	SCREENED Count	SCREENED Mean Concentration (#/1,000 m^3)	UNSCREENED Count	UNSCREENED Mean Concentration (#/1,000 m^3)
Fish Eggs (continued)						
Citharichthys stigmaeus (eggs)	speckled sanddab eggs	1	-	-	1	6.50
Lyopsetta exilis (eggs)	slender sole eggs	1	1	6.30	-	-
poss. Hexagrammidae/Cottidae (eggs)	poss. greenling/sculpin eggs	1	1	7.00	-	-
	Total Fish Eggs:	**455**	**236**		**219**	
Target Invertebrate Larvae						
Thoridae/Hippolytidae	shrimps	1,826	1,232	7,939.50	594	4,360.30
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	1,758	1,684	11,020.10	74	539.50
Cancridae (megalops)	cancer crabs megalops	1,223	1,157	7,656.50	66	483.10
Crangonidae	sand shrimps	743	688	4,694.40	55	404.70
Metacarcinus anthonyi (megalops)	yellow crab megalops	179	165	1,199.80	14	102.80
Alpheidae	shrimps	16	16	102.40	-	-
Heptacarpus spp.	tidepool shrimps	6	4	29.40	2	14.80
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	4	4	29.40	-	-
Heptacarpus paludicola	wharf shrimp	2	-	-	2	15.20
	Total Target Invertebrate Larvae:	**5,757**	**4,950**		**807**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table D1-2. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP02.

Survey: SCWP02
Survey Date: 05/12/09

Taxon	Common Name	Total Count	SCREENED Count	SCREENED Mean Concentration (#/1,000 m^3)	UNSCREENED Count	UNSCREENED Mean Concentration (#/1,000 m^3)
Entrainable Fish Larvae						
Aulorhynchus flavidus	tubesnout	30	17	109.50	13	99.80
larval fish - damaged	damaged larval fishes	11	7	51.80	4	30.60
Sebastes spp.	rockfishes	6	-	-	6	46.70
CIQ goby complex	gobies	5	5	29.70	-	-
Cyclopteridae	snailfishes	4	-	-	4	29.20
Agonidae	poachers	2	1	5.90	1	7.80
Cottidae	sculpins	2	1	5.90	1	7.80
Cebidichthys violaceus	monkeyface prickleback	1	1	7.60	-	-
Gibbonsia spp.	kelpfishes	1	1	5.90	-	-
Gillichthys mirabilis	longjaw mudsucker	1	1	5.90	-	-
Leptocottus armatus	Pacific staghorn sculpin	1	1	7.40	-	-
Oligocottus snyderi	fluffy sculpin	1	1	5.90	-	-
Osmeridae	smelts	1	1	5.90	-	-
	Total Entrainable Fish Larvae:	**66**	**37**		**29**	
Fish Eggs						
fish eggs (undeveloped)	undeveloped fish eggs	383	129	966.20	254	1,865.50
Paralichthyidae (eggs)	sand flounder eggs	8	1	7.60	7	50.50
Citharichthys spp. (eggs)	sanddab eggs	4	2	13.40	2	14.90
Genyonemus lineatus (eggs)	white croaker eggs	1	-	-	1	7.40
	Total Fish Eggs:	**396**	**132**		**264**	
Target Invertebrate Larvae						
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	7,984	5,438	32,574.50	2,546	19,436.70
Thoridae/Hippolytidae	shrimps	1,853	1,318	9,387.90	535	3,928.60
Cancridae damaged (megalops)	damaged cancer crab megalops	536	348	2,063.70	188	1,428.50
Cancridae (megalops)	cancer crabs megalops	367	301	1,954.00	66	487.30
Crangonidae	sand shrimps	288	195	1,293.60	93	722.40
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	66	24	142.30	42	323.40

Samples may have been split. Count and concentration are based on adjusted split count.

(continued)

Table D1-2 (continued). Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP02.

Survey: SCWP02
Survey Date: 05/12/09

			SCREENED		UNSCREENED	
Taxon	**Common Name**	**Total Count**	**Count**	**Mean Concentration (#/1,000 m^3)**	**Count**	**Mean Concentration (#/1,000 m^3)**
<u>Target Invertebrate Larvae (continued)</u>						
Cancridae fragment (megalops)	cancer crab megalops fragment	40	40	237.20	-	-
Metacarcinus anthonyi (megalops)	yellow crab megalops	39	23	163.80	16	124.50
Alpheidae	shrimps	13	7	41.50	6	45.50
Heptacarpus paludicola	wharf shrimp	9	-	-	9	67.10
	Total Target Invertebrate Larvae:	**11,195**	**7,694**		**3,501**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table D1-3. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP03.

Survey: SCWP03
Survey Date: 06/16/09

Taxon	Common Name	Total Count	SCREENED Count	SCREENED Mean Concentration (#/1,000 m^3)	UNSCREENED Count	UNSCREENED Mean Concentration (#/1,000 m^3)
Entrainable Fish Larvae						
Cottidae	sculpins	5	4	24.20	1	7.20
CIQ goby complex	gobies	4	4	24.70	-	-
Gobiesocidae	clingfishes	3	3	18.30	-	-
larval fish - damaged	damaged larval fishes	2	1	6.20	1	7.20
Cebidichthys violaceus	monkeyface prickleback	1	-	-	1	7.20
Gobiesox spp.	clingfishes	1	1	6.10	-	-
larvae, yolksac	yolksac larvae	1	1	7.60	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	1	7.10
	Total Entrainable Fish Larvae:	**18**	**14**		**4**	
Fish Eggs						
fish eggs (undeveloped)	undeveloped fish eggs	2,994	1,561	9,441.80	1,433	10,137.20
Citharichthys spp. (eggs)	sanddab eggs	272	232	1,387.30	40	289.60
Sciaenidae/Paralichthyidae (eggs)	fish eggs	35	16	103.20	19	137.20
Paralichthys californicus (eggs)	California halibut eggs	17	17	103.40	-	-
fish eggs (damaged)	damaged fish eggs unid.	3	3	18.30	-	-
Engraulis mordax (eggs)	northern anchovy eggs	1	1	7.60	-	-
fish eggs	fish eggs	1	-	-	1	7.20
	Total Fish Eggs:	**3,323**	**1,830**		**1,493**	
Target Invertebrate Larvae						
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	2,337	1,550	11,531.50	787	5,679.60
Thoridae/Hippolytidae	shrimps	745	428	3,057.50	317	2,284.60
Heptacarpus spp.	tidepool shrimps	137	136	837.50	1	7.10
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	127	82	618.70	45	324.80
Cancridae (megalops)	cancer crabs megalops	94	75	564.10	19	136.90
Metacarcinus anthonyi (megalops)	yellow crab megalops	66	26	188.70	40	289.30
Crangonidae	sand shrimps	15	3	21.30	12	86.40
Heptacarpus paludicola	wharf shrimp	1	-	-	1	7.10
	Total Target Invertebrate Larvae:	**3,522**	**2,300**		**1,222**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table D1-4. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP04.

Survey: SCWP04
Survey Date: 07/14/09

			SCREENED		UNSCREENED	
Taxon	**Common Name**	**Total Count**	**Count**	**Mean Concentration (#/1,000 m^3)**	**Count**	**Mean Concentration (#/1,000 m^3)**
Entrainable Fish Larvae						
Gobiesocidae	clingfishes	1	1	6.10	-	-
Gobiesox spp.	clingfishes	1	-	-	1	5.00
	Total Entrainable Fish Larvae:	**2**	**1**		**1**	
Fish Eggs						
fish eggs (undeveloped)	undeveloped fish eggs	797	370	2,393.60	427	2,620.80
Citharichthys spp. (eggs)	sanddab eggs	28	5	35.60	23	133.70
	Total Fish Eggs:	**825**	**375**		**450**	
Target Invertebrate Larvae						
Thoridae/Hippolytidae	shrimps	120	103	714.70	17	92.80
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	22	7	43.20	15	79.50
Heptacarpus sitchensis	Sitka coastal shrimp	7	7	47.00	-	-
Metacarcinus anthonyi (megalops)	yellow crab megalops	6	2	12.30	4	24.60
Crangonidae	sand shrimps	3	-	-	3	21.90
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	1	-	-	1	5.00
Cancridae (megalops)	cancer crabs megalops	1	1	7.10	-	-
	Total Target Invertebrate Larvae:	**160**	**120**		**40**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table D1-5. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP05.

Survey: SCWP05
Survey Date: 08/11/09

			SCREENED		UNSCREENED	
Taxon	**Common Name**	**Total Count**	**Count**	**Mean Concentration (#/1,000 m^3)**	**Count**	**Mean Concentration (#/1,000 m^3)**
Entrainable Fish Larvae						
CIQ goby complex	gobies	1	-	-	1	5.20
	Total Entrainable Fish Larvae:	**1**	**0**		**1**	
Fish Eggs						
fish eggs (undeveloped)	undeveloped fish eggs	136	46	324.70	90	459.10
Citharichthys spp. (eggs)	sanddab eggs	8	4	29.10	4	20.40
	Total Fish Eggs:	**144**	**50**		**94**	
Target Invertebrate Larvae						
Thoridae/Hippolytidae	shrimps	197	155	1,173.80	42	216.40
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	39	14	95.70	25	129.50
Metacarcinus anthonyi (megalops)	yellow crab megalops	25	11	74.20	14	73.60
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	10	4	26.40	6	31.10
Cancridae (megalops)	cancer crabs megalops	4	2	13.20	2	10.50
Heptacarpus sitchensis	Sitka coastal shrimp	3	3	21.00	-	-
Crangonidae	sand shrimps	1	1	7.60	-	-
Penaeidae	penaeid shrimps	1	-	-	1	5.20
	Total Target Invertebrate Larvae:	**280**	**190**		**90**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table D1-6. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP06.

Survey: SCWP06
Survey Date: 09/16/09

Taxon	Common Name	Total Count	SCREENED Count	SCREENED Mean Concentration (#/1,000 m^3)	UNSCREENED Count	UNSCREENED Mean Concentration (#/1,000 m^3)
Entrainable Fish Larvae						
Liparis spp.	snailfishes	4	1	6.30	3	18.00
larval fish - damaged	damaged larval fishes	3	1	6.30	2	13.60
CIQ goby complex	gobies	1	-	-	1	5.80
	Total Entrainable Fish Larvae:	**8**	**2**		**6**	
Non- Entrainable Fish Larvae						
Sebastes mystinus	blue rockfish	2	-	-	2	12.10
Artedius harringtoni	scalyhead sculpin	1	-	-	1	5.11
Sebastes spp.	rockfishes	1	-	-	1	5.11
	Total Non-Entrainable Fish Larvae	**4**			**4**	
Fish Eggs						
fish eggs (undeveloped)	undeveloped fish eggs	903	380	2,411.20	523	3,108.90
Citharichthys spp. (eggs)	sanddab eggs	150	71	455.50	79	470.50
Engraulidae (eggs)	anchovy eggs	5	1	5.90	4	20.50
Sciaenidae/Paralichthyidae (eggs)	fish eggs	4	3	17.80	1	5.80
	Total Fish Eggs:	**1,062**	**455**		**607**	
Target Invertebrate Larvae						
Thoridae/Hippolytidae	shrimps	682	492	3,143.00	190	1,162.10
Metacarcinus anthonyi (megalops)	yellow crab megalops	25	21	132.00	4	24.60
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	13	3	18.90	10	61.70
Cancridae damaged (megalops)	damaged cancer crab megalops	2	2	11.90	-	-
Heptacarpus spp.	tidepool shrimps	2	2	12.70	-	-
Alpheidae	shrimps	1	1	6.30	-	-
Cancridae (megalops)	cancer crabs megalops	1	-	-	1	5.80
Heptacarpus sitchensis	Sitka coastal shrimp	1	1	6.30	-	-
	Total Target Invertebrate Larvae:	**727**	**522**		**205**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table D1-7. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP07.

Survey: SCWP07
Survey Date: 10/16/09

Taxon	Common Name	Total Count	SCREENED Count	SCREENED Mean Concentration (#/1,000 m^3)	UNSCREENED Count	UNSCREENED Mean Concentration (#/1,000 m^3)
Entrainable Fish Larvae						
Aulorhynchus flavidus	tubesnout	3	1	5.60	2	10.50
Gobiesox spp.	clingfishes	2	1	5.20	1	5.40
Gobiesocidae	clingfishes	1	-	-	1	5.00
Gobiidae	gobies	1	1	5.60	-	-
Liparis spp.	snailfishes	1	-	-	1	5.10
	Total Entrainable Fish Larvae:	**8**	**3**		**5**	
Non- Entrainable Fish Larvae						
Sebastes mystinus	blue rockfish	1	-	-	1	5.40
	Total Non-Entrainable Fish Larvae	**1**			**1**	
Fish Eggs						
fish eggs (undeveloped)	undeveloped fish eggs	1,793	916	5,047.90	877	4,663.90
Genyonemus lineatus (eggs)	white croaker eggs	92	42	231.30	50	266.30
Citharichthys spp. (eggs)	sanddab eggs	67	26	139.90	41	216.50
Sciaenidae/Paralichthyidae (eggs)	fish eggs	40	20	109.10	20	107.80
Pleuronichthys spp. (eggs)	turbot eggs	10	10	55.70	-	-
	Total Fish Eggs:	**2,002**	**1,014**		**988**	
Target Invertebrate Larvae						
Thoridae/Hippolytidae	shrimps	85	37	199.00	48	252.90
Heptacarpus spp.	tidepool shrimps	19	18	97.20	1	5.40
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	16	3	16.70	13	69.00
Metacarcinus anthonyi (megalops)	yellow crab megalops	11	3	16.20	8	42.40
Alpheidae	shrimps	7	6	31.70	1	5.00
Crangonidae	sand shrimps	4	3	15.50	1	5.00
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	1	-	-	1	5.40
	Total Target Invertebrate Larvae:	**143**	**70**		**73**	

Samples may have been split. Count and concentration are based on adjusted split count.

Table D1-8. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP08.

Survey: SCWP08
Survey Date: 11/17/09

Taxon	Common Name	Total Count	SCREENED Count	SCREENED Mean Concentration (#/1,000 m^3)	UNSCREENED Count	UNSCREENED Mean Concentration (#/1,000 m^3)
Entrainable Fish Larvae						
CIQ goby complex	gobies	2	-	-	2	11.20
Cottidae	sculpins	1	-	-	1	5.60
	Total Entrainable Fish Larvae:	**3**	**0**		**3**	
Fish Eggs*						
fish eggs (undeveloped)	undeveloped fish eggs	312	157	899.60	155	845.40
Citharichthys spp. (eggs)	sanddab eggs	25	8	46.00	17	93.30
Genyonemus lineatus (eggs)	white croaker eggs	3	-	-	3	16.40
Sciaenidae/Paralichthyidae (eggs)	fish eggs	1	1	5.70	-	-
	Total Fish Eggs:	**341**	**166**		**175**	
Target Invertebrate Larvae						
Crangonidae	sand shrimps	1,238	298	1,695.70	940	5,076.40
Thoridae/Hippolytidae	shrimps	50	17	98.20	33	184.60
Alpheidae	shrimps	18	5	28.40	13	71.60
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	18	5	28.40	13	71.60
Heptacarpus spp.	tidepool shrimps	9	8	46.30	1	5.20
Metacarcinus anthonyi (megalops)	yellow crab megalops	6	2	11.60	4	22.00
	Total Target Invertebrate Larvae:	**1,339**	**335**		**1,004**	

Samples may have been split. Count and concentration are based on adjusted split count.
***** Fish eggs not sorted from all samples.

Table D1-9. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP09.

Survey: SCWP09
Survey Date: 12/15/09

			SCREENED		UNSCREENED	
Taxon	**Common Name**	**Total Count**	**Count**	**Mean Concentration (#/1,000 m^3)**	**Count**	**Mean Concentration (#/1,000 m^3)**
Entrainable Fish Larvae						
larval fish - damaged	damaged larval fishes	9	8	50.30	1	5.60
Genyonemus lineatus	white croaker	4	4	24.80	-	-
CIQ goby complex	gobies	2	-	-	2	11.70
Cottidae	sculpins	2	-	-	2	11.70
Citharichthys sordidus	Pacific sanddab	1	1	6.20	-	-
Citharichthys stigmaeus	speckled sanddab	1	-	-	1	5.60
Leptocottus armatus	Pacific staghorn sculpin	1	1	6.20	-	-
	Total Entrainable Fish Larvae:	**20**	**14**		**6**	
Non- Entrainable Fish Larvae						
Aulorhynchus flavidus	tubesnout	1	-	-	1	6.60
Cymatogaster aggregata	shiner surfperch	1	-	-	1	6.10
	Total Non-Entrainable Fish Larvae	**2**			**2**	
Target Invertebrate Larvae						
Thoridae/Hippolytidae	shrimps	53	27	172.30	26	154.00
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	22	8	50.40	14	82.90
Crangonidae	sand shrimps	21	6	37.30	15	90.20
Metacarcinus anthonyi (megalops)	yellow crab megalops	9	5	31.00	4	23.40
Cancridae (megalops)	cancer crabs megalops	4	2	12.60	2	11.20
Heptacarpus sitchensis	Sitka coastal shrimp	4	4	25.20	-	-
Alpheidae	shrimps	1	-	-	1	6.00
	Total Target Invertebrate Larvae:	**114**	**52**		**62**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table D1-10. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP10.

Survey: SCWP10
Survey Date: 01/15/10

			SCREENED		UNSCREENED	
Taxon	**Common Name**	**Total Count**	**Count**	**Mean Concentration (#/1,000 m^3)**	**Count**	**Mean Concentration (#/1,000 m^3)**
Entrainable Fish Larvae						
CIQ goby complex	gobies	1	1	6.60	-	-
	Total Entrainable Fish Larvae:	**1**	**1**		**0**	
Target Invertebrate Larvae						
Thoridae/Hippolytidae	shrimps	8	5	32.40	3	19.50
Alpheidae	shrimps	1	-	-	1	6.50
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	1	-	-	1	6.50
	Total Target Invertebrate Larvae:	**10**	**5**		**5**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table D1-11. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP11.

Survey: SCWP11
Survey Date: 02/23/10

Taxon	Common Name	Total Count	SCREENED Count	SCREENED Mean Concentration (#/1,000 m^3)	UNSCREENED Count	UNSCREENED Mean Concentration (#/1,000 m^3)
Entrainable Fish Larvae						
Genyonemus lineatus	white croaker	43	22	122.60	21	117.00
larvae, yolksac	yolksac larvae	12	6	33.40	6	33.70
larval fish - damaged	damaged larval fishes	10	3	16.60	7	38.90
Engraulis mordax	northern anchovy	4	2	11.10	2	11.30
Cottidae	sculpins	3	1	5.50	2	11.30
Leptocottus armatus	Pacific staghorn sculpin	2	2	11.20	-	-
Agonidae	poachers	1	-	-	1	5.70
Artedius spp.	sculpins	1	-	-	1	5.50
Gibbonsia spp.	kelpfishes	1	-	-	1	5.70
Neoclinus spp.	fringeheads	1	1	5.60	-	-
	Total Entrainable Fish Larvae:	**78**	**37**		**41**	
Target Invertebrate Larvae						
Alpheidae	shrimps	5	2	11.20	3	16.90
Heptacarpus sitchensis	Sitka coastal shrimp	4	1	5.50	3	16.90
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	4	1	5.60	3	16.90
Thoridae/Hippolytidae	shrimps	2	-	-	2	11.20
	Total Target Invertebrate Larvae:	**15**	**4**		**11**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table D1-12. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP12.

Survey: SCWP12
Survey Date: 03/19/10

			SCREENED		UNSCREENED	
Taxon	**Common Name**	**Total Count**	**Count**	**Mean Concentration (#/1,000 m^3)**	**Count**	**Mean Concentration (#/1,000 m^3)**
Entrainable Fish Larvae						
Pholidae	gunnels	10	1	6.00	9	54.60
Aulorhynchus flavidus	tubesnout	8	1	6.00	7	42.20
Stichaeidae	pricklebacks	6	-	-	6	36.70
Genyonemus lineatus	white croaker	2	-	-	2	12.30
Gibbonsia spp.	kelpfishes	1	-	-	1	5.80
Gobiesocidae	clingfishes	1	-	-	1	6.20
larvae, yolksac	yolksac larvae	1	1	6.10	-	-
Leptocottus armatus	Pacific staghorn sculpin	1	1	7.10	-	-
Xiphister spp.	pricklebacks	1	1	6.00	-	-
	Total Entrainable Fish Larvae:	**31**	**5**		**26**	
Target Invertebrate Larvae						
Thoridae/Hippolytidae	shrimps	227	17	109.60	210	1,271.50
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	51	16	104.70	35	209.90
Alpheidae	shrimps	24	8	54.60	16	95.10
Metacarcinus anthonyi (megalops)	yellow crab megalops	6	2	14.20	4	24.70
Cancridae (megalops)	cancer crabs megalops	5	3	21.30	2	12.40
Heptacarpus spp.	tidepool shrimps	5	1	5.90	4	24.60
Crangonidae	sand shrimps	2	-	-	2	12.00
Heptacarpus sitchensis	Sitka coastal shrimp	2	1	6.10	1	5.80
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	1	-	-	1	6.20
	Total Target Invertebrate Larvae:	**323**	**48**		**275**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

Table D1-13. Wharf station larval counts and mean concentrations (#/1,000 m^3), SCWP13.

Survey: SCWP13
Survey Date: 05/03/10

			SCREENED		UNSCREENED	
Taxon	**Common Name**	**Total Count**	**Count**	**Mean Concentration (#/1,000 m^3)**	**Count**	**Mean Concentration (#/1,000 m^3)**
Entrainable Fish Larvae						
Aulorhynchus flavidus	tubesnout	23	14	117.90	8	49.87
Genyonemus lineatus	white croaker	4	2	16.90	2	16.60
Cottidae	sculpins	2	2	16.30	-	-
Sebastes spp.	rockfishes	2	1	8.60	1	8.30
Gibbonsia spp.	kelpfishes	1	1	8.60	-	-
Gobiesocidae	clingfishes	1	1	8.60	-	-
larval fish - damaged	damaged larval fishes	1	-	-	1	8.30
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.60	-	-
Stichaeidae	pricklebacks	1	1	8.60	-	-
	Total Entrainable Fish Larvae:	**35**	**23**		**12**	
Non- Entrainable Fish Larvae						
Aulorhynchus flavidus	tubesnout	1	-	-	1	10.50
	Total Non-Entrainable Fish Larvae	**1**			**1**	
Target Invertebrate Larvae						
Romaleon anten./Metacarcinus grac. (meg.)	cancer crabs	1,828	1,257	10,649.20	571	4,738.40
Thoridae/Hippolytidae	shrimps	81	54	441.90	27	223.10
Cancridae (megalops)	cancer crabs megalops	65	56	469.10	9	73.50
Metacarcinus anthonyi (megalops)	yellow crab megalops	52	32	273.90	20	163.60
Cancer productus/Romaleon spp. (megalops)	rock crab megalops	47	31	260.50	16	132.90
Crangonidae	sand shrimps	18	11	91.70	7	58.20
Heptacarpus spp.	tidepool shrimps	3	-	-	3	22.30
Alpheidae	shrimps	1	1	8.30	-	-
	Total Target Invertebrate Larvae:	**2,095**	**1,442**		**653**	

Samples may have been split. Count and concentration are based on adjusted split count.
Fish eggs not sorted from samples in this survey.

D2. Wharf Station Larval Fish Lengths

Table D2-1. Wharf station larval fish lengths, SCWP01.

Survey: **SCWP01**
Start Date: **April 16, 2009**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
Genyonemus lineatus	white croaker	17	12	4.94-7.64	5.75	9	1.02-1.77	1.28	10	0.77-1.34	1.02
larval fish - damaged	damaged larval fishes	9	0	-	-	0	-	-	0	-	-
Aulorhynchus flavidus	tubesnout	2	2	5.82-8.35	7.09	2	0.81-0.97	0.89	2	0.81-1.14	0.98
Cottidae	sculpins	2	2	3.79-4.19	3.99	0	-	-	2	0.43-0.65	0.54
Agonidae	poachers	1	1	3.96	3.96	1	0.77	0.77	1	0.89	0.89
Artedius spp.	sculpins	1	1	2.64	2.64	0	-	-	1	0.37	0.37
CIQ goby complex	gobies	1	1	4.03	4.03	1	0.58	0.58	1	0.37	0.37
Cottus asper	prickly sculpin	1	1	4.24	4.24	1	0.52	0.52	1	0.44	0.44
Leptocottus armatus	Pacific staghorn sculpin	1	1	4.46	4.46	1	0.78	0.78	1	0.69	0.69
	SCREENED INTAKE TOTAL:	**35**	**21**			**15**			**19**		
UNSCREENED INTAKE											
larval fish - damaged	damaged larval fishes	5	0	-	-	0	-	-	0	-	-
Cottidae	sculpins	2	2	4.01-4.49	4.25	2	0.52-0.68	0.60	2	0.43-0.49	0.46
Aulorhynchus flavidus	tubesnout	1	1	6.57	6.57	0	-	-	1	0.73	0.73
Cyclopteridae	snailfishes	1	1	13.21	13.21	1	3.02	3.02	1	3.05	3.05
larval/post-larval fish	larval fishes	1	0	-	-	0	-	-	0	-	-
Pholidae	gunnels	1	1	12.06	12.06	1	1.03	1.03	1	1.01	1.01
Scorpaenichthys marmor.	cabezon	1	0	-	-	0	-	-	0	-	-
	UNSCREENED INTAKE TOTAL:	**12**	**5**			**4**			**5**		

Table D2-2. Wharf station larval fish lengths, SCWP02.

Survey: **SCWP02**
Start Date: **May 12, 2009**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	Common Name	Total Count	Meas. Count	Range (mm)	Average (mm)	Meas. Count	Range (mm)	Average (mm)	Meas. Count	Range (mm)	Average (mm)
SCREENED INTAKE											
Aulorhynchus flavidus	tubesnout	17	10	4.92-8.21	6.07	8	0.82-1.16	0.92	8	0.66-1.16	0.89
larval fish - damaged	damaged larval fishes	7	0	-	-	0	-	-	0	-	-
CIQ goby complex	gobies	5	5	3.03-3.64	3.32	3	0.36-0.46	0.43	3	0.34-0.52	0.43
Agonidae	poachers	1	0	-	-	0	-	-	0	-	-
Cebidichthys violaceus	monkeyface prickleback	1	1	14.84	14.84	1	1.40	1.40	1	1.38	1.38
Cottidae	sculpins	1	0	-	-	0	-	-	0	-	-
Gibbonsia spp.	kelpfishes	1	0	-	-	0	-	-	0	-	-
Gillichthys mirabilis	longjaw mudsucker	1	1	4.13	4.13	0	-	-	1	0.51	0.51
Leptocottus armatus	Pacific staghorn sculpin	1	1	4.98	4.98	1	0.92	0.92	1	1.05	1.05
Oligocottus snyderi	fluffy sculpin	1	1	3.72	3.72	1	0.83	0.83	1	0.64	0.64
Osmeridae	smelts	1	1	10.73	10.73	1	0.62	0.62	1	0.81	0.81
	SCREENED INTAKE TOTAL:	**37**	**20**			**15**			**16**		
UNSCREENED INTAKE											
Aulorhynchus flavidus	tubesnout	13	3	5.13-8.46	7.20	2	1.05-1.12	1.08	3	0.81-1.16	0.99
Sebastes spp.	rockfishes	6	0	-	-	0	-	-	0	-	-
Cyclopteridae	snailfishes	4	2	14.0-14.1	14.07	2	3.50-3.72	3.61	2	3.77-3.96	3.86
larval fish - damaged	damaged larval fishes	4	0	-	-	0	-	-	0	-	-
Agonidae	poachers	1	0	-	-	0	-	-	0	-	-
Cottidae	sculpins	1	0	-	-	0	-	-	0	-	-
	UNSCREENED INTAKE TOTAL:	**29**	**5**			**4**			**5**		

Table D2-3. Wharf station larval fish lengths, SCWP03.

Survey: **SCWP03**
Start Date: **June 16, 2009**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
CIQ goby complex	gobies	4	0	-	-	0	-	-	0	-	-
Cottidae	sculpins	4	2	2.15-2.17	2.16	2	0.35-0.38	0.37	1	0.38	0.38
Gobiesocidae	clingfishes	3	2	13.7-13.8	13.74	2	2.80-2.97	2.88	2	4.06-4.18	4.12
Gobiesox spp.	clingfishes	1	1	3.67	3.67	1	0.64	0.64	1	0.64	0.64
larval fish - damaged	damaged larval fishes	1	0	-	-	0	-	-	0	-	-
unid. larvae, yolksac	yolksac larvae	1	0	-	-	0	-	-	0	-	-
	SCREENED INTAKE TOTAL:	**14**	**5**			**5**			**4**		
UNSCREENED INTAKE											
Cebidichthys violaceus	monkeyface prickleback	1	1	15.25	15.25	1	1.56	1.56	1	1.63	1.63
Cottidae	sculpins	1	0	-	-	0	-	-	0	-	-
larval fish - damaged	damaged larval fishes	1	0	-	-	0	-	-	0	-	-
Rhinogobiops nicholsi	blackeye goby	1	1	2.26	2.26	1	0.36	0.36	1	0.26	0.26
	UNSCREENED INTAKE TOTAL:	**4**	**2**			**2**			**2**		

Table D2-4. Wharf station larval fish lengths, SCWP04.

Survey: **SCWP04**
Start Date: **July 14, 2009**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
Gobiesocidae	clingfishes	1	1	15.72	15.72	1	2.95	2.95	1	5.86	5.86
	SCREENED INTAKE TOTAL:	**1**	**1**			**1**			**1**		
UNSCREENED INTAKE											
Gobiesox spp.	clingfishes	1	1	3.31	3.31	0	-	-	1	0.50	0.50
	UNSCREENED INTAKE TOTAL:	**1**	**1**			**0**			**1**		

Table D2-5. Wharf station larval fish lengths, SCWP05.

Survey: **SCWP05**
Start Date: **August 11, 2009**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
No Fish											
	SCREENED INTAKE TOTAL:	**0**	**0**			**0**			**0**		
UNSCREENED INTAKE											
CIQ goby complex	gobies	1	0	-	-	0	-	-	0	-	-
	UNSCREENED INTAKE TOTAL:	**1**	**0**			**0**			**0**		

Table D2-6. Wharf station larval fish lengths, SCWP06.

Survey: **SCWP06**
Start Date: **September 16, 2009**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
larval fish - damaged	damaged larval fishes	1	0	-	-	0	-	-	0	-	-
Liparis spp.	snailfishes	1	1	7.30	7.30	1	2.19	2.19	1	2.05	2.05
	SCREENED INTAKE TOTAL:	**2**	**1**			**1**			**1**		
UNSCREENED INTAKE											
Liparis spp.	snailfishes	3	3	8.44-8.66	8.52	3	2.23-2.61	2.39	3	1.94-2.43	2.12
larval fish - damaged	damaged larval fishes	2	0	-	-	0	-	-	0	-	-
Sebastes mystinus	blue rockfish	2	0	-	-	0	-	-	0	-	-
Artedius harringtoni	scalyhead sculpin	1	0	-	-	0	-	-	0	-	-
CIQ goby complex	gobies	1	1	3.44	3.44	1	0.58	0.58	1	0.39	0.39
Sebastes spp.	rockfishes	1	0	-	-	0	-	-	0	-	-
	UNSCREENED INTAKE TOTAL:	**10**	**4**			**4**			**4**		

Table D2-7. Wharf station larval fish lengths, SCWP07.

Survey: **SCWP07**
Start Date: **October 16, 2009**

Taxon	Common Name	Total Count	Meas. Count	FISH LENGTH Range (mm)	FISH LENGTH Average (mm)	HEAD CAPSULE DEPTH Meas. Count	HEAD CAPSULE DEPTH Range (mm)	HEAD CAPSULE DEPTH Average (mm)	HEAD CAPSULE WIDTH Meas. Count	HEAD CAPSULE WIDTH Range (mm)	HEAD CAPSULE WIDTH Average (mm)
SCREENED INTAKE											
Aulorhynchus flavidus	tubesnout	1	1	9.36	9.36	1	1.01	1.01	1	1.05	1.05
Gobiesox spp.	clingfishes	1	1	3.43	3.43	1	0.59	0.59	1	0.63	0.63
Gobiidae	gobies	1	0	-	-	0	-	-	0	-	-
	SCREENED INTAKE TOTAL:	**3**	**2**			**2**			**2**		
UNSCREENED INTAKE											
Aulorhynchus flavidus	tubesnout	2	2	5.97-6.81	6.39	2	0.74-1.06	0.90	2	0.87-0.94	0.91
Gobiesocidae	clingfishes	1	1	3.44	3.44	1	0.65	0.65	1	0.69	0.69
Gobiesox spp.	clingfishes	1	1	4.56	4.56	1	0.71	0.71	1	0.82	0.82
Liparis spp.	snailfishes	1	1	8.39	8.39	1	2.71	2.71	1	2.36	2.36
Sebastes mystinus	blue rockfish	1	0	-	-	0	-	-	0	-	-
	UNSCREENED INTAKE TOTAL:	**6**	**5**			**5**			**5**		

Table D2-8. Wharf station larval fish lengths, SCWP08.

Survey: **SCWP08**
Start Date: **November 17, 2009**

			FISH LENGTH			HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	Common Name	Total Count	Meas. Count	Range (mm)	Average (mm)	Meas. Count	Range (mm)	Average (mm)	Meas. Count	Range (mm)	Average (mm)
SCREENED INTAKE											
No Fish											
	SCREENED INTAKE TOTAL:	**0**	**0**			**0**			**0**		
UNSCREENED INTAKE											
CIQ goby complex	gobies	2	2	3.42-4.34	3.88	2	0.45-0.54	0.49	2	0.34-0.39	0.36
Cottidae	sculpins	1	0	-	-	0	-	-	0	-	-
	UNSCREENED INTAKE TOTAL:	**3**	**2**			**2**			**2**		

Table D2-9. Wharf station larval fish lengths, SCWP09.

Survey: **SCWP09**
Start Date: **December 15, 2009**

			FISH LENGTH			HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
larval fish - damaged	damaged larval fishes	8	0	-	-	0	-	-	0	-	-
Genyonemus lineatus	white croaker	4	2	1.78-1.98	1.88	1	0.30	0.30	2	0.33-0.39	0.36
Citharichthys sordidus	Pacific sanddab	1	1	2.45	2.45	1	0.27	0.27	1	0.26	0.26
Leptocottus armatus	Pacific staghorn sculpin	1	1	3.54	3.54	1	0.69	0.69	1	0.56	0.56
	SCREENED INTAKE TOTAL:	**14**	**4**			**3**			**4**		
UNSCREENED INTAKE											
CIQ goby complex	gobies	2	1	3.49	3.49	1	0.46	0.46	1	0.35	0.35
Cottidae	sculpins	2	1	2.41	2.41	1	0.35	0.35	1	0.43	0.43
Aulorhynchus flavidus	tubesnout	1	0	-	-	0	-	-	0	-	-
Citharichthys stigmaeus	speckled sanddab	1	1	2.48	2.48	1	0.29	0.29	1	0.25	0.25
Cymatogaster aggregata	shiner surfperch	1	0	-	-	0	-	-	0	-	-
larval fish - damaged	damaged larval fishes	1	0	-	-	0	-	-	0	-	-
	UNSCREENED INTAKE TOTAL:	**8**	**3**			**3**			**3**		

Table D2-10. Wharf station larval fish lengths, SCWP10.

Survey: **SCWP10**
Start Date: **January 15, 2010**

			FISH LENGTH			HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
CIQ goby complex	gobies	1	1	3.63	3.63	1	0.51	0.51	1	0.50	0.50
	SCREENED INTAKE TOTAL:	**1**	**1**			**1**			**1**		
UNSCREENED INTAKE											
No Fish											
	UNSCREENED INTAKE TOTAL:	**0**	**0**			**0**			**0**		

Table D2-11. Wharf station larval fish lengths, SCWP11.

Survey: **SCWP11**
Start Date: **February 23, 2010**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
Genyonemus lineatus	white croaker	22	18	1.75-2.93	2.38	17	0.19-0.67	0.48	18	0.16-0.50	0.40
unid. larvae, yolksac	yolksac larvae	6	0	-	-	0	-	-	0	-	-
larval fish - damaged	damaged larval fishes	3	0	-	-	0	-	-	0	-	-
Engraulis mordax	northern anchovy	2	0	-	-	0	-	-	0	-	-
Leptocottus armatus	Pacific staghorn sculpin	2	0	-	-	0	-	-	0	-	-
Cottidae	sculpins	1	0	-	-	0	-	-	0	-	-
Neoclinus spp.	fringeheads	1	0	-	-	0	-	-	0	-	-
	SCREENED INTAKE TOTAL:	**37**	**18**			**17**			**18**		
UNSCREENED INTAKE											
Genyonemus lineatus	white croaker	21	16	1.88-2.74	2.23	16	0.31-0.59	0.40	16	0.29-0.43	0.36
larval fish - damaged	damaged larval fishes	7	0	-	-	0	-	-	0	-	-
unid. larvae, yolksac	yolksac larvae	6	0	-	-	0	-	-	0	-	-
Cottidae	sculpins	2	1	1.78	1.78	1	0.35	0.35	1	0.35	0.35
Engraulis mordax	northern anchovy	2	1	6.30	6.30	1	0.52	0.52	1	0.54	0.54
Agonidae	poachers	1	1	4.65	4.65	1	1.07	1.07	1	1.32	1.32
Artedius spp.	sculpins	1	1	3.28	3.28	1	0.63	0.63	1	0.37	0.37
Gibbonsia spp.	kelpfishes	1	1	9.77	9.77	1	0.97	0.97	1	1.02	1.02
	UNSCREENED INTAKE TOTAL:	**41**	**21**			**21**			**21**		

Table D2-12. Wharf station larval fish lengths, SCWP12.

Survey: **SCWP12**
Start Date: **March 19, 2010**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
Aulorhynchus flavidus	tubesnout	1	1	6.13	6.13	1	0.90	0.90	1	0.76	0.76
Leptocottus armatus	Pacific staghorn sculpin	1	1	3.75	3.75	1	0.68	0.68	1	0.66	0.66
Pholidae	gunnels	1	1	11.55	11.55	1	0.97	0.97	1	1.11	1.11
unid. larvae, yolksac	yolksac larvae	1	0	-	-	0	-	-	0	-	-
Xiphister spp.	pricklebacks	1	1	7.40	7.40	1	0.84	0.84	1	0.82	0.82
	SCREENED INTAKE TOTAL:	**5**	**4**			**4**			**4**		
UNSCREENED INTAKE											
Pholidae	gunnels	9	9	7.53-12.3	10.23	9	0.94-1.11	1.03	9	0.97-1.18	1.04
Aulorhynchus flavidus	tubesnout	7	7	5.40-6.12	5.76	7	0.84-0.95	0.92	7	0.81-0.91	0.85
Stichaeidae	pricklebacks	6	6	6.22-7.34	6.80	6	0.81-0.85	0.82	6	0.77-0.87	0.81
Genyonemus lineatus	white croaker	2	2	1.74-8.74	5.24	2	0.24-2.65	1.44	2	0.18-1.71	0.95
Gibbonsia spp.	kelpfishes	1	1	5.55	5.55	1	0.59	0.59	1	0.62	0.62
Gobiesocidae	clingfishes	1	1	5.14	5.14	1	0.94	0.94	1	0.90	0.90
	UNSCREENED INTAKE TOTAL:	**26**	**26**			**26**			**26**		

Table D2-13. Wharf station larval fish lengths, SCWP13.

Survey: **SCWP13**
Start Date: **May 3, 2010**

				FISH LENGTH		HEAD CAPSULE DEPTH			HEAD CAPSULE WIDTH		
Taxon	**Common Name**	**Total Count**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**	**Meas. Count**	**Range (mm)**	**Average (mm)**
SCREENED INTAKE											
Aulorhynchus flavidus	tubesnout	14	13	4.72-6.11	5.55	13	0.75-0.92	0.84	13	0.65-1.00	0.87
Cottidae	sculpins	2	1	1.96	1.96	1	0.43	0.43	1	0.33	0.33
Genyonemus lineatus	white croaker	2	2	4.05-7.48	5.77	2	0.95-1.81	1.38	2	0.65-1.18	0.91
Gibbonsia spp.	kelpfishes	1	1	5.89	5.89	1	0.70	0.70	1	0.81	0.81
Gobiesocidae	clingfishes	1	1	3.76	3.76	1	0.59	0.59	1	0.66	0.66
Leptocottus armatus	Pacific staghorn sculpin	1	1	2.77	2.77	1	1.33	1.33	1	1.33	1.33
Sebastes spp.	rockfishes	1	1	3.63	3.63	1	0.68	0.68	1	0.46	0.46
Stichaeidae	pricklebacks	1	1	10.56	10.56	1	1.04	1.04	1	0.94	0.94
	SCREENED INTAKE TOTAL:	**23**	**21**			**21**			**21**		
UNSCREENED INTAKE											
Aulorhynchus flavidus	tubesnout	9	9	5.13-6.39	5.69	9	0.73-6.74	1.49	9	0.81-6.08	1.45
Genyonemus lineatus	white croaker	2	2	4.09-4.66	4.37	2	1.03-1.10	1.07	2	0.67-0.76	0.71
larval fish - damaged	damaged larval fishes	1	0	-	-	0	-	-	0	-	-
Sebastes spp.	rockfishes	1	1	23.78	23.78	1	6.25	6.25	1	5.43	5.43
	UNSCREENED INTAKE TOTAL:	**13**	**12**			**12**			**12**		

D3. Wharf Station Water Quality Measurements

Table D3-1. Wharf station water quality data, April – June 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Wharf-Day							
04/16/09	15:54	0	10.93	NS	8.83	7.92	0.9
04/16/09	15:54	1	10.95	NS	8.92	7.96	0.7
Wharf-Night							
04/16/09	20:25	0	11.80	NS	8.86	7.95	1.4
04/16/09	20:25	1	11.76	NS	8.82	7.96	1.7
Wharf-Day							
05/12/09	14:20	0	16.50	32.05	10.53	7.82	-1.5
05/12/09	14:20	1	15.27	32.41	11.15	7.77	-0.9
05/12/09	14:20	2	13.88	33.24	11.45	7.75	0.1
05/12/09	14:20	3	13.37	33.33	11.69	7.77	-0.3
05/12/09	14:20	4	13.05	33.36	11.59	7.60	-0.4
05/12/09	14:20	5	12.95	33.37	11.41	7.64	0.0
05/12/09	14:20	6	12.92	33.38	11.19	7.61	-0.1
Wharf-Night							
05/12/09	19:50	0	16.05	31.38	10.65	8.04	-1.0
05/12/09	19:50	1	15.32	32.89	11.45	8.01	-1.5
05/12/09	19:50	2	15.29	33.10	11.82	8.01	-1.3
05/12/09	19:50	3	13.68	33.38	12.94	7.93	-0.3
05/12/09	19:50	4	12.97	33.42	12.58	7.85	1.1
05/12/09	19:50	5	12.53	33.41	8.48	7.67	0.4
05/12/09	19:50	6	12.42	33.47	11.08	7.75	1.3
05/12/09	19:50	7	12.28	33.44	10.06	7.67	2.7
05/12/09	19:50	8	12.24	33.48	9.35	7.54	2.0
Wharf-Day							
06/16/09	14:53	0	16.60	NS	9.81	NS	NS
06/16/09	14:53	1	16.69	34.23	9.68	8.30	0.0
06/16/09	14:53	2	16.53	34.22	10.12	8.29	0.0
06/16/09	14:53	3	16.47	34.22	10.29	8.30	0.0
06/16/09	14:53	4	16.32	34.28	10.59	8.27	0.0
06/16/09	14:53	5	16.25	34.28	10.92	8.30	0.0
06/16/09	14:53	6	16.22	34.28	11.23	8.32	0.0
06/16/09	14:53	7	16.17	34.35	11.48	8.32	0.0
06/16/09	14:53	8	15.98	34.33	11.09	8.28	0.0
06/16/09	14:53	9	15.49	34.30	10.79	8.12	22.1
Wharf-Night							
06/16/09	22:03	0	17.12	34.26	11.65	8.28	0.0
06/16/09	22:03	1	17.11	34.26	11.74	8.28	0.0
06/16/09	22:03	2	17.03	34.33	11.70	8.27	0.0
06/16/09	22:03	3	16.43	34.29	11.00	8.20	0.0
06/16/09	22:03	4	16.06	34.27	10.61	8.20	0.4
06/16/09	22:03	5	15.55	34.23	9.64	8.08	2.1
06/16/09	22:03	6	15.09	34.20	8.51	8.03	3.5
06/16/09	22:03	7	14.73	34.33	7.44	7.89	55.8

NS – Not sampled

Table D3-2. Wharf station water quality data, July – August 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Wharf-Day							
07/14/09	12:56	0	16.20	34.74	8.51	7.99	-0.1
07/14/09	12:56	1	15.88	34.62	8.39	8.01	-0.2
07/14/09	12:56	2	15.82	34.60	8.09	8.02	-0.2
07/14/09	12:56	3	15.61	34.65	7.92	8.01	-0.2
07/14/09	12:55	4	15.36	34.64	7.71	7.99	-0.2
07/14/09	12:55	5	14.48	34.73	7.90	8.00	-0.2
07/14/09	12:55	6	13.93	34.70	8.25	7.99	-0.2
07/14/09	12:55	7	13.15	34.84	8.76	7.92	0.4
07/14/09	12:55	8	12.87	34.70	8.85	7.83	17.4
07/14/09	12:55	9	12.88	34.70	9.43	7.87	79.3
Wharf-Night							
07/14/09	20:04	0	16.85	34.77	8.85	7.98	-0.3
07/14/09	20:04	1	16.10	35.03	8.98	7.96	-0.3
07/14/09	20:04	2	15.94	34.73	8.87	7.99	-0.3
07/14/09	20:04	3	15.28	34.76	8.88	7.98	-0.1
07/14/09	20:04	4	15.09	34.83	8.79	8.00	-0.5
07/14/09	20:04	5	14.96	34.78	8.73	7.99	-0.2
07/14/09	20:03	6	14.78	34.79	8.79	7.94	-0.3
07/14/09	20:03	7	14.52	34.85	8.98	7.94	-0.2
07/14/09	20:03	8	14.01	34.79	9.56	7.88	1.8
Wharf-Day							
08/11/09	13:54	0	16.42	33.17	8.85	7.83	-2.7
08/11/09	13:54	1	16.42	33.15	8.54	7.90	-2.6
08/11/09	13:54	2	16.25	33.20	8.38	7.84	-2.8
08/11/09	13:54	3	16.07	33.23	8.27	7.80	-2.7
08/11/09	13:54	4	15.87	33.22	8.30	7.87	-2.7
08/11/09	13:54	5	15.61	33.21	8.49	7.78	-2.0
08/11/09	13:54	6	15.36	33.28	8.76	7.80	-1.6
08/11/09	13:53	7	14.57	33.30	9.30	7.74	-1.6
08/11/09	13:53	8	13.74	33.16	9.92	7.74	-1.6
08/11/09	13:53	9	13.77	33.24	9.90	7.65	-1.6
Wharf-Night							
08/11/09	19:37	0	16.63	29.47	7.47	7.90	-2.3
08/11/09	19:36	1	16.56	33.24	7.32	7.82	-2.3
08/11/09	19:36	2	16.34	33.28	7.21	7.86	-2.3
08/11/09	19:36	3	15.24	33.41	7.45	7.74	-2.3
08/11/09	19:36	4	13.76	33.32	7.95	7.66	-1.5
08/11/09	19:36	5	13.46	33.36	8.38	7.69	-2.1
08/11/09	19:36	6	13.08	33.26	8.49	7.61	-2.2
08/11/09	19:36	7	12.66	33.26	8.97	7.67	-1.7
08/11/09	19:36	8	12.62	33.18	9.28	7.63	-1.4

Table D3-3. Wharf station water quality data, September – October 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Wharf-Day							
09/16/09	11:49	0	16.08	34.66	8.81	8.11	0.4
09/16/09	11:49	1	15.31	34.65	8.63	8.18	0.4
09/16/09	11:49	2	15.06	34.69	8.50	8.16	0.4
09/16/09	11:49	3	14.78	34.65	8.44	8.08	0.7
09/16/09	11:49	4	14.66	34.65	8.44	8.07	0.6
09/16/09	11:49	5	14.64	34.62	8.56	8.15	0.9
09/16/09	11:49	6	14.57	34.67	8.76	8.09	0.8
09/16/09	11:49	7	14.52	34.66	9.01	8.06	11.9
09/16/09	11:48	8	14.52	34.67	9.48	8.09	4.8
Wharf-Night							
09/16/09	19:14	0	16.41	34.65	8.79	8.14	0.2
09/16/09	19:14	1	16.38	34.65	8.17	8.22	0.2
09/16/09	19:14	2	16.38	34.60	7.95	8.19	0.2
09/16/09	19:14	3	16.35	34.60	7.65	8.18	0.2
09/16/09	19:14	4	16.15	34.68	7.63	8.11	22.4
09/16/09	19:14	5	14.95	34.61	8.02	8.17	22.2
09/16/09	19:14	6	14.41	34.74	8.43	8.11	22.1
09/16/09	19:14	7	13.88	34.75	8.57	8.02	22.1
09/16/09	19:14	8	13.66	34.72	8.96	8.00	22.0
09/16/09	19:14	9	13.68	34.61	9.47	8.02	12.7
Wharf-Day							
10/16/09	12:12	0	14.41	31.12	7.95	8.01	3.0
10/16/09	12:12	1	13.83	32.41	8.06	7.95	2.8
10/16/09	12:12	2	13.50	33.20	8.11	7.95	2.4
10/16/09	12:12	3	13.49	33.36	7.83	7.94	2.4
10/16/09	12:12	4	13.38	33.35	7.82	7.96	2.6
10/16/09	12:12	5	13.27	33.48	8.12	7.89	2.3
10/16/09	12:12	6	13.20	33.54	8.26	7.91	3.9
10/16/09	12:12	7	13.19	33.55	8.32	7.90	3.9
10/16/09	12:12	8	13.19	33.55	8.44	7.91	3.9
Wharf-Night							
10/16/09	18:03	0	14.01	34.73	7.23	7.96	2.8
10/16/09	18:03	1	13.61	33.24	7.48	7.91	2.9
10/16/09	18:03	2	13.40	33.40	7.67	7.89	1.7
10/16/09	18:03	3	13.30	33.48	7.37	7.88	1.9
10/16/09	18:03	4	13.22	33.51	7.38	7.88	2.2
10/16/09	18:02	5	13.17	33.57	7.59	7.87	1.5
10/16/09	18:02	6	13.15	33.57	8.36	7.85	0.9
10/16/09	18:02	7	13.12	33.60	8.37	7.81	4.0
10/16/09	18:02	8	13.11	33.64	8.66	7.78	1.0

Table D3-4. Wharf station water quality data, November – December 2009.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Wharf-Day							
11/17/09	16:35	0	12.40	34.45	7.80	7.92	-0.4
11/17/09	16:35	1	12.39	34.46	7.77	7.94	-0.2
11/17/09	16:35	2	12.29	34.46	7.77	7.94	-0.4
11/17/09	16:35	3	12.23	34.47	7.79	7.92	-0.7
11/17/09	16:35	4	12.18	34.46	7.80	7.93	-0.4
11/17/09	16:35	5	12.14	34.49	7.87	7.87	-0.4
11/17/09	16:35	6	12.09	34.51	7.97	7.84	0.1
11/17/09	16:34	7	12.10	34.49	8.10	7.93	-0.6
Wharf-Night							
11/17/09	21:54	0	12.24	34.24	7.68	7.97	-0.5
11/17/09	21:54	1	12.23	34.26	7.68	7.94	-0.5
11/17/09	21:54	2	12.20	34.28	7.67	7.93	-0.6
11/17/09	21:54	3	12.18	34.27	7.64	8.00	-0.2
11/17/09	21:54	4	12.17	34.28	7.64	8.00	0.0
11/17/09	21:54	5	12.14	34.30	7.64	7.95	-0.1
11/17/09	21:54	6	12.12	34.30	7.67	7.95	-0.2
11/17/09	21:54	7	12.12	34.29	7.70	8.00	0.1
11/17/09	21:54	8	12.11	34.30	7.79	7.94	0.7
11/17/09	21:54	9	12.12	34.31	7.90	7.99	1.3
Wharf-Day							
12/15/09	13:28	0	11.72	33.38	NS	7.72	NS
12/15/09	13:27	1	11.68	34.78	NS	7.70	NS
12/15/09	13:27	2	11.69	34.78	NS	7.82	NS
12/15/09	13:27	3	11.68	34.81	NS	7.77	NS
12/15/09	13:27	4	11.68	34.84	NS	7.70	NS
12/15/09	13:27	5	11.67	34.86	NS	7.70	NS
12/15/09	13:27	6	11.76	34.82	NS	7.78	NS
12/15/09	13:27	7	11.75	34.86	NS	7.75	NS
12/15/09	13:27	8	11.76	34.87	NS	7.73	NS
Wharf-Night							
12/15/09	17:20	0	11.68	33.84	NS	7.90	NS
12/15/09	17:20	1	11.67	34.67	NS	7.88	NS
12/15/09	17:20	2	11.65	34.77	NS	7.89	NS
12/15/09	17:20	3	11.66	34.80	NS	7.88	NS
12/15/09	17:20	4	11.64	34.81	NS	7.79	NS
12/15/09	17:20	5	11.62	34.85	NS	7.83	NS
12/15/09	17:20	6	11.71	34.86	NS	7.78	NS
12/15/09	17:20	7	11.73	34.86	NS	7.89	NS

NS – Not sampled

Table D3-5. Wharf station water quality data, January – February 2010.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Wharf-Day							
01/15/10	13:05	0	12.64	33.30	8.50	7.92	1.6
01/15/10	13:03	1	12.45	34.02	8.61	7.93	1.5
01/15/10	13:04	2	12.26	34.42	8.48	7.91	4.4
01/15/10	13:03	3	12.31	34.37	8.63	7.92	4.2
01/15/10	13:03	4	12.32	34.50	8.60	7.84	2.2
01/15/10	13:04	5	12.32	34.49	8.42	7.94	1.7
01/15/10	13:04	6	12.31	34.52	8.62	7.94	1.6
01/15/10	13:04	8	12.24	34.52	8.60	7.87	20.0
Wharf-Night							
No night samples due to unsafe sampling conditions							
Wharf-Day							
02/23/10	11:41	0	12.58	31.30	8.77	8.03	0.7
02/23/10	11:40	1	12.71	32.65	8.65	7.97	0.9
02/23/10	11:40	2	12.83	33.27	8.57	8.01	1.2
02/23/10	11:40	3	12.84	33.50	8.54	8.05	0.6
02/23/10	11:40	4	12.84	33.51	8.52	8.10	1.7
02/23/10	11:40	5	12.81	33.55	8.54	8.03	4.8
02/23/10	11:40	6	12.82	33.54	8.55	8.06	2.3
02/23/10	11:40	7	12.81	33.54	8.57	8.07	2.5
02/23/10	11:40	8	12.79	33.55	8.58	8.03	10.2
Wharf-Night							
02/23/10	22:37	0	12.67	32.25	8.63	8.00	1.4
02/23/10	22:36	1	12.70	32.57	8.54	7.96	0.7
02/23/10	22:36	2	12.74	32.53	8.49	8.05	1.8
02/23/10	22:36	3	12.93	33.30	8.31	7.97	0.4
02/23/10	22:36	4	12.98	33.57	8.22	8.06	0.5
02/23/10	22:36	5	12.95	33.64	8.21	7.96	0.3
02/23/10	22:36	6	12.96	33.65	8.26	8.02	0.1
02/23/10	22:36	7	12.96	33.65	8.26	7.95	0.6
02/23/10	22:36	8	12.99	33.61	8.31	8.06	1.4
02/23/10	22:36	9	12.95	33.66	8.32	7.93	15.1
02/23/10	22:36	10	12.98	33.61	8.39	8.05	18.8

Table D3-6. Wharf station water quality data, March and May 2010.

Date	Time hr:min	Depth m	Temp °C	Salinity ppt	DO Conc mg/L	pH	Turbidity NTU
Wharf-Day							
03/19/10	12:29	0	13.89	35.58	8.70	7.97	-0.6
03/19/10	12:29	1	13.74	35.88	8.70	7.94	-0.4
03/19/10	12:29	2	13.59	36.17	8.68	7.94	-0.2
03/19/10	12:29	3	13.49	36.30	8.67	7.97	-0.5
03/19/10	12:29	4	13.42	36.40	8.64	7.97	-0.5
03/19/10	12:29	5	13.34	36.46	8.64	7.96	-0.5
03/19/10	12:29	6	13.32	36.48	8.65	7.93	-0.5
03/19/10	12:28	7	13.31	36.49	8.70	7.95	-0.4
03/19/10	12:28	8	13.31	36.49	8.74	7.96	-0.1
Wharf-Night							
03/19/10	18:51	0	13.89	35.58	8.70	7.97	-0.6
03/19/10	18:51	1	13.74	35.88	8.70	7.94	-0.5
03/19/10	18:51	2	13.76	36.36	8.33	8.02	-0.4
03/19/10	18:51	3	13.47	36.43	8.36	8.00	-0.4
03/19/10	18:51	4	13.41	36.43	8.36	8.01	-0.4
03/19/10	18:51	5	13.33	36.47	8.43	8.00	-0.2
03/19/10	18:51	6	13.28	36.51	8.44	7.99	0.1
03/19/10	18:50	7	13.25	36.52	8.52	7.98	3.2
03/19/10	18:50	8	13.25	36.53	8.60	7.99	2.7
Wharf-Day							
05/03/10	12:01	0	12.92	35.16	9.84	7.95	-4.2
05/03/10	12:01	1	12.80	35.22	9.83	7.91	-4.2
05/03/10	12:01	2	12.38	35.41	9.96	7.83	-0.4
05/03/10	12:01	3	12.27	35.41	10.05	7.81	-0.7
05/03/10	12:00	4	12.23	35.41	10.14	7.84	-0.7
05/03/10	12:00	5	12.20	35.42	10.22	7.84	-0.8
05/03/10	12:00	6	12.20	35.43	10.26	7.78	-0.5
05/03/10	12:00	7	12.22	35.43	10.25	7.82	0.3
05/03/10	12:00	8	12.23	35.44	10.24	7.83	0.3
Wharf-Night							
05/03/10	19:22	0	14.07	33.97	9.01	7.90	-0.3
05/03/10	19:22	1	13.70	34.65	8.60	7.90	-0.3
05/03/10	19:22	2	12.97	35.22	8.39	7.93	-0.3
05/03/10	19:22	3	12.53	35.31	8.31	7.90	-0.4
05/03/10	19:22	4	12.23	35.30	8.26	7.84	-0.8
05/03/10	19:22	5	12.09	35.32	8.31	7.77	0.0
05/03/10	19:22	6	11.84	35.34	8.86	7.74	0.0
05/03/10	19:22	7	11.70	35.31	9.29	7.72	0.0
05/03/10	19:22	8	11.65	35.31	9.76	7.67	0.0