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Morro Bay Power Plant Modernization Project

316(b) Resource Assessment

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EXECUTIVE SUMMARY

The purpose of this report is to assess the effects of the cooling water intake system (CWIS) of the Morro Bay Power Plant's new combined-cycle (CC) units and to evaluate alternative intake technologies with the potential to cost-effectively reduce adverse effects. The modernized plant's advanced electrical generation technology will mitigate entrainment effects by significantly reducing the amount of cooling water needed to operate the existing MBPP. The existing CWIS will be redesigned to reduce the plant's present intake of Morro Bay water by 38 percent. The project, by its more efficient use of cooling water, will decrease entrainment of Morro Bay larvae by 38 percent, while at the same time producing 20 percent more electricity. The new facility's reduced intake flows will also mitigate existing impingement effects by lowering the volume and velocity of water passing through the intake screens.

A single type of larval goby represents three-quarters of all the fishes entrained during our studies. Although these larvae cannot be positively identified to species by their appearance at size of entrainment (3 to 8 mm, 0.1 to 0.3 in.), limited DNA tests results have identified them as the arrow goby. The adult arrow goby is a one- to two-inch fish common to Pacific coast bays and estuaries. It usually lives in mudflat burrows of other animals, such as clams, shrimps, and echiuroids. This small fish has no recreational or commercial value and is not known to be a common prey item for other fishes or birds. Results of this past year's MBPP studies have shown that bay source water withdrawn by the CC project's CWIS is inherently low in diversity of larval fish species, similar to other bays and estuaries. Just six other taxa (species and groupings of species) of fish larvae in addition to the unidentified goby make up 89 percent of all the entrained fish larvae. The projected fractional losses (mortality) of entrained larvae, which averaged 10 percent for the abundant target species, represent low potential impacts to their source water populations. These projected entrainment effects, which assume that the plant's pumps operate at 100 percent capacity and that there is 100 percent mortality of organisms passing through the cooling water system, are below the 30 to 40 percent levels set by fishery management practice to maintain sustainable yields of adult stocks. The potential population level impacts of the power plant's estimated withdrawal of a relatively large fraction of the bay's combtooth blenny larvae are being further investigated. At the request of the agencies, Duke Energy has agreed to undertake a study to investigate the entrainment of clam larvae; the study will be completed by September 2001.

The field studies and data analyses for the proposed modernization project followed the 316(b) Study Plan that was developed in coordination with the Technical Working Group (TWG). The TWG was established under the auspices of the Regional Water Quality Control

Board. Findings of the completed 316(b) Resource Assessment studies are presented graphically in the report using the results of our January 2000 – December 2000 entrainment and source water field studies (Section 3.0—Entrainment and Source Water Sampling). Entrainment sampling was conducted at the MBPP intakes, and source water sampling was conducted at stations in Morro Bay and Estero Bay. Source water volumes used in the calculation of entrainment effects were determined from hydrologic data collected in Morro Bay and were approved by the TWG (see Appendix E—Calculation of a Morro Bay Source Water Volume).

The results of these 24-hour site surveys of weekly entrainment and monthly source water larval fish and megalopal crabs show the following:

- Seven taxa of larval fishes make up 89 percent of all of the entrained fish larvae. The intake location is in an area that has naturally low diversity, typical of bays and estuaries, and is unlike the area's outer coast marine habitats, where a myriad of species is found.
- Gobies (Family Gobiidae) comprised the overwhelming majority of all the fishes entrained.
- Three fish species—white croaker, Pacific herring, and cabezon—having some commercial or recreational value individually represented less than one percent of the total numbers collected.
- The proportional entrainment estimates (*PE*) were relatively low for all species analyzed.
- *ETM* estimates of P_m values, which incorporate *PE* estimates, ranged from one percent to 22 percent for most individual species. The range and overall average (10 percent) were below standard fishery management practices (30 to 40 percent) for sustainable harvests or other sources of mortality. The estimated P_m value for a taxonomic complex of three possible species of combtooth blenny (49 percent) was more than double the next closest species.

Results of *Cancer* spp. megalops concentrations collected from the same weekly entrainment and monthly source water surveys show the following:

- Six species of cancer crab megalops and unidentified cancer megalops were collected in entrainment surveys at the new CC unit's intake.
- Four of these crab species (brown rock, yellow, red rock, and Dungeness) have commercial importance.
- The *ETM* estimates of P_m were low for all species, but the estimates were based on a single survey *PE* value for several species.
- The number of adult crabs that might have resulted from the entrained megalops was low based on Fecundity Hindcast (*FH*) model results.

A summary of the estimated entrainment effects (January – December 2000) of the new CC units for the most abundantly collected fishes and cancer crabs is presented below. These values are based on analyses using the Empirical Transport Model (*ETM*) and Fecundity Hindcast (*FH*) and Adult Equivalent Loss (*AEL*) models (Section 5.0—Cooling Water Intake System Impact Assessment).

Table ES-1. Summary of estimated MBPP combined-cycle entrainment for abundant fishes and cancer crabs based on *ETM*, *FH*, and *AEL* models using entrainment and source water larval concentrations and Estero Bay study area and Morro Bay volumes (January 2000 – December 2000).

(a) Fishes

	Total Entrainment	2×*FH*	*AEL*	*ETM* [(a)] P_m [(a)]
unidentified gobies	3.9×10^8	796,298	267,850	0.1153
Pacific staghorn sculpin§	1.7×10^7	*	*	0.0513
northern lampfish§	1.5×10^7	*	*	0.0238
shadow goby	1.3×10^7	12,678	7,436	0.0279
combtooth blennies	1.0×10^7	8,722	8,084	0.4913
KGB rockfishes§	6.4×10^6	26	23	0.0240
jacksmelt	6.3×10^6	*	*	0.2194
white croaker§	3.0×10^6	106	*	0.0215
Pacific herring	3.0×10^6	86	532	0.0118
cabezon§	2.9×10^6	*	*	0.0371

(a) *ETM* values calculated using average period of entrainment risk.

§ - taxa that used an *ETM* model adjusted by P_s to estimate P_m. Average $P_m = 0.10$.

* Unavailable information or value that could not be computed.

(b) Cancer Crabs

	Total Entrainment	2×*FH*	*ETM*§ P_m [(a)]
brown rock crab§	9.7×10^6	5,192	0.0275
hairy rock crab§	2.0×10^6	1,342	0.0084
yellow crab§	1.1×10^6	630	0.0310
slender crab§	4.7×10^5	1,210	0.0079
red rock crab§	8.6×10^4	42	0.0204
Dungeness crab§	5.5×10^4	54	0.0531

(a) *ETM* values calculated using average period of entrainment risk.

§ - *ETM* model adjusted by P_s to estimate P_m. Average $P_m = 0.02$.

Impingement studies conducted at the MBPP intakes from September 1999 – September 2000 (Section 4.0—Impingement) show that:

- Five fish taxa comprised 90 percent (by number) of fish impinged (Units 1–4 combined), while seven taxa made up 91 percent of impingement by weight. The three fish species impinged in the highest numbers and biomass at the MBPP were northern anchovy, topsmelt, and plainfin midshipman. Among these, only the northern anchovy is targeted commercially in a small bait fishery in Morro Bay, while topsmelt are occasionally taken by recreational fishers. The other two fishes within the top 90 percent by abundance were speckled sanddab and Pacific staghorn sculpin.

- Twelve taxa comprised 90 percent by number of the macroinvertebrates impinged at the MBPP (Units 1–4 combined), while nine taxa made up greater than 90 percent by weight. Market squid *Loligo opalescens* were collected in highest abundance, accounting for 34 percent by number and 11 percent by weight of the impingement totals. Xantus' swimming crabs *Portunus xantusii* had the highest biomass of any invertebrate collected, accounting for 26 percent of the total biomass and nine percent of the total abundance. Five other species were in the top 90 percent by number and weight: black-tailed bay shrimp *Crangon nigricauda*, hairy rock crab *Cancer jordani*, brown rock crab *C. antennarius*, northern kelp crab *Pugettia producta*, and brown shrimp *Penaeus californiensis*.

- Estimates of the dollar value of impingement losses to individual fish taxa totaled $805, while the estimate of the dollar value of entrainment losses to fishes only totaled $246 (based on $2 \times FH$ estimates). The estimated dollar losses for cancer crabs from both entrainment and impingement total $9,582.

A set of available and proven intake technologies that could be applied at the MBPP combined-cycle site was determined. An analysis of these technologies was performed to evaluate the potential effectiveness of each alternative technology to reduce biological effects of the CWIS and to meet a number of environmental, engineering, and economic criteria. The feasibility and efficacy of each proven and available technology was analyzed and evaluated in a discussion of the various assessment criteria.

The report contains the completed assessment of alternative intake technologies in Section 6.0. Based on available technologies and the relatively low entrainment and impingement impacts projected for the new CWIS, the reduced flow and intake velocities of the new CWIS represent best available technology for the site. Any remaining potential effects or other uncertainties associated with the projected CWIS effects will be addressed, as necessary, by appropriate measures currently being discussed with regulatory and resource agency representatives. Duke Energy has undertaken a study of the feasibility and effectiveness of an intake aquatic filter barrier (AFB) to further reduce or eliminate the low potential CWIS impacts. The biological benefits as well as the environmental, engineering, and economic considerations of this intake technology are discussed in Section 6.4.5. If this or other alternative technologies prove infeasible or if the cost is wholly disproportionate to the benefits, Duke Energy believes that the plant's present CWIS, which represents best technology available (BTA), will be significantly better when combined with the CC facility's 38 percent reduction in intake volume. Our analyses show that while some scientific uncertainty exists about the significance of the remaining larval entrainment mortality, the risk of population declines is low. For the remaining CWIS effects that cannot be further reduced with available and feasible intake technology, Duke Energy will follow best management practices of: 1) reducing the operation of the cooling water pumps except as needed for the level of power generation required, 2) continued periodic biofouling control, and 3) continued periodic dredging of the intake area, to further to minimize the possibility of CWIS impacts.

In summary, the proposed new combined-cycle units' CWIS design, operated following best management practices, represents the best technology available for the site. The combined-cycle project's CWIS design with significant reductions in intake volume and approach velocities meets its BTA objectives of reducing potential CWIS impacts. The new power plant's 38 percent reduction in existing intake flows makes it a relatively straightforward exercise to project a reduction in effects with the CC-CWIS. From both past MBPP CWIS and source water studies and our present study findings, potential entrainment and impingement effects are relatively minor, and probably indistinguishable at the population level. Therefore the application of different intake technology would represent minor potential for further reductions. However, our report examines various proven and available intake technologies and their cost-effectiveness to reduce even further potential intake effects. The aquatic filter barrier technology may represent a cost-effective approach to further reduce the facility's potential CWIS effects. Out of this study we conclude that along with the new combined-cycle CWIS's lower intake flows and best management practices, the combined-cycle CWIS represents best technology available with some minor entrainment effects, but no significant population-level impacts.

1.0 INTRODUCTION

The following report presents the results of a cooling water intake technology evaluation required under Section 316(b) of the Federal Clean Water Act (CWA). A 316(b) Demonstration program was conducted in 1999-2000 at Duke Energy's Morro Bay Power Plant (MBPP) to evaluate power plant cooling water intake system (CWIS) effects and the proposed new combined-cycle units intake technology relative to Best Technology Available (BTA).[1] Duke Energy is planning to modernize the power plant and submitted its Application for Certification (AFC) to the California Energy Commission (CEC) in October 2000. Modernization project changes that are proposed will reduce the amount of cooling water withdrawn from Morro Bay and will also reduce the intake approach velocities, thereby reducing CWIS effects. The necessary National Pollutant Discharge Elimination System (NPDES) permitting process for this modernization project is being administered in parallel to the AFC process by the California Central Coast Regional Water Quality Control Board (RWQCB).

Section 316(b) of the Clean Water Act (PL 92-500 and 95-217) requires that "the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact" (USEPA 1977). Because no single intake design can be considered to be the best technology available at all sites, compliance with the Act requires a site-specific analysis of intake-related organism losses and a site-specific determination of the best technology available for minimizing those losses. In this report, intake-related losses resulting from entrainment (the drawing of organisms into the cooling water system) and impingement (the retention of organisms on the intake screens) are evaluated and discussed. Intake technologies are evaluated according to operating, engineering, and biological criteria. The best technology available for minimizing entrainment and impingement losses is recommended for the Morro Bay Power Plant's new combined-cycle units cooling water intake structures.

Pacific Gas and Electric (PG&E) was required to conduct 316(b) studies at most of their steam generation power plants during the late 1970s and early 1980s. However, the Central Coast RWQCB did not require that a 316(b) Demonstration be conducted at the MBPP. They determined that the studies and results from the 316(b) Demonstration study conducted at the Moss Landing Power Plant (another ocean-sited power plant located approximately 150 miles [240 km] north) were sufficient to estimate the losses of entrained organisms. Site-specific impingement studies were conducted at the MBPP from 1977 – 1978 (Behrens and Sommerville 1982). These earlier impingement studies were undertaken to provide estimates of the

[1] The RWQCB determined that the existing permitted intake represented the Best Technology Available based on results of the MBPP 316(b) study (PG&E 1983) and the 1977–78 MBPP impingement studies.

composition and abundance of species that might be impinged at the site chosen for the Diablo Canyon Power Plant (approximately 19 km (12 miles) south of the MBPP). Samples of impinged organisms were collected in 1977 – 1978 on a weekly basis to gather information on the species composition and abundance of organisms affected by the plant's cooling water system. Data collected from numerous surveys near the plant were used in conjunction with commercial and sportfish landing data from California Department of Fish and Game (CDFG) and other agencies to examine general trends in the populations of some of the species susceptible to the effects of the cooling water systems. The information from these studies was used in conjunction with engineering and operating criteria to evaluate alternative intake technologies for the plant in the 316(b) Demonstration report (PG&E 1983).

The 1983 MBPP 316(b) Demonstration report concluded that there was no evidence that local populations were adversely affected by the operation of the MBPP (PG&E 1983). Furthermore, it was demonstrated that the feasible alternative intake technologies examined would not have substantially reduced biological losses at the plant on a cost-effective basis.

The 1983 316(b) Demonstration report was reviewed by several agencies including the State Water Resources Control Board, RWQCB, CDFG, Environmental Protection Agency (EPA), and United States Fish and Wildlife Service (USFWS). The conclusion of these agencies was that no alternative intake technologies or changes to the operations of the power plant were required based on the information presented in the demonstration report and information provided to the agencies during the review process. There are no plans in the modernization project to change the existing and previously approved Units 1 through 4 intake facilities.

1.1 Development of the 316(b) Study Plan

In 1998 Duke Energy announced their plan to modernize the Morro Bay Power Plant. The RWQCB was contacted and a series of meetings were held to discuss the renewal of the plant's NPDES permit. The RWQCB assembled a team of experts to assist the Board's staff in their review of the design and implementation of the 316(b) studies as well as the discharge related thermal effects studies. This team, the Technical Working Group (TWG), met periodically to discuss topics relevant to ongoing efforts at the MBPP, including the design of the 316(b) study plan. The study plan, entitled *Morro Bay Power Plant Modernization Project 316(b) and Thermal Effects Study Plan*, was submitted to the RWQCB on September 10, 1999. Since the September 1999 submittal, comments were received from the TWG and were addressed in a final study plan submitted on October 23, 2000 to the CEC and the RWQCB as Appendix 6.6-A of the AFC (Tenera 2000). The study plan is attached as Appendix A of this document.

The design of the 316(b) field study program was based in part on information collected during recently completed studies of the potential effects of cooling water systems at the Diablo Canyon and Moss Landing power plants and the 1977 – 1978 MBPP impingement study. The study plan was developed using information collected from these and other studies, as well as federal 316(b) guidelines and input from the TWG. Three modeling approaches, described in the *Morro Bay Power Plant Modernization Project 316(b) and Thermal Effects Study Plan* (Tenera 2000) to assess entrainment and impingement losses, were presented to the TWG: (1) fecundity hindcast (*FH*), (2) empirical transport model (*ETM*), and (3) adult equivalent loss (*AEL*).

1.2 Overview of the 316(b) Program

The basic objective of the 316(b) program is to provide a sufficient basis for regulatory agencies to determine whether the new combined-cycle cooling water intake structures (currently the Units 1 and 2 and Units 3 and 4 intake structures) reflect the best technology available for minimizing adverse environmental impacts. To accomplish this objective, 12-month field studies of entrainment (January 2000 through December 2000) and impingement (September 1999 to September 2000) were designed and conducted at the MBPP. Estimates of the total numbers of aquatic organisms entrained were calculated from plankton samples that were collected in front of the intake structures. Samples collected in Morro and Estero bays provided estimates of the source water populations that may be affected by entrainment. The numbers of aquatic organisms impinged annually were estimated from samples collected from the traveling screens at the intake structures.

1.2.1 Target Organisms Selected for Study

The TWG selected the following aquatic organism groups to be the focus of the 316(b) entrainment study at the Morro Bay Power Plant:

- larval fishes,
- megalopal cancer crabs, and
- megalopal European green crabs.

Fishes and *Cancer* spp. crabs were selected because of their role in the ecosystem and because some of them have commercial or recreational value. European green crabs, an introduced invasive species, were selected because of concerns regarding their presence in the vicinity of the Morro Bay estuary.

The impingement study focused on the following aquatic organism groups also selected by the TWG:

- fishes,
- decapod crustaceans (shrimps and crabs),
- cephalopods (squid and octopus), and
- sea urchins.

These organisms were also the focus of the previous 1977 – 1978 MBPP impingement study.

For this report, we narrowed the focus of the assessment of entrainment effects to the most abundant taxa of larval fishes and all megalopal cancer crabs. Based on the results of entrainment sampling, the seven most abundant larval species or taxa groups of fishes were chosen for assessment in this report. They are unidentified gobies, Pacific staghorn sculpin, northern lampfish, shadow goby, combtooth blennies, kelp/gopher/black-and-yellow rockfish (KGB) complex, and jacksmelt. In addition to these fishes that were chosen based on their high entrainment abundances, three more species that were entrained in lower numbers were also analyzed: white croaker, Pacific herring, and cabezon. These fishes were analyzed because they have some commercial or recreational value. All cancer crab species were assessed based on the abundances of their megalopal planktonic stage. No European green crabs were collected. This report presents the results of the three entrainment assessment models applied to the concentrations (#/1,000 m^3) of the most abundant and commercially or recreationally important fish taxa and all megalopal cancer crabs collected in the entrainment samples.

The report also presents actual numbers and biomass of selected organisms collected in weekly 24-hour impingement samples over a period of one year that were used to estimate annual impingement totals. Based on the results of impingement sampling, several species of fishes and selected macroinvertebrates were chosen for assessment in this report. The fishes discussed in detail are northern anchovy, topsmelt, plainfin midshipman, speckled sanddab, Pacific sardine, cabezon, and rockfishes. The invertebrates discussed are market squid, black-tailed bay shrimp, Xantus' swimming crab, hairy rock crab, brown rock crab, kelp crab, brown shrimp, and purple sea urchin.

An experimental study using molecular methods to identify and possibly quantify larval clams collected from the MBPP intakes and source water began in March 2001 (Section 3.5). The purpose of the study is to provide information on the composition and abundance of clam larvae potentially affected by the power plant.

1.3 Organization of the Report

This 316(b) resource assessment is a summary and analysis of the entrainment and source water data collected from January 2000 through December 2000 and of impingement data collected from September 1999 through September 2000. The design and operation of the existing Units 1 through 4 intake structures as well as the modernization project's intake structures are described in Section 2.0. The entrainment and source water experimental design, sampling and analysis methods, and results are presented in Section 3.0. Section 4.0 presents the experimental design, sampling and analysis methods, and results of the MBPP impingement study along with a comparison of the data collected during the 1977 – 1978 MBPP impingement study. Section 5.0 discusses impact assessment methods and results. Based on findings presented in the preceding sections, the best technology available (BTA) for the intake system is assessed in Section 6.0.

1.4 Literature Cited

Behrens, D. W., D. C. Sommerville. 1982. Impingement studies at the Morro Bay Power Plant. Report 026.22-80.1. Pacific Gas and Electric Company, Dep. Eng. Res., San Ramon, CA.

Pacific Gas and Electric Company (PG&E). 1983. Morro Bay Power Plant cooling water intake structures 316(b) demonstration. PG&E, San Francisco, CA.

Tenera Environmental. 2000. Morro Bay Power Plant modernization project 316(b) and thermal effects study plan *In:* Application for Certification. California Energy Commission. Morro Bay Power Plant Project. Volume III. Technical Appendices.

U.S. Environmental Protection Agency (USEPA). 1977. Guidance for evaluating the adverse impact of cooling water intake structures on the aquatic environment: Section 316(b) P.L. 92-500. 58 pp.

2.0 DESCRIPTION OF THE MORRO BAY POWER PLANT AND CHARACTERISTICS OF THE SOURCE WATER BODY

This section describes the Morro Bay Power Plant (MBPP) and its aquatic environmental setting, focusing on the various features of the existing and proposed power plant design and operations related to the facility's aquatic environment. Section 2.1 describes the plant and its existing and proposed cooling water systems. Section 2.2 briefly characterizes the aquatic environment in the vicinity of the MBPP. An analysis of whether the modernized system represents the best technology available to minimize potentially adverse cooling water intake effects is presented in Section 6.0.

2.1 The Plant and its Cooling Systems

The Morro Bay Power Plant is located on the northeastern shoreline of Morro Bay. Morro Bay is located approximately midway between San Francisco and Los Angeles, California. It is an enclosed bay opening into the larger coastal embayment of Estero Bay (Figure 2-1). The MBPP is in the City of Morro Bay, 12 miles northwest of the City of San Luis Obispo. The MBPP has two separate intake structures that are located next to each other along the shoreline of Morro Bay. The intake structures withdraw cooling water used to remove excess heat from the power generation process. After passing through the cooling water system, this water is discharged into Estero Bay through three subsurface conduits (one for Units 1 and 2 and one each for Units 3 and 4). The specifications of the existing cooling water intake structures (CWIS) are summarized in Table 2-1.

The Morro Bay Power Plant (MBPP) currently produces up to 1,002 net megawatts (MW) from four steam boilers (Units 1 through 4). Duke Energy proposes to replace the 1950s technology of Units 1 through 4 with two 600 net MW high efficiency combined-cycle (CC) units. Each combined-cycle unit will consist of two gas-fired turbines and one steam turbine driven by the heat produced by the other two turbines. The new combined-cycle units will use about 30 percent less fuel for each megawatt hour of electricity generated than the 1950s technology of the existing units.

Figure 2-1. The location of the Morro Bay Power Plant.

Table 2-1. Specifications of the existing Morro Bay Power Plant cooling water systems.

Specification(1)(2)	Units 1 and 2	Units 3 and 4
BAR RACKS		
Number	4	6
Location	Shoreline	Shoreline
Spacing On-Center, in. (cm)	4 (10.2)	4 (10.2)
Bar Size, in. (cm)	3 x 3/8 (7.6 x 0.9)	3 x 3/8 (7.6 x 0.9)
TRAVELING SCREENS		
Location	Shoreline	Shoreline
Number	4	6
Manufacturer	Envirex	Envirex
Mesh Size, in. (cm)	3/8 (0.9)	3/8 (0.9)
PUMPS		
Location	Shoreline	Shoreline
Number (per unit)	2	2
Manufacturer	Westinghouse	Kubota
Type	Vertical single-stage mixed flow	Vertical single-stage mixed flow
Capacity each pump, cfs (m^3/sec, gpm)	102 (2.9, 46,000)	156 (4.4, 70,000)
PRESSURE CONDUITS TO CONDENSER		
Number	2	2
Diameter, ft (m)	4.5 (1.4)	5.5 (1.7)
Length, ft (m)	650 (200) (3)	900 (275) (4)
CONDENSER		
Number of Tubes	9,550	10,342
Tube Material	Copper Nickel	Copper Nickel
Tube Outside Diameter, in. (cm)	7/8 (2.2)	1 (2.5)
Design delta-T, ºF (ºC)	15.5 (8.6)	18.9 (10.5)
DISCHARGE CONDUITS		
Number	1	2
Size, ft (m)	7 x 10 (2.1 x 3.0)	5.5 (1.7)
Length, ft (m)	3,450 (1,050) (5)	900 (275) (6)
APPROXIMATE TRAVEL TIMES, sec	(7)	(8)
Bay to Pumps	60	64
Pumps to Condenser	89 (+22)	130 (-3)
Through Condenser	5	5
Condenser to Discharge	522 (+8)	537 (+45)
Total Through Plant	676 (+30)	736 (+42)
Total Heated	527 (+8)	542 (+45)
DESIGN WATER VELOCITIES, fps (cm/sec)		
Approach to Bar Racks	0.5 (15)	0.5 (15)
Through Bar Racks	0.5 (15)	0.5 (15)
Approach to Screens	0.7 (21)	0.6 (18)
Through Screens	1.4 (43)	1.4 (43)
Pump to Condenser	7.3 (220)	6.9 (210)
Through Condenser	7.0 (215)	7.0 (215)
Condenser to Discharge	6.6 (200)	6.5 (200)

(1) Units 1 and 2 share bar racks, traveling screens and a discharge tunnel; Units 3 and 4 share bar racks and traveling screens.

(2) Except as noted, specifications for the two units in a unit pair are identical.

(3) Unit 1; for Unit 2 add 160 ft (50 m).

(4) Unit 3; for Unit 4 add 25 ft (8 m).

(5) Unit 1; for Unit 2 subtract 55 ft (17 m).

(6) Unit 3; for Unit 4 add 290 ft (90 m).

(7) Unit 1; for Unit 2 add number in parentheses.

(8) Unit 3; for Unit 4 add number in parentheses.

2.1.1 Existing Once-Through Seawater Cooling System

The existing seawater cooling facilities consist of:

- dual inlet structures on the Morro Bay inner harbor (one inlet for Units 1 and 2 side by side with the inlet for Units 3 and 4) with stop logs, trash racks, traveling screens, and large capacity seawater pumps,
- interconnecting piping,
- three discharge tunnels (one discharge tunnel for Units 1 and 2, and one each for Units 3 and 4), and
- a discharge structure with a short open channel adjacent to the north side of Morro Rock that discharges into Estero Bay.

The common cooling water intake structures for Units 1 through 4 are located on the northeastern shore of Morro Bay (Figure 2-2). Water is drawn through bar racks and then passes through traveling screens to circulating water pumps located downstream of the screens. Each of the four existing generating units has two circulating water pumps that pump the cool seawater to the condensers through two conduits, one serving each condenser half. Figures 2-3 and 2-4 show the major features of the two intake bays of the current intake structure. The design seawater approach velocity to the bar racks is 0.5 feet per second (fps). The approach velocities are maintained to design levels by periodic removal of sediment that builds up around the intake structures, which has the effect of reducing the cross sectional area of the intake opening. Yearly measurements are taken at the intake structures and maintenance activities (i.e., removal of silt and or debris) are conducted as required to maintain the design approach velocities.

Each pair of circulating water pumps at Units 1 and 2 has a combined operating capacity of 92,000 gpm; and each pair serving Units 3 and 4 has a combined capacity of 140,000 gpm. Under maximum base load and peak operating conditions, the combined design flow rate of Units 1 through 4 is 464,000 gpm. Each pair of pumps provides a relatively constant flow rate of cooling water when the associated generation unit is on line, regardless of the level of power generation. For example, the Unit 3 cooling water pumps will pump about 140,000 gpm whenever Unit 3 operates, whether it is generating at a reduced load of 150 MW or at the maximum capacity of 338 net MW.

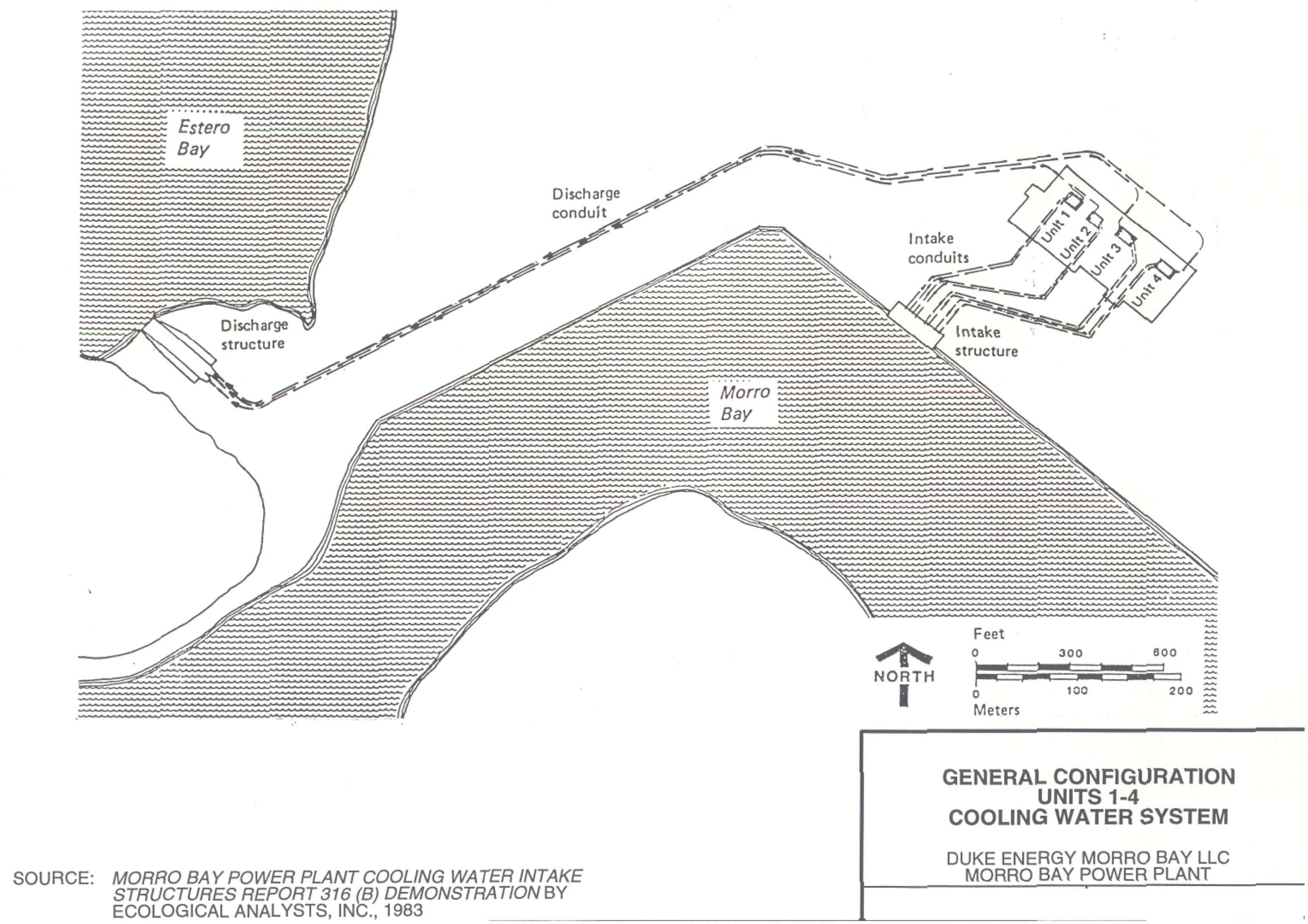
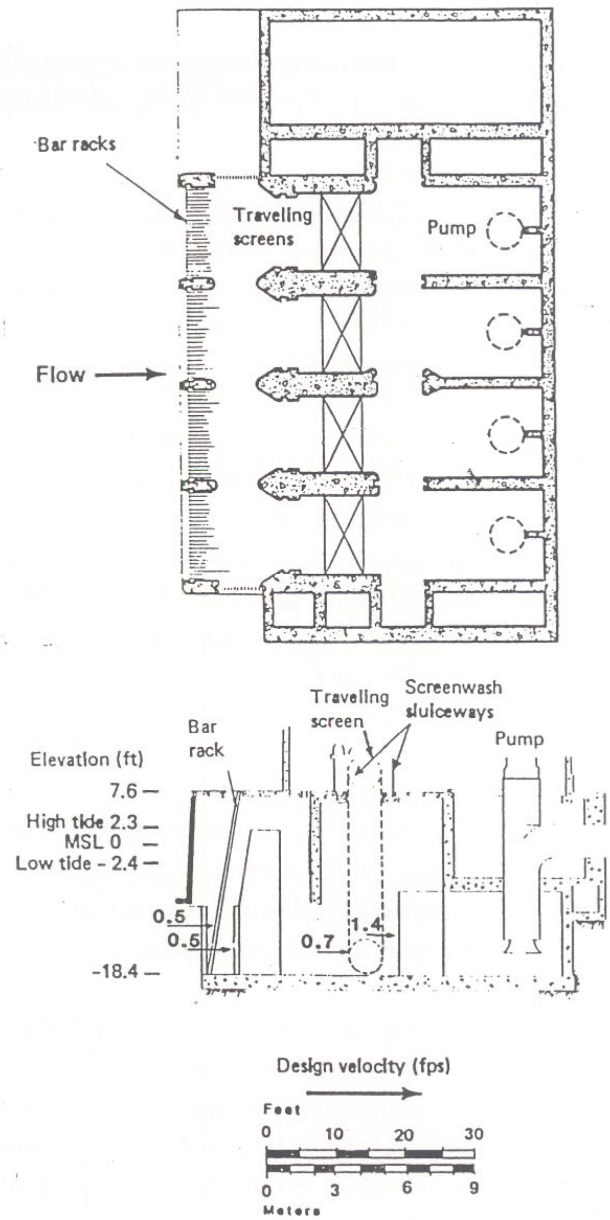


Figure 2-2. General configuration of the MBPP Units 1 through 4 cooling water system. Source: PG&E 1983.



PLAN AND SECTION DIAGRAMS
UNITS 1 AND 2 INTAKE STRUCTURE

DUKE ENERGY MORRO BAY LLC
MORRO BAY POWER PLANT

SOURCE: *MORRO BAY POWER PLANT COOLING WATER INTAKE STRUCTURES REPORT 316 (B) DEMONSTRATION* BY ECOLOGICAL ANALYSTS, INC., 1983.

Figure 2-3. MBPP Units 1 and 2 intake structure. Source: PG&E 1983.

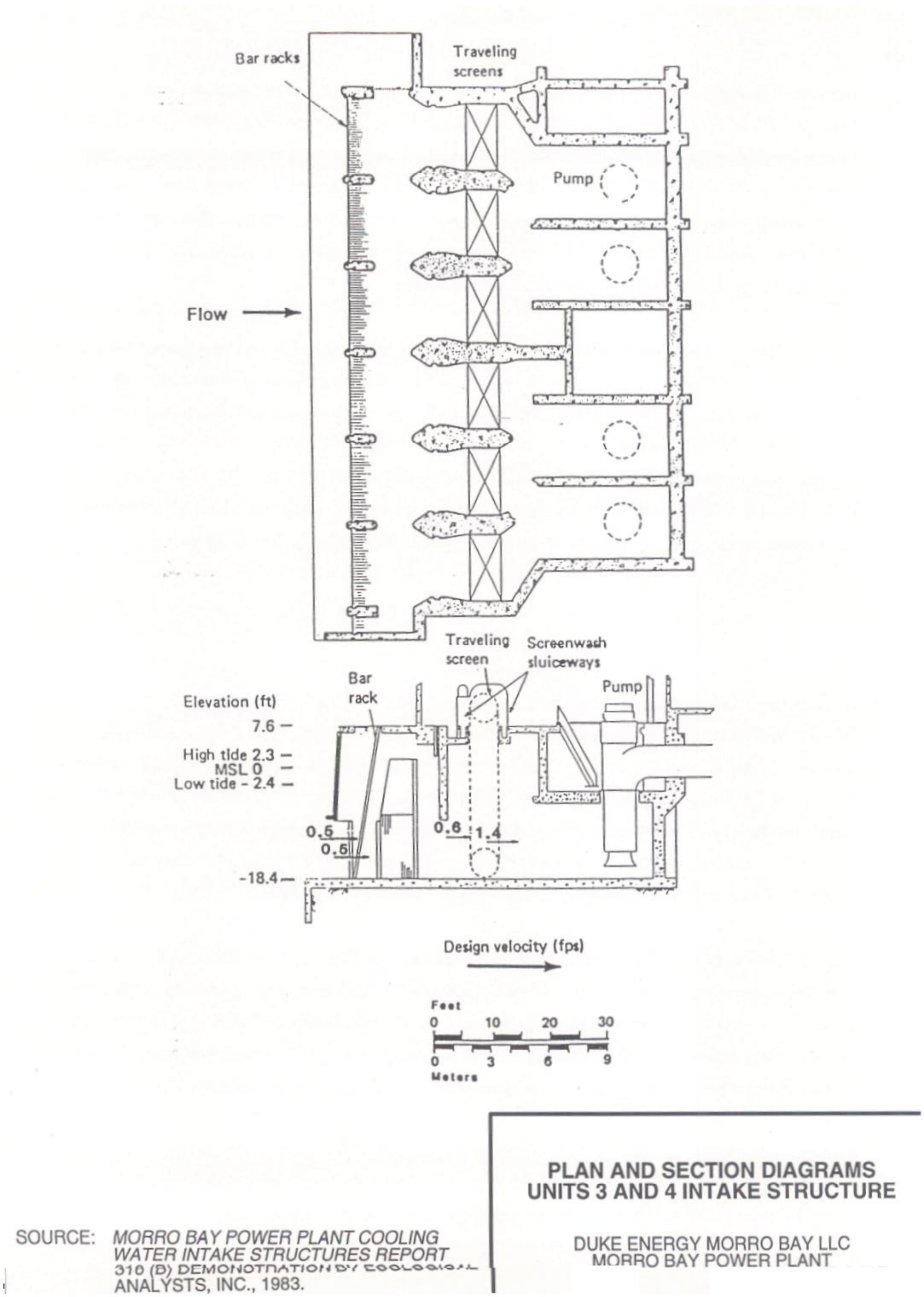


Figure 2-4. MBPP Units 3 and 4 intake structure. Source: PG&E 1983.

Biofouling

When seawater is used for cooling, biological organisms may grow within the cooling water system, thereby leading to the biofouling of heat transfer equipment. Biofouling reduces the efficiency of the plant in a variety of ways: it restricts cooling water flow, promotes corrosion, and reduces overall heat transfer efficiency. Mussels attach themselves to surfaces in the cooling water system. Left undisturbed, mussels will multiply and grow until cooling water flow is impeded. Reducing or blocking cooling water flow adversely affects the performance of the unit. Periodic heat treatment (demusseling) of each cooling water system is used to remove mussels and minimize the growth of other macro-fouling organisms on the piping and heat exchangers. The goal of demusseling is to periodically clear the system of the infestation before the shells get too big to pass through small passages (such as condenser tubes) in the cooling system. No toxins or chemicals are used by the MBPP for demusseling. The required frequency of this operation varies seasonally. Demusseling of the circulating water intake tunnels is typically performed once per quarter. Historically, the discharge tunnels were treated approximately once per year, but this practice was discontinued around 1990. Durations of heat treatments are a function of maximum temperature reached. Normally each heat treatment lasts about three hours, with the maximum temperature held for one hour.

Micro-fouling of the condensers is controlled by chlorination at the Units 1 through 4 condensers for about 90 minutes (45 minutes for each condenser half) one time per day for a combined total of six hours per day. Chlorination of each unit is performed sequentially to maintain a maximum total residual chlorine (TRC) of less than 70 parts per billion (ppb) measured at the outfall canal.

2.1.1.1 Existing Units 1 and 2 Cooling Water System

Cooling water is provided to the Units 1 and 2 condensers from the intake structure (Figure 2-3). The discharge from the Units 1 and 2 condensers is combined in a single discharge conduit that runs approximately 3,500 feet to a short discharge canal in Estero Bay. Specifications of the system are presented in Table 2-1. Figure 2-3 shows the major features of the intake bay for Units 1 and 2. Bar racks, spaced 4 inches on center and located about 20 feet in front of the vertical traveling screens, prevent the entry of large objects into the cooling water system. The vertical traveling screens, with a mesh size of 3/8 inch, retain smaller objects. Material retained by the screens is removed during screen rotation and washing, which is initiated either by a timer at approximately 4-hour intervals or when the hydraulic differential across the screen exceeds a predetermined maximum. During screen washing, spray nozzles wash the material into a surrounding sluiceway. The sluiceway empties into a screenwash well equipped with a large diameter pump that drains the well and discharges into the common condenser discharge conduit of Units 1 and 2.

2.1.1.2 Existing Units 3 and 4 Cooling Water System

The cooling water system serving Units 3 and 4 is shown in Figure 2-4. The intake bay for Units 3 and 4 is located adjacent to the intake bay for Units 1 and 2 and consists of bar racks, traveling screens, a chlorinator, and circulating water pumps. Four separate intake conduits deliver cooling water to the Units 3 and 4 condenser halves, which then combine into a single discharge tunnel for each unit. The cooling water flows from the two units through separate, parallel 4,000-foot-long discharge tunnels which discharge into Estero Bay through the common discharge canal. Cooling system design specifications for Units 3 and 4 are presented in Table 2-1.

The major features of the intake bay for Units 3 and 4 are shown in Figure 2-4. Bar racks, spaced 4 inches on center, are located about 20 feet in front of the vertical traveling screens. The traveling screens have 3/8-inch mesh. Material retained by the screens is removed during screen rotation and washing, which is initiated either by a timer at approximately 4-hour intervals under normal operating conditions, or when the hydraulic differential across the screens exceeds a predetermined maximum.

During screen washes, spray nozzles wash the retained material into a surrounding sluiceway that empties into a common screenwash well. The debris is sent to Estero Bay by a large diameter pump that empties into the discharge conduits of Units 3 and 4.

Heat treatment and chlorination procedures at Units 3 and 4 are similar to those described for Units 1 and 2.

2.1.2 Proposed New Combined-Cycle Units Cooling Water System: Design and Operational Procedures

2.1.2.1 Cooling Water System Modifications

Units 1 through 4 will be permanently replaced as a result of the Project. The existing Units 1 through 4 intake structures, located on the shoreline of Morro Bay, will be used essentially "as is" to provide once-through cooling water to the new combined-cycle units. The eight existing Units 1 through 4 cooling water pumps in the intake structures will be replaced with eight new pumps, each with an operating capacity of approximately 41,250 gpm. New pipelines will be installed onsite to connect the new combined-cycle units to the existing Units 1 through 4 cooling water supply and discharge conduits. Traveling screens will be refurbished. No further modifications to the existing cooling water system are planned. The cooling water return flow from the new units will utilize the existing Units 1 through 4 discharge tunnels that extend from the MBPP to the existing discharge canal structure adjacent to Morro Rock in Estero Bay.

Operational Changes

The combined-cycle units will require a cooling water flow of about 330,000 gpm at maximum peak operation with a maximum temperature increase of 20° F (Table 2-2). During maximum peak operation, the new combined-cycle units will generate more electricity, utilize 38 percent less cooling water (weighted maximum), and reject about 35 percent less heat to the ocean than the existing Units 1 through 4. The new combined-cycle units will be capable of both peak power operation (duct firing of Heat Recovery Steam Generators [HRSGs]) and base load, or non-peak power (no duct firing) operation. Cooling water flow rates and thermal loads for the operation of the new combined-cycle units and maximum operation of the existing units are compared in Table 2-2. During base load operation of the combined-cycle units, the power generation of the new plant will slightly exceed (by three percent) the current capacity of existing Units 1 through 4. However, since in a combined-cycle plant only a portion of the total electricity generated is produced in the steam cycle, the cooling water flow rates and heat loads for the new plant will be dramatically reduced as compared to the 100 percent steam cycle design of the existing units.

Table 2-2. Comparison of generating loads, discharge flows, temperatures, and heat loading between the existing Morro Bay Power Plant and the modernized plant.

	Existing Boiler Units 1-4	New Combined-Cycle Units	Change
Base Load[1] Net Power Generation (MW)	1,002	1,030	+ 3 %
Peak Load[2] Net Power Generation (MW)	1,002	1,200	+ 20 %
Maximum Base Load Flow Rate (gpm)	464,000	247,500	- 47 %
Maximum Peak Load Flow Rate (gpm)	464,000	330,000	- 29 %
Weighted Maximum[3] Flow Rate (gpm)	464,000	287,000	- 38 %
Average Flow Rate[4] (gpm)	394,000	258,000	- 35 %
Temperature Increase at Maximum Base Load (°F) [5]	22°	19.3°	- 2.7°F
Temperature Increase at Maximum Peak Load (°F) [5]	22°	20°	- 2.0°F
Weighted Temperature Increase at Maximum Load (°F) [5]	22°	19.6°	- 2.4°F
Average Temperature Increase [6] (°F)	16.4	17.6	+ 1.2°F
Maximum Base Load Heat Load to Discharge (Million Btu/min)	85.2	40	-53 %
Maximum Peak Load Heat Load to Discharge (Million Btu/min)	85.2	55	-35 %
Weighted Maximum Heat Load to Discharge (Million Btu/min)	85.2	47	-45%
Maximum Base Load Flow per kW Generated (gpm)	0.463	0.240	- 48 %
Maximum Peak Load Flow per kW Generated (gpm)	0.463	0.275	- 41 %
Weighted Maximum Flow per kW Generated (gpm)	0.463	0.257	- 44 %
Discharge Heat Load per kW at Maximum Base Load (Btu/min/kW)	85.0	38.8	- 54 %
Discharge Heat Load per kW at Maximum Peak Load (Btu/min/kW)	85.0	45.8	- 46 %
Weighted Maximum Discharge Heat Load per kW (Btu/min/kW)	85.0	42.1	- 50 %

[1] Base Load for the combined-cycle units is maximum generation without duct firing. This can occur more than 50 percent of the time.

[2] Peak Load for the combined-cycle units is maximum generation with duct firing. This will be limited to no more than 4,000 hours per year (less than 50 percent of the time).

[3] Weighted Maximum is average annual maximum assuming that new combined-cycle units operate the maximum allowed 4,000 hours per year peak load (with duct firing), and operate an additional 4,400 hours per year at maximum base load.

[4] Average Flow Rate is the year 2000 average for the existing boiler units, and a conservatively high 90 percent of the Weighted Maximum flow rate for the combined-cycle units.

[5] Average of instantaneously recorded paired intake and discharge temperature differences with existing plant operating at maximum generating capacity.

[6] Average Temperature Increase is the Year 2000 average for the existing boiler units (which averaged 13.6°F in the first six months, and 19.3°F in the last six months), and a conservatively high 90 percent of the Weighted Temperature Increase at Maximum Load for the combined-cycle units. If the existing plant remains in operation, it is likely that it will be operated more as it was in the latter half of 2000, which would make the indicated + 1.2°F change negative (i.e., - 1.7°F if existing units averaged 19.3°F).

Base load operation of the new combined-cycle units will generate more power than the existing units with nearly half the cooling water usage and thermal load discharged to Estero Bay (Table 2-2). At these base load levels, which are expected to occur more than half the time for the new units, the modernized plant will use 47 percent less water than required by the existing plant per MW of generation. Also at these base load levels, the modernized plant will reject 53 percent less heat into the cooling water than required by the existing plant per MW of generation. Even though more cooling water is needed for peak power operation of the new units compared to base load operation, since duct firing produces additional power by generation of additional steam, peak operation will also result in significantly reduced cooling water use compared to the existing units.

The use of multiple cooling water pumps for the new units (four pumps per unit) will provide flexibility to reduce cooling water flows during certain operating conditions, unlike Units 1 through 4 which must run both cooling water pumps for each operating unit, even during significantly reduced operation. It is expected that each of the new combined-cycle units will operate with only three of the four cooling water pumps in operation at base load (non-duct fired), which should be the most common operating mode.

The ability to operate the new combined-cycle units with reduced cooling water flows at less than maximum loads will significantly reduce the intake structure approach velocities, as shown in Table 2-3.

Table 2-3. Historic, current, and projected bar rack approach velocities (fps) at the MBPP intake structures.

	Historic (Design)	Current at full load (Actual)	Projected at peak load (Design)	Projected at base load (Design)
Units 1 and 2 Intake Structure	0.5 (1)	0.37 (2)	0.33 (3)	0.25
Units 3 and 4 Intake Structure	0.5 (1)	0.51 (2)	0.30 (3)	0.23

(1) Original design values at mean lower low water (MLLW) (PG&E 1983).

(2) Average velocity at curtain wall opening in front of bar racks measured in 1999. The water level during the Units 1 and 2 intake measurement was 2.64 to 2.51 feet above MLLW; the corresponding water level for the Units 3 and 4 intake measurement was 3.63 to 3.22 feet above MLLW (DES January 2000).

(3) Estimated average velocity at curtain wall opening in front of bar racks based on 1999 measured data, prorated for maximum flowrate at peak load for combined-cycle units.

Duke Energy proposes to limit peak power, duct fired operation to no more than 4,000 hours per year. Assuming that base load, non-duct fired operation occurs for an additional 4,400 hours per year, the annual average cooling water flow rate for this maximum combined cycle operations scenario would be about 287,000 gpm. By comparison, the actual average cooling water flow for

Units 1 through 4 for the 12-month period ending in December 31, 2000, based on plant records maintained for the RWQCB, was 393,750 gpm.

The new combined-cycle units will use the existing seawater channels to provide cooling water for the steam turbine condensers. As the combined-cycle units' construction nears completion, new cooling water pumps will be installed in the pump house structure and connections made inside the plant property to reroute the seawater to the new units. The existing Units 1 through 4 will then be effectively decommissioned.

Biofouling Control in the Proposed Cooling Water System

To minimize biofouling the circulating seawater will undergo two types of treatment: chemical treatment with sodium hypochlorite and demusseling using heat treatment.

A chemical feed system consisting of a storage tank with injection pumps will be used intermittently, as required, to supply sodium hypochlorite (12 to 14 percent solution), a biofouling inhibitor, into the cooling water supply lines immediately before the condenser to reduce biofouling of the condensers. Residual chlorine will not exceed the permitted concentration of 200 ppb in the outfall. For comparison, note that the maximum residual disinfectant concentration permitted under Code of Federal Regulations (CFR) Title 40, Parts 141.54 and 141.65 is four milligrams per liter (mg/L) (approximately 4,000 ppb) for chlorine in drinking water during normal public delivery system operation.

Integral to the design of the circulating water system will be provisions for demusseling. This procedure recirculates heated cooling water using the online condenser to supply the heat. Heated water will be recirculated by restricting the condenser discharge flow and stopping one of the cooling water pumps. Water supplied by the pump still in operation reverses the flow through half of the condenser, causing it to flow back to the intake structure. At the intake structure the intake stop logs will be lowered, preventing flow of the heated water to the harbor and directing it to the operating pump. The demusseling procedure usually lasts several hours, depending on the treatment temperature, but is expected to require about one hour at the highest temperature. The procedure will be repeated, as necessary, approximately every 4 to 6 weeks.

2.2 Aquatic Biological Resources in the Vicinity of the MBPP

The MBPP is situated at the intersection of two distinct marine geographic areas: Morro Bay and Estero Bay. Estuarine and lagoon habitats are found within the boundaries of Morro Bay, while Estero Bay is distinctly marine. Each of these areas has its own unique aquatic biological habitats. Distinct aquatic habitats present within the boundaries of Morro Bay include shallow open water, submerged aquatic vegetation, sand/mud/salt flats, fresh/salt/brackish marshes, rocky subtidal and intertidal. Distinct habitats present in Estero Bay include sandy beach, rocky intertidal and subtidal, and open water areas. Provided in the following sections are summary descriptions of estuarine and marine habitats, including the associated plant and animal species of sandy subtidal areas, intertidal mudflats, submerged aquatic vegetation, coastal salt marsh, brackish marsh, rocky intertidal areas, and open water nekton and plankton.

A variety of data exist describing the fish assemblages within the Morro Bay estuary. These data were derived from a number of independent investigations. The fish communities associated with shallow eelgrass and tidal flat habitats in the southern reaches of the bay were investigated by Horn between 1974 – 1976 (Horn 1980). Trawl gear was used by Fierstine et al. (1973) from 1968 – 1970 and later by CDFG from 1992 to present (CDFG unpubl. otter trawl data) to sample the fishes occurring within the main channels of the bay. Fierstine et al. (1973) also employed other sampling methods. Both trawl studies investigated the species composition, abundance, and geographic distribution of fish communities within the bay. Stations outside of the Morro Bay estuary were sampled using trawl gear and gillnets during a 1971 – 1972 study to evaluate the effects of cooling water discharges on the beneficial uses of receiving waters at the MBPP (PG&E 1973). The species composition and abundance of fishes impinged on the traveling screens at the MBPP was studied by Behrens and Sommerville (1982) during 1977 – 1978 for PG&E. This report presents the results of a second impingement study conducted September 1999 – September 2000 (see Section 4.0) and the results of an entrainment and source water study of larval fish and megalopal cancer crabs conducted January 2000 – December 2000 (see Section 3.0). A comparison of the data collected from all these studies is presented in Appendix B.

2.2.1 Morro Bay

Morro Bay is a shallow estuary, approximately 4.3 miles (6.9 kilometer) long and 1.8 miles (2.9 km) wide. Morro Rock, a 578-foot-tall (176 m) stone monolith which marks the entrance to the bay and harbor, dominates the bay's landscape and is visible from any point in Estero Bay and the surrounding coastal plain.

Two breakwaters form the entrance to the bay. The first extends 1,800 feet (549 m) in a south-southwesterly direction from the base of Morro Rock. The second extends a similar distance to the west from the northern terminus of the sand spit that separates Morro Bay from Estero Bay. The ends of the breakwaters are separated by approximately 800 feet (244 m). A boat channel is maintained by the U.S. Army Corps of Engineers (USCOE) from the bay's entrance to White

Point, a distance of approximately 2.5 miles (4 km). The channel is dredged every three to four years to a nominal depth of 15 feet (4.6 m) below Mean Lower Low Water (MLLW) (USCOE 1990). A network of natural channels also extends throughout much of the back bay. The channels vary in depth from about 2 feet (0.6 m) to more than 30 feet (9 m) below MLLW and ultimately drain into the main boat channel. Morro Bay receives freshwater input from the seasonally variable drainage flows of Chorro and Los Osos creeks. The total watershed of the creeks encompasses an area of approximately 48,000 acres. At high tide the bay contains 2,100 acres of surface water. At low tide 1,305 acres of tidal mud flat, 87 acres of eelgrass, 148 acres of algal mats, and 436 acres of marsh are exposed (MBNEP 2000 GIS Theme). The rate of tidal exchange in Morro Bay, as described in Appendix C, varies as a function of distance from the mouth of the bay. For those species of Morro Bay fishes and invertebrates with planktonic larvae, these differences in tidal exchange rates mean that larvae in the bay's lower reaches are approximately 15 times more likely to be transported out of the bay during medium streamflow (Tetra Tech 1999) than larvae in the uppermost reaches. The lower rates of exchange in the upper bay provide several days of additional residence time for these larvae before they are transported by tidal action out of their adult habitat. This tidal delay in the transport of planktonic larvae from the upper bay effectively reduces the risk of their entrainment near the harbor entrance and shifts any potential entrainment effects to populations residing in the lower bay and open ocean.

The natural circulation patterns of Morro Bay have been highly modified due to its use as a boating and marina harbor. Before dredging began, a coastal lagoon would normally form during the summer and fall where the present-day opening is located. It is also during this season that many of Morro Bay's resident goby species spawn, possibly to take advantage of the normally closed or reduced open ocean circulation. These gobies' spawning patterns, may reflect the dramatic modification of Morro Bay tidal circulation from dredging activities. Dredging of these bay channels and the marina continue to maintain the modifications to the bay's many marsh and shallow water habitats. However, the delayed residence time of the back bay may also continue to provide an extended period of larval development that may be significant to the ability of the larvae to avoid tidal transport to open ocean conditions via the harbor's entrance or the MBPP.

The National Estuary Program was established in 1987, by amendments to the Clean Water Act (CWA), to identify, restore, and protect the nationally significant estuaries of the United States. Morro Bay has been designated a State and National Estuary and became part of the National Estuary Program in 1995. The Morro Bay National Estuary Program (MBNEP) has directed research aimed at gathering scientific information on sediment processes and of resource trends. MBNEP research may also include demonstration studies of interaction between watershed management and the bay's ecological processes.

Dominant ecological communities in Morro Bay are intertidal mud flats, eelgrass *Zostera marina* beds, and a coastal salt marsh. The bay also contains habitats consisting of sandy subtidal, rocky intertidal (including areas created by the breakwater, wharves and pilings), and brackish marshes. Most of these habitats support aquatic vegetation. The estuary also accommodates a sizable commercial shellfish lease.

2.2.1.1 Morro Bay Subtidal Channels

The salt marshes and mud flats of the Morro Bay estuary are drained and flooded twice a day by tidal flow through a network of channels that provide corridors between marine habitats and intertidal feeding and nursery grounds. The main artery of this network is a navigable channel that extends from the harbor entrance inland to within 1,500 feet (457 m) of Baywood Point, before splitting into two secondary channels. Both secondary channels extend in a southerly direction for more than 3,200 feet (975 m) before rising to an average depth of less than 10 feet (3 m). The main channel averages 15 feet (5 m) in depth (U.S. Department of Commerce 1983). A majority of the subtidal substrate within the estuary is a composition of sand and fine sediment. A soft mixture of mud, fine sediment, and organic material is present in sections of the main channel adjacent to and between the confluence of Los Osos and Chorro creeks and in the main channel, where secondary channels deposit sediment eroded from the mud flats.

Drifting mats of eelgrass and algae carpet large areas of the channel bottom in the fall and winter (R. Hardy CDFG pers. comm. 1999). Of the several flatfish species occurring within the main channel, the most common is the speckled sanddab *Citharichthys stigmaeus* (CDFG unpubl. otter trawl data). Surfperches are represented in the back bay by the shiner perch *Cymatogaster aggregata* and pile surfperch *Damalichthys vacca.* Bat rays *Myliobatis californica* are also present. Common crab species are the brown rock crab *Cancer antennariu*s, red rock crab *Cancer productu*s, yellow crab *Cancer anthonyi*, and slender crab *Cancer gracilis* (CDFG unpubl. otter trawl data). The swimming crab *Portunus xantusii* is frequently found near eelgrass beds. Mats of eelgrass, *Ulva* spp., *Enteromorpha* spp., and *Gracilaria* spp. drift along the bottom of the main channel and are abundant in the central potions of the bay, where they form a microhabitat for juvenile fishes and crustaceans. Associated species include English sole *Parophrys vetulus*, juvenile plainfin midshipmen *Porichthys notatus*, and postlarval gobies (e.g., arrow goby *Clevelandia ios* and bay goby *Lepidogobius lepidu*s) (CDFG unpubl. otter trawl data).

2.2.1.2 Morro Bay Intertidal Mudflats

The intertidal mud flats, a distinct region of the Morro Bay estuary, provide habitat for a diverse community of burrowing and surface dwelling invertebrates. Approximately 1,300 acres of mud flats are exposed during low tide (MBNEP 2000 GIS Theme), with about 148 acres covered by vegetation, primarily sea lettuce *Ulva* spp. and green alga *Enteromorpha* spp. Numerous species of polychaetes, gastropods, and crustaceans are distributed throughout the mud flats (USCOE 1973), as are bivalves, including the geoduck *Panope generosa*, Washington clam *Saxidomus nuttalli*, gaper/horseneck clam *Tresus nuttalli*, and bentnose clam *Macoma nasuta* (Spear 1973). Other inhabitants are grapsid and xanthid crabs, innkeeper worm *Urechis caupo*, blue mud shrimp *Upogebia pugettensis*, and ghost shrimp *Callianassa californiensis* (Gerdes et al. 1974). Bat rays and leopard sharks *Triakis semifasciata* are the largest of the mud flat predators. Williams Shellfish Company is allotted approximately 270 acres of California's tide and submerged lands in the back bay area of Morro Bay for aquaculture use. The company cultivates and harvests Pacific oyster *Ostrea lurida*, Manila clam *Tapes philipinarum*, Quahog clam *Mercenaria mercenaria*, and bay mussels *Mytilus edulis* (R. Hardy CDFG pers. comm. 1999).

2.2.1.3 Morro Bay Submerged Aquatic Vegetation

Eelgrass grows in quiet, protected bays in the lower intertidal zones and subtidally (Kozloff 1983). Most of the eelgrass beds in Morro Bay are on the lower parts of the tidal flats and in the shallow channels in the southern bay (J. Chesnut, consultant, pers. comm. 1999). Eelgrass beds provide forage, spawning substrate, nursery habitat, protection, and cover for invertebrates and fishes. Larger invertebrates associated with eelgrass beds include bay shrimp *Crangon* spp., spiny cockle *Trachycardium quadragenarium*, nudibranchs (e.g., *Hermissenda crassicornis*), and anemones (e.g., *Pachycerianthus fimbriatus*) (Ware 1996, M. Behrens, Tenera, pers. comm. 1999). Cancer crabs, yellow shore crab *Hemigrapsus oregonensis*, moon snail *Polinices lewsii* (genus name changed to *Euspira*) and sea hare *Aplysia californica* are also common (Ware 1996). Fish species include topsmelt *Atherinops affinis*, shiner perch, speckled sanddab, and Pacific staghorn sculpin *Leptocottus armatus* (CDFG unpubl. otter trawl data).

2.2.1.4 Morro Bay Coastal Salt Marsh

Salt marshes rise above the mud flats in areas where tidal flooding favors salt-tolerant terrestrial vegetation. Salt marshes moderate the effects of erosion and siltation and may act as pollution buffers. They also absorb runoff and can trap and degrade organic waste (McConnaughey and McConnaughey 1990). Chorro and Los Osos creeks drain westward into the central part of Morro Bay, forming a delta where the majority of salt marsh is located. The remainder is scattered along the southern edges of the bay. Of the 17 plant species identified four are dominant: pickleweed *Salicornia* spp., jaumea *Jaumea carnosa*, alkali heath *Frankenia salina*, and salt grass *Distichlis spicata* (Jarque 1998). Polychaete worms, crabs, snails, and amphipods are abundant and provide a food-rich habitat for fishes. Topsmelt is the most abundant fish found in the marsh at high tide, followed by Pacific staghorn sculpin and arrow goby (Tetra Tech unpublished). The longjaw mudsucker *Gillichthys mirabilis* occupies crab burrows beneath the marsh vegetation, and remains in wetted burrows during low tide.

2.2.1.5 Morro Bay Brackish Marsh

Brackish-water marshlands border many salt marshes. Freshwater flow in Morro Bay occurs at small springs along the shores of Baywood Park, Cuesta-by-the-Sea, and the sand spit. Brackish marsh habitat occurs adjacent to Los Osos Creek and along the upper portion of the Chorro Creek floodplain. The marsh near the Chorro Creek inlet is composed of a stand of cattails *Typha* spp., tules *Scripus* spp. (WESTEC Services 1988), sedges *Carex* spp., and rushes *Juncus* spp. (Jarque 1998). Many polychaete worms and amphipod crustaceans are found in the brackish marshes. Fish species in Chorro Creek and in the marsh include three-spine stickleback *Gasterosteus aculeatu*s, Sacramento squawfish *Ptychocheilus grandi*s, speckled dace *Rhinichthys osculu*s, and California killifish *Fundulus parvispinnis* (MBNEP 1999).

2.2.1.6 Morro Bay Rocky Intertidal/Shallow Subtidal (Pilings, Breakwaters, and Wharves)

Rocky intertidal habitat is limited within Morro Bay but supports one of the bay's most diverse plant and animal communities. Nearly every phyla of marine organism is represented in and around the bay's rocky intertidal zone (PG&E 1974). Hard substrate within the bay includes the two breakwaters and the area along the bay's northern shore from the west breakwater to Coleman Beach. It also extends south from the MBPP intakes, under the City's waterfront wharves, to just south of the boat launch. Fairbanks Point and White Point contain the bay's only natural rocky intertidal habitat. Pier/wharf pilings and floating docks along the waterfront also support communities similar to those found in rocky intertidal areas.

The most prolific rocky intertidal communities occur on the hard substrate provided by the breakwater and adjacent to Morro Rock. The pilings of the North T-Pier also support a diverse fouling community. Encrusting invertebrate fauna are dominated by barnacles *Balanus* spp. Crab species are abundant, including commercial species such as brown rock crab *Cancer antennarius* and red rock crab *Cancer productu*s. Smaller species include moss crab *Loxorhynchus crispatu*s, decorator crab *Oregonia gracilis,* and northern kelp crab *Pugettia* *producta*. The sheep crab *Loxorhynchus grandis* is the largest of the bay's crab species. Fish species include pile surfperch *Damalichthys vacca*, black surfperch *Embiotoca jacksoni*, and rubberlip surfperch *Rhacochilus toxote*s. Cottid species are numerous. Rockfishes, a commercial and recreational group outside the bay, are abundant as juveniles near Target Rock, and under the North T-Pier. Populations of juvenile rockfishes vary considerably from year to year. In 1996, the top five species by landing weight for hook-and-line boats were cabezon *Scorpaenichthys marmoratu*s, gopher rockfish *Sebastes carnatu*s, grass rockfish *Sebastes rastrellige*r, lingcod *Ophiodon elongatu*s, and black-and-yellow rockfish *Sebastes chrysomelas* (CDFG 1996).

2.2.2 Estero Bay

Estero Bay is a shallow bay extending from Point Estero in the north to Point Buchon in the south. The bay is situated on the northeastern edge of the Santa Lucia Bank, a prominent extension of the continental shelf and an important fishing ground. The majority of the substrate in Estero Bay consists of sand and silt. Rocky substrate is concentrated near Estero and Buchon points and adjacent to Morro Rock and its breakwaters.

2.2.2.1 Estero Bay Sandy Beach Intertidal

Sandy beaches provide the majority of the intertidal habitat of Estero Bay. Relatively few species are able to live in this unstable habitat. Sand beaches are an important interface between land and sea that support organisms such as sand crabs, beach hoppers, clams, and worms.

Tenera Environmental surveyed Morro Strand State Beach in August and November 2000 (Tenera 2001a). Data showed 32 taxa comprised of several species of polychaete worms, crustaceans (isopods, amphipods, anomuran crabs, mysid shrimps), clams, and nemertean worms. Anomuran crabs were represented in the collections by the sand crab *Emerita analoga* and the spiny mole crab *Blepharipoda occidentalis* (Tenera 2001a). Pismo clams *Tivela stultorum* and bean clams *Donax gouldii* were the dominant mollusks collected in the 2000 surveys. The local population of Pismo clams has declined with expansion of the sea otters' range (R. Hardy CDFG pers. comm. 1999).

Many species of birds are found in Estero Bay’s sandy beach intertidal area. Twenty-one species of birds were identified during the August 2000 survey (Tenera 2001a). The three most abundant species were Heermann’s gull *Larus heermanni*, western gull *Larus occidentalis*, and brown pelican *Pelecanus occidentalis*. The federally endangered snowy plover *Charadrius alexandrinus* was the fourth most abundant taxa counted during the survey. The most common shorebirds were the long-billed curlew *Numenius americanus*, whimbrel *Numenius phaeopus*, and marbled godwit *Limosa fedoa*.

2.2.2.2 Estero Bay Rocky Intertidal and Subtidal

Rocky intertidal and subtidal habitats occur primarily between Point Estero and Cayucos to the north, and from Hazard Canyon to Point Buchon in the south. Morro Rock and the harbor entrance breakwaters account for the only rocky intertidal habitat near the MBPP.

Qualitative and quantitative studies of subtidal algae and invertebrate species found in the rocky intertidal habitat of the Estero Bay were published by North (1969) and Tenera (2001b). The rocky shore algal and invertebrate community found on Morro Rock and on the adjoining area of rocky substrate on the northwest jetty was surveyed September 2000 to obtain specific data on the abundance and distribution of species. Subtidal areas of Morro Rock were nearly completely covered by the sand tube-building polychaete worm *Phragmatopoma californica* (Tenera 2001b). The tubes themselves were coated with short (0.4 in.[1 cm] tall) filamentous red algal turf species (e.g., *Pterosiphonia*, *Polysiphonia*). Dense strands of subtidal surfgrass *Phyllospadix torreyi*, subtidal oar kelp *Laminaria setchellii* , and intertidal kelp *Alaria marginata* were present, as well as intertidal iridescent seaweed *Mazaella flaccida*, a thinly branched alga *Gelidium coulteri*, and feather boa kelp *Egregia menziessi*. The intertidal zone was densely populated with mussels, barnacles, sea anemones (e.g., *Anthopleura xanthogrammica*), and sea stars (e.g., *Pisaster ochraceus*).

2.2.2.3 Estero Bay Sand-Mud Benthos

Bottom-dwelling (benthic) species appear in clumped distributions within the bay's vast expanses of sand and soft bottom. Fine sands are the predominant bottom type in the shallow waters of Estero Bay, adjacent to the MBPP. The benthic fauna can be categorized into epifauna, invertebrates occurring mainly on the sediment surface, and infauna, burrowing or sessile invertebrates occurring mainly beneath the surface. Tenera conducted two benthic and epibenthic surveys in Estero Bay in September and December 2000. Data from 65 core samples and from epibenthic observations yielded 30 taxa comprised of polychaete worms, nemertean worms, crustaceans (amphipods, crabs, shrimps), clams, echinoderms, and one species of fish (Tenera 2001c). The most abundant polychaete worm was *Magelona pitelkai* in the September 2000 survey, while the most abundant polychaete in the December survey was *Chaetozone bansei*. The most abundant amphipod collected in both surveys belongs to the family Phoxocephalidae. Sand dollars *Dendraster excentricus* were also found at all stations during the

September 2000 survey (Tenera 2001c), although only one sand dollar was collected in the December 2000 survey.

Another recent benthic study was completed in the Estero Bay area as part of an environmental impact report for the offshore construction component of a fiber optic cable project (Morro Group 1999). The predominant benthic fauna that characterized the nearshore samples included polychaete worms (e.g., *Scoloplos* spp., *Nephtys* spp., *Chaetozone* spp.), amphipod crustaceans (e.g., *Eohaustorius, Mandibulophoxus*), spiny mole crab *Blepharipoda*, olive shell *Olivella biplicata*, and sand dollar.

Many fish species utilize the sand/mud habitat of Estero Bay. Pacific sanddab are frequently caught by recreational anglers in Estero Bay. Other common demersal species include starry flounder *Platyichthys stellatus*, sand sole *Psettichtys melanostictus*, and turbot *Pleuronichthys* spp. Numerous elasmobranch species are well adapted for this habitat, including Pacific angel sharks *Squatina californica*, thornbacks *Platyrhinoidis triseriata*, and round stingrays *Urolophus halleri*. Aggregations of round stingrays are commonly found in the thermal effluent of MBPP (D. Dugan, Tenera, pers. comm. 1999). Shovelnose guitarfish *Rhinobatos productus* are often found in shallow regions, while spiny dogfish sharks *Squalus acanthias* are more common in deeper regions.

2.2.2.4 Estero Bay Kelp Beds

Kelp beds are one of the most prominent features along the Pacific coast. In kelp beds all major phyla are represented, but the most conspicuous are gastropods, polychaetes, sea stars, bivalves, sponges, tunicates, and crabs. In Estero Bay, kelp beds are distributed within the subtidal rocky areas from Point Estero to Cayucos Creek in the north and Hazard Canyon to Point Buchon in the south. Kelp is also present within Morro Bay near its entrance. Two dominant species of canopy-forming kelp are found in Estero Bay, giant kelp *Macrocystis pyrifera* and bull kelp *Nereocystis leutkeana.* In the early 1970s, kelp beds in the bay consisted almost entirely of bull kelp (Burge and Schultz 1973). Giant kelp is now the dominant species in the northern regions of the bay. Stands of individual giant kelp plants are also present along the subtidal rocky substrate formed by the jetty adjacent to Morro Rock. Kelp is economically important and CDFG regulates its harvest. Kelp harvested from Estero Bay is primarily used as food for farmed abalone.

2.2.2.5 Estero Bay Open Water Nekton and Plankton

Phytoplankton (represented by diatoms and dinoflagellates) form the base of the marine food chain and reside in the top 50 to 165 feet (12 to 50 m) in coastal areas (Smith 1993). Diatoms bloom in the spring. During summer, dinoflagellates become more common as diatoms decline. When light, nutrient level, salinity, and temperature are in certain proportions, blooms may occur causing "red tides." California Department of Health Services monitors phytoplankton along the coast, conducting sampling off of Cayucos in Estero Bay and inside Morro Bay. Seasonal abundances of northern anchovy *Engraulis mordax* and Pacific sardine *Sardinops sagax* occur in Estero Bay. Populations fluctuate dramatically, with several decades of abundance followed by greater periods of scarcity. During one sampling (PG&E 1973), a total of 553 fishes, representing 32 species were caught. The white surfperch *Phanerodon furcatus* was the most dominant species. Walleye surfperch, jacksmelt, silver surfperch, Pacific sanddab, and topsmelt were also common. The barred surfperch *Amphistichus argenteus* is the focus of a small but stable commercial fishery in the area. Landings of mostly barred surfperch totaled 32,000 pounds (41 percent of state total) in San Luis Obispo County in 1996 (CDFG 1996). The most important commercial fish species in Estero Bay is king salmon *Oncorhynchus tshawytsch*a, typically present from before the opening of sport salmon season in March, until mid or late July. County landings of king salmon totaled 122,000 pounds in 1996 (CDFG 1996). Although Estero Bay accounted for only a minor percentage of this total, the recreational salmon fishery is important economically to the Morro Bay area.

2.3 Literature Cited

Behrens, M. 1999. Research Assistant. Tenera Environmental. Personal communication.

Behrens, D. W., and D. C. Somerville. 1982. Impingement studies at the Morro Bay Power Plant. Report 026.22-80.1. Pacific Gas and Electric Company, Dep. Eng. Res., San Ramon, CA.

Burge, R. T., and S. A. Schultz. 1973. The marine environment in the vicinity of Diablo Cove, with special reference to abalones and bony fishes. Marine Resources Tech. Rept. No. 19.

California Department of Fish and Game (CDFG). 1996. Commercial Fisheries Newsletter No. 5. December 1996.

California Department of Fish and Game (CDFG). Unpublished Morro Bay otter trawl survey data.

Chesnut, J. 1999. Independent Consultant. Personal communication.

Duke Engineering and Services. 2000. Annual bathymetric and current measurements.

Dugan, D. Scientist. 1999. Tenera Environmental. Personal communication.

Fierstine, H. L., K. F. Kline, and G. R. Garman. 1973. Fishes collected in Morro Bay, California between January, 1968 and December, 1970. Calif. Dept. Fish and Game. No. 59(1):73-78

Gerdes, G. L., E. R. J. Primbs, and B. M. Browning. 1974. Natural resources of Morro Bay. Calif. Dept. Fish and Game.

Hardy, R. 1999. Associate Marine Biologist. Calif. Dept. Fish and Game. Morro Bay, California. Personal communication.

Horn, M. H. 1980. Diel and seasonal variation in abundance and diversity of shallow water fish populations in Morro Bay, California. Calif. Dept. Fish and Game. Fish. Bull. No. 78(3):759-770.

Jarque, A. B. 1998. Vegetative survey of Morro Bay estuary salt marsh with an aerial photograph. Biological Sciences Department, College of Science and Math, California Polytechnic State University, San Luis Obispo, California.

Kozloff, E. N. 1983. Seashore life of the northern Pacific Coast. University of Washington Press.

McConnaughey, B. H., and E. McConnaughey. 1990. Pacific Coast. Chanticleer Press, Inc., New York.

Morro Bay National Estuary Program (MBNEP). 1999. Draft CCMP, 11 June 1999.

Morro Bay National Estuary Program (MBNEP). 2000. GIS Shapefile Theme Data.

Morro Group, Inc. 1999. MFS Globenet Corp./WorldCom Network Services Fiber Optic Cable Project. EIR. Prepared in association with Arthur D. Little, Inc. and Marine Research Specialists. Submitted to County of San Luis Obispo Dept of Planning and Building.

North, W. J. 1969. Biological effects of a heated water discharge at Morro Bay, California. Proceedings of the International Seaweed Symposium. 6:275-286. Madrid, Spain.

Pacific Gas and Electric (PG&E). 1973. Evaluation of the effect of cooling water discharges on the beneficial uses of receiving waters at Morro Bay Power Plant. PG&E. San Francisco, CA.

Pacific Gas and Electric (PG&E). 1974. Environmental report-Morro Bay. Expansion of fuel oil facilities. PG&E. San Francisco, CA.

Pacific Gas and Electric (PG&E). 1983. Morro Bay Power Plant cooling water intake structures 316(b) demonstration. PG&E. San Francisco, CA.

Smith, P. 1993. Plankton critical to food chain and much of the earth's climate. Between the tides. Vol. 7 (4).

Spear, F. 1973. Underwater resources inventory of Morro Bay, California. For a proposed underwater reserve: Natural Resources Management Department, California Polytechnic State University.

Tenera Environmental. 2001a. Sand beach fauna study *in* Morro Bay Power Plant Modernization Project Draft Thermal Discharge Assessment Report. Prepared for Duke Energy Morro Bay LLC. Morro Bay, CA.

Tenera Environmental. 2001b. Rocky shore community study *in* Morro Bay Power Plant Modernization Project Draft Thermal Discharge Assessment Report. Prepared for Duke Energy Morro Bay LLC. Morro Bay, CA.

Tenera Environmental. 2001d. Subtidal benthic fauna study *in* Morro Bay Power Plant Modernization Project Draft Thermal Discharge Assessment Report. Prepared for Duke Energy Morro Bay LLC. Morro Bay, CA.

Tetra Tech, Inc. 1999. Morro Bay National Estuary Program hydrodynamic circulation model, Lafayette, CA, various pages.

Tetra Tech, Inc. unpublished. Morro Bay National Estuary Program hydrodynamic survey results.

U.S. Corps of Engineers. 1973. Draft Environmental Statement - Operation and maintenance of Morro Bay Harbor, San Luis Obispo County, California.

U.S. Corps of Engineers. 1990. Los Angeles District: Morro Bay Harbor maintenance dredging project, FY-1990, San Luis Obispo County, California.

U.S. Department of Commerce. 1983. Chart 18703.

Ware, R. 1996. Eelgrass (*Zostera marina*) habitat survey and impact analysis and mitigation plan to compensate for eelgrass habitat loss, City of Morro Bay Mooring Area A Dredge Project. Prepared for City of Morro Bay Harbor Department.

WESTEC Services, Inc. 1988. Twin Bridges replacement project draft environmental impact statement/report and 4(f) evaluation. Prepared for County of San Luis Obispo, County Government Center, San Luis Obispo, California.

3.0 ENTRAINMENT AND SOURCE WATER SAMPLING

3.1 Introduction

The purpose of the Morro Bay Power Plant entrainment and source water studies was to evaluate the potential impacts of the MBPP modernized combined-cycle power plant. These studies focused on larval fishes and cancer crab megalopae whose adult populations might be affected by power plant operation. Sampling was directed at characterizing the composition and abundance of both the early life stages of fishes and cancer crabs entrained by the power plant and those at risk of being entrained from the source waters.

The studies were designed to specifically address the following questions:

- What are the species composition and abundance of larval fishes and cancer crab megalopae entrained by the MBPP?
- What are the local species composition and abundance of entrainable larval fishes and cancer crab megalopae in Morro and Estero bays?
- What are the potential impacts of entrainment losses on larval fish and megalopal cancer crab populations due to operation of the power plant's cooling water intake system (CWIS)?

A Technical Working Group (TWG) was formed by the Regional Water Quality Control Board (RWQCB); the purpose of this group was, in part, to develop a plan to direct the studies of potential effects of the modernization of the MBPP on the local larval fish and megalopal cancer crab populations. The MBPP TWG consisted of representatives of Duke Energy North America, Tenera Environmental, the RWQCB and their consultants (Drs. Raimondi and Cailliet), the California Department of Fish and Game (CDFG), and the California Energy Commission (the CEC) and their consultant (Dr. Mike Foster). Working group meetings were scheduled to coincide with the completion of written products. The TWG members reviewed and commented on several drafts of the Cooling Water Intake Study Plan. The final study plan is attached as Appendix A. Six quarterly reports describing the progress of entrainment, source water, and impingement sampling were also submitted to the TWG. These quarterly reports contained data from the entrainment, source water, and impingement surveys. The final quarterly report was submitted to the TWG on January 31, 2001.

An experimental study using molecular methods to identify and possibly quantify larval clams collected from the MBPP intakes and source water began in March 2001 (Section 3.5). The purpose of the study is to provide information on the composition and abundance of clam larvae potentially affected by the power plant. We anticipate that the results of this study will be published in March 2002. Members of the TWG acknowledged (at the December 4, 2000 meeting) that due to the experimental nature of the proposed larval clam studies, the study's completion would not delay project certification or renewal of the facility's NPDES permit. The study plan for the clam study is presented in Appendix D.

The MBPP CWIS consists of bar racks, traveling screens, and circulating water pumps (Section 2.0). The traveling screens are constructed of 3/8-in. (1 cm) stainless steel wire mesh to exclude small debris from entering the intake conduits. Organisms small enough to pass through the screens and enter the CWIS become entrained. The weighted maximum flow rate of the cooling water withdrawn by the modernized power plant will be approximately 38 percent less than the existing power plant's water withdrawal (Table 2-2), thereby reducing existing entrainment effects. The volume of cooling water pumped by the existing power plant is compared to the modernized power plant's water withdrawals under various operating scenarios in Section 2.0 (Table 2-2).

Plankton surveys were conducted to characterize the taxonomic composition and abundance of larval fishes and cancrid crab megalopae potentially entrained in the MBPP CWIS and from the surrounding source water. Plankton samples collected from in front of the MBPP intake structures provided an estimate of the total number and types of these organisms passing through the power plant's CWIS. Data collected from source water surveys were used to estimate the abundance of fish larvae and megalopal cancer crabs at risk of entrainment. The rationale used to calculate the source water volume is presented in Appendix E. The estimates of larval abundance from entrainment and source water samples were used to calculate estimates of fractional losses that were translated into potential impacts on local fisheries (see Section 5.0—Impact Assessment).

Many marine organisms have planktonic forms that can be entrained in cooling water intake systems. The TWG decided to focus on two groups of representative target organisms; larval fishes and cancrid crab megalopae. The non-indigenous European green crab *Carcinus maenas* was labeled a species of concern by the CDFG, and they requested that we search for them in all of our plankton samples. From these groups, particular taxa were selected for further analyses by the TWG on the basis of their sampled abundance or economic or recreational value. The TWG determined that several assessment approaches would be applied to each taxon, where possible, to yield more robust and comparable impact assessments.

Cooling water system entrainment effects were evaluated using a variety of methods; all assuming 100 percent entrainment mortality (see Section 5.0 – Impact Assessment). The three analytical techniques used were Empirical Transport Modeling (*ETM*), Fecundity Hindcasting (*FH*), and Adult Equivalent Loss (*AEL*), which are described in Section 5.0—Impact Assessment. The TWG reviewed, provided input, and approved the use of the analytical methods chosen. We assessed the potential impacts on species population demographics using the results of these analyses.

3.2 Methods

3.2.1 Entrainment Sample Collection

Weekly entrainment sampling began June 21, 1999 and continued through August 10, 1999 (Table 3-1). A species initially identified as tidewater goby *Eucyclogobius newberryi*, a federally listed endangered species, was collected during Survey 2 (June 28, 1999). This species was identified and confirmed by taxonomists in early August 1999. The U.S. Fish and Wildlife Service (USFWS) and the CDFG were immediately notified regarding the collection of tidewater goby. All plankton sampling was suspended, at their direction, because we did not possess a permit to allow for the destructive sampling of the tidewater goby. A USFWS Endangered Species Recovery Permit Application to allow for the collection of the tidewater goby was filed. We received a permit on December 2, 1999 and weekly sampling resumed December 14, 1999 and continued through December 29, 2000.

Samples were collected from in front of the MBPP intake structures (Station 2; Figure 3-1) by towing a bongo frame with 0.71 m (2.3 ft) diameter openings and equipped with two 335 µm white mesh plankton nets. Samples were collected over a continuous 24-hour period; each period was divided into six, 4-hour sampling cycles. Two tows were conducted during each cycle. Sample collection methods were similar to those developed and used by the California Cooperative Oceanic and Fisheries Investigation (CalCOFI) in their larval fish studies (Smith and Richardson 1977). The bongo nets were lowered as close to the bottom as possible. Once the nets were at the correct depth, the boat was moved forward and the nets retrieved at an oblique angle (winch cable at a 45° angle). The winch retrieval speed was constant at approximately 1 ft/sec. In contrast to CalCOFI plankton sampling protocols, the bongo net was deployed and retrieved directly aft of the vessel rather than off to one side. However, the slow speed of the vessel and the use of the winch minimized problems of vessel turbulence discussed by Smith and Richardson (1977). Each net mouth was fitted with a calibrated flowmeter to measure the water volume filtered.

The target water volume filtered by both bongo nets combined was 40 m^3 (i.e., 20 m^3/net). The sample volume (as measured by the flowmeter) was checked when the nets reached the surface. If the target volume was not collected, the nets were placed back in the water and the tow repeated until the target volume was reached. Upon successful completion of a tow, the nets were retrieved from the water and all of the collected material was rinsed into the ends of the nets (codend). The contents of both nets were combined into a single, labeled jar (constituting one sample) immediately after collection, and were preserved in ethanol (ETOH). Preservation using ETOH allows specimen identifications to be genetically validated and allows for age and growth studies should the need arise. Each sample was given a serial number based on the location, date, time, and depth of collection. In addition, the information was logged onto a sequentially numbered data sheet. The sample serial number was used for tracking during laboratory processing, data analyses, and reporting.

3.2.2 Source Water Sample Collection

Fifteen monthly source water surveys were conducted during the study that began in June 1999 (Table 3-1). Monthly source water surveys were collected at four sampling stations (Figure 3-1). Source water sampling initially ran from June – July 1999, but began again in December 1999 after issuance of the Recovery Permit, and then continued through mid-December 2000. Station 1 was located at the entrance to Morro Bay, two stations (stations 3 and 4) were located in the back bay, and Station 5 was located approximately 2.5 nautical miles (2.9 statute miles) downcoast (i.e., south of the harbor mouth) (Figure 3-1). Initially, source water surveys were collected twice per day during daylight hours on high and low tides. In February 2000, sample collection for source water surveys was expanded to cover a 24-hour period and was no longer directly linked to tidal cycle. Collection, preservation, and sample tracking methods for Morro Bay source water stations 1, 3, and 4 and Estero Bay Station 5 were identical to the entrainment sampling methods. However, at the Estero Bay source water Station 5 (average depth = 12 m [40 ft]), the net was lowered to within approximately 3 m (10 ft) of the bottom and then retrieved obliquely.

Table 3-1. Frequency of collections for Morro Bay Power Plant sampling stations 1 through 5, June – August[1] 1999 and December 1999 – December 2000.

Frequency of Collection	Dates	Number of Samples Collected per Survey						Total Samples per Station
Station 1 (Morro Bay Entrance)		Daytime High Tide			Daytime Low Tide			
Monthly	Jun–Jul 1999[1]	2			2			4
	Dec 1999–Jan 2000	2			2			4
	Time PST	0800	1200	1600	2000	2400	0400	
	Feb 2000–Dec 2000	2	2	2	2	2	2	12
Station 2 (MBPP Intake)		1000	1400	1800	2200	0200	0600	
Weekly	Jun–Aug 9, 1999[1]	2	2	2	2	2	2	12
	Dec 14, 1999–Dec 29, 2000	2	2	2	2	2	2	12
Station 3 (Morro Bay back bay)		Daytime High Tide			Daytime Low Tide			
Monthly	Jun–Jul 1999[1]	2			2			4
	Dec 1999–Jan 2000	2			2			4
	Time PST	0800	1200	1600	2000	2400	0400	
	Feb 2000–Dec 2000	2	2	2	2	2	2	12
Station 4 (Morro Bay back bay)		Daytime High Tide			Daytime Low Tide			
Monthly	Jun–Jul 1999[1]	2			2			4
	Dec 1999–Jan 2000	2			2			4
	Time PST	0800	1200	1600	2000	2400	0400	
	Feb 2000–Dec 2000	2	2	2	2	2	2	12
Station 5 (Estero Bay)		Daytime High Tide			Daytime Low Tide			
Monthly	Jun–Jul 1999[1]	2			2			4
	Dec 1999–Jan 2000	2			2			4
	Time PST	0800	1200	1600	2000	2400	0400	
	Mar 2000[2]–Dec 2000	2	2	2	2	2	2	12

See Figure 3-1 for station locations.

1. Sampling was suspended from August 10 through December 13, 1999 while Tenera Environmental acquired a USFWS Recovery Permit for the collection of tidewater goby. Source water stations were not sampled in August 1999.

2. Station 5 could not be sampled in February 2000 because of unsafe sea conditions.

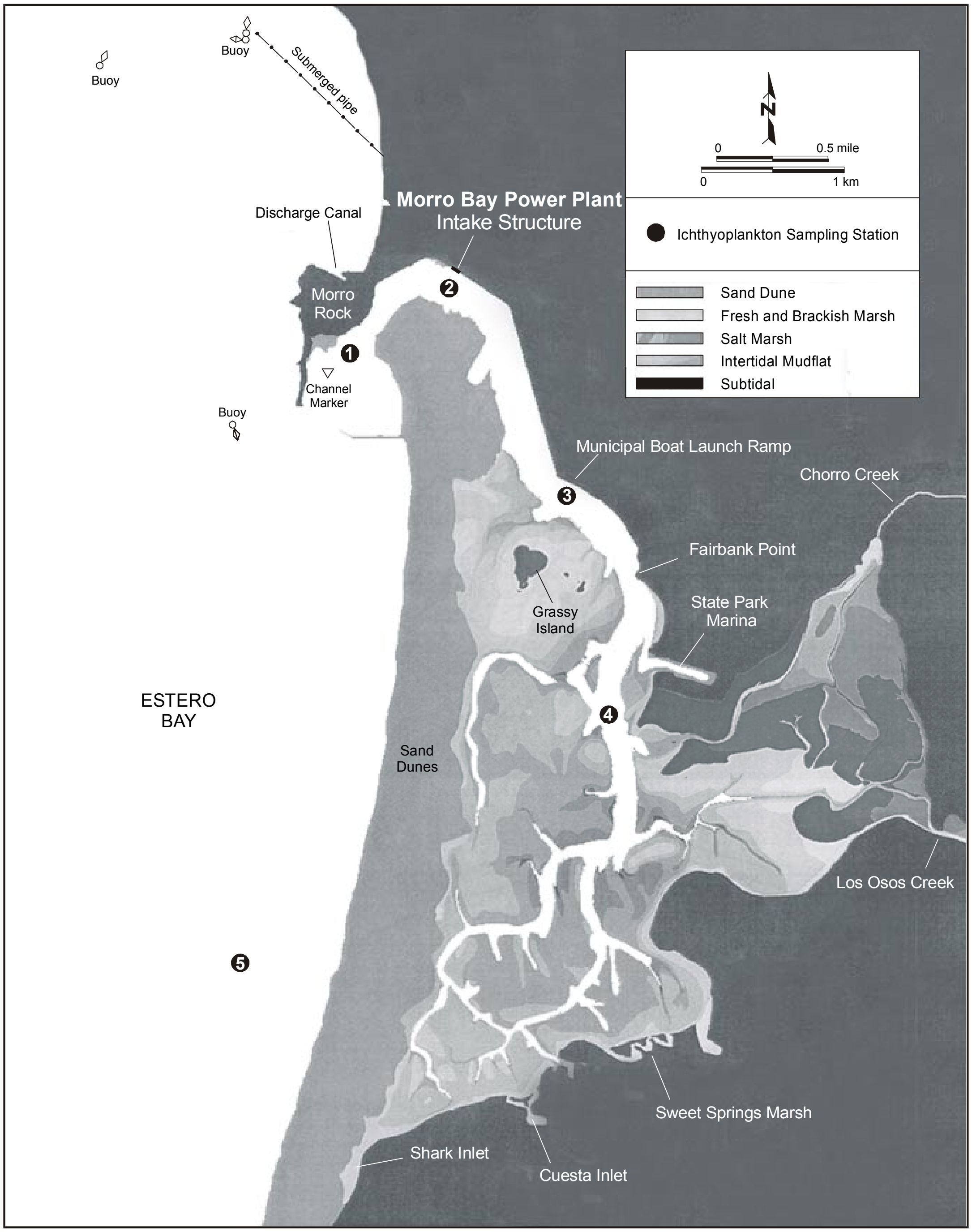


Figure 3-1. Locations of Morro Bay and Estero Bay sampling stations.

3.2.3 Laboratory Processing

Laboratory processing consisted of sorting, removing, identifying, and enumerating all larval fishes and megalopal stages of *Cancer* spp. and European green crabs. Sorting and identification accuracy was verified and maintained by Tenera Environmental's quality control (QC) program. All field and laboratory data were entered into a computer database, which was verified for accuracy against the original data sheets.

Many larval fishes cannot be identified to the species level; these fishes were identified to the lowest taxonomic classification possible (e.g., genus and species are lower orders of classification than order or family). Myomere and pigmentation patterns were used to identify many species, however this can be problematic for some species. For example, sympatric members of the family Gobiidae share morphologic and meristic characters during early life stages (Moser 1996) making identification to the species level difficult. We grouped those gobiids we were unable to identify to species into an "unidentified gobiid" category (i.e., unidentified Gobiidae). Larval combtooth blennies *Hypsoblennius* spp. can be easily distinguished from other larval fishes (Moser 1996). However, the three sympatric species along the central California coast cannot be distinguished from each other on the basis of morphometrics or meristics. These combtooth blennies were grouped into the "unidentified combtooth blennies" category (i.e., *Hypsoblennius* spp.). Many rockfish species are closely related, and the larvae share many morphological and meristic characteristics, making it difficult to visually identify them to species (Moser et al. 1977, Moser and Ahlstrom 1978, Baruskov 1981, Kendall and Lenarz 1987, Moreno 1993, Nishimoto in prep.). Identification of larval rockfish to the species level relies heavily on pigment patterns that change as the larvae develop (Moser 1996). Of the 59 *Sebastes* spp. known from California marine waters (Lea et al. 1999), at least five can be reliably identified to the species level as larvae (Laidig et al. 1995, Yoklavich et al. 1996): blue rockfish *Sebastes mystinus*, shortbelly rockfish *S. jordani*, cowcod *S. levis*, bocaccio *S. paucispinis*, and stripetail rockfish *S. saxicola*. Other species within this genus can only be resolved to broad sub-generic groupings based on pigment patterns; these larvae were grouped using information provided by Nishimoto (in prep.; Table 3-2).

Length measurements were taken on a representative sample of the larval fish taxa presented in the following sections. Approximately 100 fish from each taxon were measured using a video capture system and Optimus™ image analysis software. The 100 fish from each taxon were selected from the intake station (Station 2) during the 12 paired entrainment source water surveys based on the percentage frequency of occurrence of a taxon in each survey. For example, if 20 percent of the cabezon were collected from the intake station during the June paired source water survey, then approximately 20 fish were measured from that survey. The total number of fish measured for each taxon does not exactly equal 100 because at least one or two larvae were measured from surveys that had less than one or two percent of the total for that taxon.

Table 3-2. Preflexion larval rockfish pigment groups from Nishimoto (in preparation).

The code for each group is based on the following letter designations:

V_ = long series of ventral pigmentation (starts directly at anus)	De = elongating series of dorsal pigmentation; scattered melanophores after continuous ones stop)
V = short series of ventral pigmentation (starts 3-6 myomeres after anus)	d = develops dorsal pigmentation (1-2 or scattered melanophores)
D_ = long series of dorsal pigmentation (4 or more in a continuous line) extending to above anus	P = pectoral blade pigmentation
D = short series of dorsal pigmentation (4 or more in a continuous line) not extending to anus	p = develops pectoral pigmentation (1-2 or scattered melanophores)

LETTER CODE	SPECIES	COMMON NAME
V_P	**Long ventral series, no dorsal, pectoral pigment**	
	S. chlorostictus	greenspotted
	S. ensifer	swordspine
V_D	**Long ventral series, short dorsal series, no pectoral pigment**	
	S. saxicola	stripetail
V_D_	**Long ventral series, long dorsal series, no pectoral pigment**	
	S. atrovirens	kelp
	S. chrysomelas	black and yellow
	S. maliger	quillback
	S. nebulosus	China
	S. semicinctus	halfbanded
V_De or V_DeP or V_dep	**Long ventral series, elongating dorsal series, pectoral pigment**	
	S. auriculatus	brown
	S. carnatus	gopher
	S. caurinus	copper
	S. dalli	calico
	S. rastrelliger	grass
V	**Short ventral series, no dorsal series, no pectoral pigment**	
	S. aleutianus	rougheye
	S. alutus	Pacific ocean perch
	S. brevispinis	silvergrey
	S. crameri	darkblotched
	S. diploproa	splitnose
	S. elongatus	greenstriped
	S. macdonaldi	Mexican
	S. miniatus	vermilion
	S. nigrocinctus	tiger
	S. proriger	redstripe
	S. rosaceus	rosy
	S. ruberrimus	yelloweye
	S. serriceps	treefish
	S. umbrosus	honeycomb
	S. wilsoni	pygmy
	S. zacentrus	sharpchin
VP	**Short ventral series, no dorsal series, various patterns of pectoral pigmentation**	
	S. constellatus	starry
	S. eos	pink
	S. goodei	chilipepper
	S. helvomaculatus	rosethorn
	S. levis	cowcod
	S. melanostomus	blackgill
	S. paucispinis	bocaccio
	S. rosenblatti	greenblotched
	S. rubrivinctus	flag
Vdp	**Short ventral series, develops dorsal series, develops various patterns of pectoral pigmentation** (at younger stages can be confused with V above due to lack of dorsal and pectoral pigmentation)	
	S. entomelas	widow
	S. flavidus	yellowtail
	S. melanops	black
	S. mystinus	blue
	S. rufus	bank
	S. serranoides	olive
VD	**Short dorsal series, short dorsal series**	
	S. aurora	aurora
	S. babcocki	redbanded
	S. gilli	bronzespotted
	S. hopkinsi	squarespot
	S. jordani	shortbelly
	S. ovalis	speckled
	S. pinniger	canary
Species without descriptions or illustrations		
	S. philipsi	chameleon

3.2.4 Data Analysis

Sample concentrations of larval fishes and megalopal cancrid crabs, identified to the lowest taxonomic level practical, were computed by dividing the number of each taxon or species in each sample by the sample volume. The taxon-specific mean survey concentrations found in Appendix F (Table F-1) were calculated as simple arithmetic averages of the sample concentrations for a survey.

Data collected in entrainment and source water plankton surveys were compiled in one of two ways for the three types of analyses conducted for the impact assessment. All plankton surveys conducted at the MBPP intake structures to estimate entrainment were used to parameterize the demographic approaches to impact assessment (i.e., *FH* and *AEL*). A slightly different data set was used for the *ETM*. Concentrations of larval fishes and cancrid crab megalopae were estimated from monthly source water surveys and the concurrent entrainment survey to estimate proportional entrainment (*PE*) used in *ETM* calculations. These 'paired surveys' were collected over a continuous 12-month period from January – December 2000.

The mean survey concentrations were calculated by treating each cycle as a stratum and computing a mean and variance for each cycle. These means and variances were then combined to compute estimates of the mean and variance for the survey treating the *n* for each cycle as a weight. The variance was calculated using the standard calculation for stratified sampling (Snedecor and Cochran 1967). The data used to estimate the entrainment impacts (Section 5.0) were from the continuous 12-month period from January – December 2000.

Mean concentrations for ebb and flood tidal currents were also analyzed for all the stations from the paired monthly surveys. Sampling cycles were designated as occurring during either ebb or flood tides by examining the changes in tidal height during the sampling periods. Tidal heights matching the average start time for the two plankton tows within each cycle were determined from tide charts generated by the WXTide32™ program. Changes in tidal height (computed from the tide data) of greater than 0.15 m (0.5 ft) per hour were designated as either ebb or flood tides depending on the direction of change. Changes of less than 0.15 m (0.5 ft) per hour were considered slack tides. Mean concentrations were computed for the ebb and flood tides for each station during each paired entrainment-source water survey. These concentrations do not sum to the overall mean for the survey period because cycles during slack tides were omitted and sample sizes were not equal among stations for ebb and flood tides.

To characterize species composition and abundance among the stations, data from sampling stations were compared on the basis of rank order abundance and similarity. The annual mean concentrations of the top 25 taxa at each station were computed to compare the rank order abundance among stations. The pooled list of the top 25 taxa from each station produced a list of 40 taxa for comparison across stations. The composition and abundance among stations were analyzed using a Bray-Curtis distance computed between each pair of stations (Digby and Kempton 1987). The scale of the Bray-Curtis distance measure is from 0 to 1.0, with a value of 0 indicating zero distance between samples or 100 percent similarity and a value of 1.0 indicating a high degree of dissimilarity.

3.3 Entrainment and Source Water Results

Totals of approximately 83,600 larval fishes and nearly 11,000 megalopal *Cancer* spp. crabs were collected in plankton tows from June and August 1999 and from December 1999 – December 2000. Slightly less than half of the larval fishes were collected in weekly surveys at the MBPP intake station (Appendix F, Table F-1) while the rest were collected in monthly source water surveys (Appendix F, Table F-2). Approximately 92 percent of the *Cancer* spp. megalopae were collected in the monthly source water surveys (Appendix F, Table F-2). There were 40 species, 13 genera, 19 families, one suborder, and one order of larval fishes identified during this study. Slightly more than 1 percent of the larval fish specimens were too damaged to identify, and approximately 0.1 percent of the larval fish specimens, although undamaged, could not be identified. All *Cancer* spp. megalopae were identified to the lowest taxonomic level practical.

Unidentified gobies were the most abundant larval fish taxon collected at each of the five stations (Figure 3-2). The percent composition of the total number of larval fishes represented by unidentified gobies ranged from a low of 35 percent at Station 5 (Estero Bay) to a high of 82 percent at Station 3 (mid bay). The greatest dissimilarities occurred between Station 5, located offshore, and the mid and back bay stations (3 and 4). Stations 3 and 4 had the fewest number of species and were also the most similar to each other. Overall, the diversity of species was far greater at the Estero Bay station (Station 5) than at stations located within the bay.

The brown rock crab *Cancer antennarius* was the most abundant megalopal cancer crab species collected at each of the five stations (Figure 3-3). The percent composition of the total number of cancer crabs represented by brown rock crab ranged from a low of 49 percent at Station 1 to 95 percent at Station 5. Although the species composition was fairly similar among the stations, the abundance of species at each sampling station was most similar between the stations located within the bay. Station 5 (located outside the bay) had a proportionally greater abundance of brown rock crab larvae than stations within the bay.

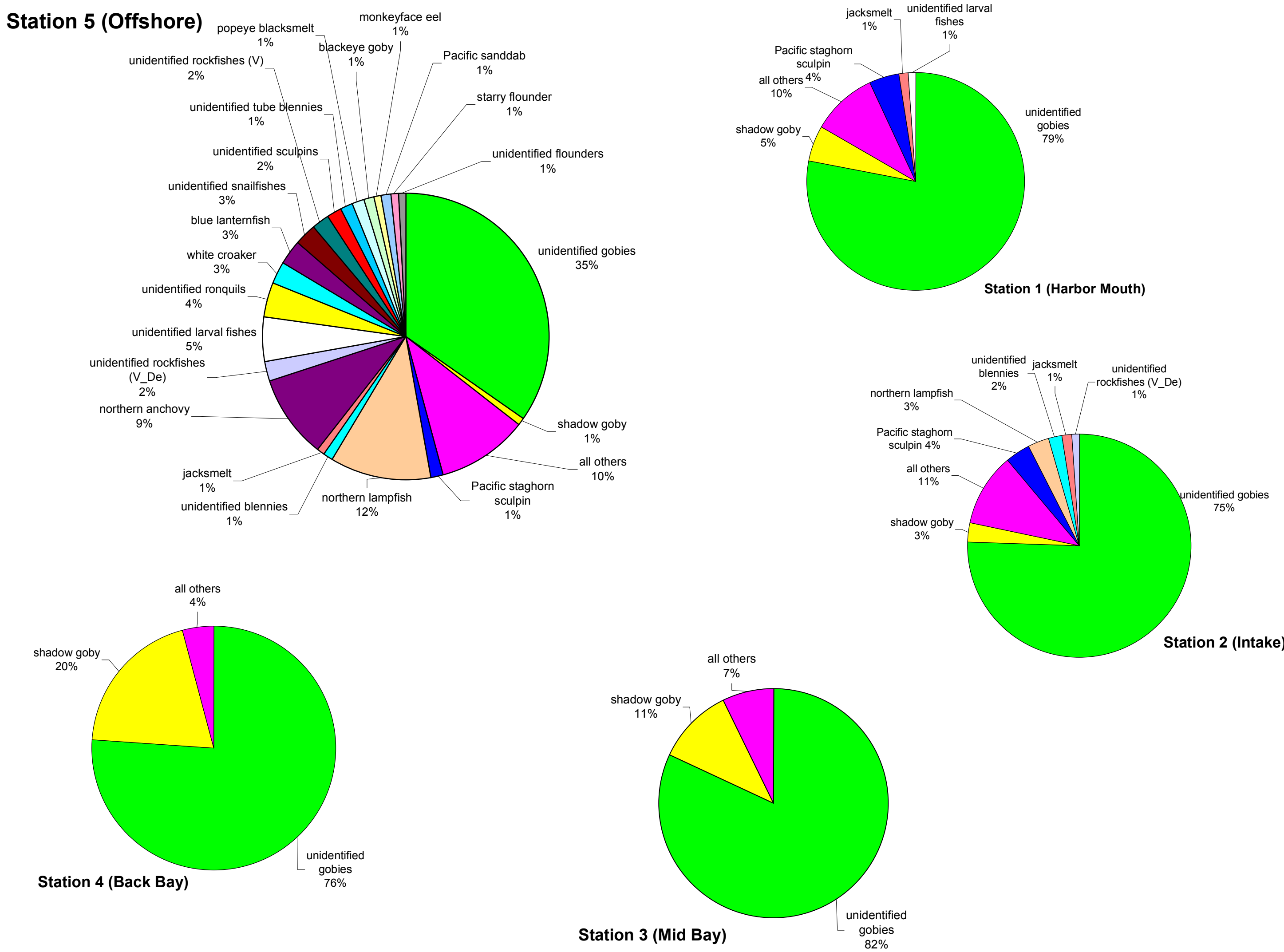


Figure 3-2. Percent composition of the total number of larval fishes collected by station in the vicinity of the Morro Bay Power Plant: January – December 2000.

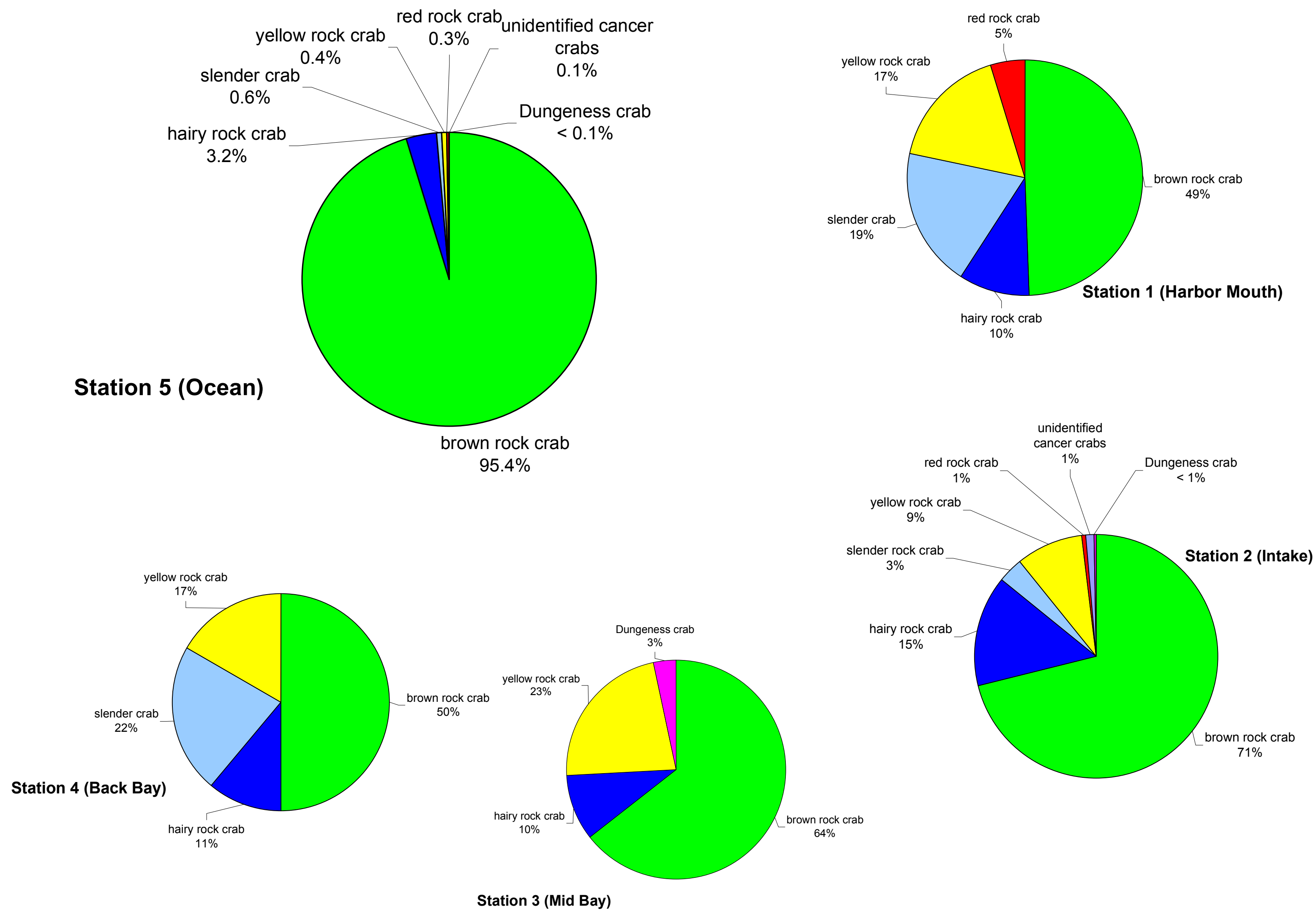


Figure 3-3. Percent composition of the total number of cancer crab megalopae collected by station in the vicinity of the Morro Bay Power Plant: January – December 2000.

In 1998, adults of the introduced European green crab were collected from Morro Bay (T. Grosholz, UCD, pers. comm. 1999). Therefore, an attempt was made to identify and enumerate megalopae of this crab from MBPP entrainment and source water plankton samples. Early life stage descriptions of this crab are from European specimens and may not describe the morphologic characters of the local populations in sufficient detail to separate European green crab larvae from other locally co-occurring crabs (D. Innis, Tenera Environmental, pers. comm. 2000). In cooperation with Dr. Grosholz, we were unable to either definitively identify megalopal European green crabs in the MBPP 316(b) plankton samples or duplicate Grosholz' observations of adult green crabs in Morro Bay. Megalopal crabs that had been tentatively identified as European green crab are thought to closely resemble the native pebble crabs *Lophopanopeus* spp. European green crab megalopae were not found in our plankton surveys from Morro and Estero bays.

Our initial larval fish identifications, based on existing morphometric and meristic descriptions, (Wang 1986, Matarese et al. 1989, Moser 1996) classified a number of gobiid larvae as the endangered tidewater goby *Eucyclogobius newberryi*. The USFWS and taxonomic experts recommended DNA testing to confirm the tidewater goby identification. A total of 53 larval fish were sent to Dr. David Jacobs (at the University of California Los Angeles) for DNA testing. DNA sequencing results were obtained for 52 of the 53 larval fishes; one fish could not be sequenced. Five of the 53 larval fishes were not morphometrically identified as tidewater goby but were sent with the other gobies to verify the DNA sequencing procedure; Dr. Jacobs did not know the specimen numbers of these fishes. These five specimens were from the unidentified gobiid category (Gobiidae) and their taxonomic characters did not match tidewater goby. These five specimens were genetically identified as arrow goby *Clevelandia ios*. The DNA analyses performed on the 48 other larvae did not match their morphometric identifications as tidewater goby. None of these specimens were tidewater goby based on the DNA test results. Most (96 percent) of the tidewater goby-like specimens sent to Dr. Jacobs were genetically identified as shadow goby *Quietula y-cauda*. Two of the 48 tidewater-goby-like specimens were from unknown gobies whose DNA did not match any of the sequencing information in the laboratory's data banks; these "unknown gobies" also did not match sequencing information for tidewater goby. In this report, we have presented numbers, concentrations, and percent composition information about specimens that were originally identified as tidewater goby and are now referred to as shadow goby[*]. Dr. Jacobs' report, and a response by Dr. Giacomo Bernardi (U.C. Santa Cruz) are attached to this document as Appendix G.

[*]Ninety-six percent of the larval fishes displaying the same taxonomic characteristics as tidewater goby were genetically identified as shadow goby. These were therefore classified as shadow goby. No tidewater goby were identified in the DNA analyses.

The larval fish concentration (all taxa) at the MBPP intake station was highest during the winter and spring months (Figure 3-4). This is consistent with spawning periods of most coastal California fishes (Moser 1996). These fishes typically release their larvae in the water column prior to the spring upwelling season, possibly to reduce the risk of being transported away from shore to areas of lower potential food sources (Parrish et al. 1981).

Larval fish abundance at all five stations were compared for the paired intake and source water plankton surveys (Figure 3-5). Results from these monthly surveys revealed that mid and back bay stations 3 and 4 consistently had some of the highest larval fish concentrations. In contrast, larval fish concentration was consistently lower at the Estero Bay station (Station 5) than at the other stations.

These same data were also compared among the five stations for ebb and flood tidal current conditions (Figure 3-6). While some of the differences may be due to the absence of flood tide currents during a survey, it appears that larval fish concentrations were consistently greater during ebb tidal currents. Ebb tides are drawing water out of the interior portions of Morro Bay, which are breeding areas for many of the fishes collected in our samples. This is most apparent at stations 3 and 4 in the interior areas of Morro Bay where concentrations of larval fishes were greatest (Figure 3-5). The concentrations of larvae at these stations may be increased during ebb tide currents that draw water out of the shallower areas of the back bay where eelgrass *Zostera marina* and other important habitat for fishes are located. The differences were less for stations 1 and 2 in the outer areas of the bay.

Mean concentrations of the top 25 taxa (40 pooled across all five stations) were compared among the five sampling locations (Figure 3-7). The top 25 taxa were those in highest abundance at each station and co-occurring at all five of the stations. Unidentified gobies were the most abundant larval fish taxon at all five stations. Concentrations of the more abundant taxa were similar among stations within Morro Bay (i.e., Stations 1–4). Overall, larval concentrations in Estero Bay (Station 5) were lower and more evenly distributed among the 25 taxa. Station 4 (back bay) and Station 5 (offshore of the sand spit in Estero Bay) had the fewest taxa in common.

The annual mean concentrations of the pooled list of 40 taxa were also analyzed using a Bray-Curtis distance computed between each pair of stations (Table 3-3). Stations 1 and 2 at the harbor entrance and intake, respectively, had the lowest Bray-Curtis value and were the most similar. Stations 3 and 4 in the mid and back bay also had a low Bray-Curtis value. The greatest dissimilarities occurred between Station 5, located offshore, and the two back bay stations (3 and 4). Dissimilarity also increased between Station 1 at the harbor entrance and stations further back in the bay. Even though Station 1 was located at the harbor entrance it was more dissimilar to the station located in Estero Bay (5) than it was to Station 4 located furthest inside Morro Bay. The similarities between adjacent stations in Morro Bay as compared with Estero Bay may indicate that tidal influences within Morro Bay had the greatest influence on species distribution and abundance throughout the bay and input from offshore sources was less important in determining larval abundance and composition within Morro Bay.

The concentrations (#/m^3) of larval fishes and cancrid crab megalopae collected at the MBPP intake station were analyzed to determine the proportional contribution of each taxon to the total abundance over the period January 1, 2000 through December 29, 2000 (Appendix F, Table F-1).

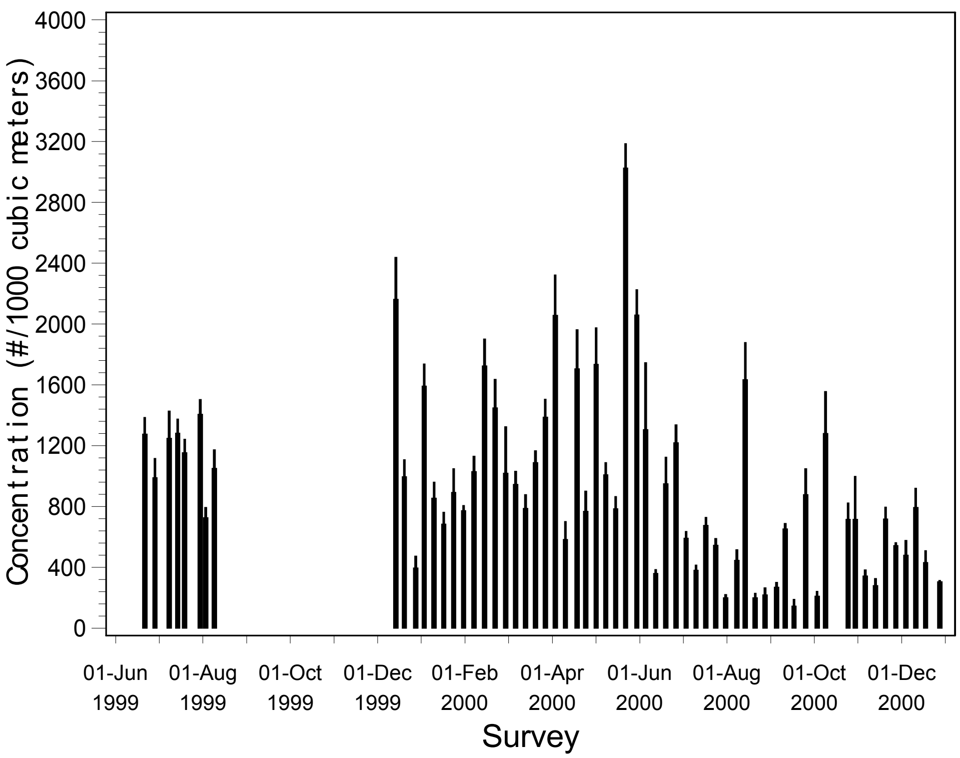


Figure 3-4. Weekly survey mean larval fish concentrations at the MBPP intake station for all taxa combined with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

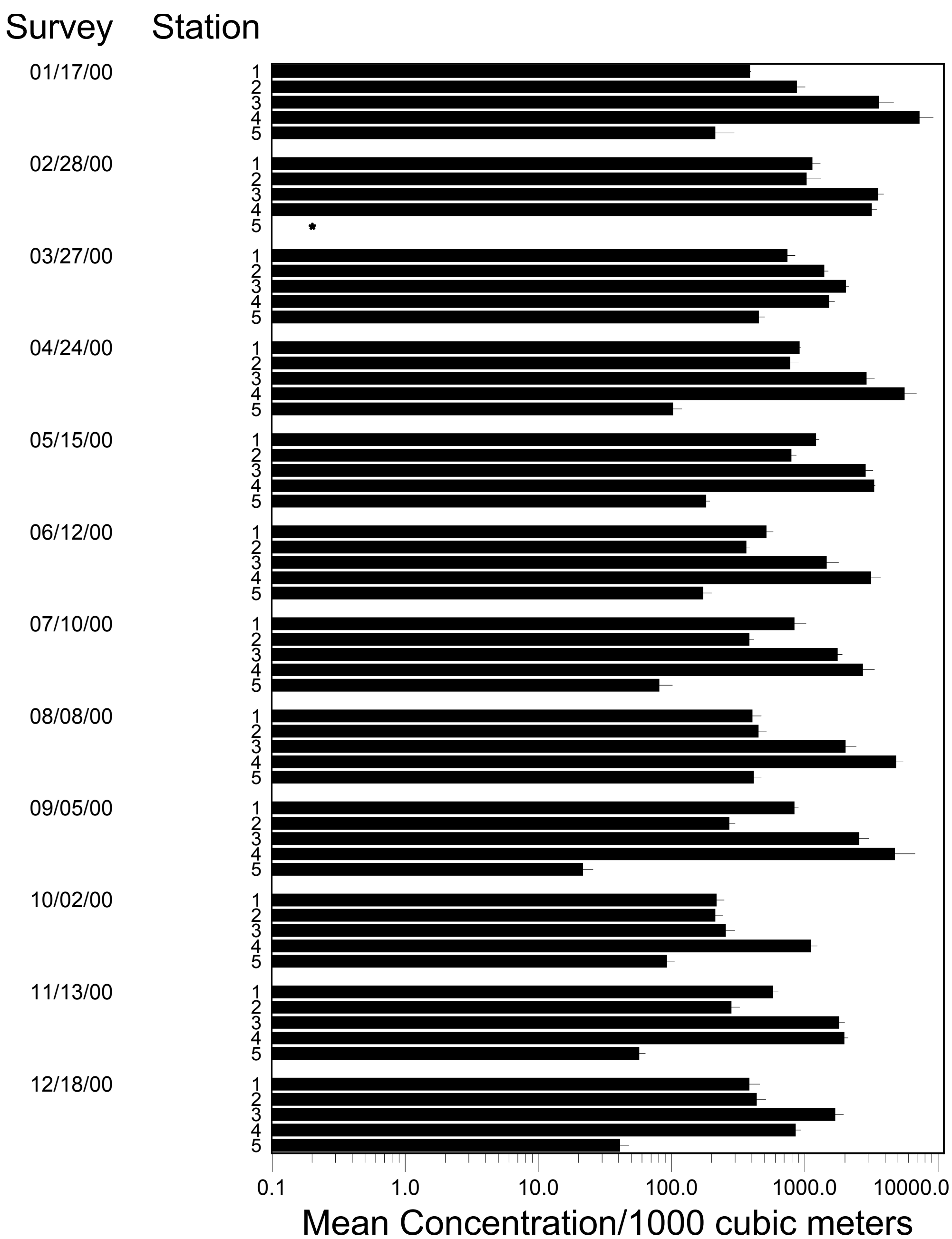


Figure 3-5. Mean larval fish (all taxa combined) concentration in monthly paired surveys at the MBPP intakes (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

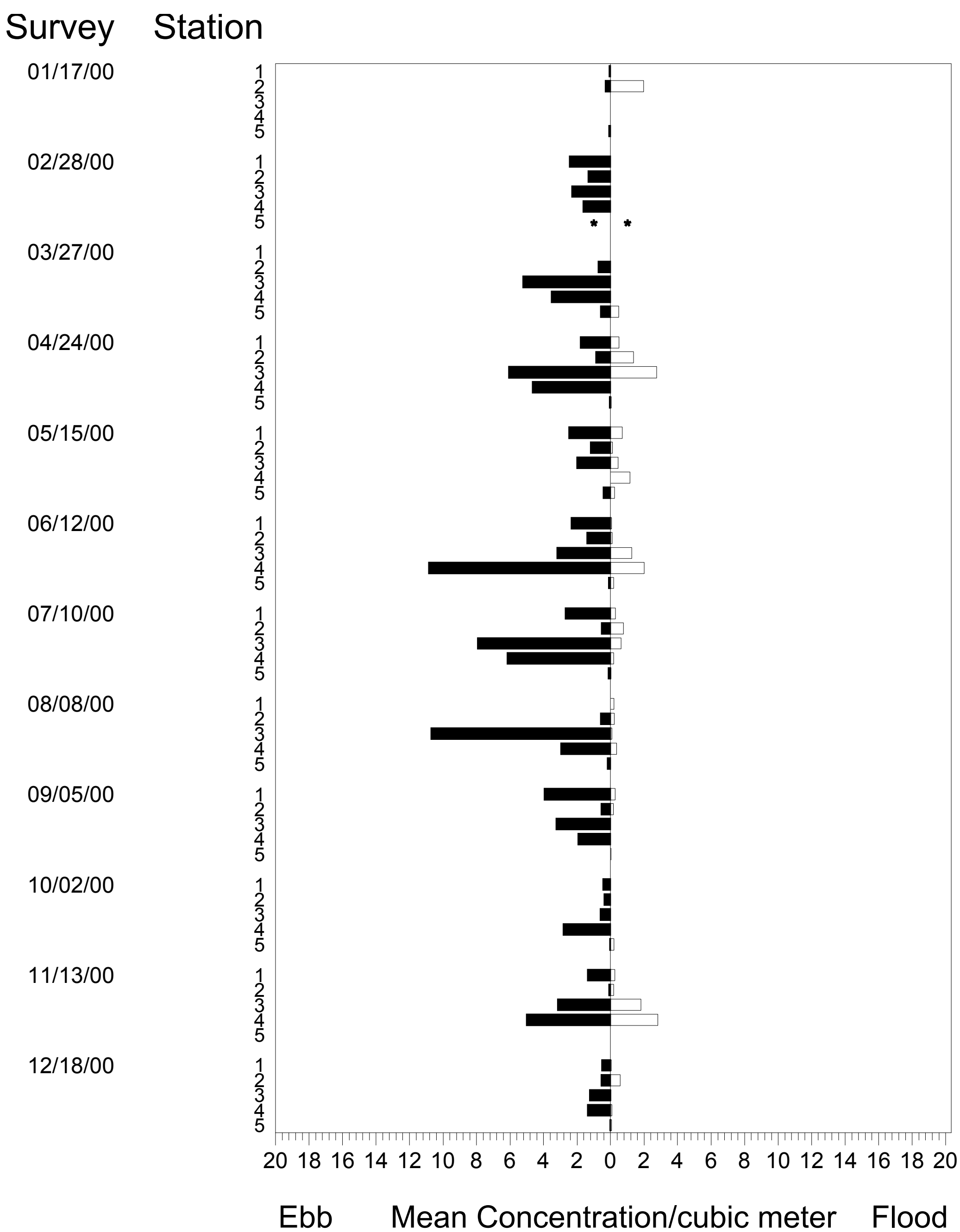


Figure 3-6. Mean concentration of all larval fish taxa from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

Table 3-3. Bray-Curtis dissimilarities in diversity among Morro Bay (stations 1, 3, and 4) and Estero Bay (Station 5) and the MBPP Intake (Station 2) based on mean survey concentrations from twelve surveys collected from January – December 2000.

Station	1	2	3	4
1	0			
2	0.082	0		
3	0.567	0.596	0	
4	0.700	0.716	0.218	0
5	0.756	0.740	0.924	0.951

Nearly 81 percent of the larval fishes collected at the intake station during the year analyzed were gobies: Gobiidae unidentified (75 percent), shadow goby *Quietula y-cauda* (approximately 3 percent), blackeye goby *Coryphopterus nicholsi*, longjaw mudsucker *Gillichthys mirabilis*, bay goby *Lepidogobius lepidus*, and blind goby *Typhlogobius californiensis*; each of the latter four comprised less than 1 percent of the total. The majority of fish taxa collected at the intake station are found in estuaries at some point in their life cycle (e.g., Pacific staghorn sculpin *Leptocottus armatus*, jacksmelt *Atherinopsis californiensis*, Pacific herring *Clupea pallasii*, Pacific sandlance *Ammodytes hexapterus*, and others). Rockfish larvae *Sebastes* spp. were notable for their low abundance during the year; kelp/gopher/black-and-yellow (KGB) complex rockfish larvae comprised approximately 1 percent of the total and the remaining *Sebastes* spp. comprised less than 1 percent overall. Brown rock crab *Cancer antennarius*, hairy rock crab *C. jordani*, and yellow crab *C. anthonyi* (comprising 95 percent of the cancrid crab megalopae collected at the MBPP intake station) are all coastal crabs often found in bays and estuaries.

Seven larval fish taxa and three *Cancer* spp. megalopae comprised approximately 90 percent of the larval fishes and cancrid crab megalopae concentrations from samples collected at the intake station for the one year period from January 1, 2000 – December 29, 2000 (Figures 3-2 and 3-3, respectively). The top 85 percent of larval fishes collected at the MBPP intake station were dominated by demersal and pelagic estuarine taxa (i.e., unidentified gobies [75 percent], Pacific staghorn sculpin [4 percent], shadow goby [3 percent], and northern lampfish *Stenobrachius leucopsarus* [3 percent]) (Figure 3-2). Megalopal cancrid crab abundance was dominated by brown rock crab (71 percent), followed by hairy rock crab (15 percent), and yellow crab (9 percent) (Figure 3-3). Results for the seven fish taxa comprising 89 percent of all larval fishes are presented in the following sections. In addition, results for three commercially important taxa (white croaker *Genyonemus lineatus*, Pacific herring *Clupea pallasii*, and cabezon *Scorpaenichthys marmoratus*) that were collected in lower abundances are also presented along with the results for all cancrid crab megalopae.

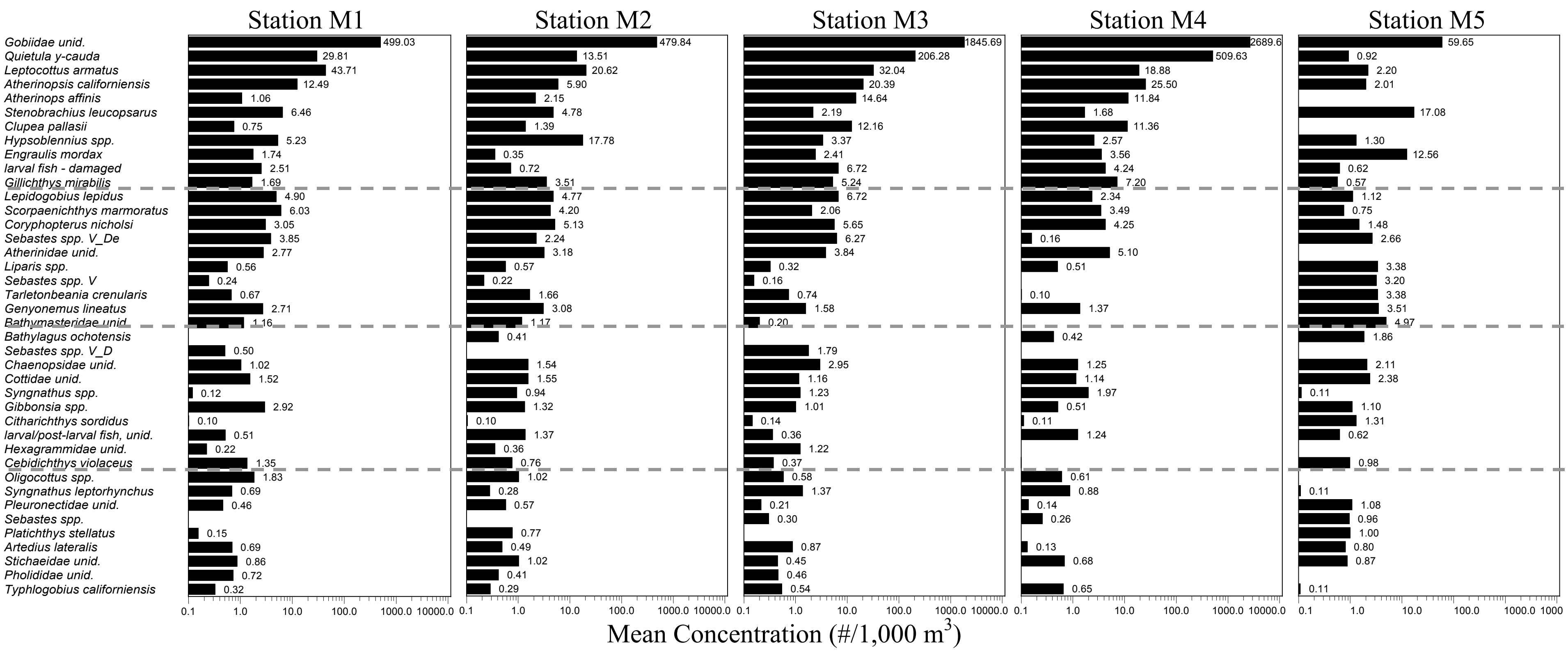


Figure 3-7. Comparison of the mean concentration (#/1,000 m^3) of the 25 most abundant fishes (39 taxa pooled) from the intake station (2) and source water stations (1, 3, 4 and 5) from January – December 2000.

3.3.1 Gobies Gobiidae

Gobies belong to a speciose family (Gobiidae) of small, demersal fishes that are found worldwide in shallow tropical and subtropical environments. The family contains around 1,875 species in 212 genera (Nelson 1994, Moser 1996). Twenty-one goby species from 16 genera occur from the northern California border to south of Baja California (Moser 1996) and eight of these species are common in the MBPP study area (Miller and Lea 1972, Love et al. 1996).

Members of the family Gobiidae share many life history characteristics. Adult gobies are oviparous and produce demersal eggs that are elliptical in shape, typically adhesive, and attached to a nest substratum at one end (Wang 1986, Matarese et al. 1989, Moser 1996). Most species that occur in Morro Bay inhabit burrows in mud flats and other shallow regions of bays and estuaries (Miller and Lea 1972). The fecundity of the arrow goby *Clevelandia ios* ranges from 750 to 1,000 eggs (Wang 1986). Goby larvae enter the plankton following hatching and remain in this pelagic phase until they transform and become benthic-oriented juveniles.

The duration of the planktonic phase varies greatly within the family and is not well described for most of the goby species in the study area. Larval gobiids are distinct from larvae of other families of fishes in the study area, but in many cases are difficult to separate from other sympatric gobiids at these early life stages. The period of entrainment risk used in the *ETM* model were estimated from a growth rate for blackeye goby *Coryphopterus nicholsii* reported by Steele (1997).

Myomere counts and pigmentation characteristics can be used to identify many larvae to the species level (Moser 1996). However, identification of larval gobies to the species level can be problematic since several sympatric gobiids share morphologic and meristic characters during early larval stages. Larval gobies collected during MBPP sampling that could not be identified to the species level were left at the family level (i.e., Gobiidae). These were probably composed of some combination of morphologically similar species that co-occur in the study area. Five larval specimens from the "unidentified goby' group were sent to Dr. David Jacobs for DNA testing and all were genetically identified as arrow goby. We believe that the majority of the larval fishes in this group are arrow goby.

In early stages, bay goby *Lepidogobius lepidus* may also share similar morphologic characters with yellowfin and arrow goby making it difficult to separate them especially when the specimens are not in good condition. Moser (1996) indicates that arrow goby, cheekspot goby, and the shadow goby cannot be differentiated during any larval stage. Brothers (1975) reported difficulty in separating more developed arrow and cheekspot goby that were less than 65 mm

(2.6 in.) long. Recent genetic identifications undertaken during this study (Appendix G) indicated that the endangered tidewater goby and the shadow goby might share sufficient meristic and morphologic characters to render them inseparable during their larval phase. Results from these studies also showed that none of the larvae tentatively identified from morphologic characters as tidewater goby were genetically identified as tidewater goby and that the majority (96 percent) of the specimens initially identified as tidewater goby were shadow goby.

Many of the adults of the gobiid larvae are known to occur in the study area (Appendix B). Adult shadow goby were collected in shallow waters in the back bay, south of our source water Station 4 (Horn 1980). Arrow and bay gobies were collected in surveys conducted by Fierstine et al. (1973), Horn (1980), and in CDFG otter trawls (CDFG, unpubl. otter trawl data). Bay goby were collected in both MBPP impingement studies, while arrow goby were not collected in either impingement study (Behrens and Sommerville 1982; Section 4.0 – Impingement). Longjaw mudsucker *Gillichthys mirabilis* were collected by Fierstine et al. (1973) and were also collected in the 1999-2000 impingement study.

3.3.1.1 Unidentified Goby Results

Larvae identified to the family Gobiidae were the most abundant and most frequently collected at the MBPP intake station. Based on the results of the DNA analysis, we believe that the majority of these unidentified gobiids were arrow goby. They were collected in nearly 100 percent of the weekly surveys conducted at the MBPP intake station (Figure 3-8) and accounted for 75 percent of the total number of fishes collected at the MBPP intakes (Figure 3-2). Goby concentration varied seasonally and spawning activity appeared to continue year-round in the vicinity of the MBPP.

The length frequency distribution for a representative sample of unidentified Gobiidae larvae showed that the majority of the larvae were small (average size of 3.7 mm [0.15 in.]) and likely to be recently hatched (Figure 3-9). The samples also contained larger larvae up to 8.2 mm (0.32 in.). Most of the unidentified Gobiidae larvae are thought to be arrow goby *Clevelandia ios* and are probably represented by the distinct peak in the frequency distribution at 3.5 mm (0.14 in.). The break in the frequency distribution may represent a species other than arrow goby that have a larger hatching size or different larval behavior.

Unidentified gobiids were also the most common and abundant larval fish taxa collected in the monthly paired surveys (Figure 3-10). The majority of these larvae were collected from stations inside Morro Bay. The greatest concentrations of unidentified gobiid larvae were consistently collected from the stations in the southernmost enclosed portion of Morro Bay (stations 3 and 4).

Concentrations (#/m^3) of unidentified gobiid (Gobiidae) larvae were compared among stations for collections made at ebb and flood tides (Figure 3-11). Larval goby abundance was generally higher on ebb tides. Goby larvae were not very abundant at the Estero Bay station (Station 5) and therefore no conclusion could be made on the relationship between their abundance at that station and the tidal current in which they were collected. Inside the bay, the concentrations of goby larvae probably increased during ebb tides at the stations in the southernmost enclosed portion of Morro Bay (stations 3 and 4) when larvae were drawn out of the shallow mudflat and eelgrass habitats of the bay where adult gobies are most abundant.

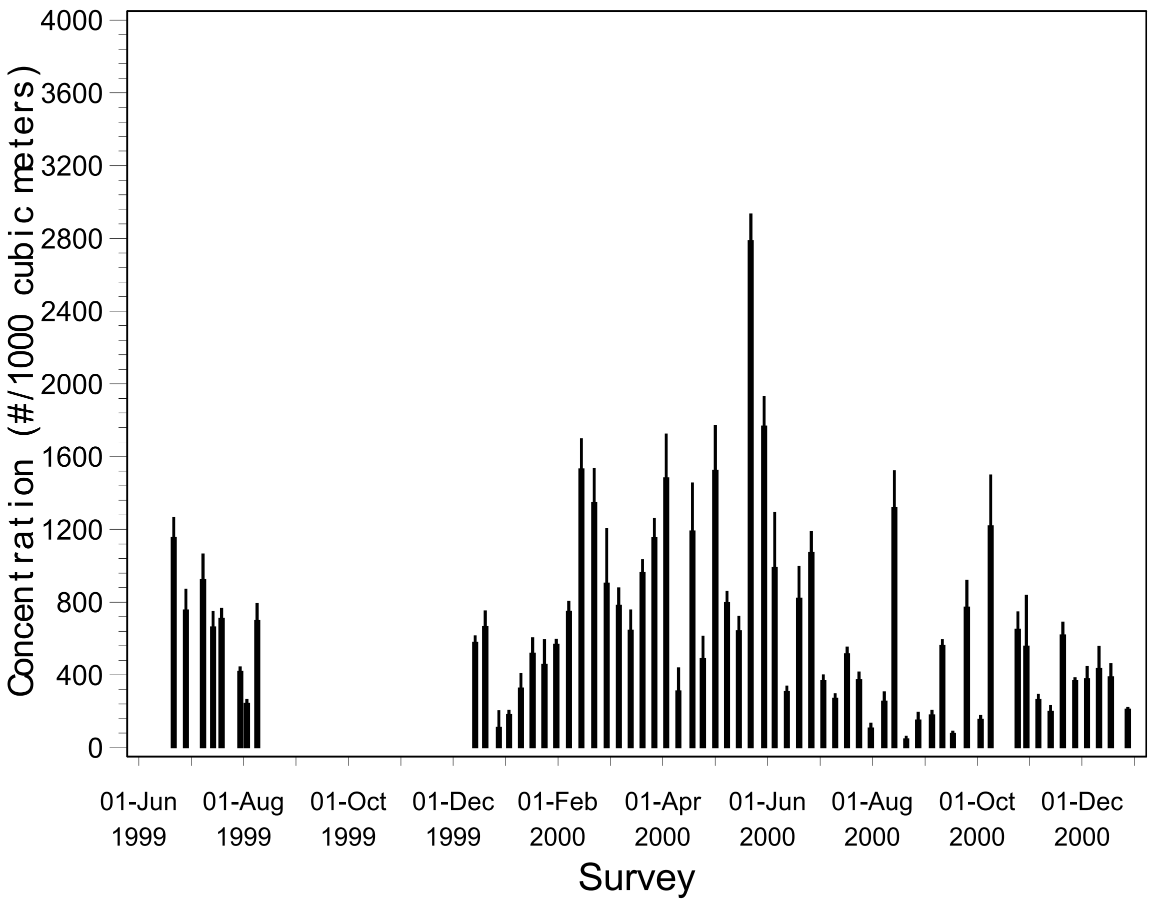


Figure 3-8. Weekly survey mean concentrations of unidentified larval Gobiidae collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

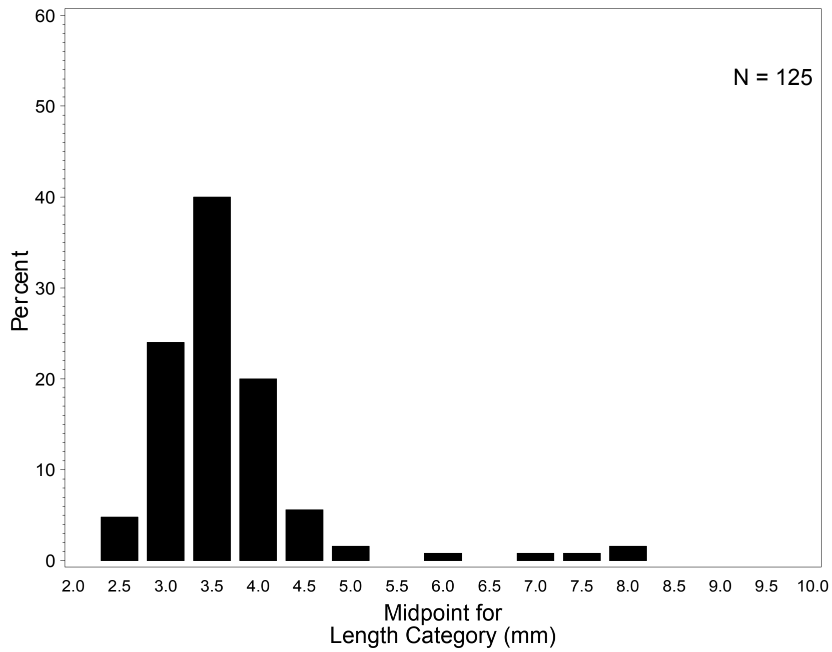


Figure 3-9. Length frequency (mm) distribution for larval Gobiidae collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

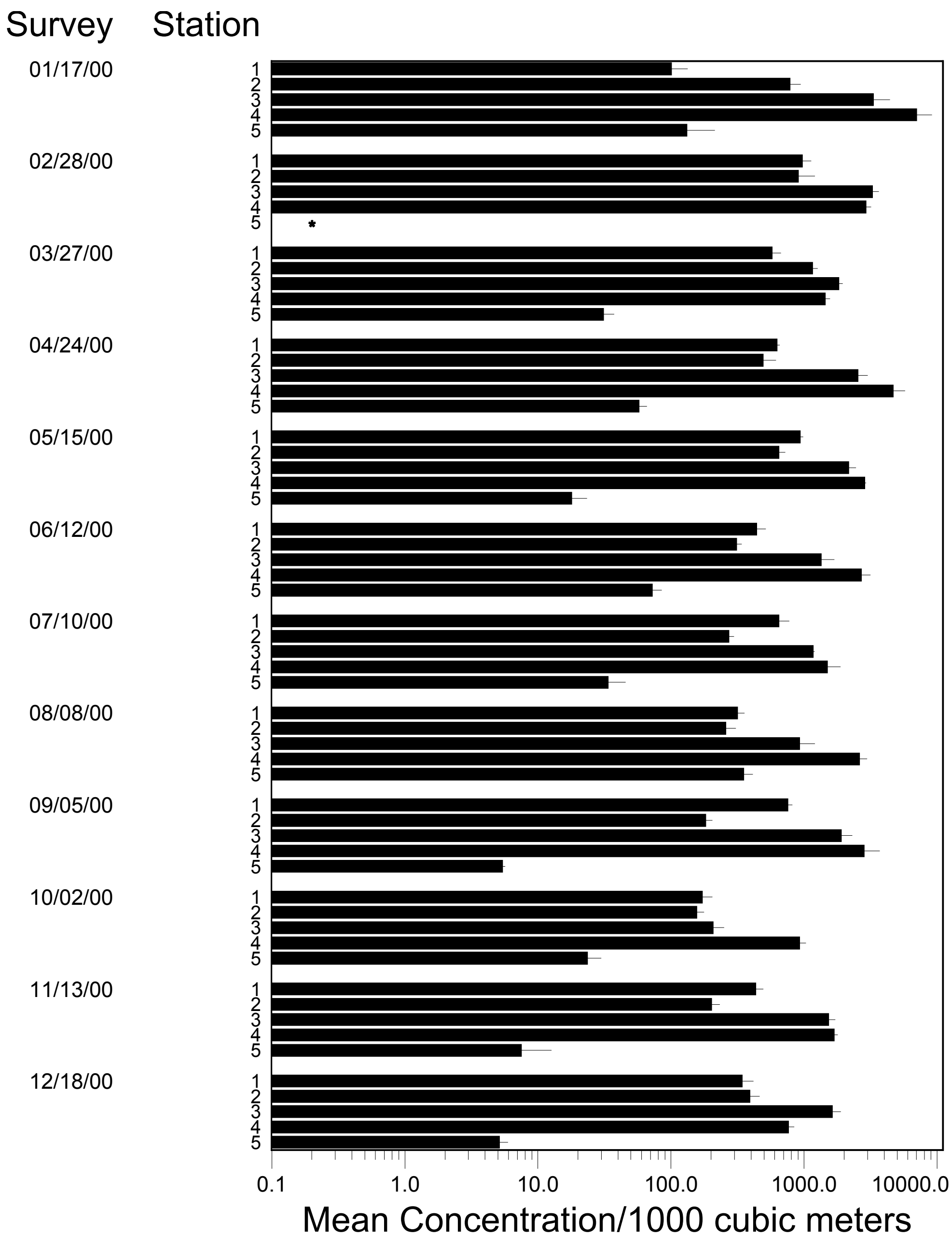


Figure 3-10. Mean unidentified larval Gobiidae concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

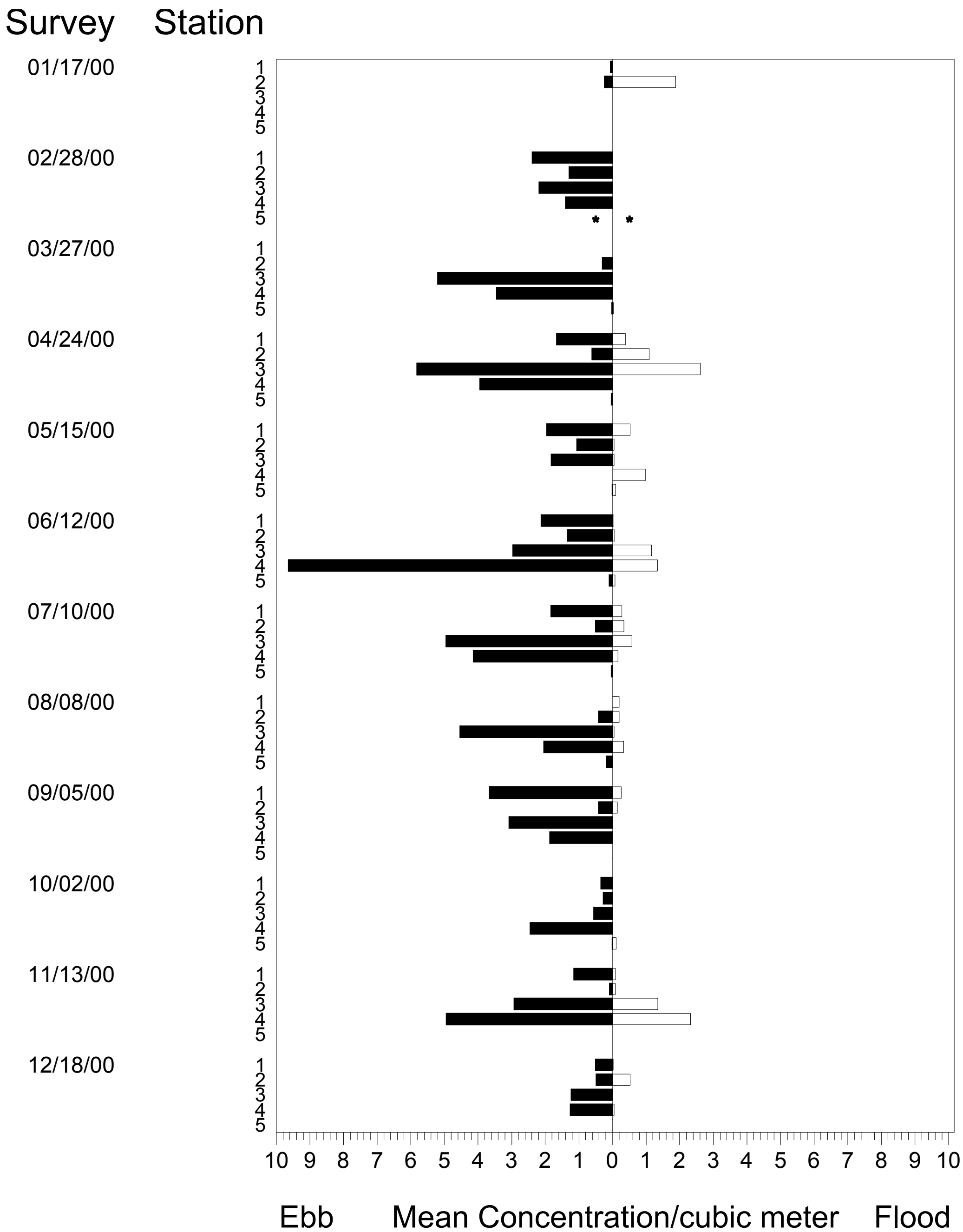
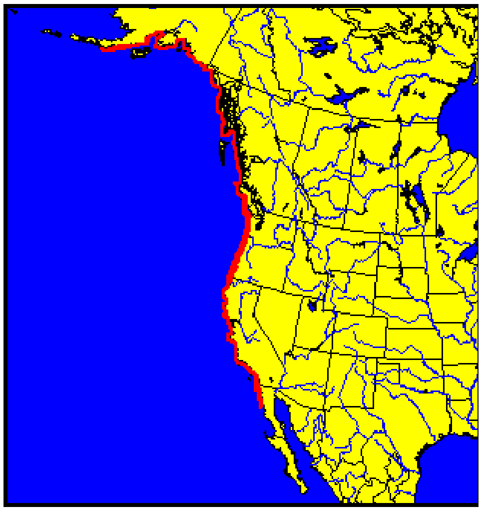


Figure 3-11. Mean concentration of unidentified larval Gobiids from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.2 Pacific staghorn sculpin Leptocottus armatus



Distribution map for adult Pacific staghorn sculpin

Adult Range: From San Quintin Bay, Baja, California to Chignik, Alaska in the southern Bering Sea.

Life History: Size: commonly less than 254 mm (10 in.); Age at maturity: approximately one year old; Fecundity: 2,000 to 11,000 eggs; Life span: maximum age unknown.

Adult Habitat: Lower reaches of bays and estuaries; shallow muddy and silty substrates; intertidal to depths of 91 m (300 ft).

Adult Fishery: Recreational; common catch from piers, used as bait, primarily in striped bass fishery. Commercial; by-catch in trawl fishery, small bait-fish market.

The Pacific staghorn sculpin belongs to the family Cottidae, a large group (more than 300 species) of bottom-dwelling fishes (Nelson 1994). Pacific staghorn sculpin range from San Quintin Bay in northern Baja California to Chignik, Alaska in the southeastern Bering Sea (Miller and Lea 1972). In the southern half of their range they commonly occur in freshwater (Moyle 1976). Pacific staghorn sculpin were collected during all Morro Bay fish studies (Fierstine et al. 1973, Horn 1980, Behrens and Sommerville 1982, CDFG unpubl. otter trawl data, 1999-2000 impingement study [Section 4.0]).

The Pacific staghorn sculpin is classified as a non-dependent marine fish, meaning that although commonly found in estuarine environments, it does not require this habitat type to complete its life cycle (Moyle and Cech 1988). Pacific staghorn sculpin are usually found in shallow subtidal waters, but may be found as deep as 91 m (300 ft). They commonly burrow into the sandy mud bottoms of bays and estuaries leaving only their head and eyes exposed. They are occasionally found in the lower reaches of freshwater streams.

Spawning takes place from October through April, peaking in January and February. Spawning locations tend to be shallow coastal bays, inlets, sounds, and sloughs (Jones 1962). The spawning substrata varies from mud and sand bottoms to more firm rocky areas. The females spawn only once per season. After spawning, the adults leave the shallow spawning areas for deeper offshore waters (Tasto 1975). Eggs hatch in about ten days and the larvae (averaging 4.5 mm [0.2 in.] in length) swim to the surface, becoming planktonic (Jones 1962). Wang (1986) suggested that the larvae might remain on the bottom for a short period of time before they ascend to the surface. It takes approximately eight weeks from hatching until larvae metamorphose into juveniles at a length of 15 to 20 mm total length (TL; 0.6 to 0.8 in.; Matarese et al. 1989). While Matarese et al. (1989) reported that it took approximately eight weeks from the time of hatching until the larvae metamorphosed into juveniles, at a length of 15 to 20 mm (0.6 to 0.8 in.) TL, the time period that the larvae are subject to entrainment appears to be considerably less.

Juvenile Pacific staghorn sculpin recruit to shallow inshore waters and sloughs. It has been reported that juveniles move up estuaries and into freshwater and remain there for about three months before moving to a more saline environment (Moyle 1976, Love 1996). The prey of Pacific staghorn sculpins includes amphipods, nereid worms, and small anchovy (Jones 1962).

3.3.2.1 Pacific Staghorn Sculpin Results

Pacific staghorn sculpin larvae were collected at the MBPP intake station every month, with a marked peak in December 1999 (Figure 3-12). This suggests that incubation times could be on the order of a month or two for this species, given the start of spawning activity in October as reported by Moser (1996). They were collected at the MBPP intake station at a much lower rate during December 2000 as compared with the same month of the previous year.

The length frequency distribution for a representative sample of Pacific staghorn sculpin larvae showed a relatively wide size range of 3.3 to 9.9 mm (0.13 to 0.38 in.) with an average size of 7.5 mm (0.3 in.) (Figure 3-13). While a group of smaller larvae were collected, most of the larvae were in the 8 to 9 mm (0.31 to 0.35 in.) range in the bimodal frequency distribution. This distribution may verify the findings of Wang (1986) that the larvae may remain on the bottom for a short period of time before they ascend to the surface and are subject to entrainment. The smaller larvae in the samples were close to hatch size and may have represented larvae that were trapped in tidal currents immediately after hatching and as a result were exposed to entrainment.

Larval Pacific staghorn sculpin abundance at each of the five sampling locations varied from month to month (Figure 3-14). Their abundance in Estero Bay was consistently lower than at other stations within Morro Bay except in October and December 2000. At stations inside Morro Bay, Pacific staghorn sculpin larvae were slightly more abundant at stations nearer the harbor mouth when compared with Station 4 in the more protected, southern area of Morro Bay during January through June. Pacific staghorn sculpin larvae were more common inside of Morro Bay than at Station 5 (Estero Bay).

Concentration (#/m^3) of larval Pacific staghorn sculpin was compared among stations for collections made at ebb and flood tides (Figure 3-15). Their abundances at the sampling locations do not appear to be related to tidal current.

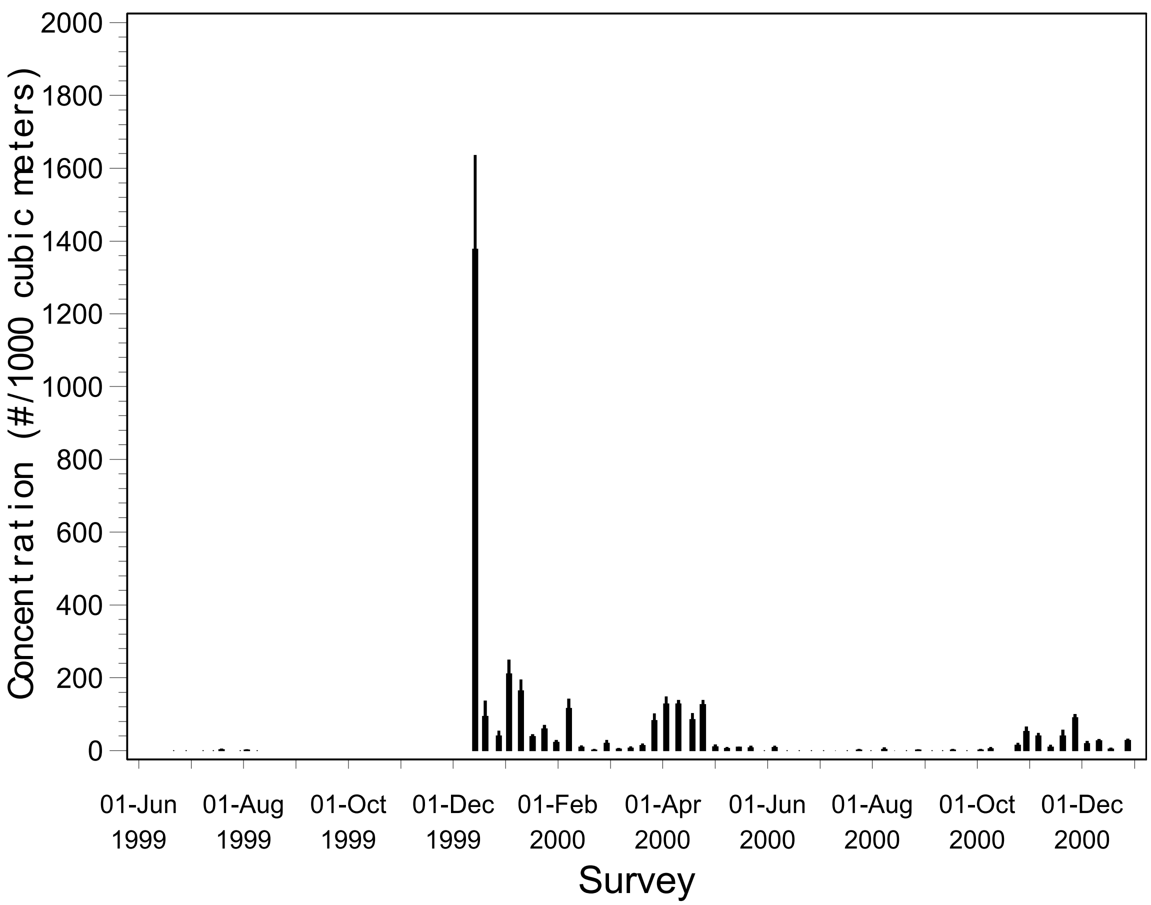


Figure 3-12. Weekly survey mean concentrations of larval Pacific staghorn sculpin collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

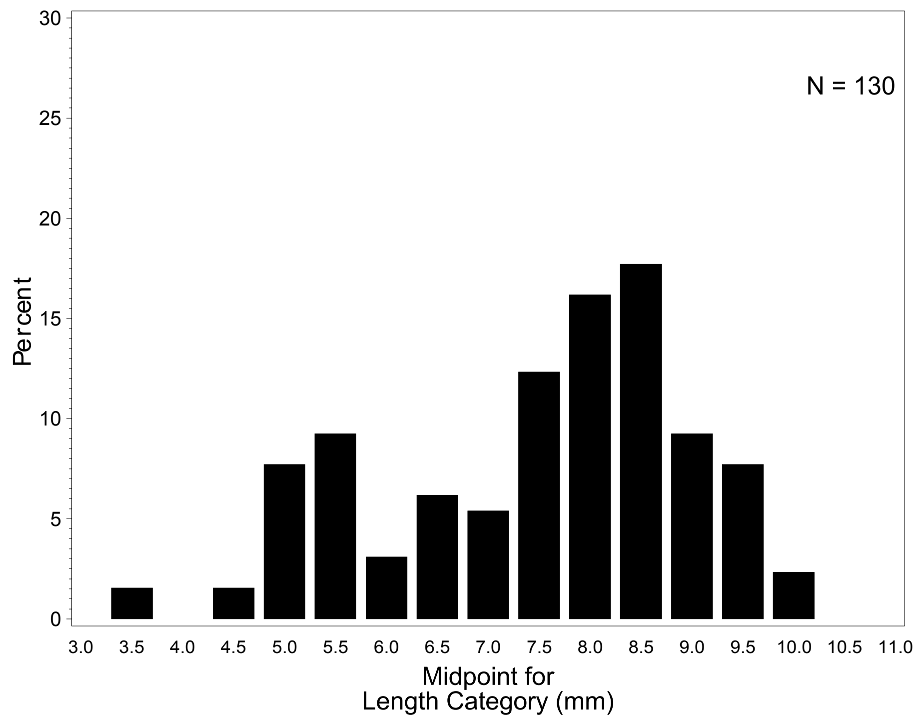


Figure 3-13. Length frequency distribution (mm) for larval Pacific staghorn sculpin collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

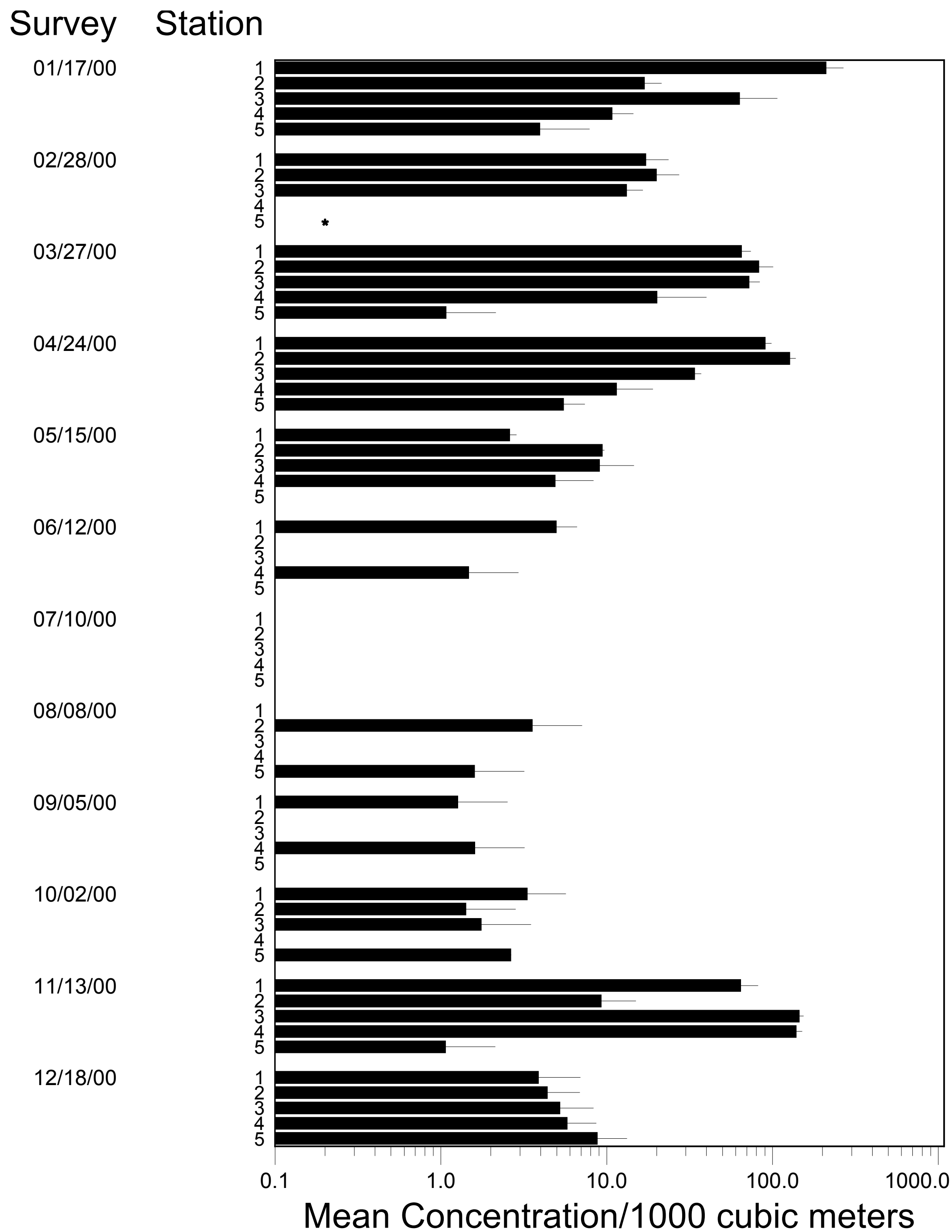


Figure 3-14. Mean larval Pacific staghorn sculpin concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

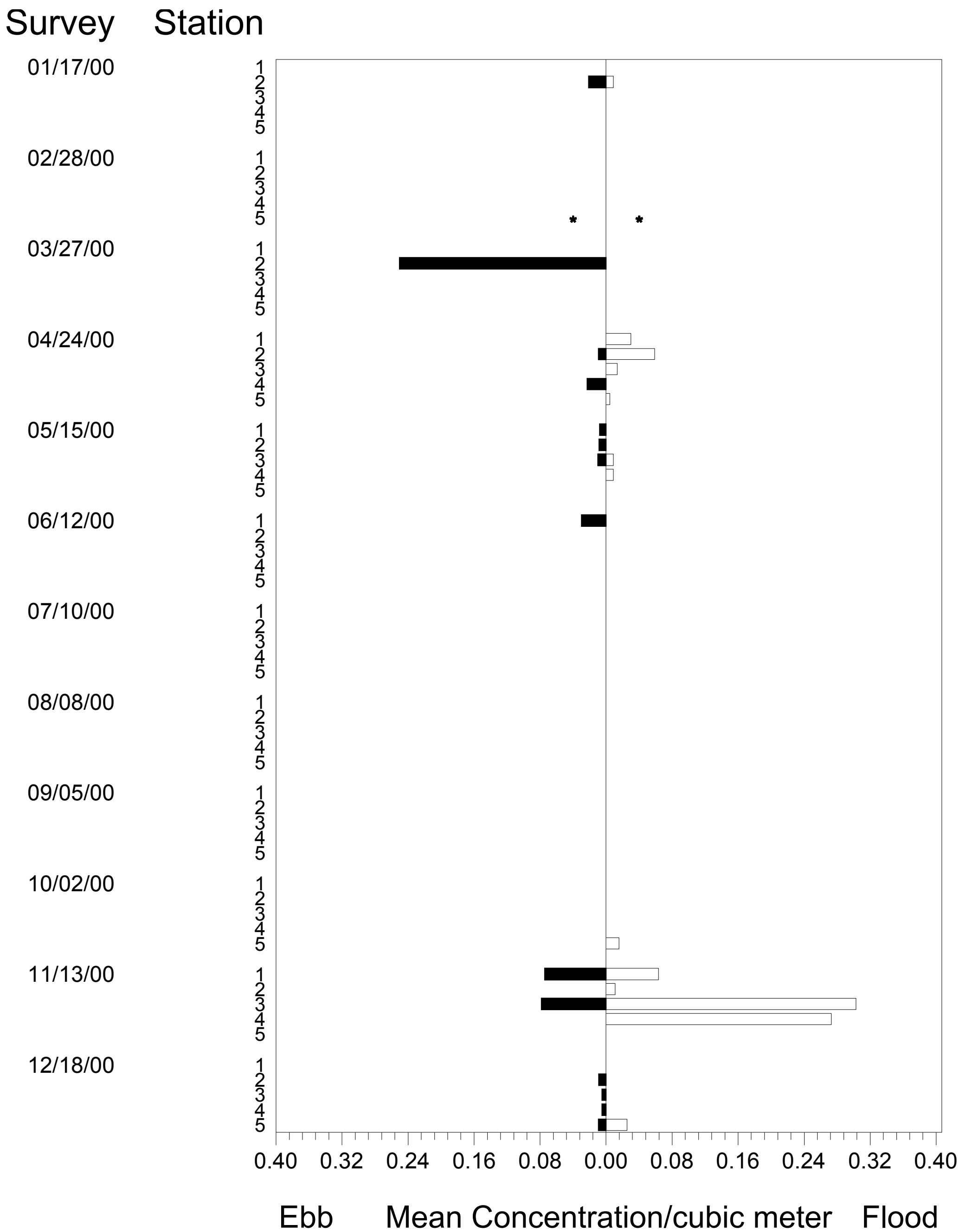
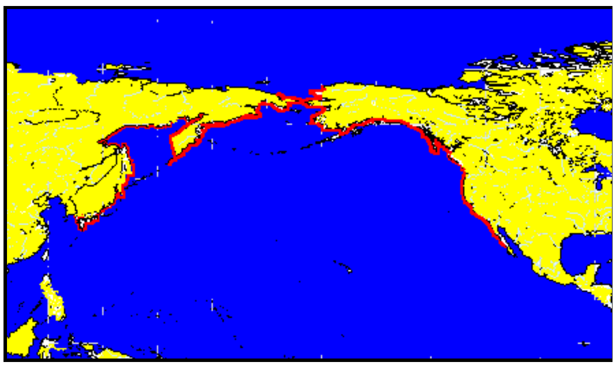


Figure 3-15. Mean concentration of larval Pacific staghorn sculpin from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.3 Northern lampfish Stenobrachius leucopsarus



Distribution map for adult northern lampfish

***Adult Range*:** California Current System from northern Baja California to Bering Sea and Japan.

***Life History*:** Size: to 12 cm (5 in.); Age at maturity: about four years; Fecundity: no information available; Life span: up to eight years.

***Adult Habitat*:** From shoreline to 3,000 m (9,800 ft).

***Adult Fishery*:** No commercial or recreational fishery.

Adult northern lampfish *Stenobrachius leucopsarus* are found from the shoreline to approximately 3,000 m (9,800 ft) (Miller and Lea 1972). The center of their adult population is well offshore of Morro Bay. Northern lampfish juveniles and adults were not collected in any of the fish studies conducted in Morro Bay (Fierstine et al. 1973, Horn 1980, CDFG unpubl. otter trawl data) or in the two MBPP impingement studies (Behrens and Sommerville 1982, this study) (see Appendix B). Northern lampfish are oviparous and produce planktonic eggs and larvae (Moser 1996). Larvae can be found throughout the CalCOFI sampling area from the tip of Baja California to the California-Oregon border and out to about 400 nautical miles offshore. The highest abundance of northern lampfish larvae occurs in the winter and spring (Moser 1996).

3.3.3.1 Northern Lampfish Results

Northern lampfish larvae were collected at the MBPP intake station in winter and spring (Figure 3-16). The timing of peak concentration during January 2000 differed from recorded peak larval abundance in CalCOFI surveys, which typically occurs in March (Moser 1996). Intake station concentrations in December 2000 were reduced from 1999 levels.

The length frequency distribution for a representative sample of northern lampfish larvae showed a relatively wide size range of 3.2 to 9.7 mm (0.13 to 0.38 in.) with an average size of 4.7 mm (0.19 in.) (Figure 3-17). While a group of larger larvae were collected, most of the larvae were in the 4 to 5 mm (0.16 to 0.2) range.

Northern lampfish larvae were present in source water surveys in winter and spring months (Figure 3-18). Adults of this species are pelagic to bathypelagic, with the center of their population well offshore. Their larvae occurred from the southernmost reaches of Morro Bay (Station 4) out into Estero Bay. Similar to their adult distribution, northern lampfish larvae were generally most abundant in Estero Bay (Station 5) and at the mouth of Morro Bay harbor (Station 1). The highest concentration of northern lampfish larvae occurred in Estero Bay.

Concentration ($\#/m^3$) of larval northern lampfish was compared among stations for collections made on ebb and flood tides (Figure 3-19). Their abundances at the sampling locations did not appear to be related to tidal current.

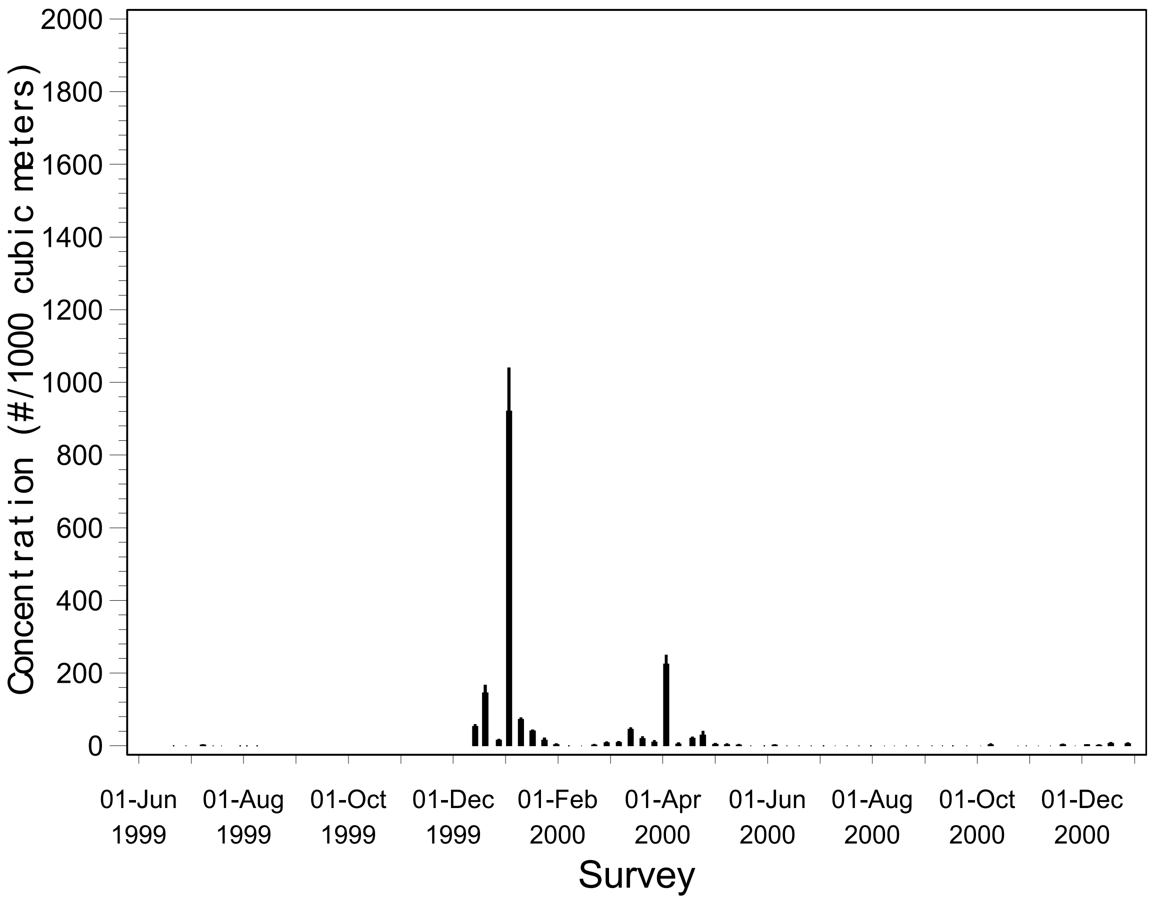


Figure 3-16. Weekly survey mean concentrations of larval northern lampfish collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

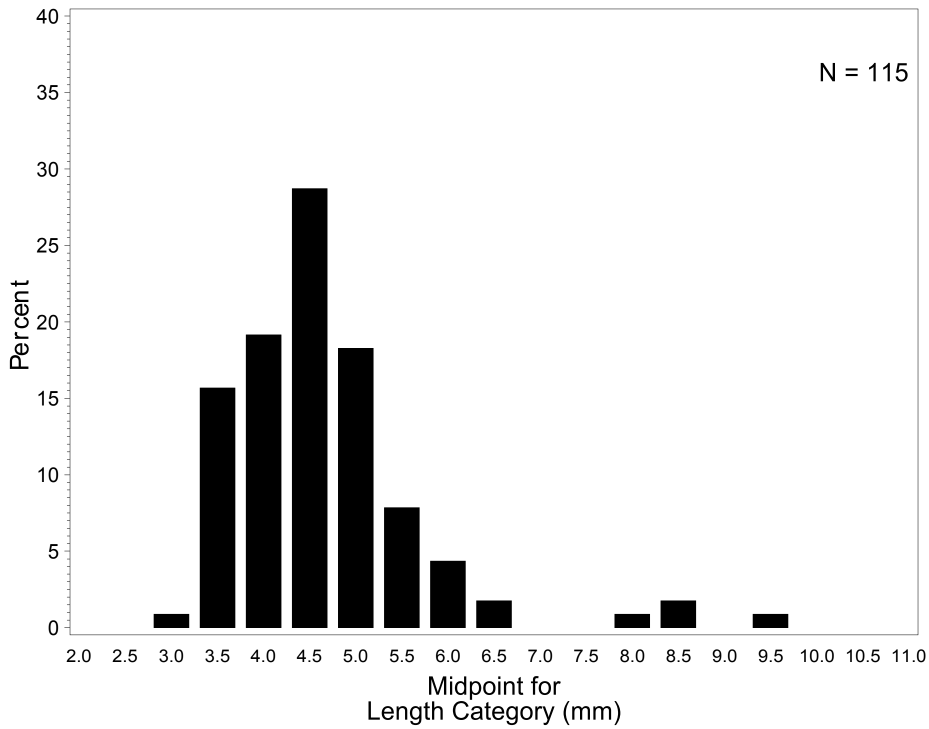


Figure 3-17. Length frequency distribution (mm) for larval northern lampfish collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

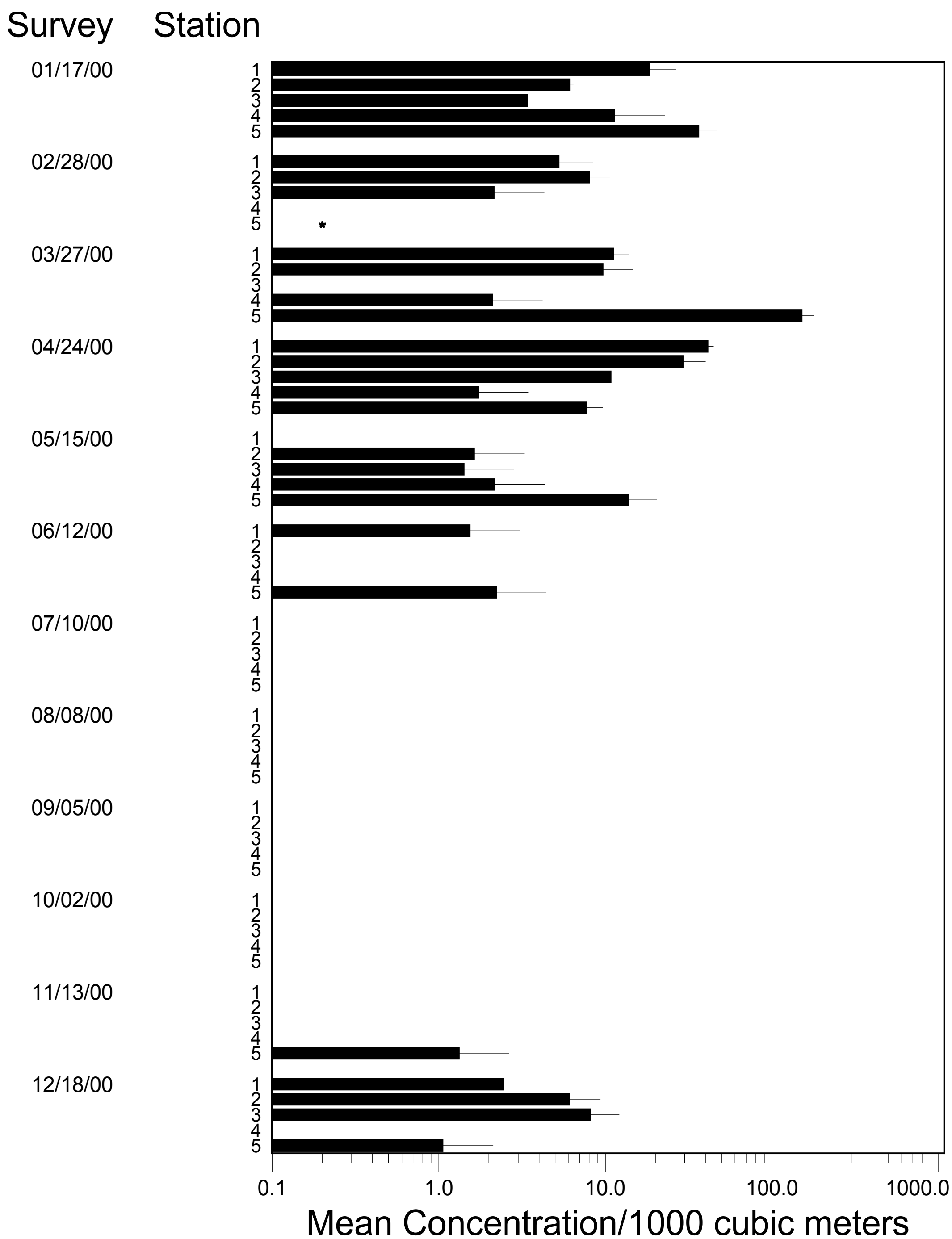


Figure 3-18. Mean larval northern lampfish concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

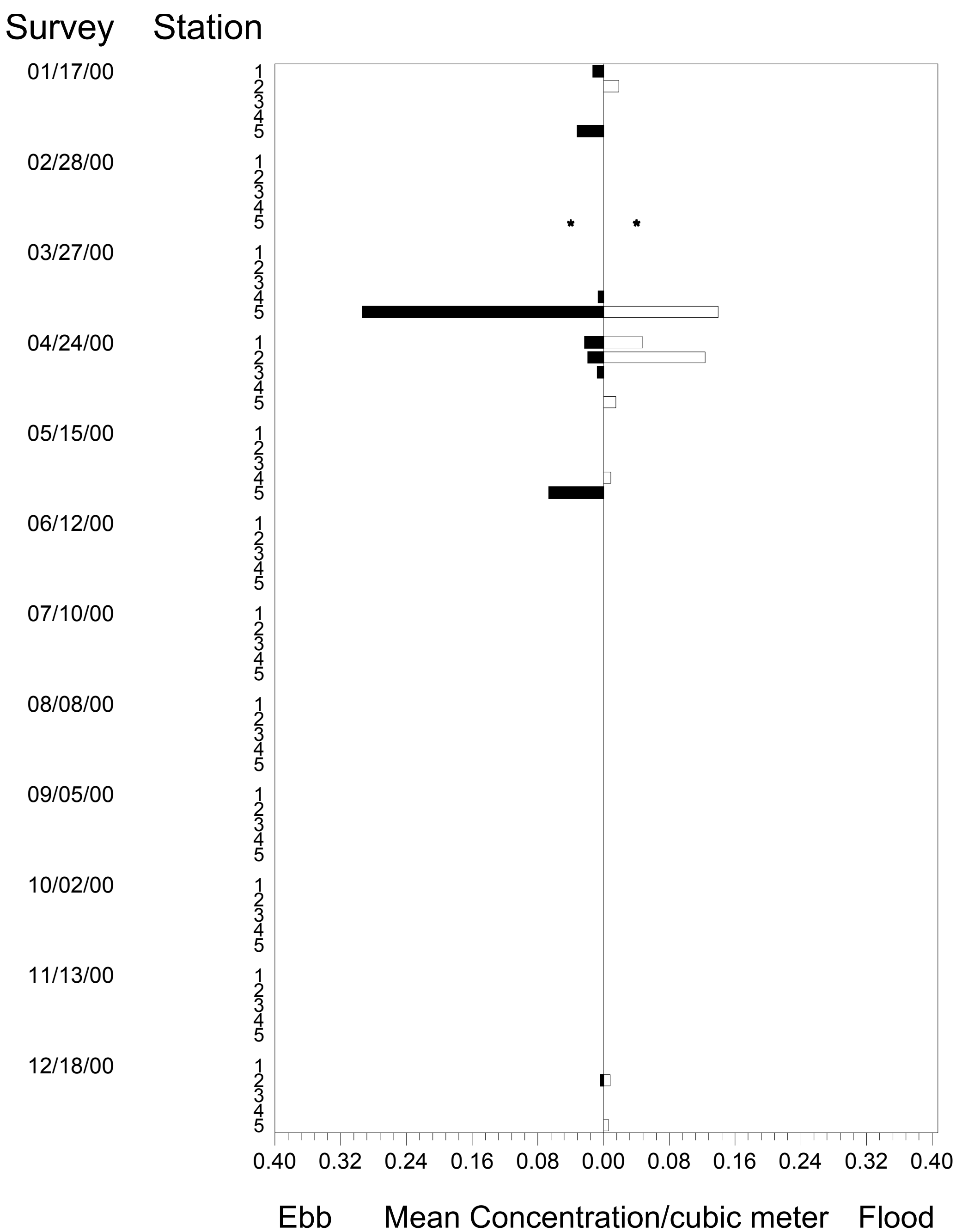
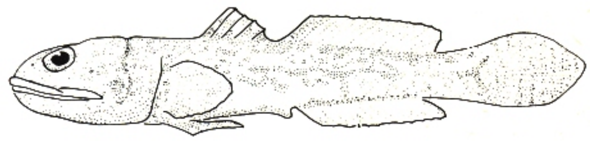


Figure 3-19. Mean concentration of larval northern lampfish from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

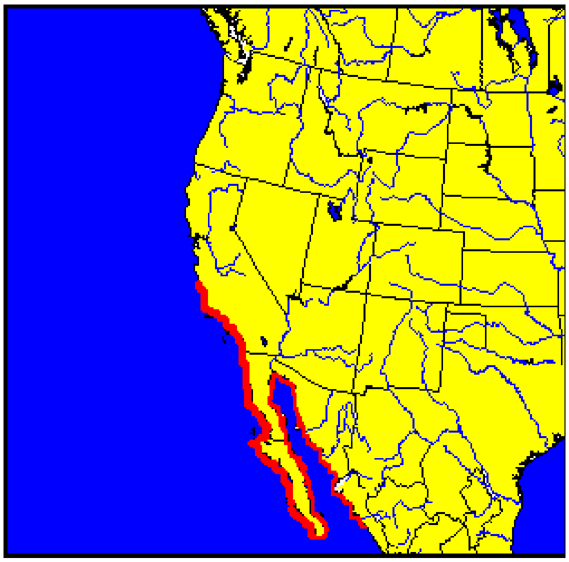
Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.4 Shadow Goby Quietula y-cauda



Source: Miller and Lea 1972



Distribution map for adult shadow goby

Adult Range: From Bahía Magdalena, Baja California Sur to Morro Bay, California.

Life History: Size: to 70 mm (2.75 in.); Age at maturity: mature around 1½ years and 25 mm (1.0 in.) standard length (SL), achieving around 100 percent maturity by three years and around 30 mm (1.2 in.); Fecundity: 400-2,000 eggs per female; Life span: approximately 4.5 years.

Adult Habitat: Shallow soft-bottom habitats in bays, estuaries, lagoons, and open coastal areas; often inhabit invertebrate burrows.

Adult Fishery**:** No commercial or recreational fishery.

Shadow goby range from Bahía Magdalena, Baja California Sur to Morro Bay, California (Eschmeyer et al. 1983). Adults are typically found in shallow soft-bottom habitats in bays, estuaries, lagoons, and open coastal areas. While they often inhabit invertebrate burrows the males will also build burrows (Moser 1996).

Female shadow goby first mature at around 1.5 years and 25 mm (1.0 in.) standard length (SL), achieving around 100 percent maturity by three years and around 30 mm (1.2 in.) SL (Brothers 1975). Their fecundity ranges from 400-2,000 eggs per female. Gravid females are abundant in early summer in central and southern California and settling post-larvae are present from spring through early fall. Shadow goby females spawn year-round in central and southern California, producing multiple batches during the year. Burrow-building males brood eggs until they hatch; apparently guarding one female's reproductive output at a time. Longevity of shadow goby is on the order of four to five years (Brothers 1975).

Shadow and arrow gobies are often the most abundant larvae in bays (Snyder 1965, Eldridge and Bryan 1972, Pearcy and Myers 1974) but are not common in other nearshore collections (Tenera 2000a, b). Shadow goby larvae spend less than two months in the plankton before settling to the bottom of shallow bays and estuaries in spring through early fall. Shadow goby larvae can be difficult to distinguish from cheekspot *Ilypnus gilberti* and tidewater goby *Eucyclogobius newberryi* larvae prior to settlement (see Appendix G for tidewater goby DNA analysis report).

Shadow goby spawning is reported to occur year-round (Brothers 1975, Moser 1996). Adults are oviparous, attaching demersal eggs to the walls of burrows. Eggs are guarded by males until they hatch releasing planktonic larvae (Moser 1996).

3.3.4.1 Shadow Goby Results

Shadow goby larvae were collected at the MBPP intake station between June and August 1999 and February and October 2000 (Figure 3-20). Their greatest abundance in intake station samples occurred in late spring and summer. They are reported to spawn year round (Moser 1996) although, while in Morro Bay, their spawning activity appears to be limited to around nine months of the year.

The length frequency distribution for a representative sample of shadow goby larvae showed a relatively narrow size range of 2.5 to 4.8 mm (0.1 to 0.19 in.) with an average size of 3.5 mm (0.14 in.) (Figure 3-21). While a small fraction of larger larvae were collected, most of the larvae were in the 3 to 4 mm (0.12 to 0.16 in.) range.

Shadow goby larvae did not occur in the paired surveys during January 2000 (Figure 3-22). Following their bay and estuarine adult distribution patterns, larval shadow goby concentrations inside Morro Bay were greater than concentrations found in Estero Bay. Their peak concentrations at source water stations occurred between April and September. As larval abundance declined, shadow goby first disappeared from Estero Bay, followed by declining abundance within Morro Bay. Shadow goby larvae occurred rarely and in low abundance at Estero Bay Station 5.

Concentration (#/m^3) of larval shadow goby was compared among stations for collections made at ebb and flood tides (Figure 3-23). Larval shadow goby abundance was generally higher on ebb tides. The concentrations of larvae probably increased during ebb tides at the stations in the southernmost enclosed portion of Morro Bay (stations 3 and 4) when larvae were drawn out of the shallow mud flat and eelgrass habitats of the bay were adults are most abundant.

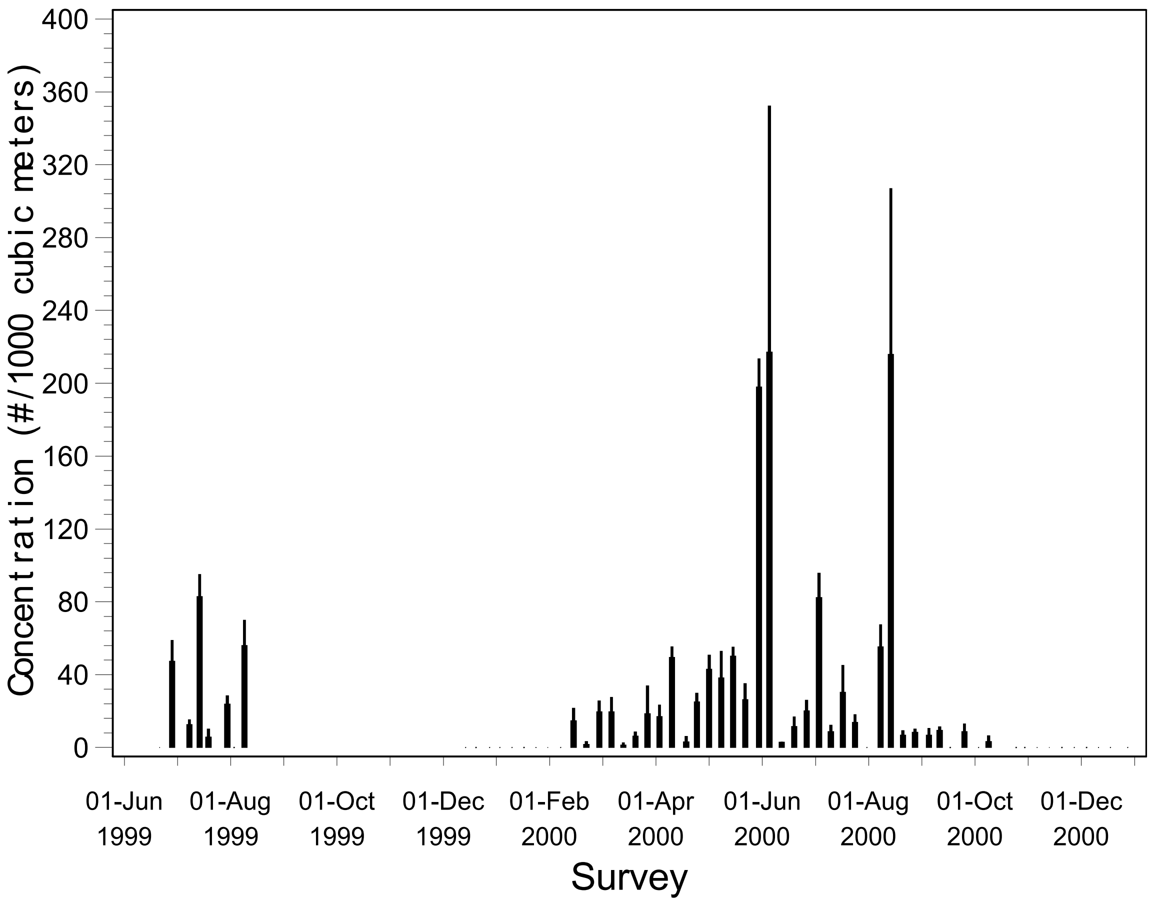


Figure 3-20. Weekly survey mean concentrations of larval shadow goby collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

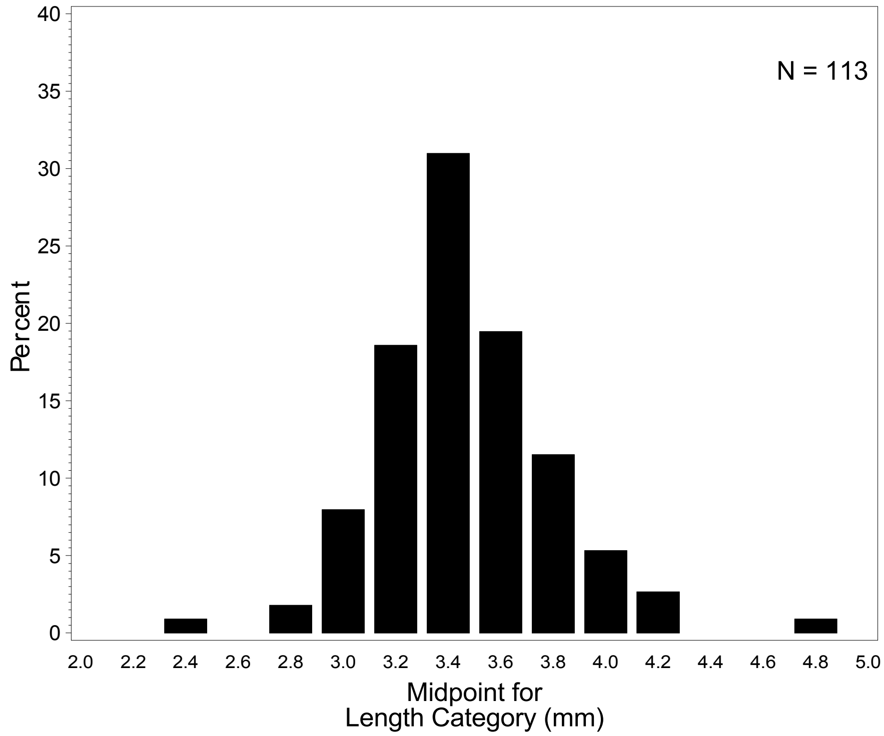


Figure 3-21. Length frequency distribution (mm) for larval shadow goby collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

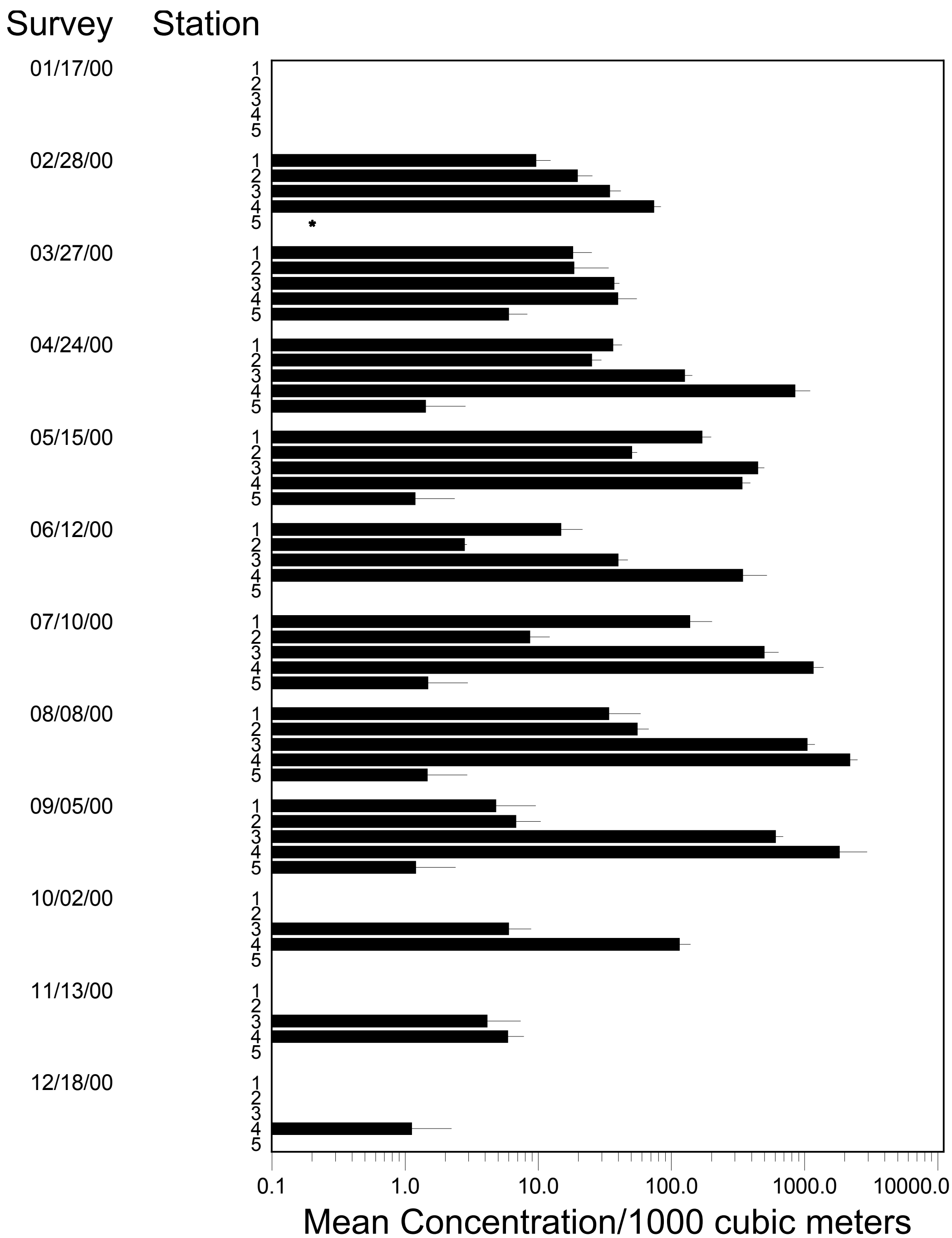


Figure 3-22. Mean larval shadow goby concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

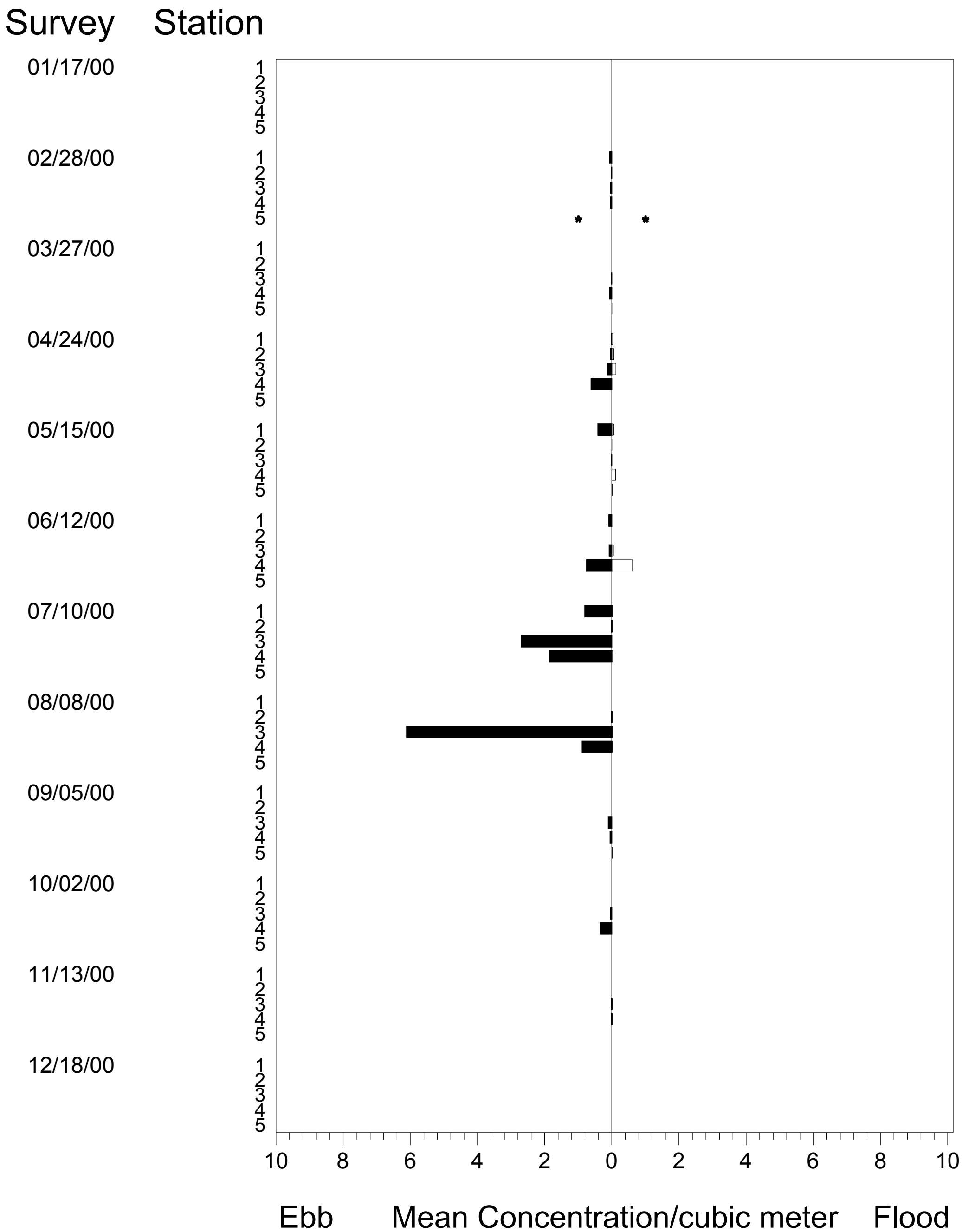
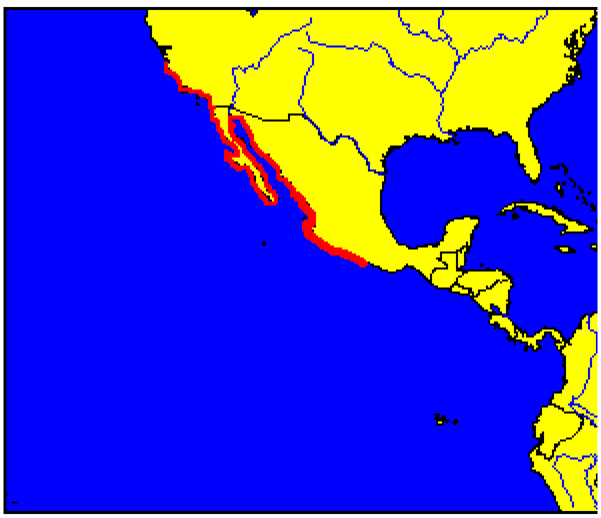


Figure 3-23. Mean concentration of larval shadow goby from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.5 Combtooth Blennies Hypsoblennius spp.



Distribution map for combtooth blennies

Adult Range: **Bay blenny**: from Gulf of California (not present at Cape San Lucas) to Monterey (see text for possible range extension); *Rockpool blenny*: from Magdalena Bay to Point Conception (see text for possible range extension); and **Mussel blenny**; from Puerto Marquis, Mexico, including Gulf of California to Coal Oil Point, Santa Barbara County.

Life History: **Bay blenny** Size: to 148 mm (5.8 in.); Age at maturity: No information available; Fecundity: No information available; Life span: No information available. **Rockpool blenny** Size: to 141mm (5.5 in.); Age at maturity: some at end of first year; Fecundity: spawn three to four times over a period of several weeks; 600 to 3,200 eggs per spawn; Life span: up to nine years. **Mussel blenny** Size: to 112 mm (4.4 in.); Age at maturity: estimated at two years; Fecundity: estimated at 1,180 eggs; Life span: up to seven years.

Adult Habitat: **Bay blenny**: subtidal to 24 m (80 ft), common in bays and estuaries and in *Mytilis* beds on mooring buoys; **Rockpool blenny**: hard substratum within intertidal to 10 m (33 ft); **Mussel blenny**: subtidal to 21m (70 ft), found in crevices and burrows.

Fishery: No commercial or recreational fishery.

Combtooth blennies are represented along the California coast by three members of the genus *Hypsoblennius*; bay blenny *Hypsoblennius gentilis*, rockpool blenny *Hypsoblennius gilberti*, and mussel blenny *Hypsoblennius jenkinsi*. These species co-occur throughout much of their range. The bay blenny is found along both coasts of Baja California and up the California coast as far north as Monterey Bay (Stephens et al. 1970). The distribution of the rockpool blenny extends from Magdalena Bay, Baja California to Pt. Conception, California (Miller and Lea 1972, Stephens et al. 1970). The reported range of the mussel blenny occurs from Puerta Marquis, Mexico to Coal Oil Point in Santa Barbara County (Miller and Lea 1972, Stephens et al. 1970).

We have observed possible range extensions for two of the combtooth blennies described above. It has been reported that the northern range of the bay blenny extends to Monterey Bay, while the ranges of adult rockpool and mussel blenny do not extend north of Point Conception, Santa Barbara County (Miller and Lea 1972). However, adult mussel and rockpool blennies were collected (and the identifications subsequently verified by CDFG) in the 1999-2000 MBPP impingement study; one rockpool blenny was collected in 1999 at CDFG otter trawl Station 3 located between our source water stations 2 and 3 (CDFG unpubl. otter trawl data).

The spawning season of the three California *Hypsoblennius* species begins in the spring and may extend into September (Stephens et al. 1970). Blennies are oviparous and lay demersal eggs that are attached to the nest substratum by adhesive pads or filaments (Moser 1996). Females spawn three to four times over a period of several weeks and the number of eggs a female produces varies proportionately with her size (Stephens et al. 1970). The smaller and shorter-lived mussel blenny carries relatively more eggs per body length than the rockpool blenny (Stephens et al. 1970). A female mussel blenny may carry 1,500 eggs (Stephens et al. 1970). Female rockpool blenny may produce from 600 to 3,200 eggs per spawn (Love 1996). Incubation time is temperature-dependent and eggs typically hatch in four to 18 days (Love 1996).

Larval blennies can be distinguished from other larval fishes through a combination of myomere counts, pigmentation patterns, and their elongated form (Moser 1996). However, larval combtooth blennies are not easily distinguished from each other. Therefore, these larvae were identified to just the generic level (i.e., *Hypsoblennius*). All combtooth blenny larvae were combined into a single combtooth blenny category for analyses.

3.3.5.1 Combtooth Blenny Results

Despite the extended spawning period suggested by Stephens et al. (1970), *Hypsoblennius* spp. in the vicinity of the MBPP appeared to undergo a single spawning period annually (Figure 3-24). Samples were not collected between August and December of 1999 so it cannot be determined if spawning continued into fall 1999 for this taxon. Larval combtooth blennies were more abundant during June and July 1999 than in the same months in 2000.

The length frequency distribution for a representative sample of combtooth blenny larvae showed a relatively narrow size range of 2.0 to 3.2 mm (0.08 to 0.13 in.) with an average size of 2.5 mm (0.1 in.) (Figure 3-25). These results indicate that the larvae are close to hatch size and subject to entrainment for a relatively short period of time.

Combtooth blennies did not occur in January, November, or December in paired surveys (Figure 3-26). Peak larval abundance occurred from May through October. Initial occurrence of combtooth blenny larvae in plankton samples during February – April were limited to waters inside of Morro Bay. This reflects their adult distribution inside of bays, near pier pilings, and in jetty rocks (Stephens et al. 1970, Moyle and Cech 1988).

The concentration (#/m^3) of larval combtooth blennies was compared among stations for samples collected at ebb and flood tides (Figure 3-27). Results were variable among surveys. This may occur if the source of the larvae is relatively close to the sampling stations and tidal currents are only moving larvae within a narrow portion of the bay.

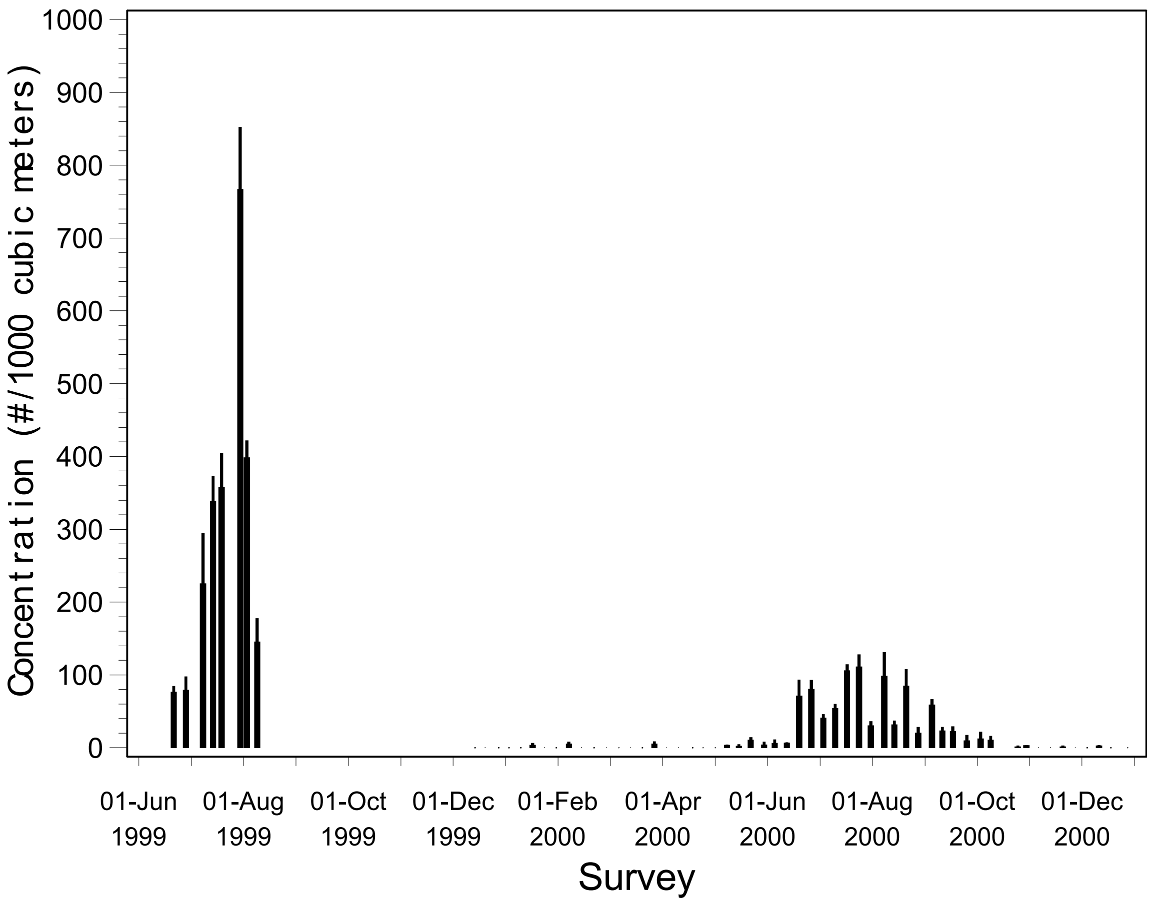


Figure 3-24. Weekly survey mean concentrations of larval combtooth blennies collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

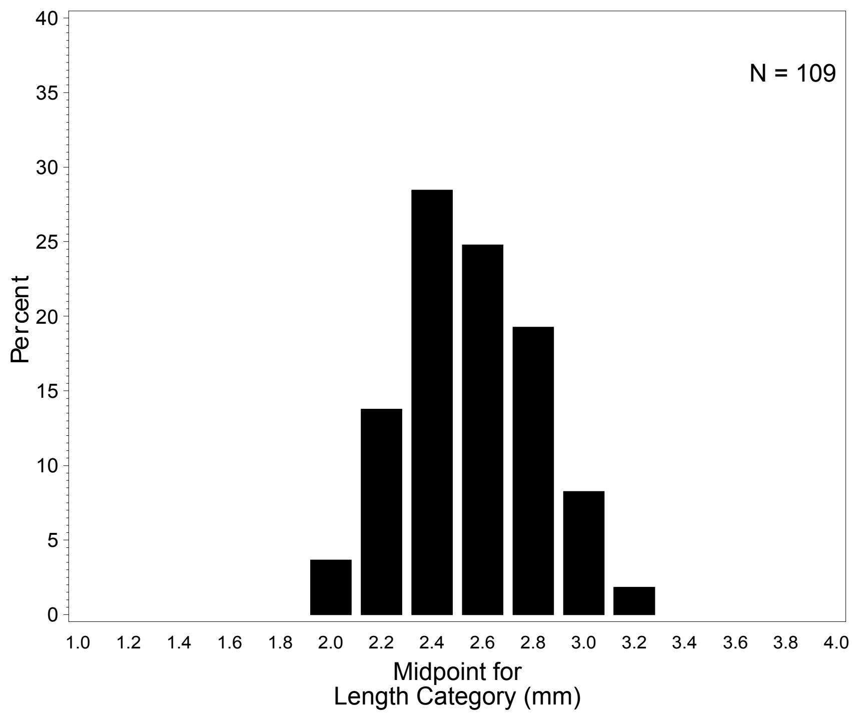


Figure 3-25. Length frequency distribution (mm) for larval combtooth blennies collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

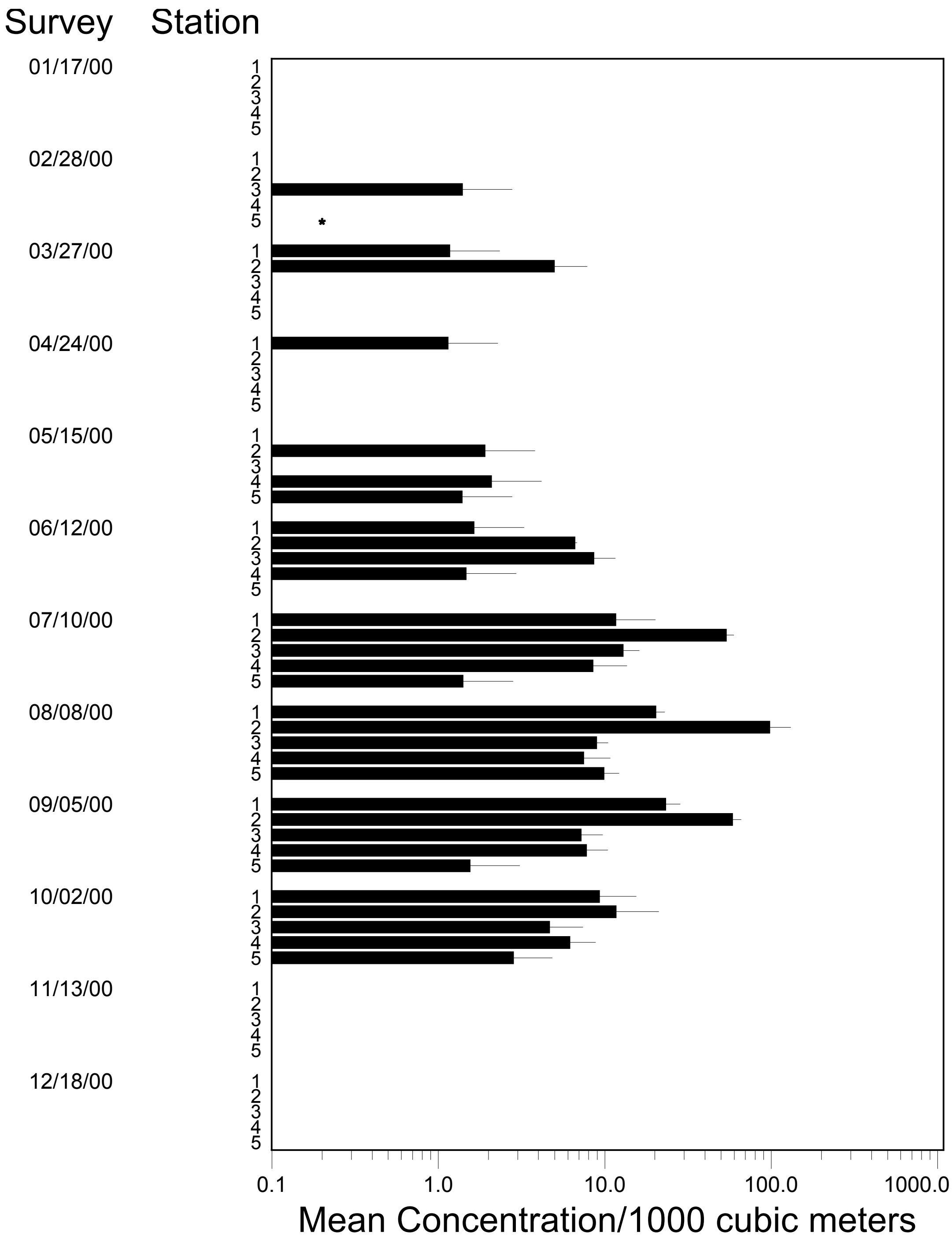


Figure 3-26. Mean larval combtooth blenny concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

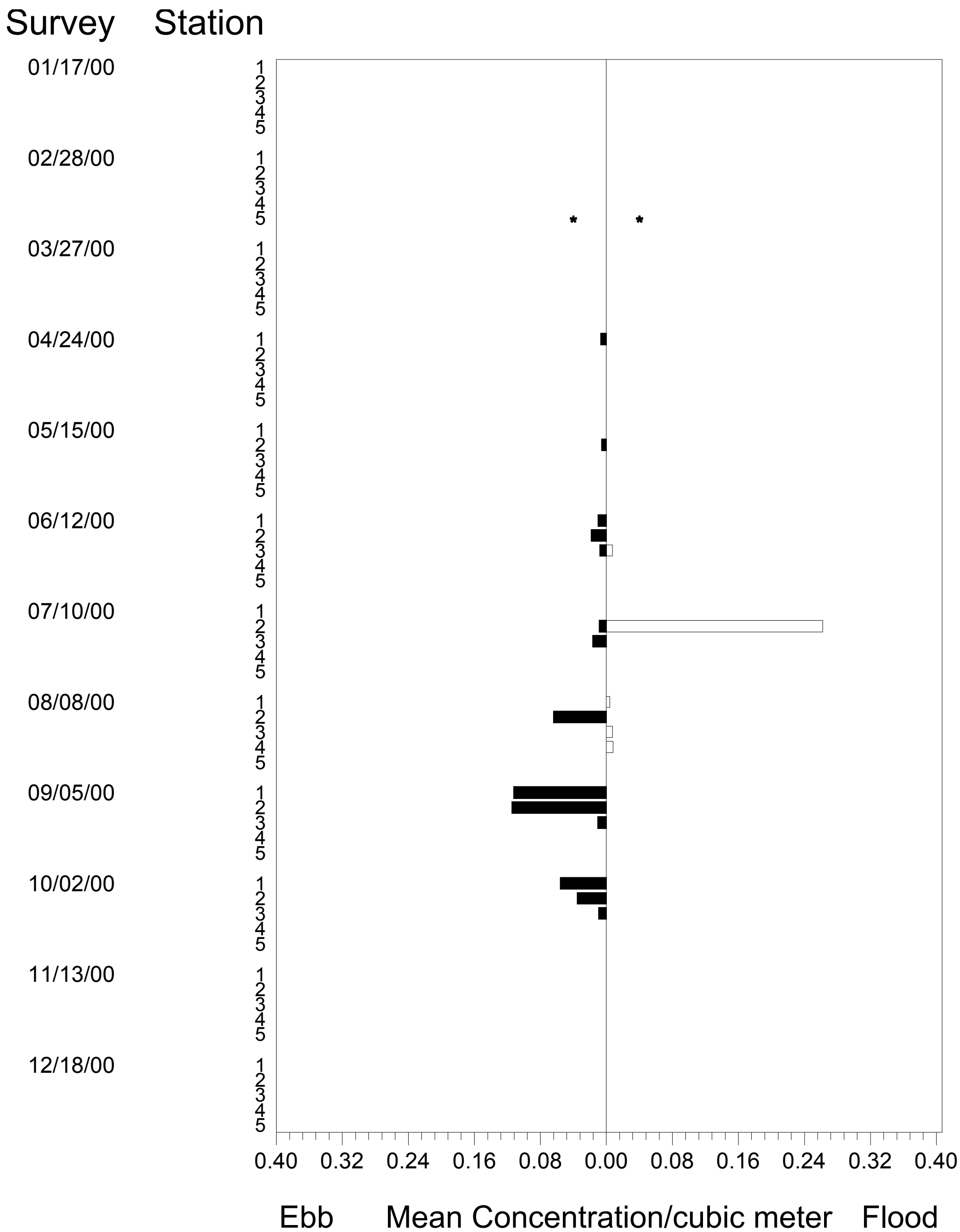


Figure 3-27. Mean concentration of larval combtooth blennies from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

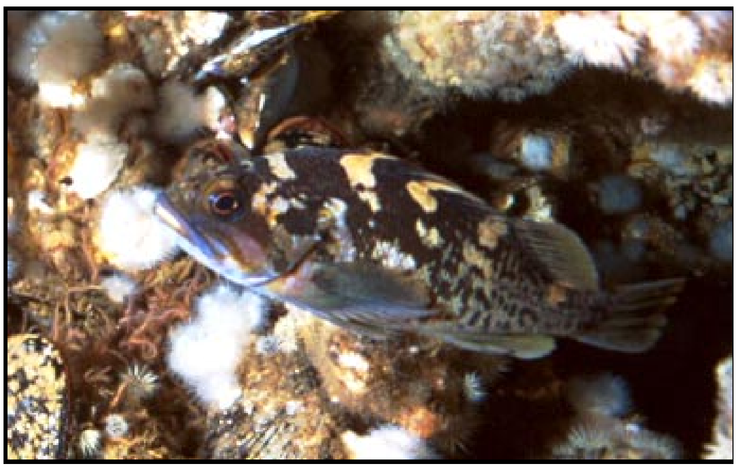
Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.6 *Rockfishes* Sebastes spp.

Rockfishes *Sebastes* spp. belong to the family Scorpaenidae that contains two other genera: the scorpionfishes *Scorpaena* spp. and the thornyheads *Sebastolobus* spp. Scorpaenidae comprise the largest number of commercially and recreationally important California marine fish species. They are also abundant in nearshore California habitats and play important trophic and ecological roles in these communities. They comprise a large component of the shallow subtidal fish community, ranging from nearshore coastal habitats (e.g., kelp forests) to the continental shelf. The rockfishes are the most diverse genus in the Scorpaenidae with some 62 species reported from California coastal waters (Starr et al. 1998), approximately 85 percent of which are harvested in California commercial or sport fisheries.

3.3.6.1 Kelp/Gopher/Black-and-Yellow (KGB) Rockfish Complex



Fishes that are classified into the kelp/gopher/black-and-yellow (KGB) rockfish complex pigment groupings (V_De and V_D_) (Table 3-2) are also genetically similar (Vetter and Stannard 1999 in Tenera 2000a). Since most of the species in this complex have similar life histories and share the same adult habitats, the KGB complex can be considered an assemblage of nearshore, benthic, or epi-benthic rockfishes. In addition to the morphometric, meristic, and genetic similarities of their larval forms, they share similar ecological roles that form the basis for their combination into this complex.

Most members of the KGB complex dwell on or near the bottom of nearshore kelp beds and rocky reefs, with peak abundance found at less than 50 to 100 m (165 to 330 ft) deep (Love 1996). The notable exception to this distribution is the halfbanded rockfish (*Sebastes semicinctus*, which is commonly observed on hard and soft, flat bottom habitat in waters up to 402 m (1,325) deep (Miller and Lea 1972, Eschmeyer et al. 1983, Love 1996). Geographic ranges for all members of this group begin off central Baja California, Mexico, with the exception of quillback and China rockfishes (Miller and Lea 1972, Eschmeyer et al. 1983, Love 1996). These latter two species begin their distribution near San Miguel Island off southern California (Miller and Lea 1972, Eschmeyer et al. 1983, Love 1996). The northern distribution of this group ranges from Monterey Bay and San Francisco, California for halfbanded and calico, and to the northern Gulf of Alaska for brown, copper, and China rockfishes (Miller and Lea 1972, Eschmeyer et al. 1983, Love 1996).

Fishes with the most northerly distributions in this group typically attain both the greatest total lengths and ages for the complex. Brown, copper, quillback, and grass rockfishes can attain maximum lengths of greater than 50 cm (20 in.) (Miller and Lea 1972, Eschmeyer et al. 1983). Copper and quillback rockfishes may reach 41 years and 76 years, respectively, in the Canadian fishery (Yamanaka and Kronlund 1997). The smallest and shortest living rockfish of this group is the calico rockfish that attains a total length of 25 cm (10 in.) and has an estimated longevity of about 12 years (Chen 1971, Miller and Lea 1972, Eschmeyer et al. 1983). The calico rockfish also has the lowest fecundity recorded in the KGB complex at about 2,000 eggs per female at 50 percent maturity but ranging to as high as 113,000 eggs per female (Haldorson and Love 1991). The most fecund rockfish from this group is the grass rockfish with about 760,000 eggs for a 26-cm (10-in.) female (Love and Johnson 1999). The greatest age at 50 percent maturity is six to 11 years for quillback rockfish (Wyllie Echeverria 1987, Yamanaka and Kronlund 1997).

Reproductive capacity of rockfishes is directly related to size, with larger females carrying significantly more eggs than smaller females. Rockfishes are viviparous with internal fertilization (Yoklavich et al. 1996), and the female retains the eggs until she extrudes hundreds to millions (e.g., *Sebastes paucispinis*) (Moser 1967) of eyed, live larvae (Bloeser 1999). The larvae and juveniles can remain in the plankton from one month to approximately one year before settling into primarily benthic habitats as juveniles (Matarese et al. 1989, Moser 1996, Starr et al. 1998). This extended planktonic period makes environmental variation an important determinant of the population abundance of many rockfish species since their vulnerable life stages are exposed to potentially adverse conditions for greater periods of time. Once on the bottom, individuals of many species migrate to deeper water as they mature.

Little is known about the planktonic duration or natural mortality of the fish in the KGB complex. Planktonic duration was estimated for brown, calico, and gopher rockfishes at about three months, one to two months, and two to three months, respectively (Larson 1980, Moser and Butler 1981, Matarese et al. 1989, D. Woodbury 1999, NOAA, Tiburon Laboratories pers. comm.). Larval growth rates have been estimated for larval brown rockfish *Sebastes auriculatus* at 0.14 mm/day (Love and Johnson 1999, Yoklavich et al. 1996).

3.3.6.2 KGB Rockfish Complex Results

Larval KGB rockfishes were collected at the MBPP intake station during the winter and spring of 1999 – 2000 (Figure 3-28). This is the period that larval rockfishes are typically abundant along the Pacific coast of the United States (Parrish et al. 1989). Occurrence of larval KGB rockfishes collected at the MBPP matches reported spawning periodicity of these species.

The length frequency distribution for a representative sample of KGB rockfish larvae showed a relatively narrow size range of 3.4 to 5.4 mm (0.13 to 0.21 in.) with an average size of 4.3 mm (0.17 in.) (Figure 3-29). These results indicate that the larvae are close to hatch size and subject to entrainment for a relatively short period of time.

Results from source water surveys showed the same abundance peaks seen in samples collected at the MBPP intake station (Figure 3-30). Although not collected every month, KGB rockfish larvae were collected from all of the stations inside Morro Bay in paired surveys. During the weekly surveys at the MBPP intake, their occurrence was less consistent. They reached their greatest concentration at the Estero Bay Station 5 during the May survey when they were less common at the stations within Morro Bay.

Concentration (#/m^3) of larval KGB complex rockfishes was compared among stations for samples collected at ebb and flood tides (Figure 3-31). KGB rockfish larvae are probably in greater concentrations in offshore areas outside the bay and were only collected at Station 4 during one of the paired entrainment-source water surveys. As expected for a taxon with a primarily offshore distribution, there is no clear relationship between larval concentration and tidal current.

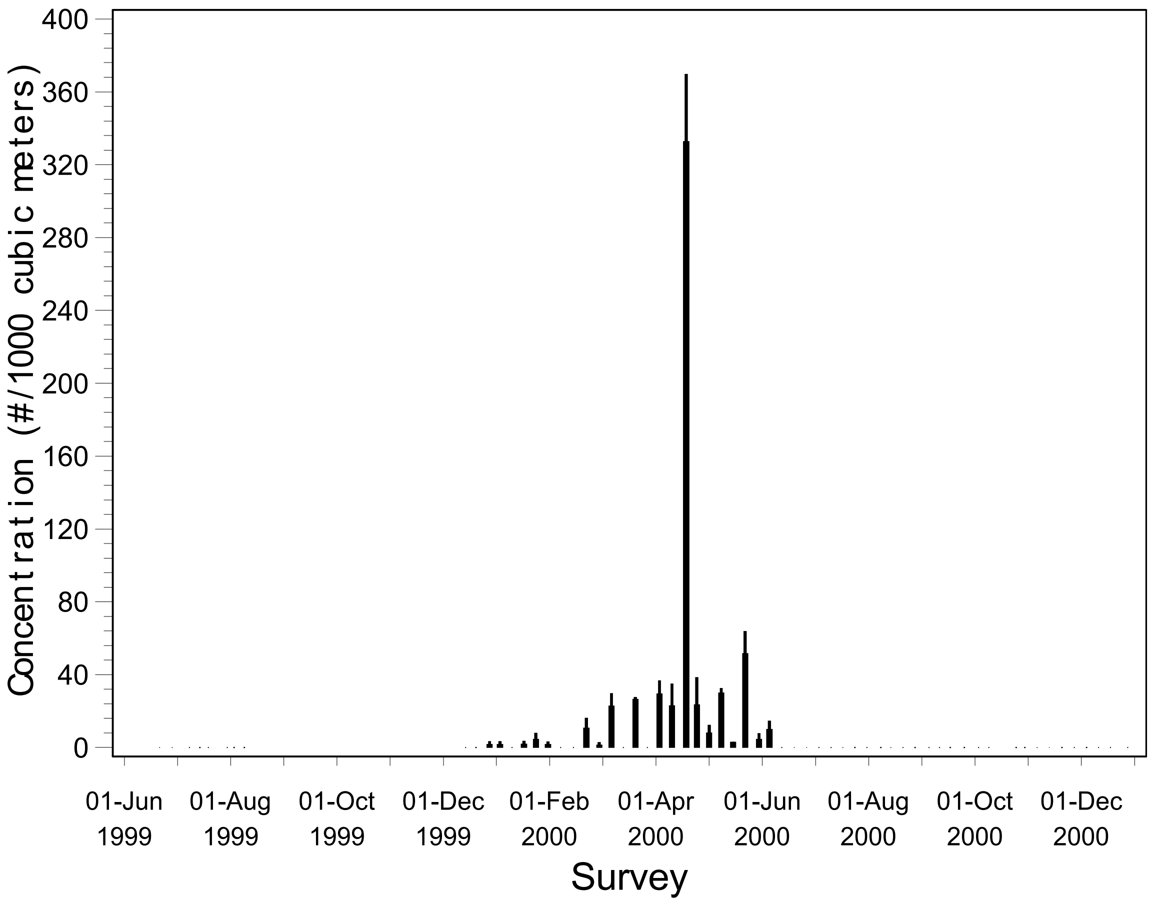


Figure 3-28. Weekly survey mean concentrations of larval KGB complex rockfishes (kelp/gopher/black-and-yellow) collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

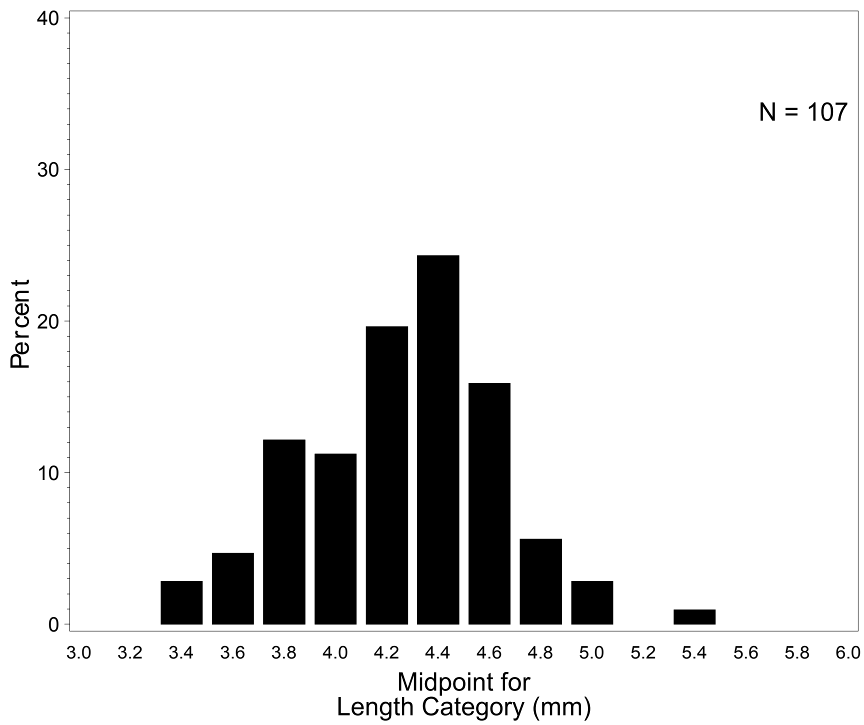


Figure 3-29. Length frequency distribution (mm) for larval KGB rockfish collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

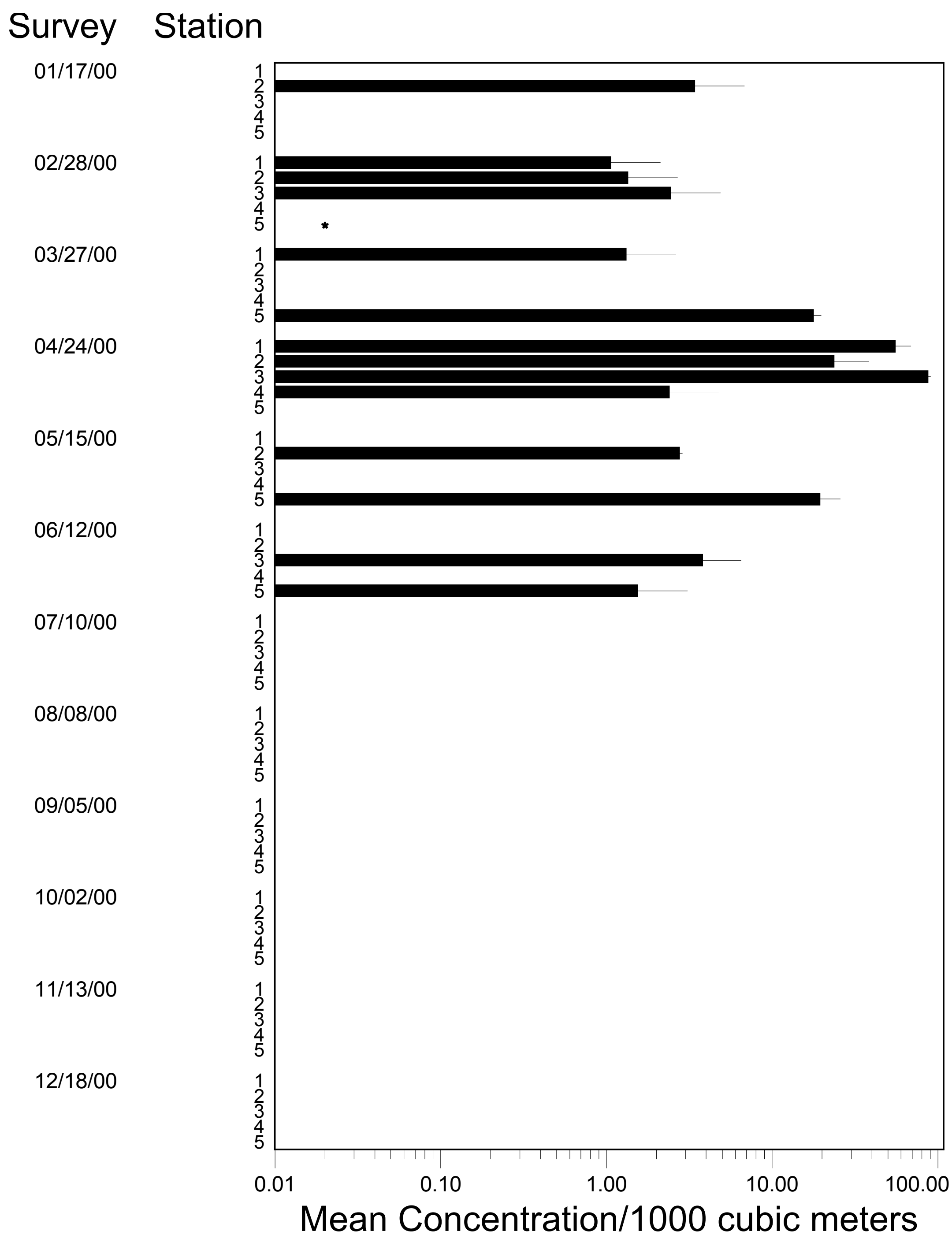


Figure 3-30. Mean larval KGB complex rockfishes concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

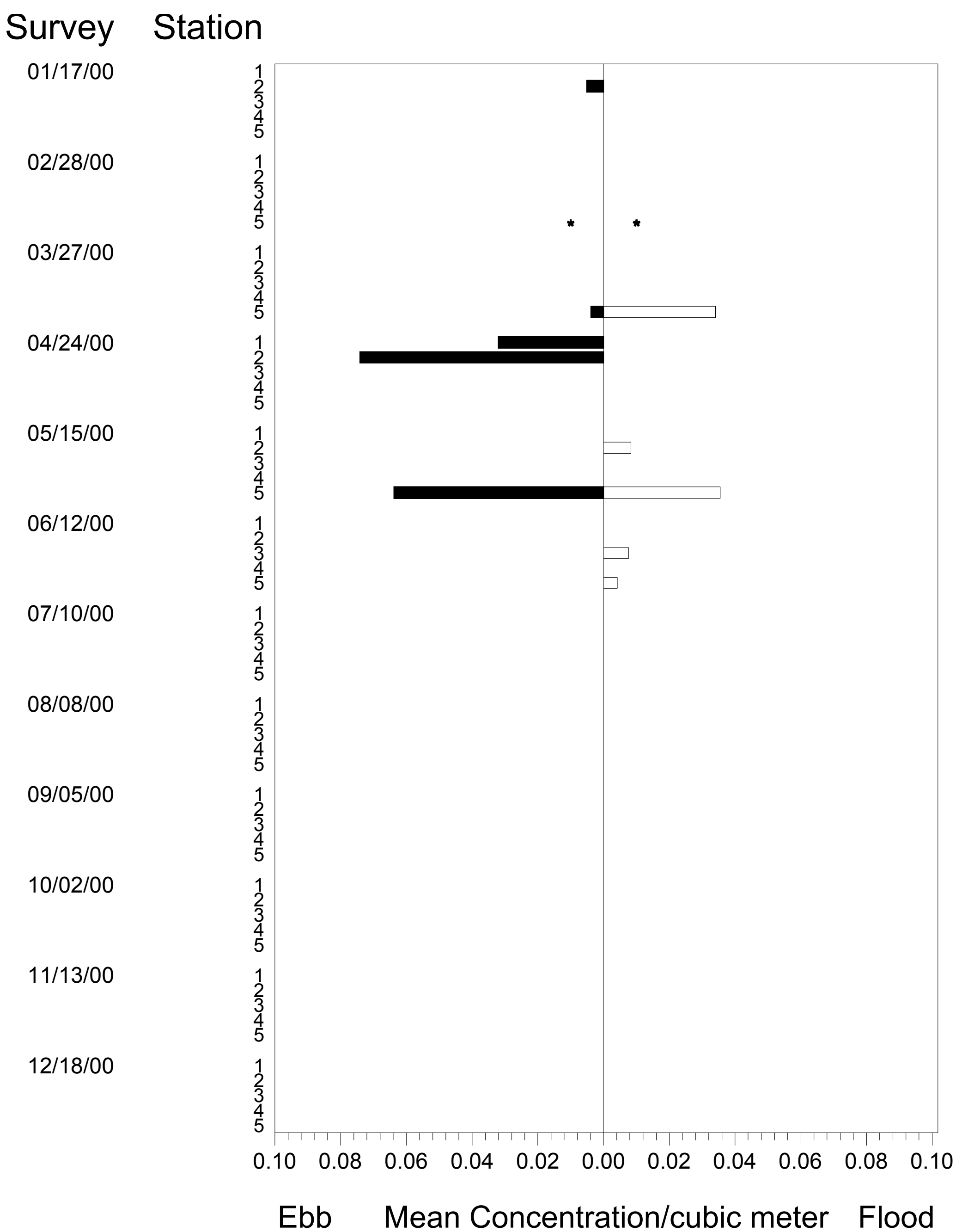
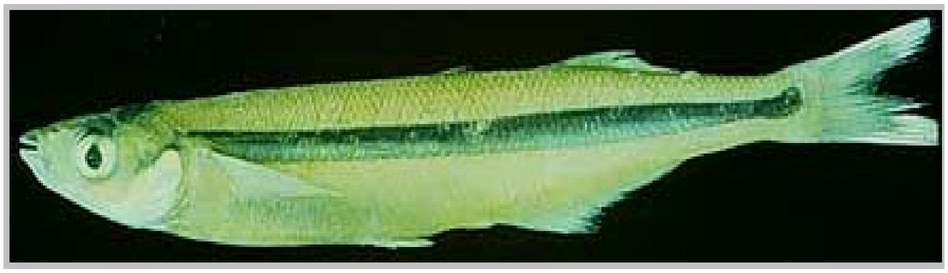


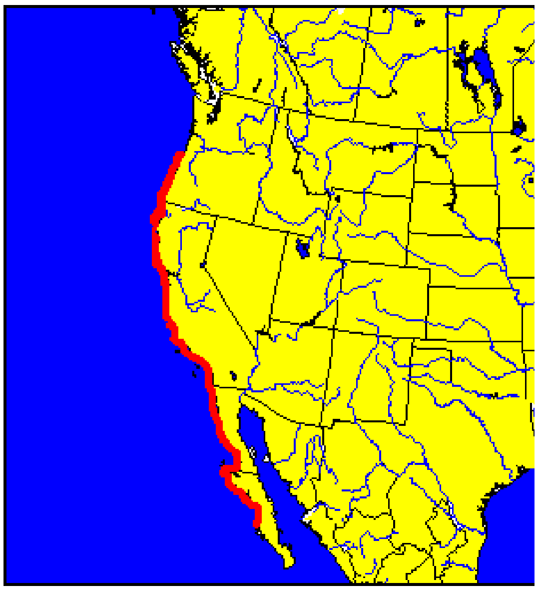
Figure 3-31. Mean concentration of larval KGB rockfish complex from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.7 Jacksmelt Atherinopsis californiensis





Distribution map for adult jacksmelt

***Adult Range*:** Yaquina Bay, Oregon to Bahia Magdalena, Baja California.

***Life History*:** Size: to 44 cm (17 in.); Age at maturity: two years; Life span: nine to 10 years.

***Adult Habitat*:** Bays, estuaries, nearshore surface to 29 m (95 ft).

***Adult Fishery*:** Incidental commercial; recreational.

Jacksmelt *Atherinopsis californiensis* are a pelagic fish found in estuaries and coastal marine environments from Yaquina Bay, Oregon to at least Bahía Magdalena, Baja California Sur (Eschmeyer et al. 1983, Cruz-Aguero et al. 1994). Jacksmelt are the largest member of the three species of the family Atherinidae that occur in California coastal waters (Clark 1929, Miller and Lea 1972). The other members of the Atherinidae, or silversides, that occur in California are California grunion and topsmelt (Miller and Lea 1972). Although jacksmelt are not a targeted fishery in California they are commonly caught from piers and in other nearshore areas (Love 1996). Jacksmelt are distributed from Santa Maria Bay, Baja California north to Yaquina Bay, Oregon, and are mostly found in nearshore areas and in bays (Miller and Lea 1972). Jacksmelt were collected during all Morro Bay fish studies (Fierstine et al. 1973, Horn 1980, Behrens and Sommerville 1982, CDFG unpubl. otter trawl data, 1999-2000 impingement study [Section 4.0]; Appendix B). The adults can reach a maximum length of 44 cm (17 in.) SL (Miller and Lea 1972). The fish reach maturity after two years at a size range of 18 to 20 cm (7 to 7.8 in.) SL, and probably can live to a maximum age of nine or ten years (Clark 1929).

The spawning season for jacksmelt is from October through March (Clark 1929), with peak activity from January through March (Allen et al. 1983). Inspection of reproductive females showed that eggs of various sizes and maturities were present because the fish spawn multiple times over the reproductive season (Clark 1929). The spawning activity of another member of the silversides, the topsmelt, corresponded to changes in water temperature (Middaugh et al. 1992). The diameter of mature eggs ranges from 2.0 to 2.5 mm (0.08 to 0.1 in.) (Clark 1929). The females lay the eggs on marine plants and other floating objects where fertilization by male jacksmelt occurs (Love 1996). Topsmelt eggs maintained in the laboratory hatched 10 to 14 days after fertilization (Middaugh et al. 1992). Jacksmelt larvae hatch at an average size of 8 mm (0.31 in.) SL and reach a size of 15 to 16 mm (0.59 to 0.63 in.) after 24 days (Middaugh et al. 1990).

3.3.7.1 Jacksmelt Results

Jacksmelt are reported to spawn from October to April and primarily from November through March (Moser 1996). Peak larval concentration for this species collected at the MBPP intake station occurred in January, which agrees with reported spawning times (Moser 1996) (Figure 3-32). Similar to recorded spawning periodicity, larval jacksmelt reappeared at the MBPP intake in early October 2000.

The length frequency distribution for a representative sample of jacksmelt larvae showed a wide size range of 5.2 to 15.7 mm (0.20 to 0.61 in.) with an average size of 9.6 mm (0.38 in.) Figure 3-33). The results show that the majority of the larvae are close to the estimated hatch length of 8 mm (0.31 in.) (Middaugh et al. 1990).

Most of the jacksmelt larvae in monthly source water surveys were collected from stations inside of Morro Bay (Figure 3-34). Stations 3 and 4 in the southernmost reaches of Morro Bay yielded the greatest concentrations of jacksmelt larvae during the peak spawning period reported by Moser (1996). As the season progressed, there was a shift in their distribution toward the harbor mouth. Jacksmelt larvae were less abundant and less common at Station 5 in Estero Bay though they did occur there.

Concentration (#/m^3) of larval jacksmelt was compared among stations for samples collected at ebb and flood tides (Figure 3-35). Larval jacksmelt concentration was generally highest during ebb tides as would be expected for a taxon that may utilize habitat in the back bay for spawning.

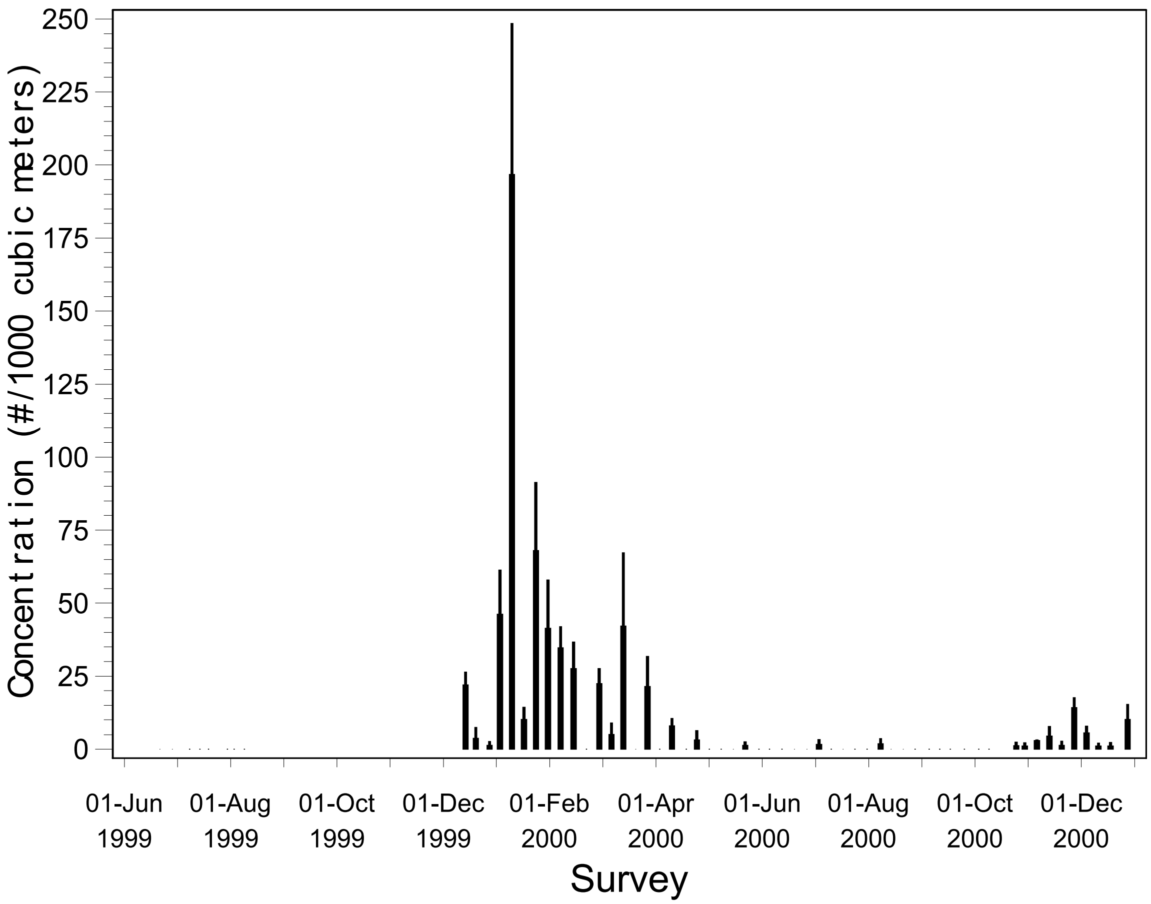


Figure 3-32. Weekly survey mean concentrations of larval jacksmelt collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

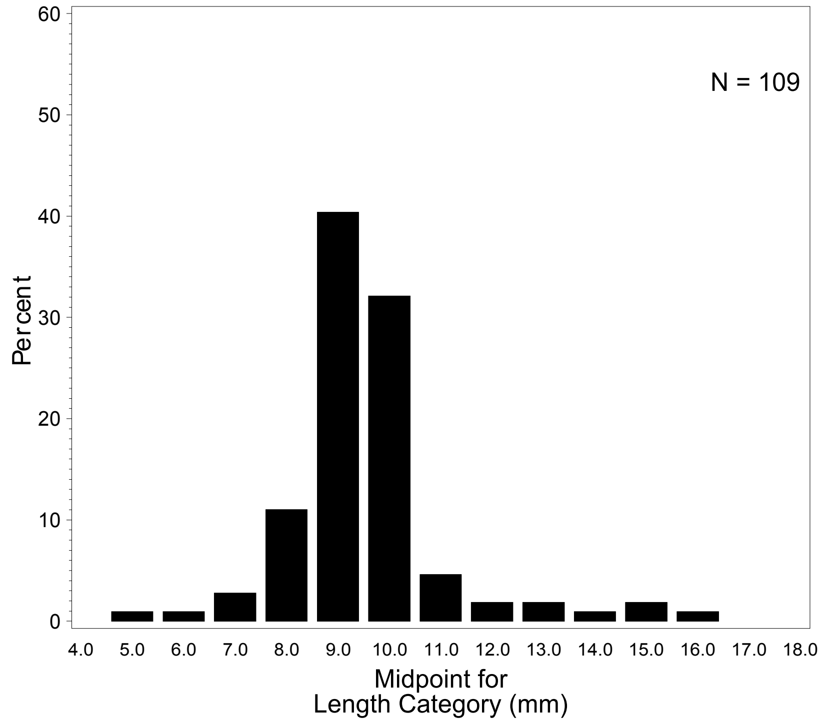


Figure 3-33. Length frequency distribution (mm) for jacksmelt larvae collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

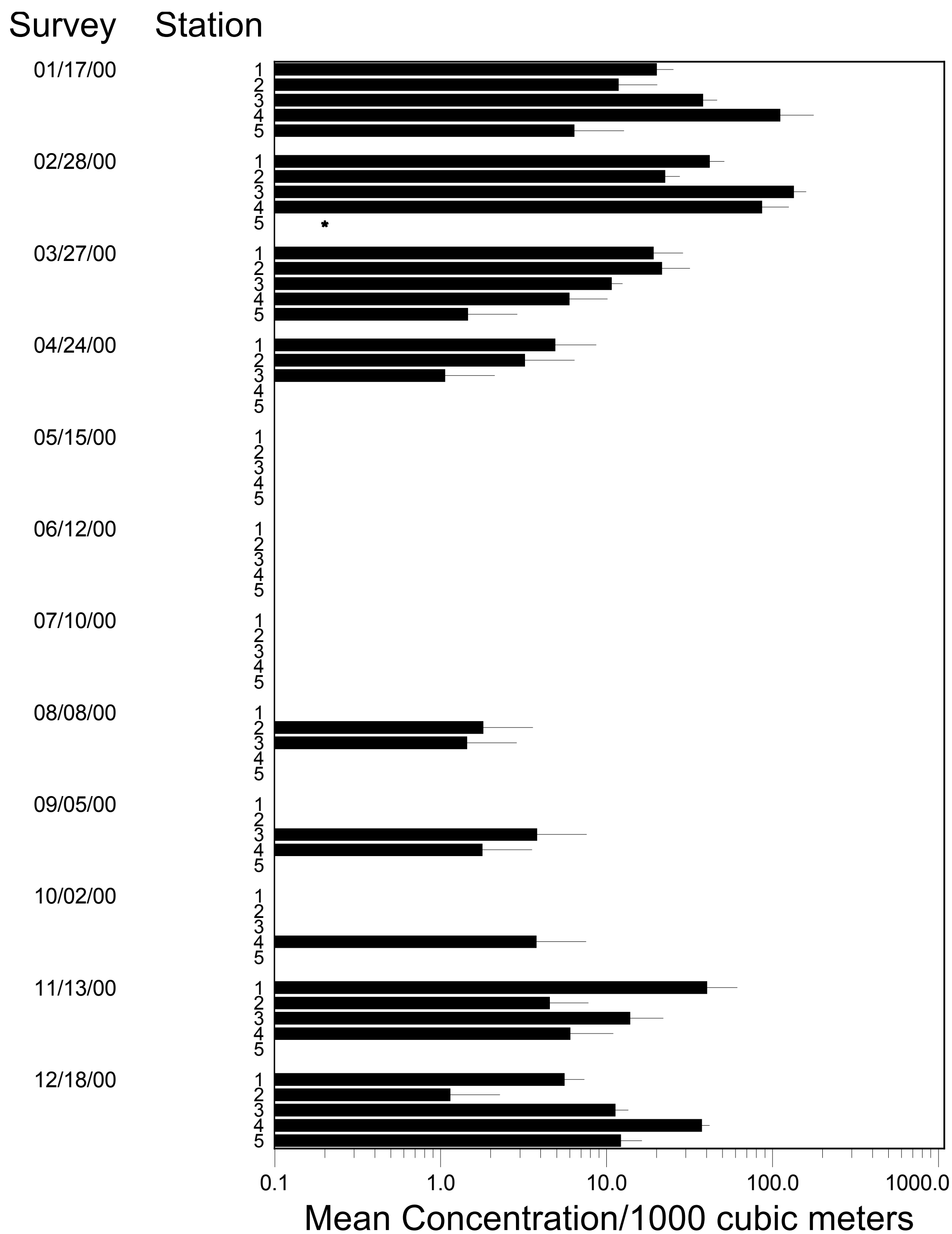


Figure 3-34. Mean larval jacksmelt concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

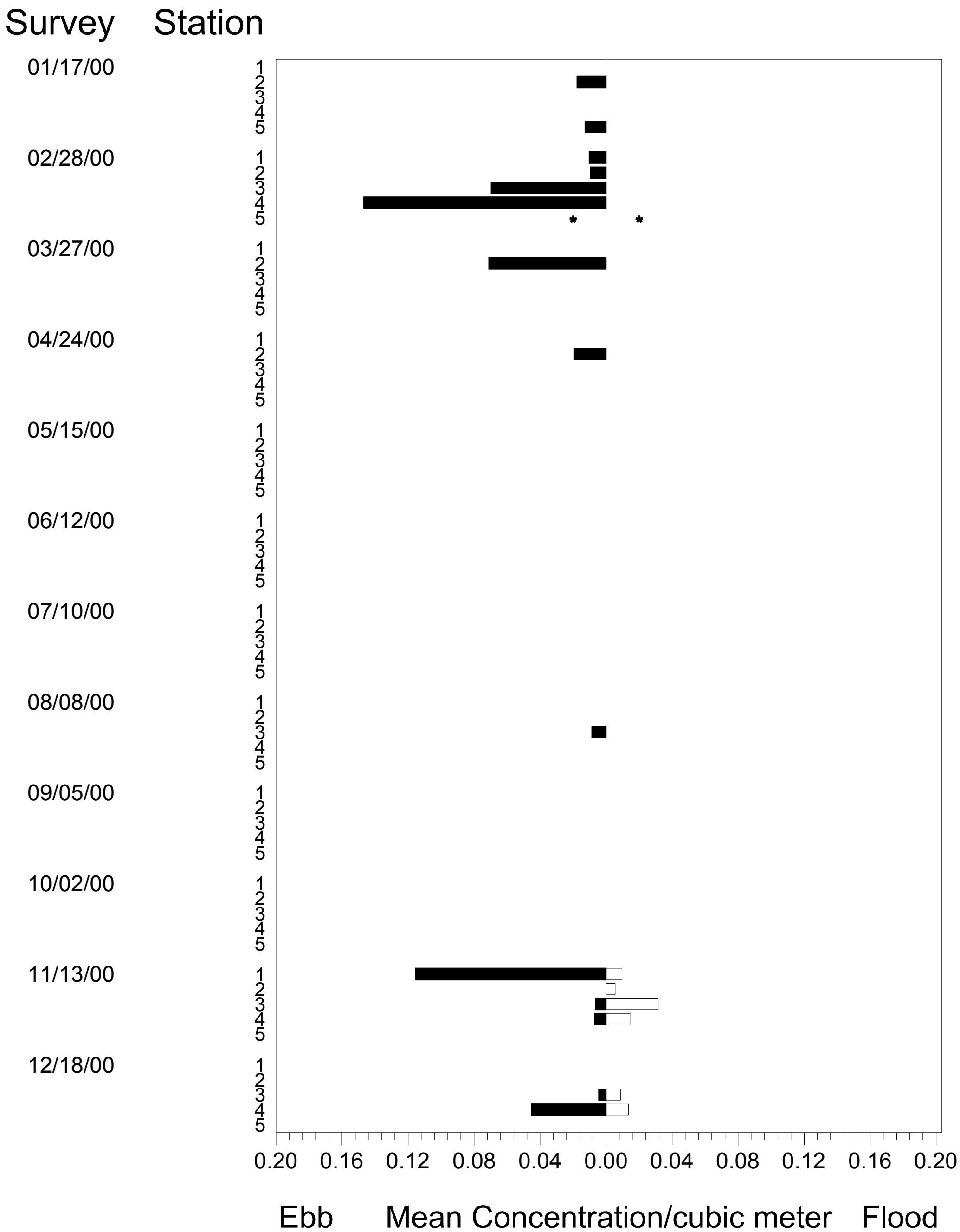
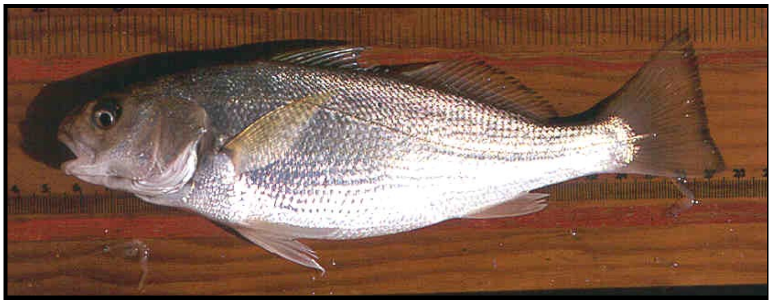


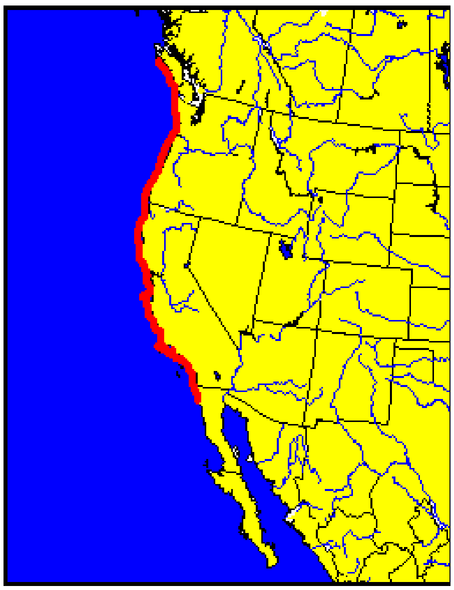
Figure 3-35. Mean concentration of larval jacksmelt from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.8 White croaker Genyonemus lineatus





Distribution map for adult white croaker

Adult Range: From Todos Santos Bay, Baja California north to Barkley Sound, Vancouver Island, British Columbia.

Life History: Size: up to 380 mm (15 in.) and 0.5 kg (1 lb); Age at maturity: one to four years; Fecundity: spawns 18 to 24 times a season, annual fecundity–105,000 eggs; Life_span: twelve years.

Adult Habitat: Near shore areas less than 30 m (98 ft) deep just outside the surf zone; offshore waters to 100 m (328 ft) in depth.

Adult Fishery: Recreational, small commercial market.

The white croaker belongs to the family Sciaenidae (order Perciformes), which contains over 210 species. In North America, there are about 34 species of croaker, many of them important sport and commercial fishes (Moyle and Cech 1988). White croaker are found from southern Baja California to Vancouver Island, British Columbia. They are most abundant from southern California northward to about Monterey and are uncommon north of San Francisco (Love 1996). White croaker were collected during both MBPP impingement studies (Behrens and Sommerville 1982, 1999-2000 impingement [Section 4.0]) and in the CDFG otter trawls (CDFG unpubl. otter trawl data); they were not collected by either Fierstine et al. (1973) or Horn (1980) (Appendix B).

White croaker are bottom-dwelling fishes found schooling and feeding along warm, shallow, nearshore coasts. White croaker are usually found in loose schools over sand or mud bottoms of bays and estuaries and in areas less than 30 m (98 ft) deep just outside the surf zone (Streamnet 1999). They may also, however, inhabit offshore waters up to 100 m (328 ft) deep

(Frey 1971). These fish seem to move inshore during summer months and offshore in winter. White croaker can reach 380 mm (15 in.) in length and can weigh over 0.5 kg (1 lb) (Streamnet 1999). These fish reach maturity in one to four years and may live from 12 to 15 years (Frey 1971, Love et al. 1984).

Although some spawning takes place throughout the year, most occurs between November and May (Skogsberg 1939) with the heaviest concentration during the early spring months. Adults spawn in both near-shore shallow waters and the open waters of bays and estuaries. A large spawning center is located north and south of the Palos Verdes Peninsula, from Redondo Beach to Laguna Beach, and a smaller center is found north of Ventura (Love et al. 1984). Females lay from 800 to 37,000 eggs, and are able to spawn 18 to 24 times a season (Love et al. 1984). The fertilized eggs are pelagic and most drift into the shallow sand and gravel bottom regions of the bays and estuaries.

The spherical eggs hatch in about one week, with the newly hatched larvae averaging about 1.6 mm (0.06 in.) (Watson 1982). The young larvae are pelagic and post-flexion larvae settle out to the sand and gravel bottom substrate as they develop (Love et al. 1984). The shallows of bays and estuaries are used as nursery grounds for the white croaker, but larvae are found in open water as well (Wang 1986). While a few larvae have been taken as far as 150 miles offshore, most larvae reside within 20 miles of the coast (Love 1996). Murdoch et al. (1989) estimates a daily larval growth rate of 0.20 mm/day (0.008 in./day).

3.3.8.1 White Croaker Results

Larval white croaker entrainment concentrations show several peaks through the year (Figure 3-36), which is consistent with literature reports of year-round spawning. The largest concentrations were observed in December 1999, January 2000, and October 2000.
A representative sample of white croaker larvae had a relatively wide size range of 1.2 to 7.6 mm (0.05 to 0.3 in.), but the majority of the larvae were small with an average size of 2.8 mm (0.11 in.) (Figure 3-37). These larvae are only a few days old based on the estimated hatch size of 1.6 mm (0.06 in.) (Watson 1982).

There was considerable variability in the concentrations of white croaker larvae among the stations collected in the monthly source water surveys (Figure 3-38). Concentrations were generally highest at the stations in the upper bay (stations 1, 2 and 3) or in Estero Bay (Station 5), but there was no consistent pattern between surveys. White croaker larvae were generally in lower concentration and less common at Station 4 in the back bay, except in November 2000 when concentration was highest at that station.

Concentrations (#/m^3) of larval white croaker were compared among stations for samples collected at ebb and flood tides (Figure 3-39). There was no clear relationship between larval concentration and tidal current. During the March 2000 survey concentrations were higher on ebb tides, while during the November and December surveys they were higher on flood tides. The absence of any clear pattern is consistent with the comparison of concentrations among stations (Figure 3-38) showing that white croaker larval abundances are highly variable in the bay over time.

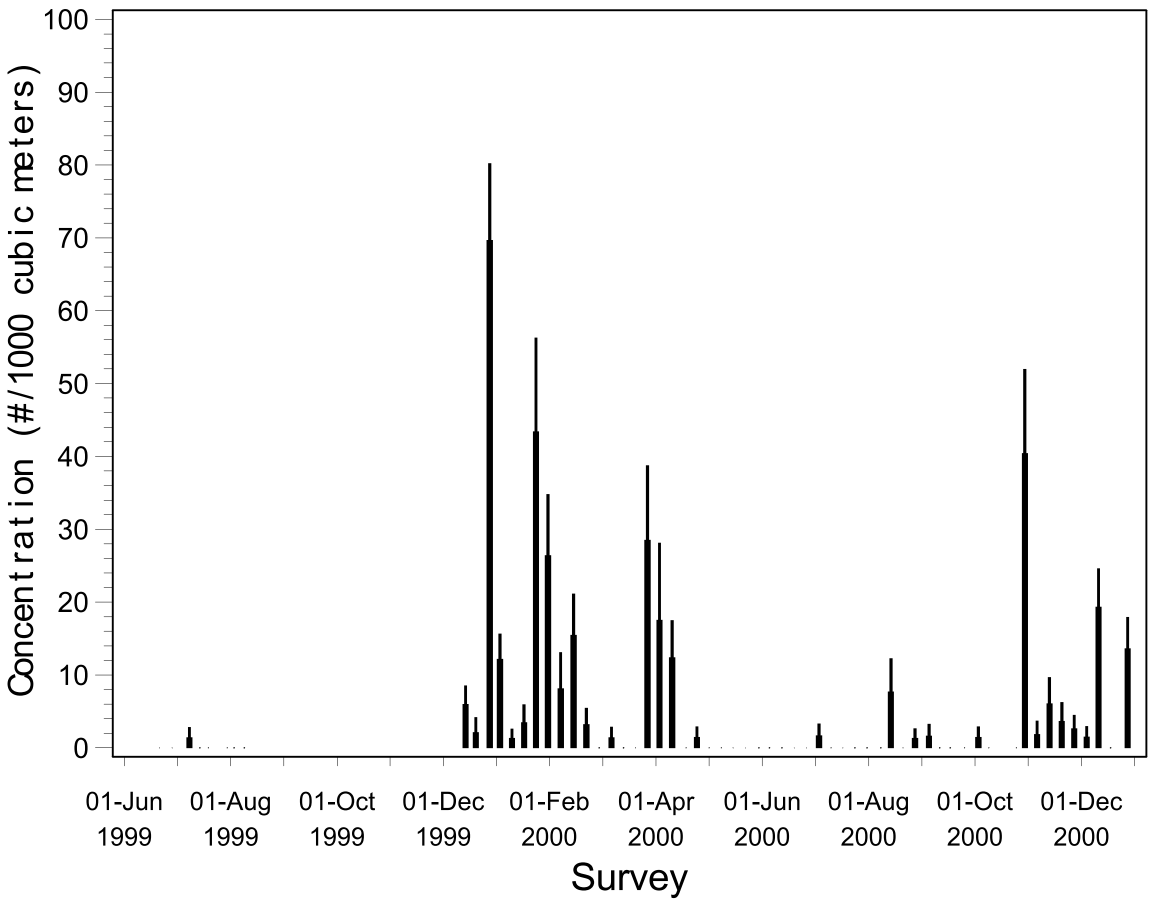


Figure 3-36. Weekly survey mean concentrations of larval white croaker collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

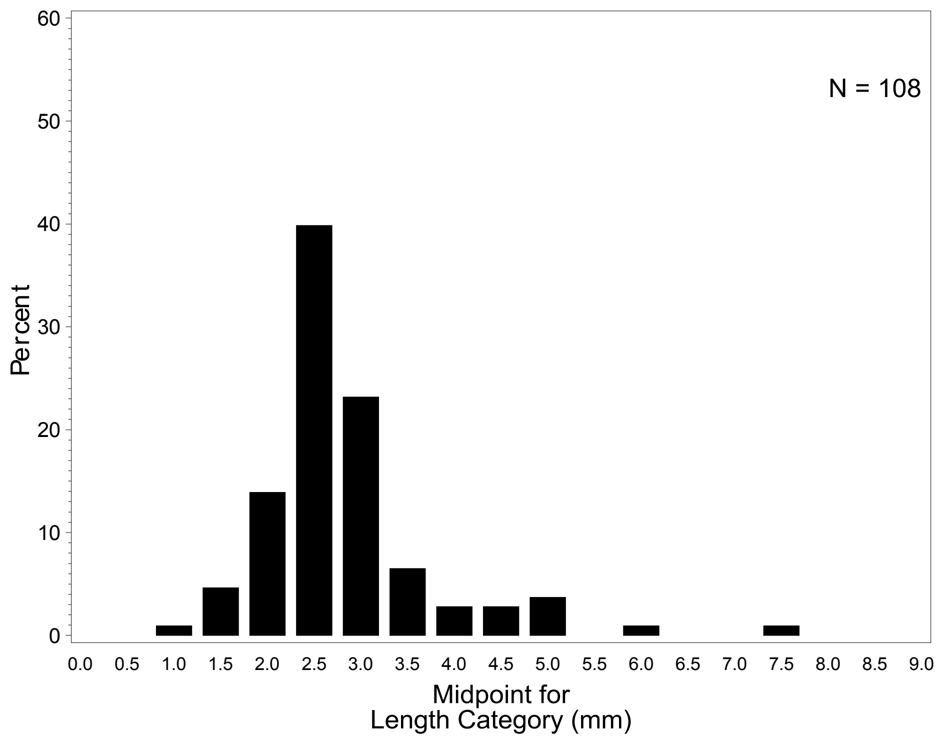


Figure 3-37. Length frequency distribution (mm) for white croaker larvae collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

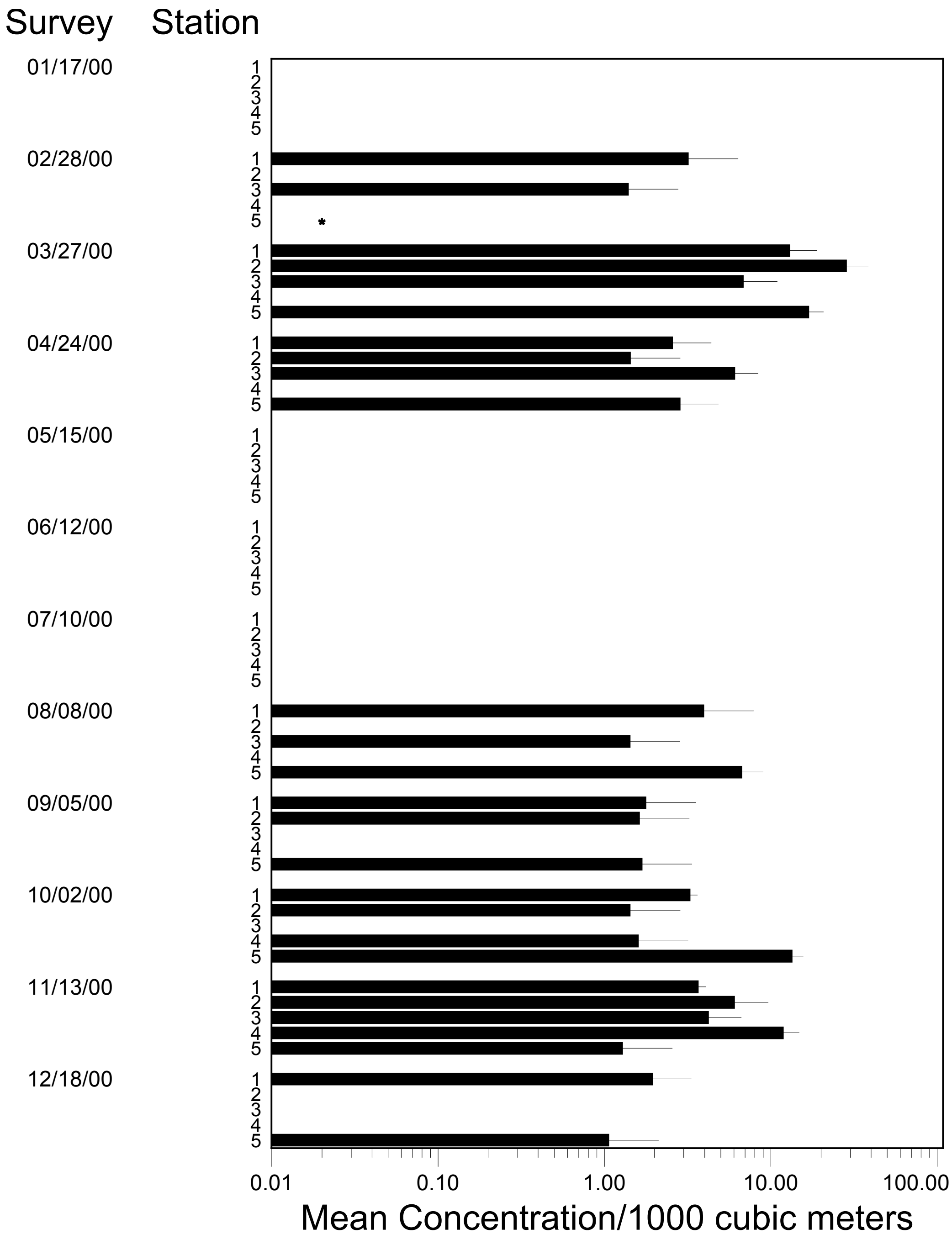


Figure 3-38. Mean larval white croaker concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

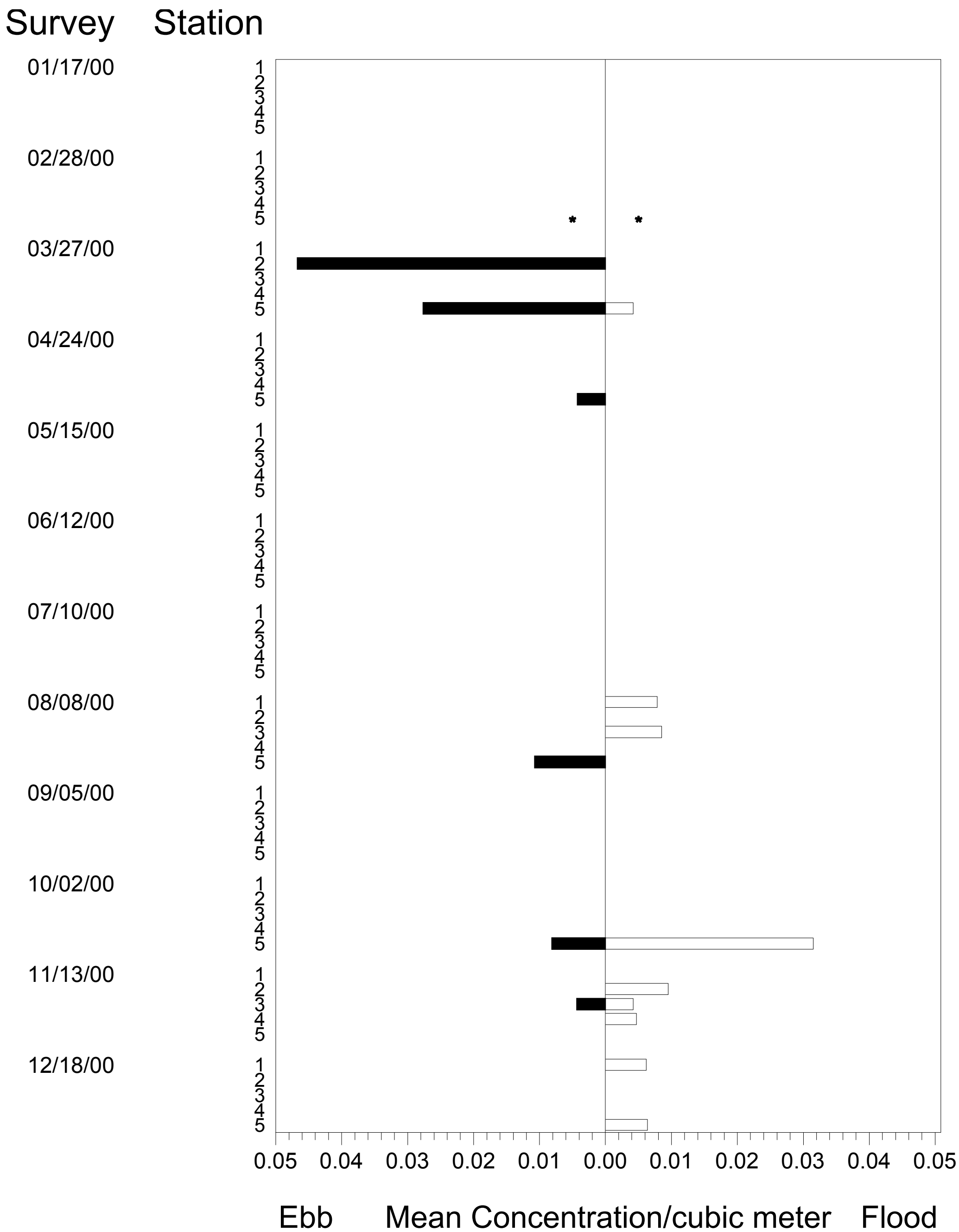
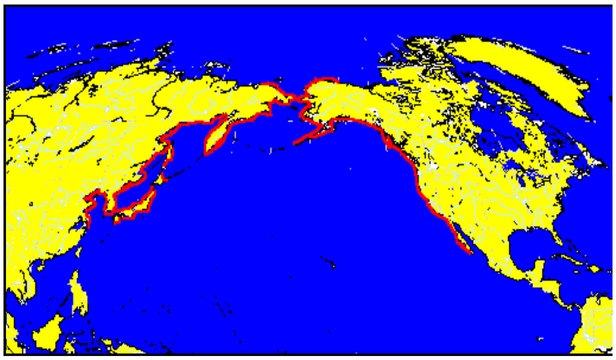


Figure 3-39. Mean concentration of larval white croaker from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January through December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.9 Pacific Herring Clupea pallasii



Distribution map for adult Pacific herring

Adult Range: From northern Baja California to Toyama Bay, Japan, westward to the Yellow Sea.

Life History: Size: Up to 46 cm (18 in.) and 550 g (1.2 lb); Age at maturity: two to three years old; Fecundity: 4,000 to 130,000 eggs; Life Span: Alaska- to nineteen years, California- to eleven years.

Adult Habitat: A schooling species found near shore to hundreds of miles off shore; spawns in intertidal and sub-tidal zones.

Adult Fishery: Commercial: valuable roe fishery; Recreational: small pier and shore angler fishery.

Pacific herring belong to the order Clupeiformes, which contains some of the world's most numerous and economically important fishes (e.g., herring, sardine, anchovy). The distribution of the Pacific herring extends from Baja California to the north Pacific and westward to Japan and the Yellow Sea (Miller and Lea 1972). In North America, Pacific herring range from Baja California north to arctic Alaska (PSMFC 1999a) and are most abundant off Alaska and British Columbia. In California, most of the populations are found in the San Francisco and Tomales bay areas (Fitch and Lavenberg 1975). Pacific herring are found from nearshore areas to hundreds of miles off the coast (Love 1996). They were collected in all Morro Bay fish studies (Appendix B this document, Fierstine et al. 1973, Horn 1980, Behrens and Sommerville, CDFG unpubl. otter trawl data, 1999–2000 impingement study [Section 4.0]).

Pacific herring are small, streamlined marine fishes, measuring up to 46 cm (18 in.) in length and weighing up to 550 g (1.2 lb) (PSMFC 1999a). While Pacific herring stocks living in the waters off of Alaska and Canada tend to grow larger and live longer, in California they may live to eleven years of age and rarely exceed 30.5 cm (12 in.) in length (Fitch and Lavenberg 1975). California Pacific herring reach maturity at two to three years of age and at a length of 16.5 to 17.8 cm (6.5 to 7 in.) (Love 1996).

The spawning activity of Pacific herring is largely influenced by their geographical location. In California, spawning is known to occur in San Diego Bay, San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, Russian River, Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor (Leet et al. 1992). Fish begin entering protected coastal bays, estuaries, and shallow nearshore environments approximately two months prior to spawning (Eldridge 1977). In the Moss Landing and Elkhorn Slough area spawning has been observed from November through July (Hardwick 1973).

The majority of spawning habitat is near vegetation in shallow waters ranging from the mean low-tide level to a depth of approximately 4 m (13 ft). The substrate of the spawning grounds tends to be clean, hard, and covered with gravel. Other substrate may include rocks, pilings, and jetties. A soft, muddy bottom may be used if a vegetative cover is available. Males and females spawn simultaneously over a period of one to seven days (Miller and Schmidtke 1956). The fertilized eggs, broadcast mostly at night, are adhesive and commonly attach to eelgrass, algae, and other intertidal vegetation (Hardwick 1973). Thousands of females repeatedly deposit their eggs on the vegetation, which can result in egg masses from 10 to 15 layers thick (about 5 cm [2 in.]) (Love 1996). In large spawning runs, a 9-m (30-foot) wide band of herring eggs may span a distance of 20 miles along the shoreline (Leet et al. 1992). In Elkhorn Slough, Pacific herring are known to broadcast eggs on pickleweed *Salicornia* spp., a brackish marsh vegetation (Wang 1986). Females are capable of spawning only once per season, and after producing between 4,000 and 130,000 eggs, they promptly return to the ocean, leaving the eggs to incubate and hatch. The rate of egg development varies with surrounding water temperature; Pacific herring eggs commonly hatch within 10 to 14 days at 11.8° to 13.5° C (53.2° to 56.3° F) (Wang 1986).

Hatch length is reported as 5.6 to 7.5 mm (0.2 to 0.3 in.) (Moser 1996). Shortly after hatching, and as the eyes become pigmented, the threadlike larvae move toward the surface waters. They tend to concentrate near the surface and remain for a long time in the area of the spawning grounds. Some larvae, however, have been found several miles out to sea, drifting with the currents (Fitch and Lavenberg 1975). It takes about 70 days (when larvae are approximately 26 mm TL [1.0 in.]) for the larvae to metamorphose (Hay 1985). Metamorphosis is complete by 35 mm TL (1.4 in.) (Stevenson 1962). Juveniles, depending on geographical region, range from 35 to 150 mm TL (1.4 to 5.9 in.) (Reilly 1988).

Herring usually reach maturity in two to three years in California and three to four years in Washington (Hart 1973). Pacific herring are pelagic, and while some may remain in the bays and estuaries, most leave and return to the ocean (Eldridge 1977). At all life stages Pacific herring are plankton feeders, primarily selecting copepods, amphipods, fish larvae, and mollusks. They do not feed during the spawning season, but feed intensively in the summer after spawning.

Pacific herring are a well-described species with both age-and stage-specific mortality estimates available from the scientific literature. Egg mortality has been estimated to range from 20 percent (Hourston and Haegele 1980) to as high as 99 percent (Hardwick 1973, Leet et al. 1992). Larval mortality can also be derived from the literature and is assumed to be 99 percent through settlement (survivorship = 0.221). Data on larval age and growth (e.g., Stevenson 1962, Alderdice and Hourston 1985) are also important for estimating survivorship. Total adult mortality has been estimated as about 50 percent annually ($z = 0.69$) by Hourston and Haegele (1980). Estimates of natural adult mortality (m) are in close agreement from a variety of studies: $m = 0.4$ to 0.5 (Trumble and Humphreys 1985), $m = 0.39$ (Fried and Wespestad 1985), $m = 0.36$ (Schweigert and Hourston 1980), $m = 0.56$ (Gunderson and Dygert 1988), and $m = 0.31$ to 0.71 (Stocker et al. 1985).

The harvest of Pacific herring is a multi-million dollar industry in the United States, with most of the fish coming from Alaska, Washington, and California. The Pacific herring fishing industry is highly regulated north of San Francisco Bay. There are small fisheries in the Monterey and San Francisco area that target Pacific herring for bait and food, but the more valuable fishery involves herring eggs (roe). There is a very lucrative export market for herring roe, especially for kazunoko kombu (roe-on-kelp) which is considered a delicacy in Japan. There are a limited number of gill net and roe-on-kelp permits issued for this fishery in San Francisco Bay. Large amounts of giant kelp, transported from the Channel Islands, are suspended from rafts, which are then anchored in the Pacific herring spawning grounds. At the end of the spawning period, the kelp and attached eggs are collected, packed in salt, and exported to Japan.

3.3.9.1 Pacific Herring Results

Peak larval concentration for Pacific herring collected at the MBPP intake station occurred in December of both 1999 and 2000 (Figure 3-40), which agrees with reported spawning periods from November through July (Hardwick 1973). Larval concentrations were significantly higher in December 2000 than in December 1999. Pacific herring larvae continued to be collected through April but in much lower concentrations. A representative sample of Pacific herring larvae had a size range of 4.2 to 9.1 mm (0.17 to 0.36 in.), with an average size of 7.1 mm (0.28 in.) (Figure 3-41). These larvae are newly hatched and only a few days old, based on the estimated hatch length of 5.6 to 7.5 mm (0.2 to 0.3 in.) (Moser 1996).

Pacific herring utilize Morro Bay for spawning and therefore the highest concentrations of larvae occurred at stations 3 and 4 inside the bay (Figure 3-42). No Pacific herring larvae were collected at the Estero Bay station (Station 5), but they were found at Station 1 at the harbor entrance. Although the larvae were most common at the back bay stations their concentrations were not large enough to allow for a comparison between ebb and flood tides (Figure 3-43).

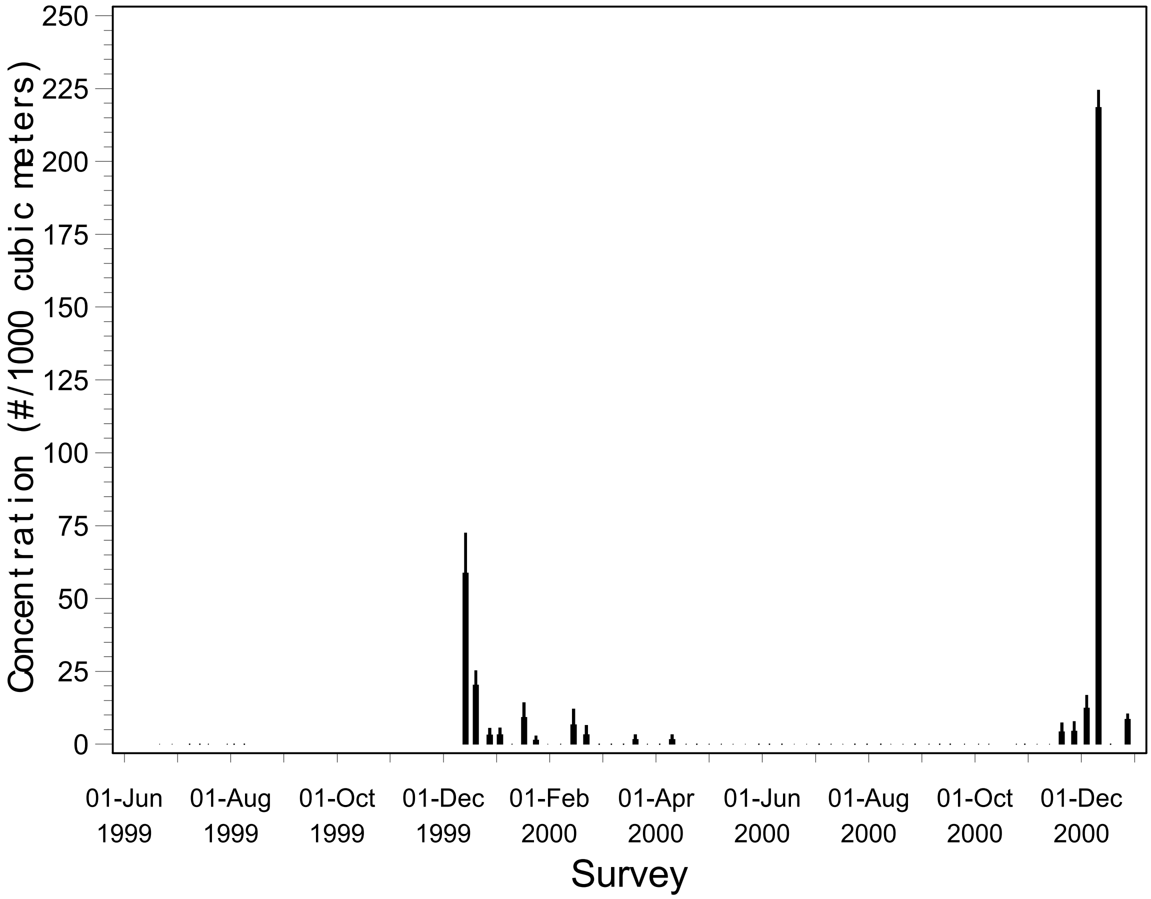


Figure 3-40. Weekly survey mean concentrations of larval Pacific herring collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

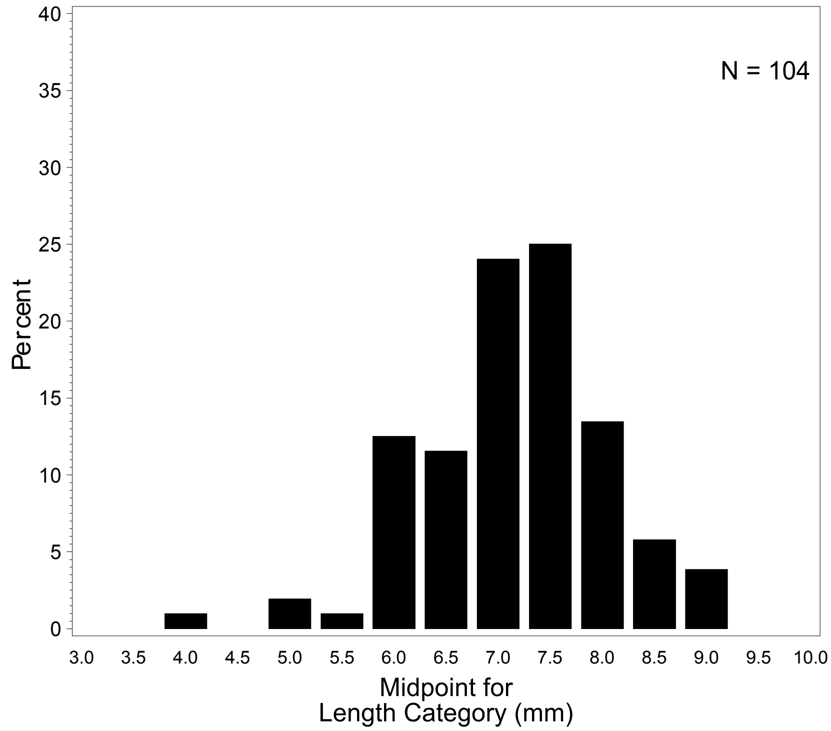


Figure 3-41. Length frequency distribution (mm) for Pacific herring larvae collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

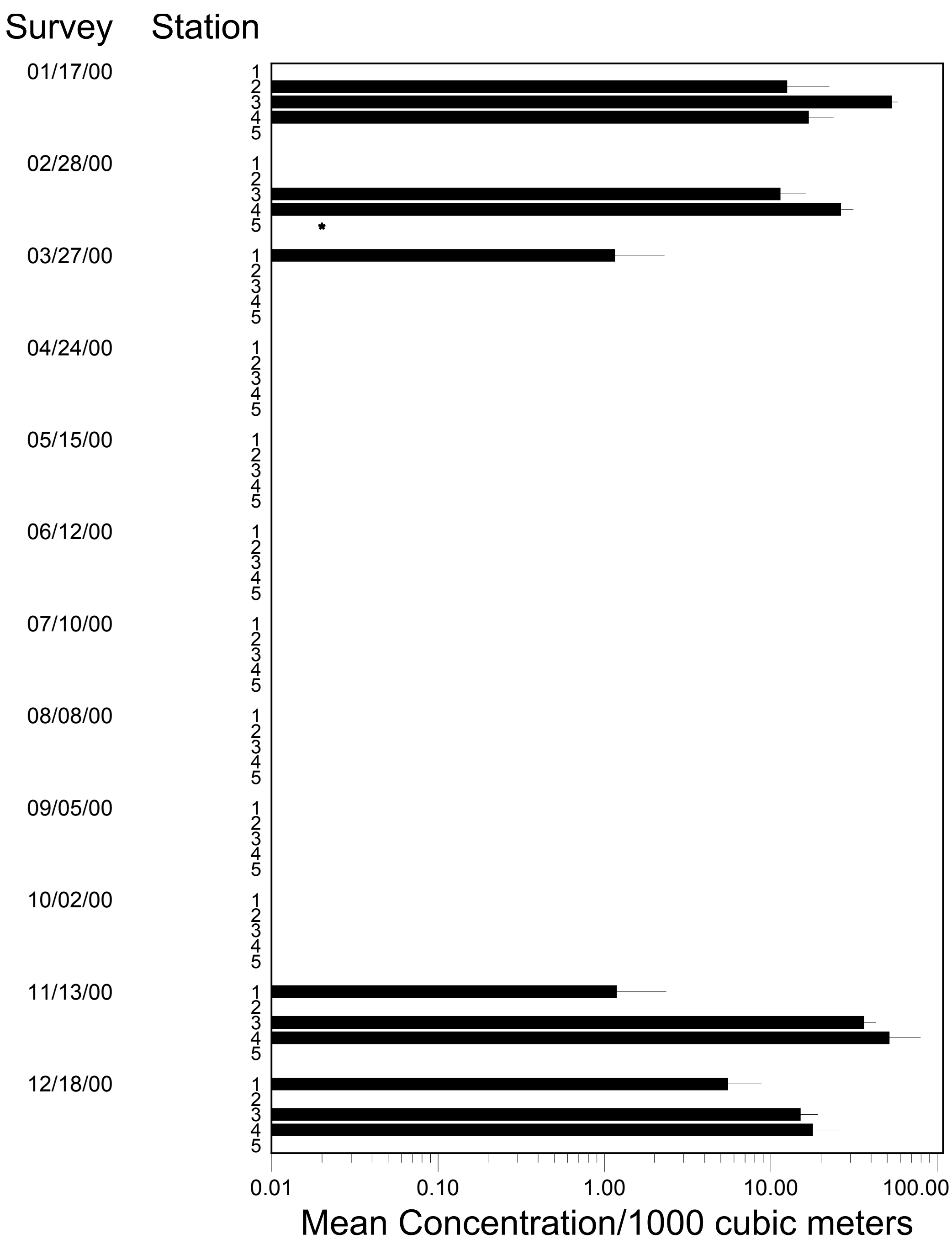


Figure 3-42. Mean larval Pacific herring concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

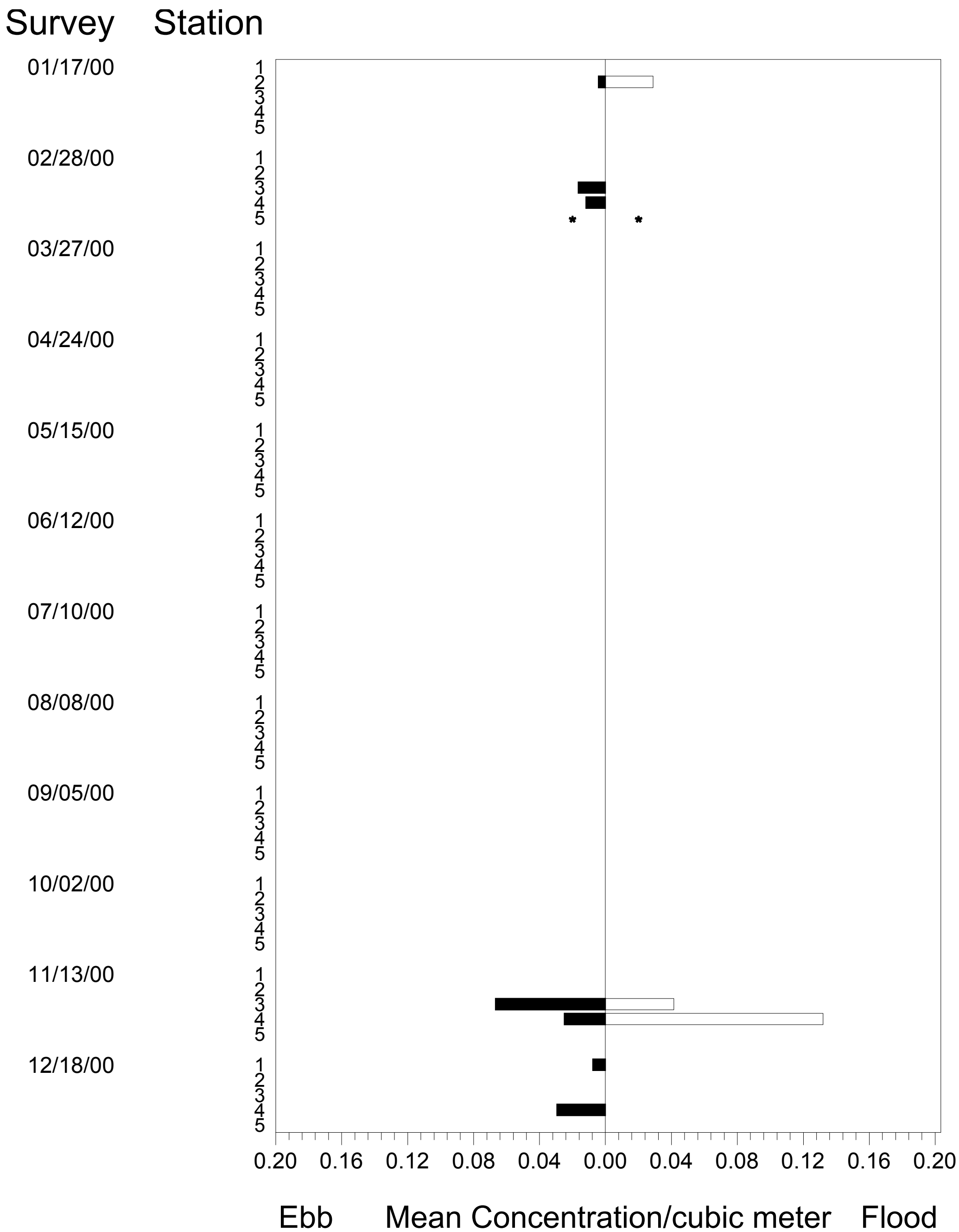
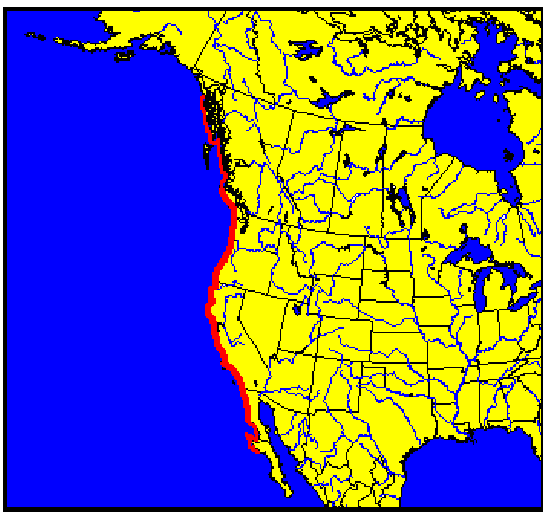


Figure 3-43. Mean concentration of larval Pacific herring from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.10 Cabezon Scorpaenichthys marmoratus



Distribution map for adult cabezon

Adult Range: From Sitka, Alaska to central Baja California.

Life History: Size: to 99 cm (39 in.); Age at maturity: males - 2 to 3 years, females - 3 to 5 years; Fecundity: 45,000 to 152,000 eggs; Life span: females to 13 years; males to nine.

Adult Habitat: Hard bottom, intertidal to 85 m (280 ft.).

Adult Fishery: Small commercial market, recreational fishery.

Cabezon *Scorpaenichthys marmoratus* belongs to the family Cottidae that comprises 70 genera worldwide (Nelson 1994). Forty-two species of sculpin occur along the California coast (Miller and Lea 1972), primarily in intertidal or shallow subtidal habitats. The cabezon is the largest North American species of marine cottid and occurs over the nearshore continental shelf from depths of 85 m (280 ft) up to the intertidal zone (O'Connell 1953, Matarese et al. 1989). They were collected in all Morro Bay fish studies except for the studies of Horn (1980) (Appendix B this document, Fierstine et al. 1973, Behrens and Sommerville 1982, CDFG unpubl. otter trawl data, 1999-2000 impingement study [Section 4.0]).

Cabezon are a popular sport fish and are also landed commercially (Fitch and Lavenberg 1971, Lamb and Edgell 1986). Females are oviparous and lay demersal, adhesive eggs in rocky crevices or on algae; males guard the egg nest until the pelagic larvae hatch (Burge and Schultz 1973, Matarese et al. 1989). Moser (1996) indicates that cabezon larvae hatch at 3 to 6 mm (0.12 to 0.24 in.).

Larvae appear in the water column around November or December and recruit to tidepools at around 40 mm (1.6 in.) SL in March off Moss Beach, California (R. R. Harry unpubl. data cited in O'Connell 1953), implying a three- to four- month planktonic duration. Females begin to mature in their third year between 25 to 48 cm (10 to 19 in.) SL (Fitch and Lavenberg 1971), and all are mature by year five (Starr et al. 1998). Fecundity for this species has been reported in several sources: 45,000 eggs for a 43 cm (17 in.) SL specimen and 95,000 eggs for a 65 cm (26 in.) SL specimen (Hart 1973); mean fecundity of 48,700 eggs for a 1.4 kg (3 lb) female and 97,600 eggs for a 4.6 kg (10 lb) female (O'Connell 1953, Bane and Bane 1971); and up to 152,000 eggs from a 76 cm (30 in.) SL female (Starr et al. 1998). O'Connell (1953) states that females spawn more than a single batch of eggs per year. Females live to 13 years and males to nine years (O'Connell 1953).

3.3.10.1 Cabezon Results

Peak larval concentration for cabezon collected at the MBPP intake station occurred in January, February, and November 2000 (Figure 3-44), which agrees with reported spawning times (R. R. Harry unpubl. data cited in O'Connell 1953). A representative sample of cabezon larvae had a size range of 3.2 to 6.9 mm (0.13 to 0.27 in.), with an average size of 5.3 mm (0.21 in.) (Figure 3 45). The two peaks in the distribution may represent differences in hatch size between the two spawning seasons. The estimated hatch size for cabezon of 3 to 6 mm (0.12 to 0.24 in.) indicates that the larvae in the entrainment samples were only a few days old.

Based on the expected distribution of adult cabezon in Morro Bay, larval concentrations among all stations should follow the pattern observed during the February and December source water surveys with concentrations decreasing from the outer bay stations (1 and 2) towards the inner bay stations (3 and 4) (Figure 3-46). This pattern was not present during the other surveys. For example, cabezon larval concentration was highest in November at Station 4, the station furthest inside the bay. The concentration of cabezon larvae was highest on flood tides during this survey providing a potential mechanism for their transport into the back bay (Figure 3-47). Otherwise, cabezon concentrations were generally too low to allow for a comparison between ebb and flood tides.

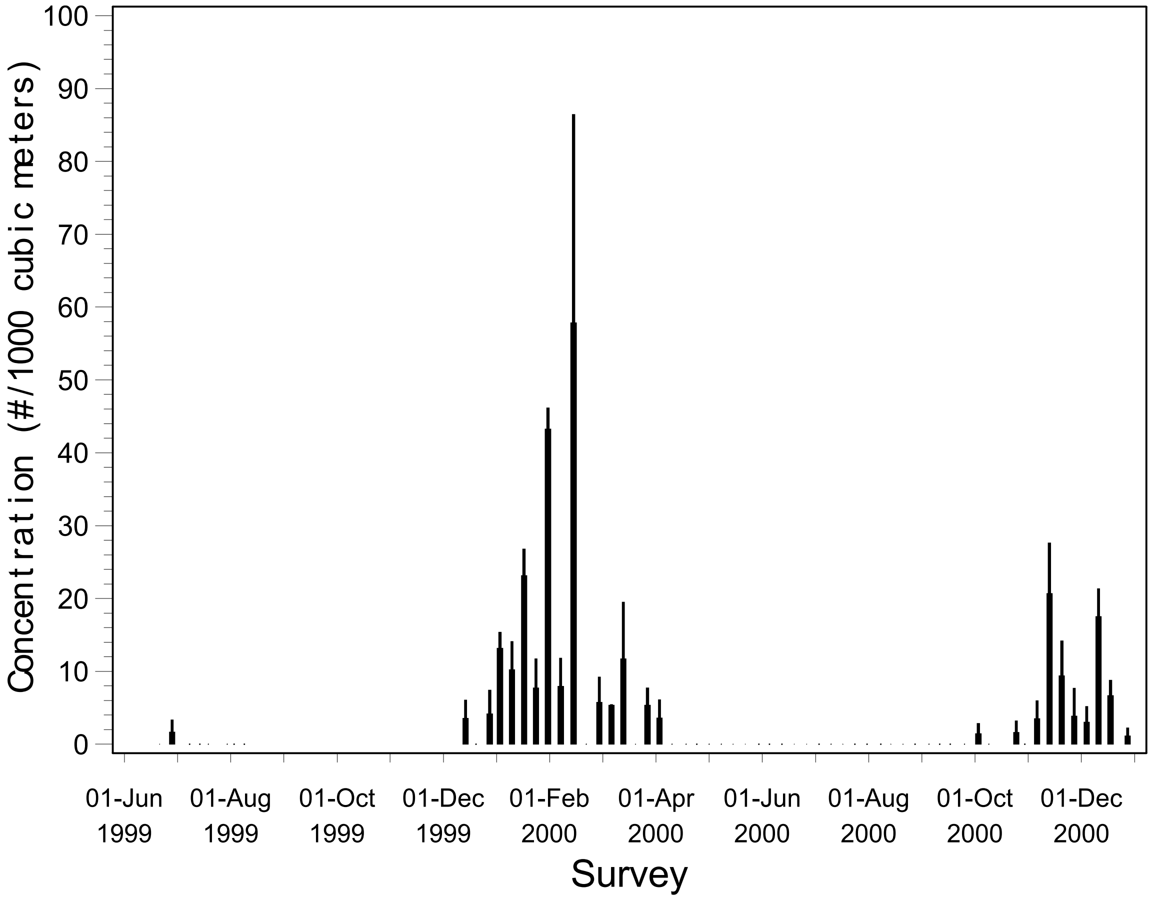


Figure 3-44. Weekly survey mean concentrations of larval cabezon collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

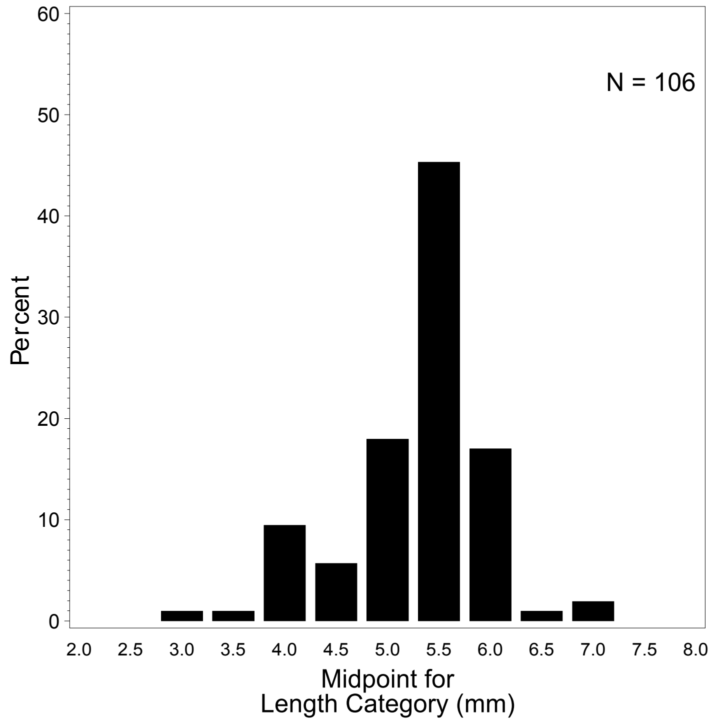


Figure 3-45. Length frequency distribution (mm) for cabezon larvae collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

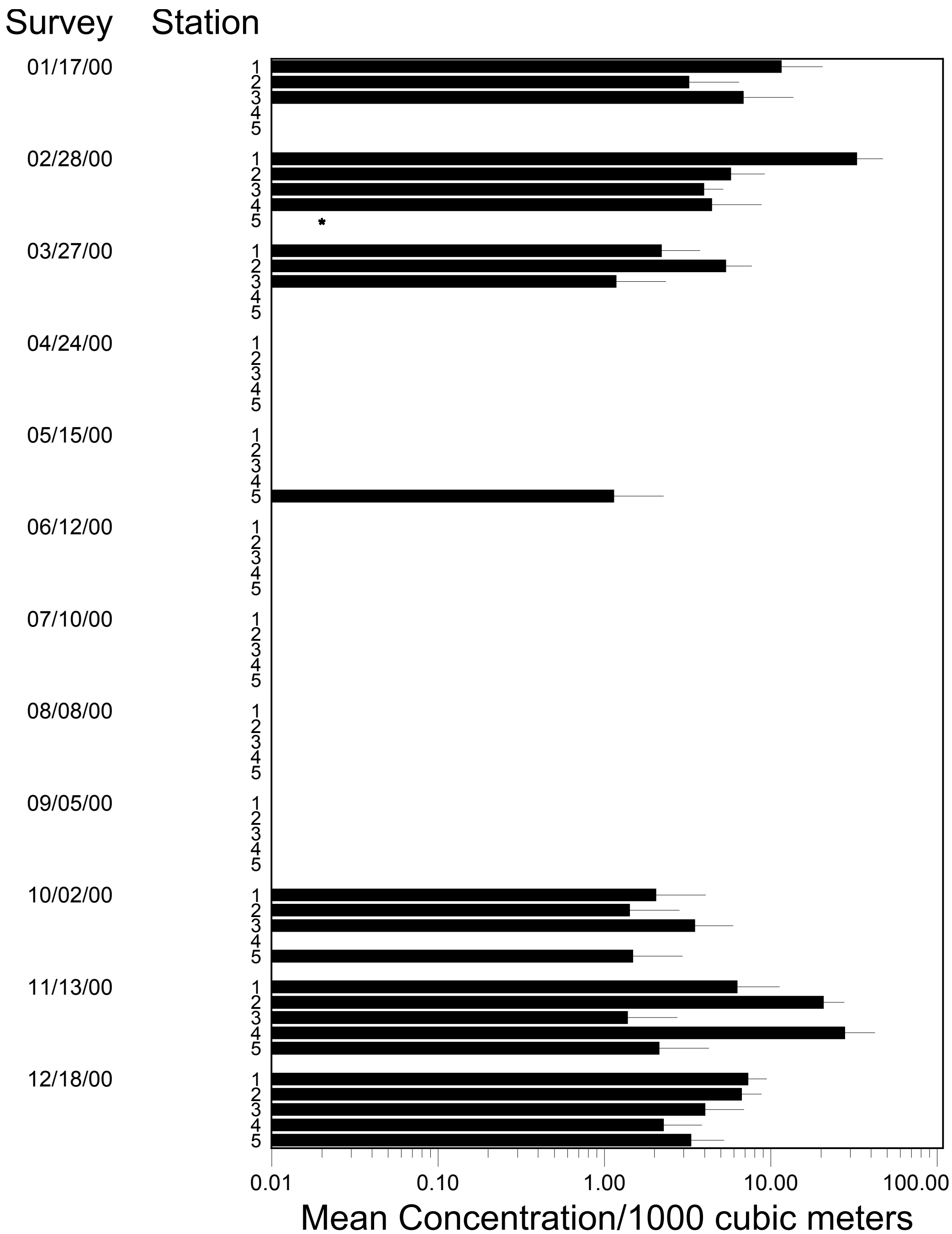


Figure 3-46. Mean larval cabezon concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

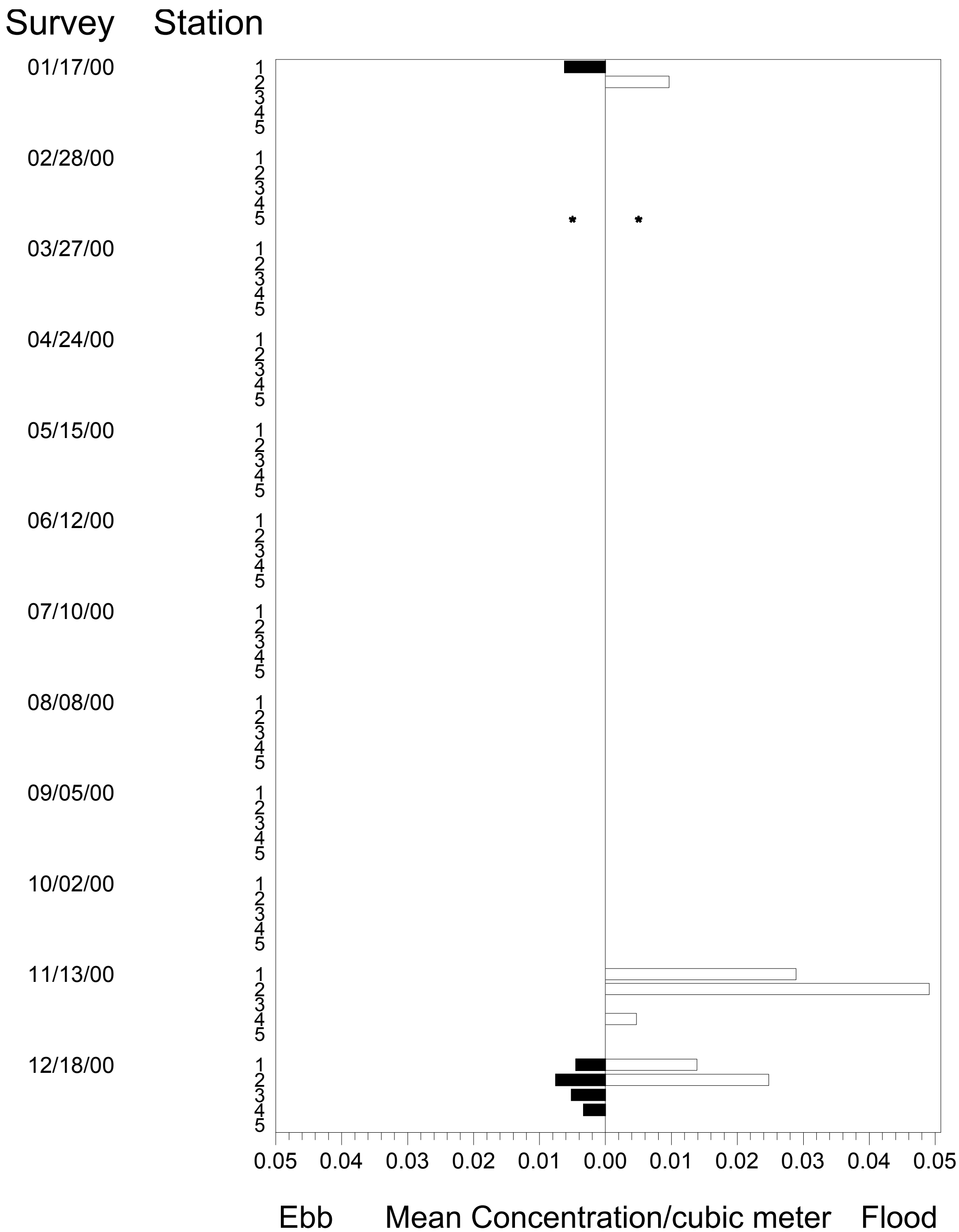


Figure 3-47. Mean concentration of larval cabezon from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

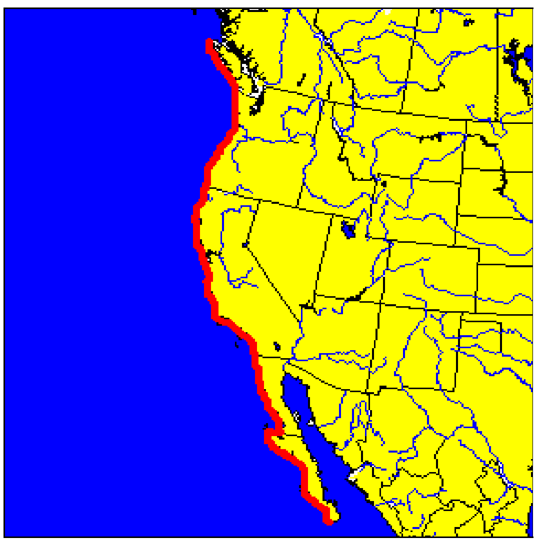
3.3.11 Cancer Crabs

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

Each species in the genus has characteristic differences in distribution, preferred habitat, growth rates, and demographic parameters. For example, brown rock crab *Cancer antennarius* is a relatively large species (CW up to 200 mm [8 in.]) that lives primarily on sand and mud substrata in estuarine and coastal shelf areas. The slender crab *Cancer gracilis* is a smaller species (CW up to 130 mm [5 in.]) associated with mixed rock-sand substrata in shallow outer coast habitats. Maximum clutch sizes in cancer crabs can range from as many as 5,000,000 eggs in yellow crab *C. anthonyi* to approximately 50,000 in *C. 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 cancer species.

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

3.3.11.1 Brown Rock Crab *Cancer antennarius*



Distribution map for adult brown rock crab

Adult Range**:** From Queen Charlotte Sound, British Columbia to Cabo San Lucas, Mexico.

Life History**:** Adult crabs sexually dimorphic; Size: males to 178 mm (7 in.), females to 148 mm (5.8 in.); Size at maturity: 60 to 80 mm (2.4 in. to 3.1 in.); Fecundity: 156,000 to 5 million eggs; Life span: estimated to be five to six years.

Adult Habitat**:** A variety of substrates including rock, gravel, sand, and sandy-silt. Occurs from the lower intertidal to depths exceeding 100 m (328 ft).

Adult Fishery**:** Small recreational fishery; moderate commercial fishery.

The brown rock crab *Cancer antennarius* is distributed in nearshore waters along the Pacific coast of North America from British Columbia to Mexico (Jensen 1995). Their range of peak abundance extends from San Francisco Bay to coastal areas south of the U.S.-Mexico border (Carroll and Winn 1989). Brown rock crab are a marine species that inhabit nearshore coastal regions but may also be found in sloughs and estuaries. They are, however, unable to osmoregulate and do not tolerate brackish conditions well (Garth and Abbott 1980).

Brown rock crab inhabit a variety of substrata including rock, gravel, sand, and sandy-silt (Winn 1985). They occur from the lower intertidal zone to depths exceeding 100 m (330 ft) but are typically found near the rock-sand interface in depths of less than 55 m (180 ft) (Carroll and Winn 1989). Ovigerous brown rock crabs have been observed buried in sand at the base of rocks in shallow water. Juvenile brown rock crab inhabiting the intertidal zone survive exposure to the air during low tide by sheltering themselves under rocks and algae (Ricketts et al. 1985).

Brown rock crab fecundity varies with female body size. Brown rock crab females can extrude between approximately 156,000 and five million eggs per batch (Hines 1991). Females on average produce a single batch per year. However, due to occasional multiple spawning, the average number of batches per year may be greater than one (Carroll 1982). Brown rock crab eggs require a development time of approximately seven to eight weeks from extrusion to hatching (Carroll 1982). Brown rock crab are between 60 to 80 mm (2.4 to 3.1 in.) CW at maturity (Carroll 1982).

Larval development in the brown rock crab was described by Roesijadi (1976). Eggs hatch into pre-zoea larvae that molt to first stage zoea in less than one hour. Average larval development time (from hatching through completion of the fifth stage) was 36 days at 13.8 °C (56.8 °F). Although some crabs molted to the megalopal stage, none molted to the first crab instar stage, so the actual duration of the megalopal stage is unknown. A reasonable estimate can be derived from studies of slender crab by Ally (1975), who found an average duration of megalopal stage of 14.6 days. Therefore, the estimated length of time from hatching to settling for brown rock crab is assumed to be 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 brown rock crab stage 1 zoeae are most abundant close to shore and that subsequent zoeal stages tend to remain within a few kilometers of the coastline. The adult population primarily resides in relatively shallow rocky areas, and the nearshore retention of larvae in Graham's study (1989) was related to the formation of an oceanographic frontal zone in northern Monterey Bay that prevented substantial offshore transport during upwelling periods.

The nearshore distribution of crab larvae depends upon developmental stage. Shanks (1985) presented evidence that early stage larvae of rock crabs (probably yellow crab in his southern California study) generally occur near the bottom, in depths up to 80 m (264 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 (megalopae) generally begin to recruit to the nearshore habitat in spring (Winn 1985).

Brown Rock Crab Results

Brown rock crab megalopae were collected episodically at the MBPP intake station (Figure 3-48). They were collected in winter and again in the late-spring and summer with peak concentrations in June 2000. The concentrations during the late-spring through summer period were much greater than those during the winter in 1999 and 2000.

While concentrations of brown rock crab megalopae peaked in June 2000 at the MBPP intake station, their greatest abundance occurred in Estero Bay during April and May (Figure 3-49). Megalopal brown rock crabs were consistently most abundant in the paired surveys in Estero Bay during the course of the study. Early life stages of cancer crabs are often distributed along gradients perpendicular to shore (Tenera, unpubl. data, Carrasco et al. 1985).

Concentration ($\#/m^3$) of megalopal brown rock crab was compared among stations for samples collected at ebb and flood tides (Figure 3-50). The highest brown rock crab megalopae concentrations were recorded in Estero Bay (Station 5) where tidal currents would be expected to have little effect on larval concentrations. The concentrations at this station were an order of magnitude or more greater than concentrations at stations inside the bay.

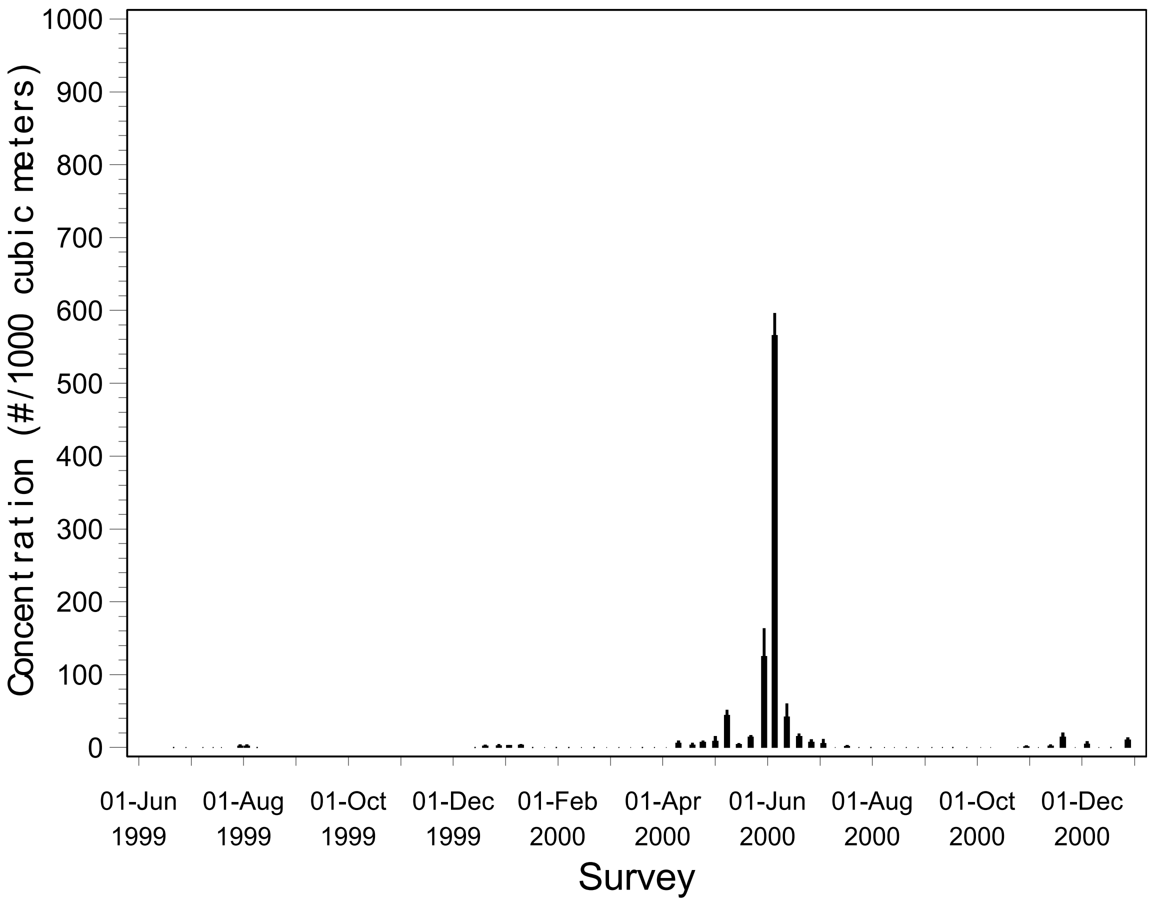


Figure 3-48. Weekly survey mean concentrations of megalopal brown rock crab collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

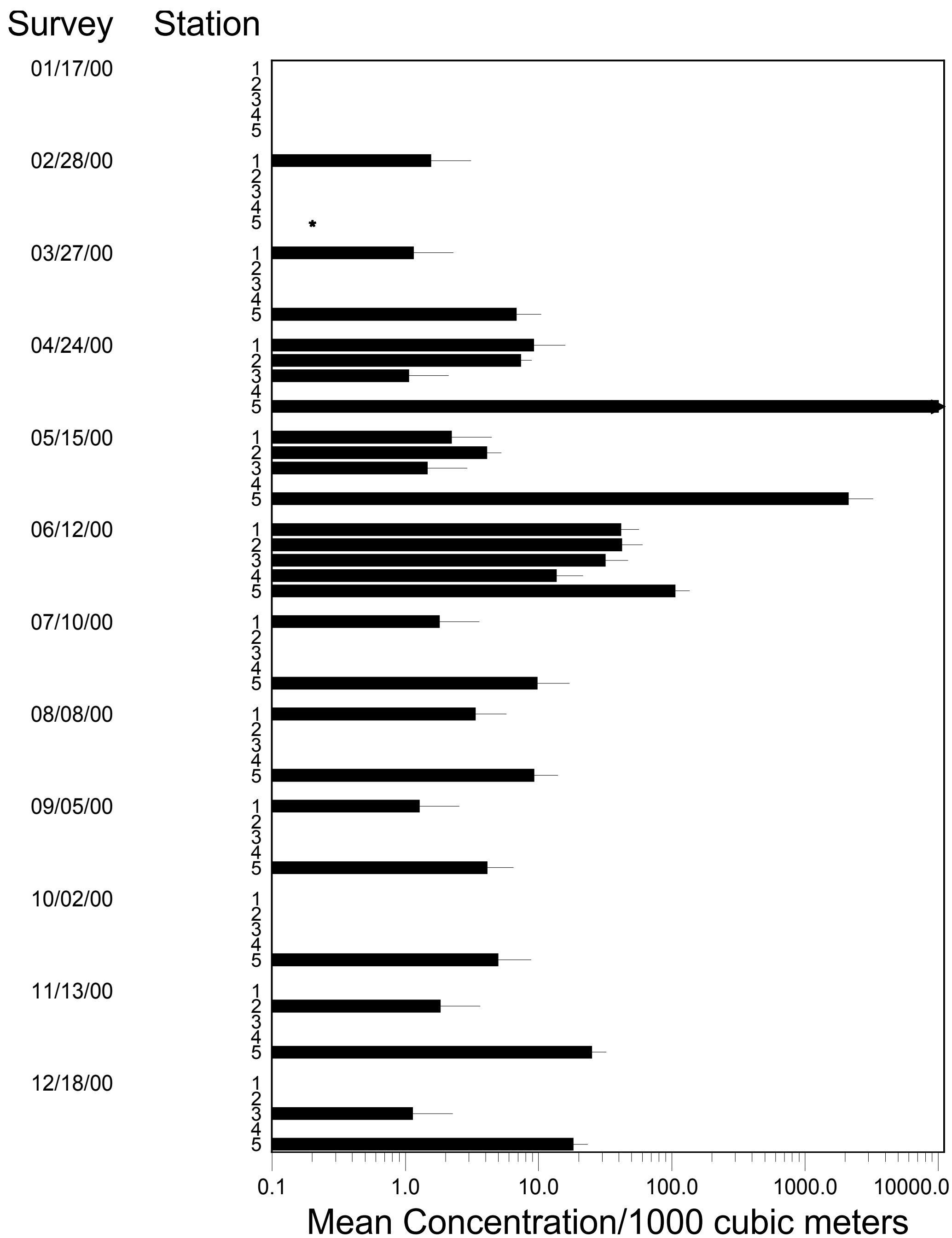


Figure 3-49. Mean megalopal brown rock crab concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

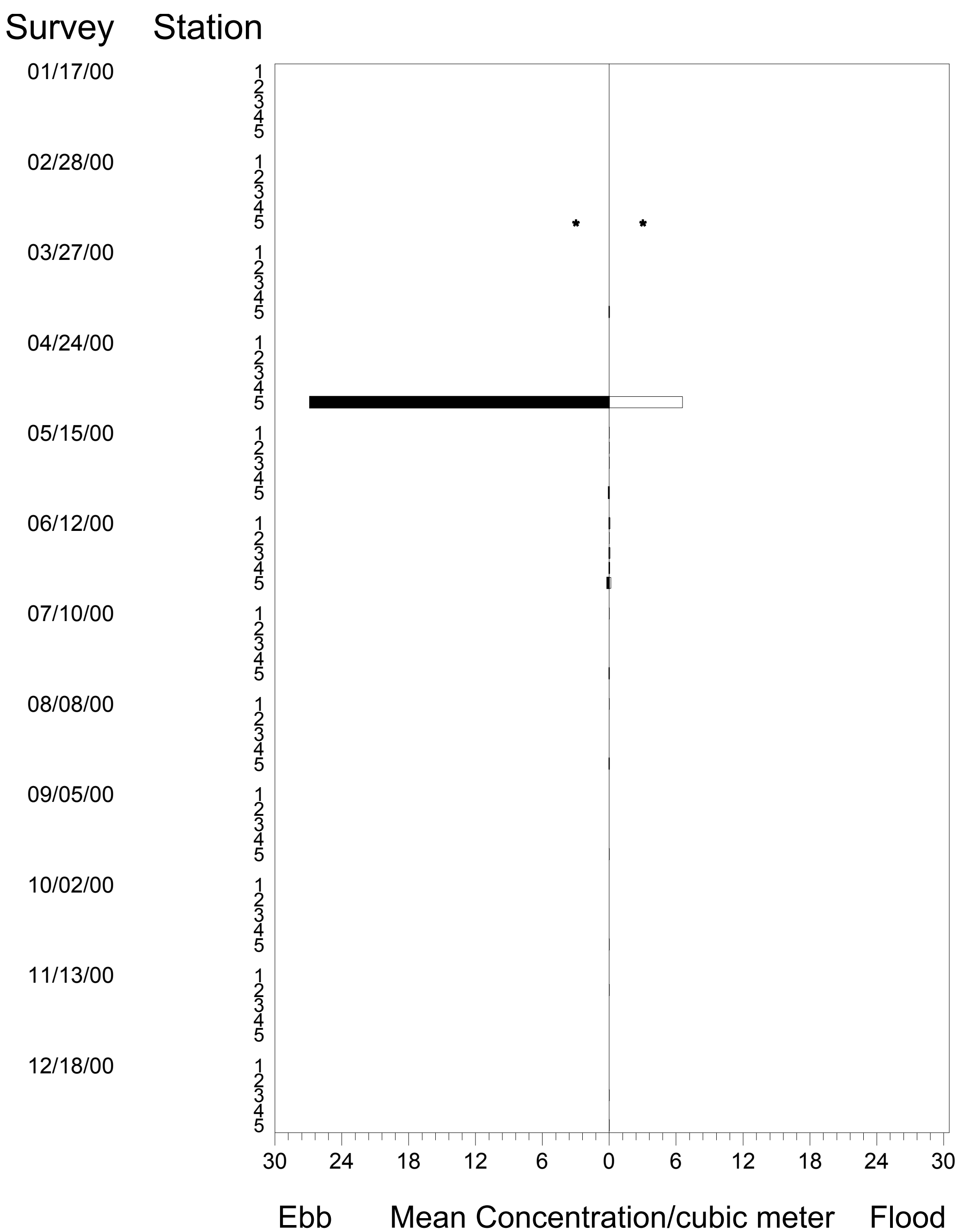
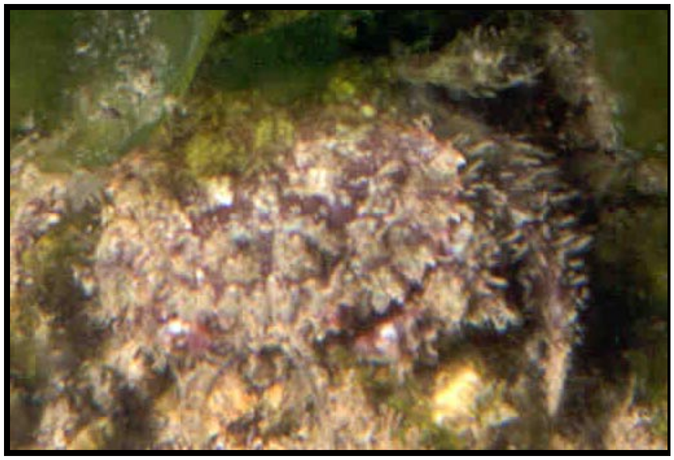


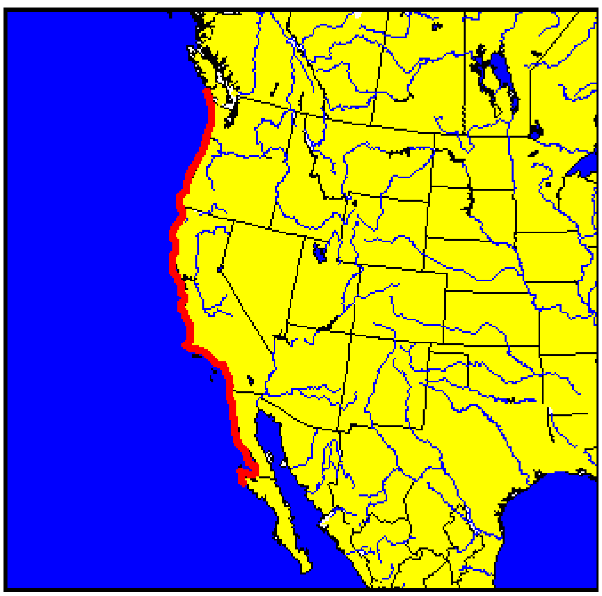
Figure 3-50. Mean concentration of megalopal brown rock crab from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.11.2 Hairy Rock Crab *Cancer jordani*





Distribution Map for adult hairy rock crab

Adult Range: From Neah Bay, Washington to Bahía de Tortuga, Baja California.

Life History: Size: males up to 39.3 mm (1.5 in.); females to 19.5 mm (0.7 in.); Size at maturity: no information available; Fecundity: no specific information available; Life span: no estimate available.

Adult Habitat: Under rocks in shallow bays, subtidally in kelp holdfasts; intertidally to depths of 104 m (340 ft).

Adult Fishery: No commercial or recreational fishery.

The hairy rock crab is one of the smallest members of the family Cancridae. The species ranges from Baja California to Washington (Jensen 1995). Hairy rock crab occur from the intertidal zone down to depths of 104 m (340 ft) (Garth and Abbott 1980). They are most often observed under rocks in the shallow waters of bays, but may also be found subtidally in the holdfasts of kelp. In Monterey Bay, up to 78 hairy rock crab have been documented per square meter of kelp holdfast (Garth and Abbott 1980).

Hairy Rock Crab Results

Similar to the brown rock crab, the collection of hairy rock crab megalopae at the MBPP intake station was episodic during the study (Figure 3-51). The periodicity of hairy rock crab abundance at the MBPP intake was also similar to that of brown rock crab megalopae with highest concentration occurring in the late spring. Despite the similarities, hairy rock crab megalopae were collected in markedly lower concentrations than brown rock crab megalopae.

Hairy rock crab megalopae were most abundant at Estero Bay Station 5 during monthly paired surveys (Figure 3-52). In months following high megalopal abundance in Estero Bay, hairy rock crab megalopae were abundant and common at the stations within Morro Bay suggesting onshore movement of the megalopal hairy rock crabs from Estero Bay. Greater abundance of megalopal hairy crabs in Estero Bay follow the pattern for Dungeness crab (Carrasco et al. 1985) and other megalopal cancrid crabs in central California (Tenera, unpubl. data).

Concentration ($\#/m^3$) of megalopal hairy rock crab was compared among stations for samples collected at ebb and flood tides (Figure 3-53). Hairy rock crab megalopal abundance was greatest in Estero Bay (Station 5) where tidal currents have little effect.

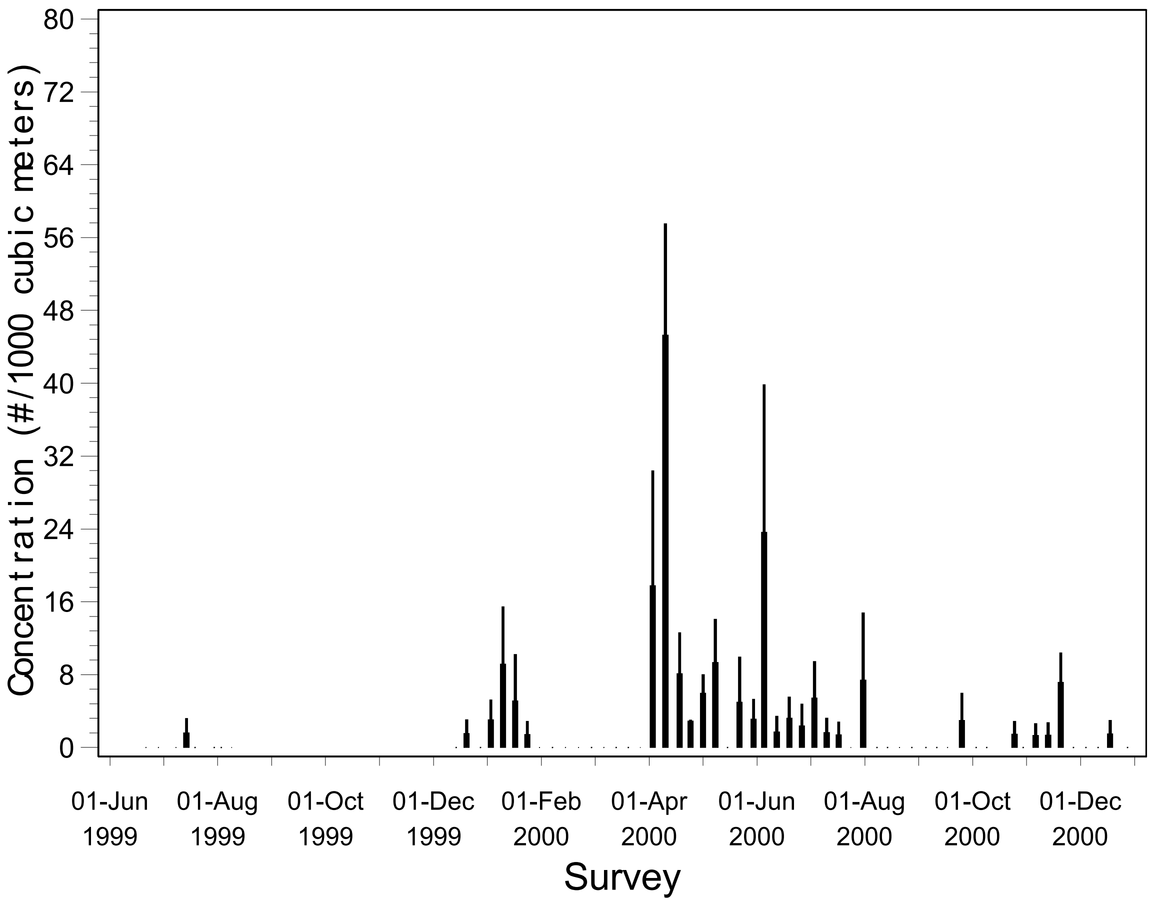


Figure 3-51. Weekly survey mean concentrations of megalopal hairy rock crab collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

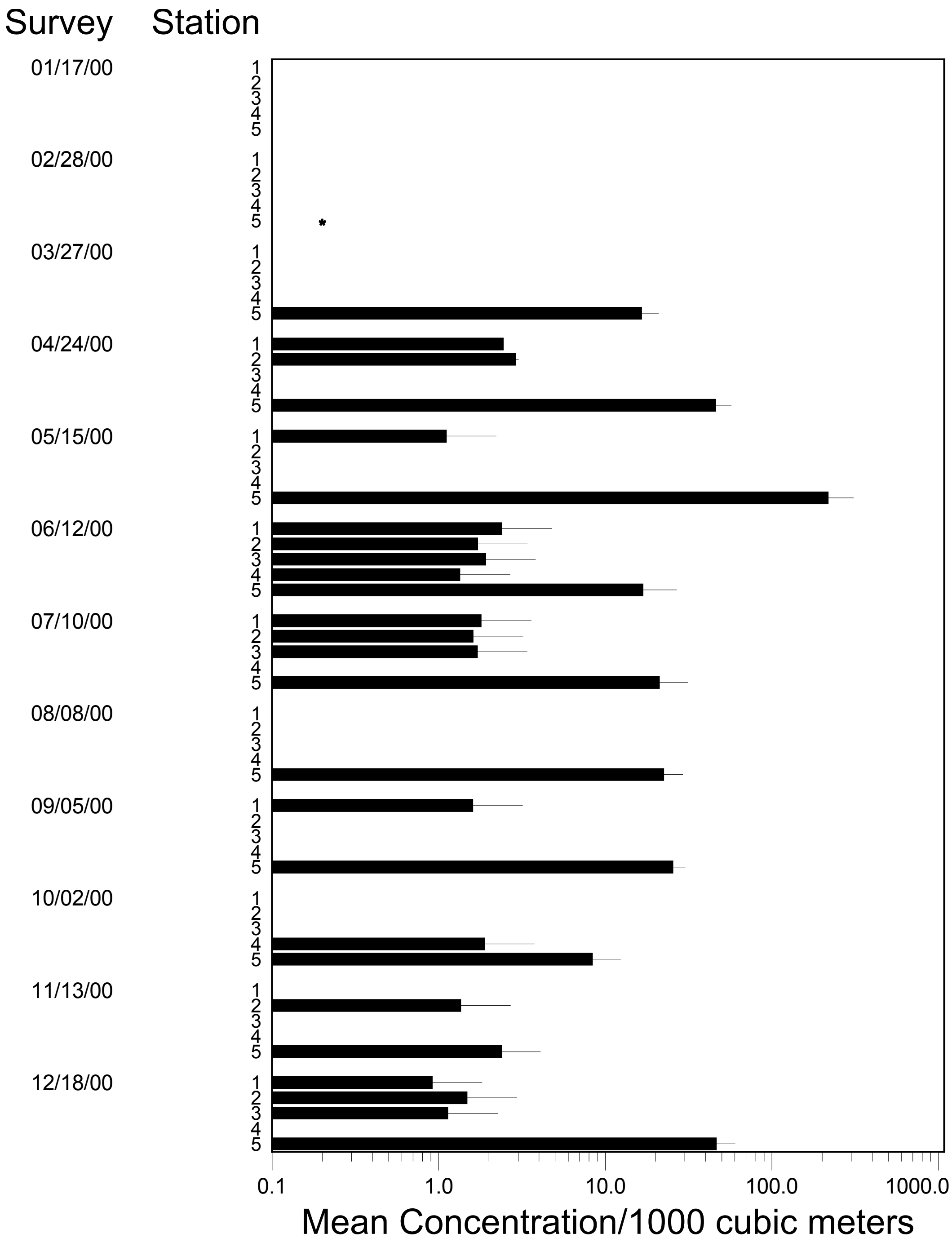


Figure 3-52. Mean megalopal hairy rock crab concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

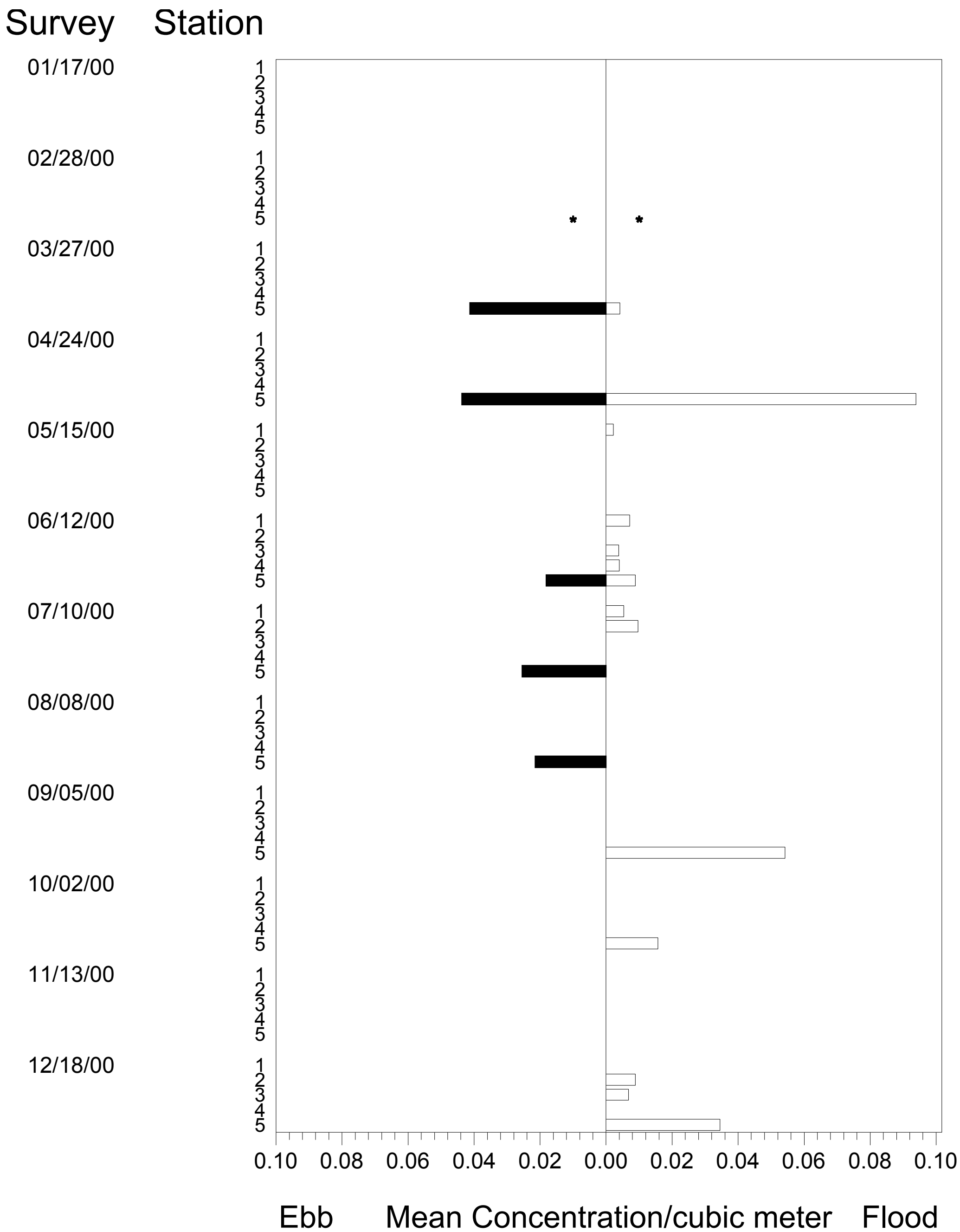
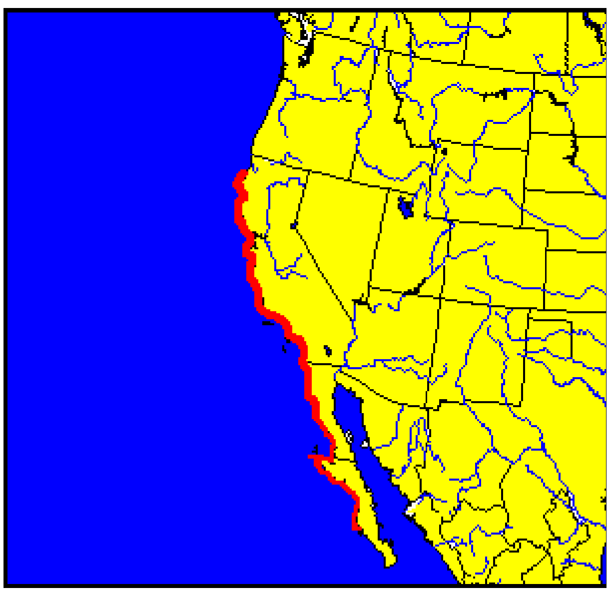


Figure 3-53. Mean concentration of megalopal hairy rock crab from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.11.3 Yellow Crab *Cancer anthonyi*



Distribution map for adult yellow rock crab

Adult Range: From Humboldt Bay, California to Bahía Magdalena, Baja California.

Life History: Adult crabs sexually dimorphic; Size: males to 176 mm (6.9 in.), females reach 144 mm (5.6 in.); Size at maturity: 90 to 100 mm (3.5 to 3.9 in.) for laboratory-reared animals; Fecundity: 680,000 to 3.85 million eggs; Life span: no estimate available.

Adult Habitat: Soft substrates such as sand, sandy-silt, and mud; occur in the vicinity of rock reefs or artificial structures; the lower intertidal zone to depths exceeding 130 m (427 ft).

Adult Fishery: Moderate commercial fishery, small recreational fishery.

The yellow crab *Cancer anthonyi* occurs along the Pacific coast of North America from Humboldt Bay, California to Bahía Magdalena, Baja California (Jensen 1995). Their distribution is almost exclusively associated with sand habitat within this range (Winn 1985, Carroll and Winn 1989). The species is most abundant on the expanses of open, sandy substrata, although it is also commonly encountered near the rock-sand interface of natural and artificial reefs (Morris et al. 1980, Carroll and Winn 1989). Yellow crab are also common underneath and in the vicinity of offshore oil and gas platforms south of Point Conception (Page et al. 1999). In the northern parts of their range, where rocky benthic substrata predominate, their distribution appears to be confined to bays, sloughs, and estuaries (Jensen 1995). Yellow crab occur from the lower intertidal zone to depths exceeding 130 m (427 ft) but are most commonly found in depths between 18 to 55 m (59 to 180 ft) (Morris et al. 1980, Winn 1985, Carroll and Winn 1989, Jensen 1995). They are the most abundant cancer crab species harvested in southern California, often comprising 70 to 95 percent of the total crab catch in the region (Carroll and Winn 1989).

Yellow Crab Results

Yellow crab megalopae were collected at the MBPP intake station almost year-round (Figure 3-54). There may be two spawning peaks during the year analyzed; June through July and November through December. Their highest concentrations occurred during winter.

Yellow crab megalopae occurred between April and December 2000 in the monthly source water surveys (Figure 3-55). Unlike brown and hairy rock crabs, their abundance appeared, in most cases, to be about equally distributed between Estero and Morro bays. In May and September they were collected only in Estero Bay.

Concentration (#/m^3) of megalopal yellow crab was compared among stations for samples collected at ebb and flood tides (Figure 3-56). Yellow crab megalopal abundance patterns were unique among the crabs examined. In particular, yellow crab megalopae occurred in relatively high abundance inside of Morro Bay on flood tides, although their greatest concentrations were recorded from the sampling station in Estero Bay, generally on ebb tides.

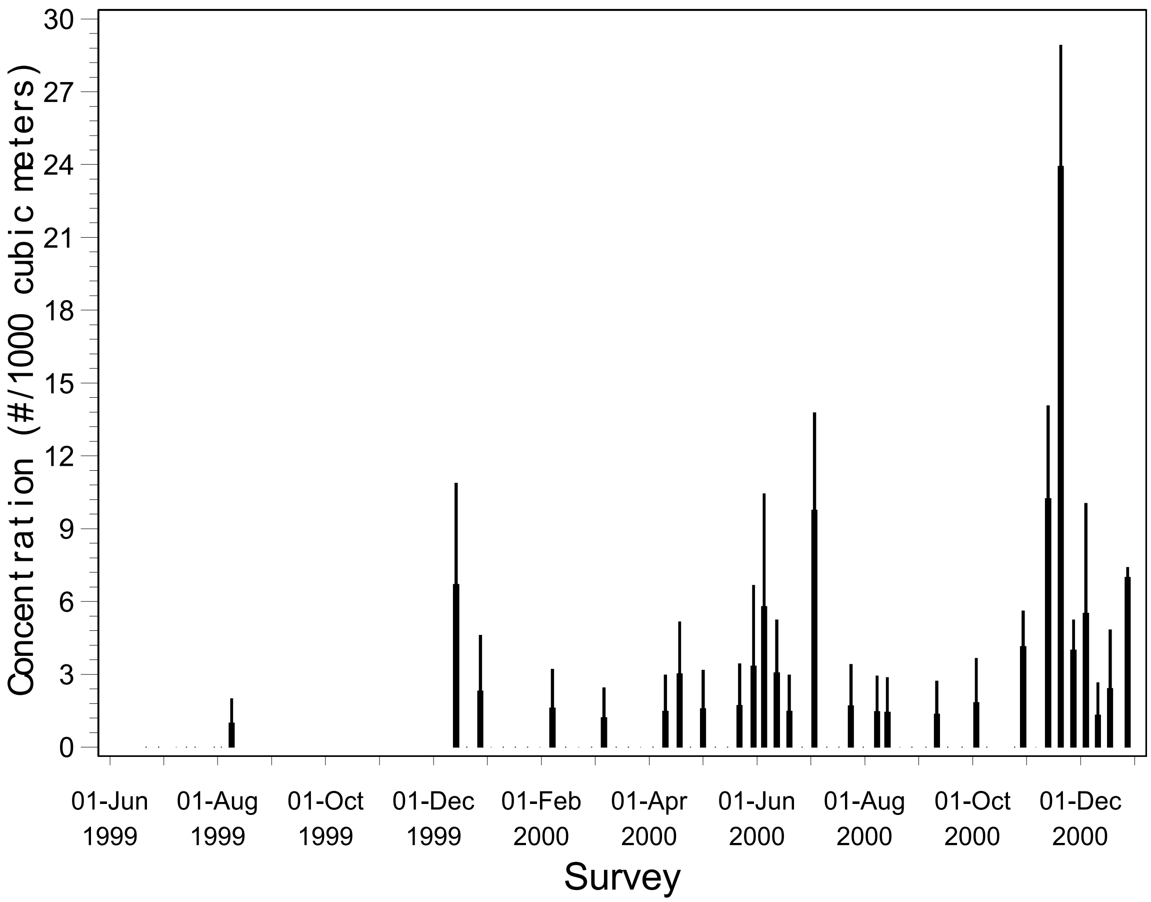


Figure 3-54. Weekly survey mean concentrations of megalopal yellow crab collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

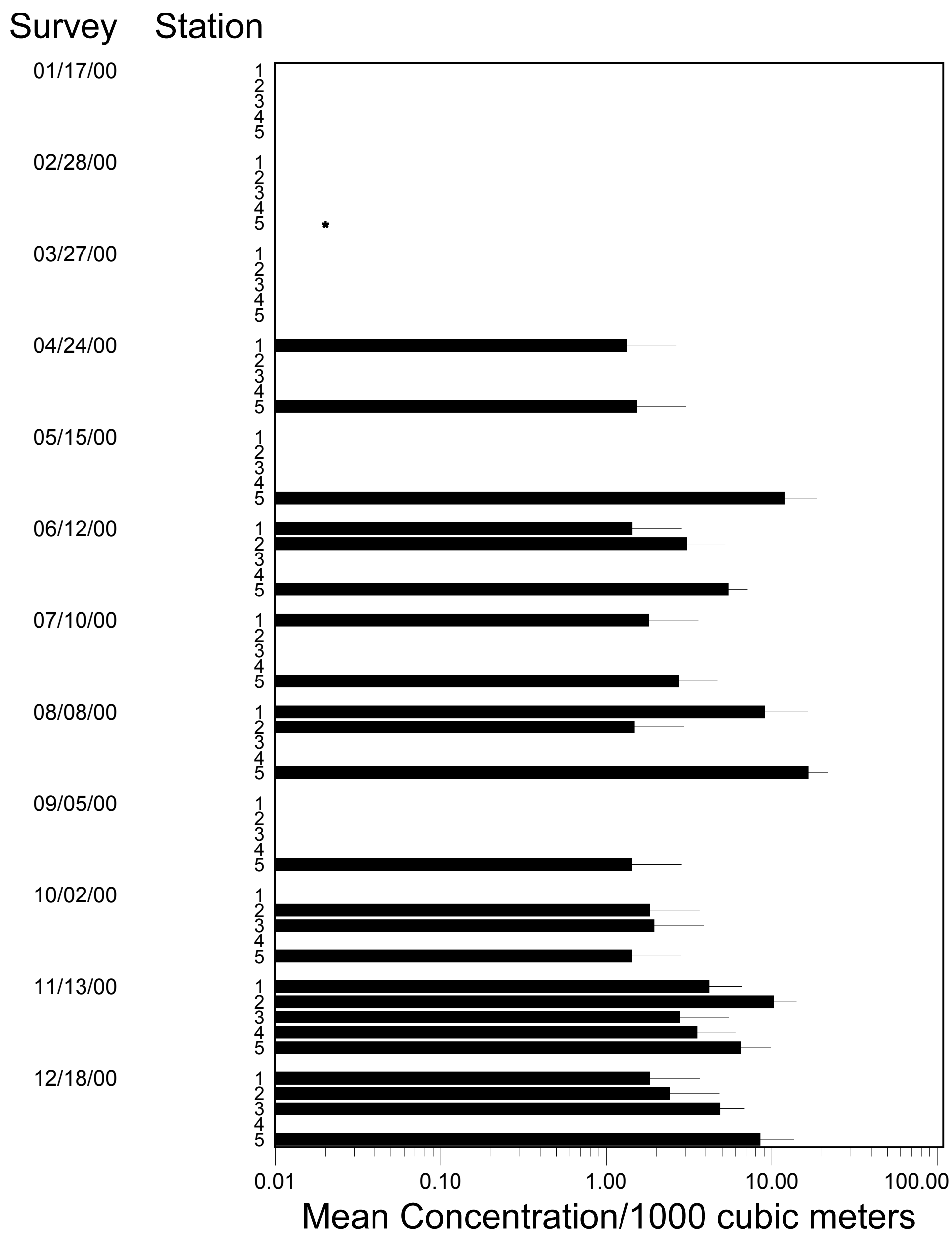


Figure 3-55. Mean megalopal yellow crab concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

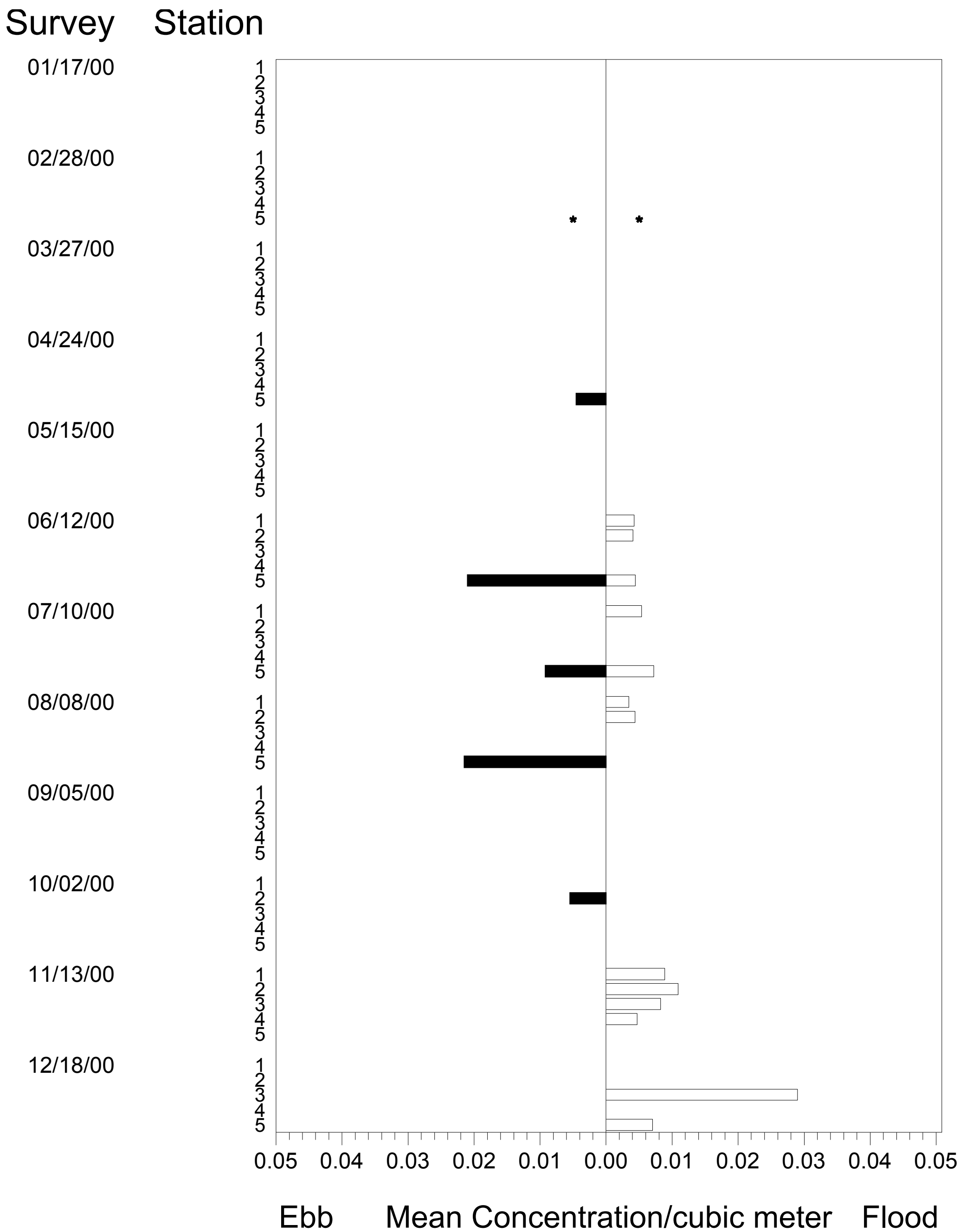
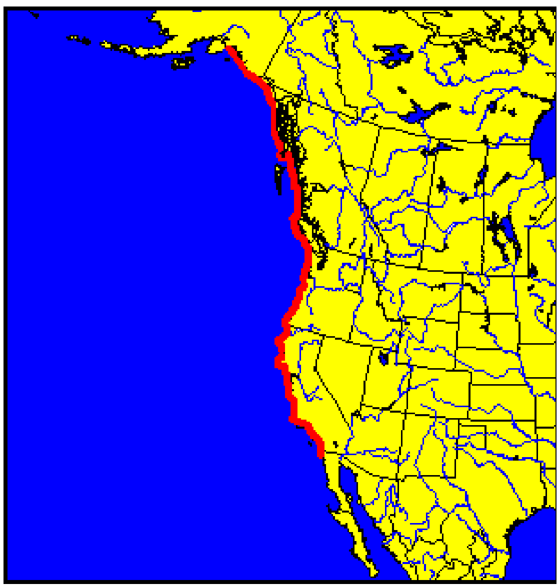


Figure 3-56. Mean concentration of megalopal yellow crab from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.11.4 Slender crab *Cancer gracilis*



Distribution map for adult slender crab

Adult Range: From Prince William Sound, Alaska to Bahía Playa Maria, Mexico.

Life History: Size: males to 115 mm (4.5 in.), females to 87 mm (3.4 in.); Age at maturity: approximately 10 months of age (post-settlement), about 60 mm (2.4 in.); Fecundity: spawns once a season, 143,000 to one million eggs; Life span: approximately three years.

Adult Habitat: Sandy and muddy bottoms of intertidal areas to 174 m (571 ft), kelp and eelgrass beds, seasonally in bays and sloughs.

Adult Fishery: Occasionally taken in the sport fishery.

Slender crab are found from Prince William Sound, Alaska to Bahía Playa Maria, Mexico (Jensen 1995). They inhabit the sandy and muddy bottoms of intertidal areas and are found subtidally, often in kelp beds to depths of 174 m (571 ft) and in eelgrass beds (Garth and Abbott 1980). Slender crab do not osmoregulate and therefore cannot tolerate low salinity brackish environments. They are usually not found in estuaries, but may be found seasonally in bays and sloughs (Jensen 1995).

Slender crab are often misidentified as Dungeness crab, but are much smaller in size. Their carapace width measures up to 115 mm (4.5 in.) in males and up to 87 mm (3.4 in.) in females (Jensen 1995). Their white-tipped claws lack the serrations belonging to Dungeness crab and their walking legs are slender.

In Monterey Bay, spawning of slender crab has been reported to occur in the spring and fall (Graham 1989). Females produce one batch per year, although in a laboratory setting, some females produced a small second batch. The number of eggs extruded per female can range from 143,000 to one million. Females are able to spawn for at least two, and possibly three seasons, over their lifetime (Orensanz and Gallucci 1988).

After hatching, slender crab exist in a pre-zoeal stage for a very short time before molting to first stage zoeae. Slender crab progress through five zoeal stages to a megalopal stage in an average of 48.9 days at 17 ºC (63 ºF); each stage lasting approximately one week (Ally 1975). All larval stages are planktonic and the crab larvae may become widely distributed. It is estimated that slender crab mature at a size of about 60 mm (2.4 in.) CW and at approximately 10 months of age (post-settlement) (Orensanz and Gallucci 1988). Slender crab molt approximately 11 to 12 times, and live for about four years.

Slender Crab Results

Slender crab megalopae were collected at the MBPP intake station during all months (Figure 3-57). Their highest concentration at the intake station occurred during the late spring and summer months and their lowest concentrations were observed from November through January.

Slender crab megalopae were collected in monthly paired surveys during nine of the twelve months (Figure 3-58). They were collected at all sampling stations (although not every month) except Station 3 and were typically found in the highest concentrations at the Estero Bay station (Station 5) and harbor mouth station (Station 1). During eight of the nine months that slender crab megalopae were present in samples, the highest mean concentrations were collected at the Estero Bay station (Station 5). Slender crab megalopae were collected at the back bay Station (Station 4) only during the late fall and winter months and were collected at the intake station (Station 2) only during the March, June, and December 2000 monthly paired surveys.

Concentration (#/m^3) of megalopal slender crab was compared among stations for samples collected at ebb and flood tide (Figure 3-59). The highest concentrations of slender crab megalopae were typically recorded at the Estero Bay station (Station 5) where tidal currents would be expected to have little effect on megalopal concentrations. Slender crab megalopae mainly collected during flood tides at all stations except Station 3 in December 2000.

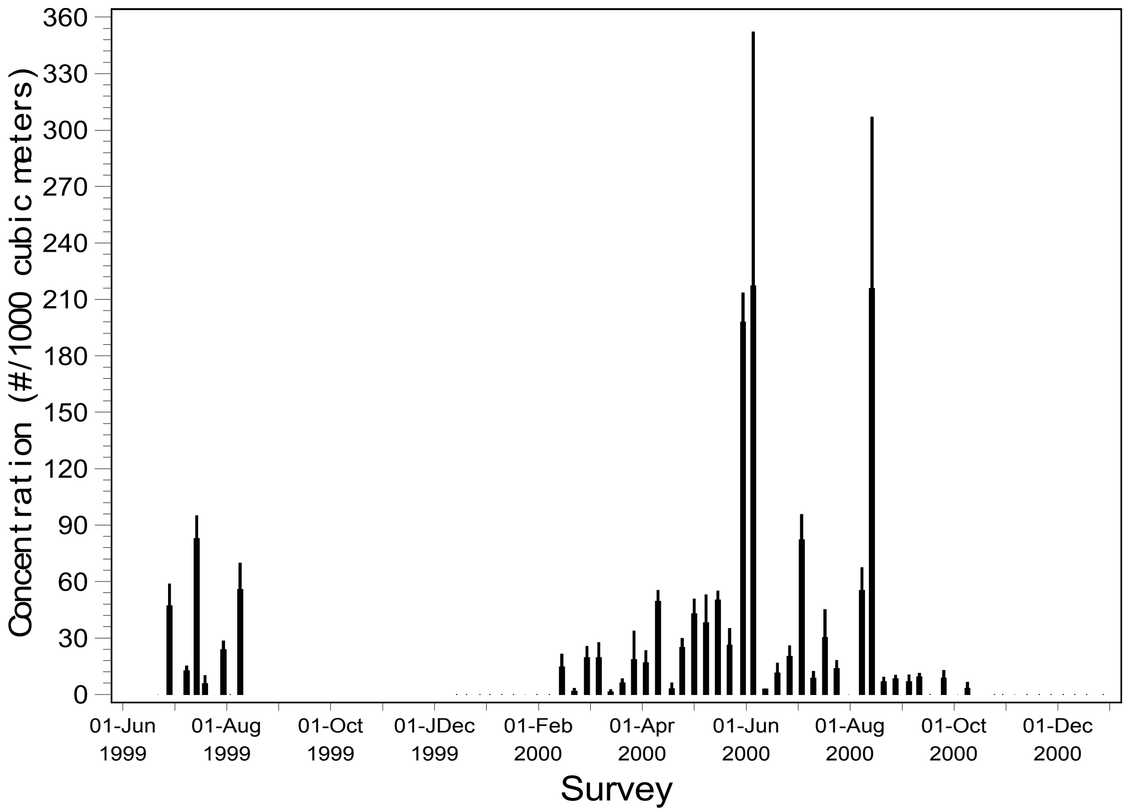


Figure 3-57. Weekly survey mean concentrations of megalopal slender crab collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

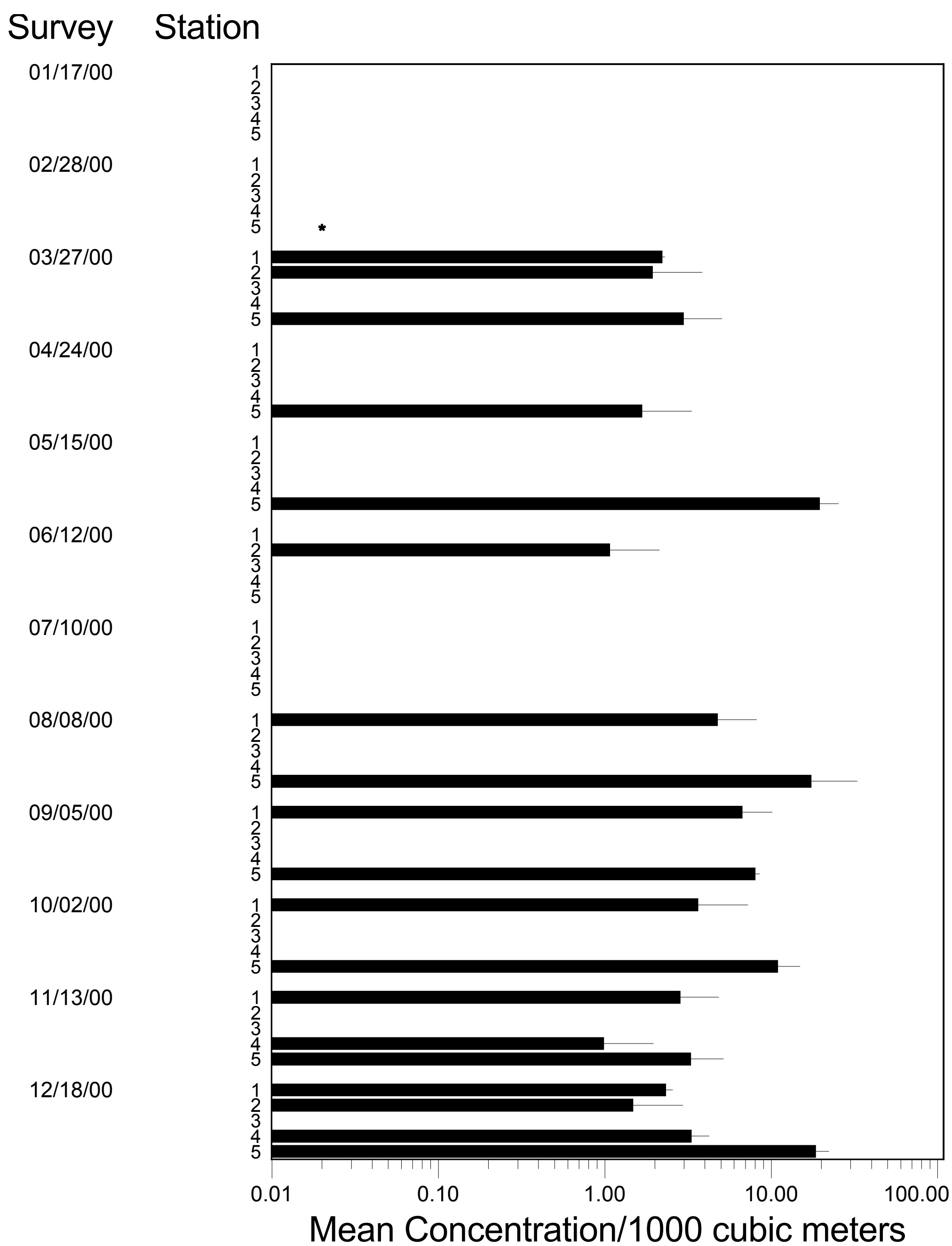


Figure 3-58. Mean megalopal slender crab concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

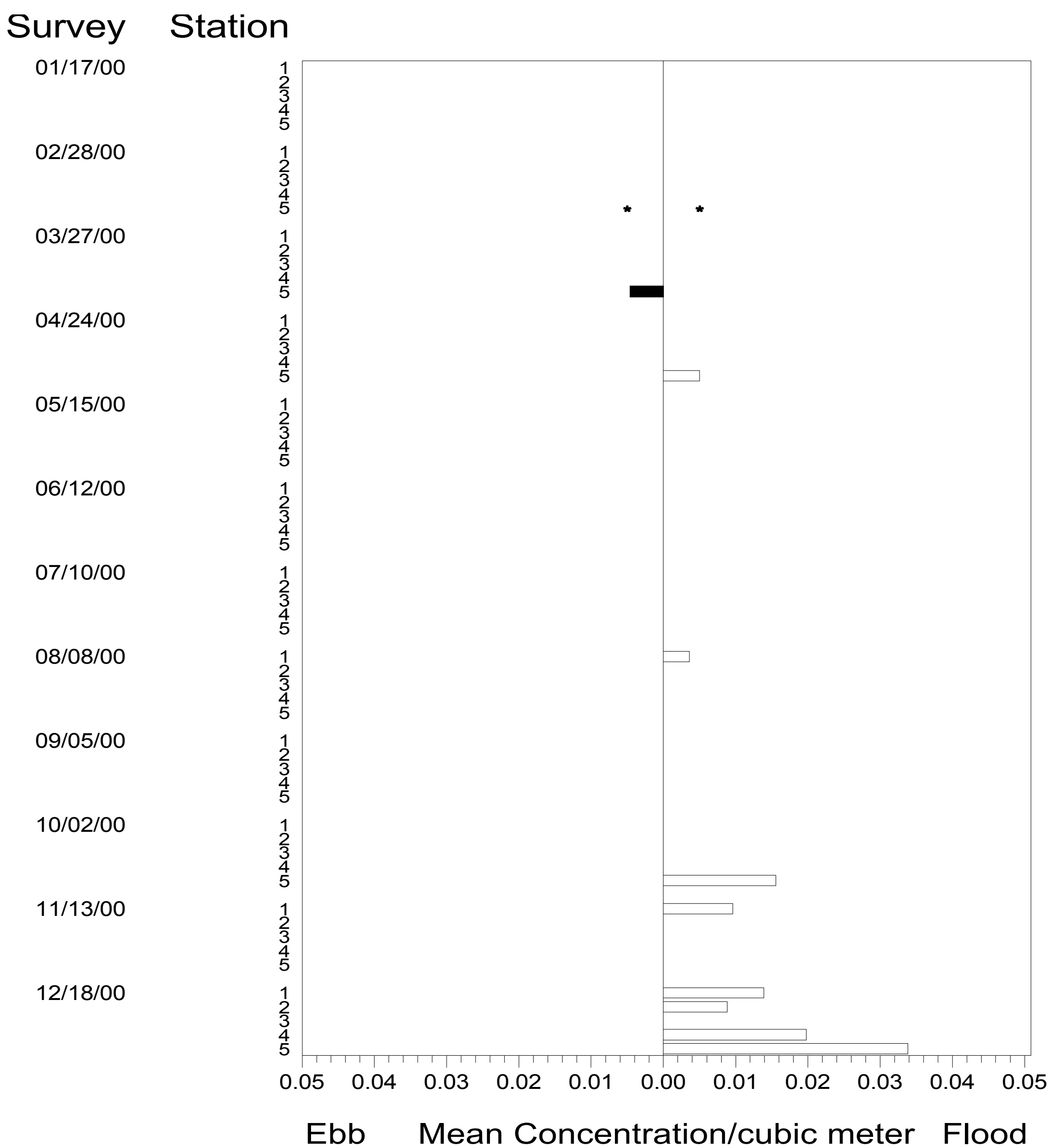


Figure 3-59. Mean concentration of megalopal slender crab from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

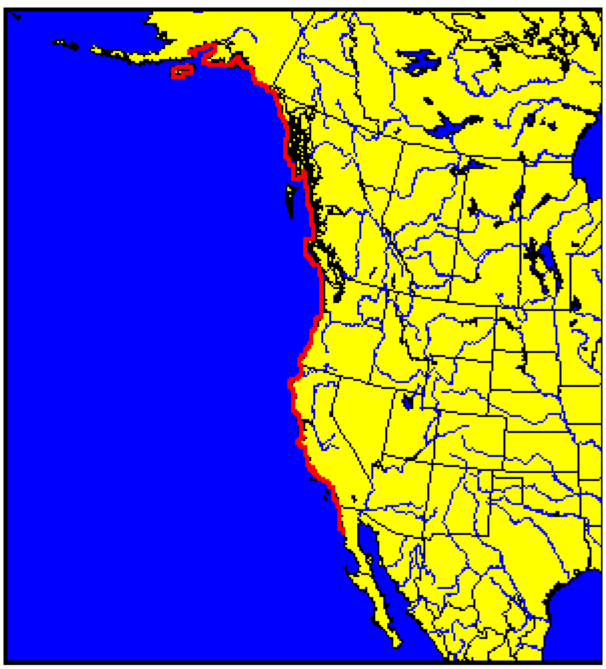
Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3. 3.11.5 Red Rock Crab *Cancer productus*

Source: CDFG

Cancer productus



Distribution map for red rock crab

***Adult Range*:** From Kodiak Island, Alaska to Isla San Martin, Baja California.

***Life History*:** Adult crabs sexually dimorphic; Size: males to 200 mm (7.8 in.), females to 158 mm (6.2 in.); Fecundity: up to 1.5 million eggs.

***Adult Habitat*:** Hard substrate such as rocky reefs, well-protected boulder-strewn beaches, and gravel beds. Occur from the lower intertidal zone to depths of at least 91 m (299 ft).

***Adult Fishery*:** Recreational; small commercial fishery.

The red rock crab *Cancer productus* occurs along the Pacific coast of North America from Kodiak Island, Alaska to Isla San Martin, Baja California (Jensen 1995). The southern extent of the species is in southern California, based on low densities of red rock crabs collected during trapping studies in San Diego County (Carroll and Winn 1989). The abundance of red rock crab, relative to the other rock crab species, increases with latitude within the state. Red rock crab inhabit a variety of substrata including intertidal and subtidal rocky areas, gravel, coarse sand, and mud (Carroll and Winn 1989). They are commonly found in close association with hard substratum such as rocky reefs, well-protected boulder-strewn beaches, and gravel beds (Morris et al. 1980, Carroll and Winn 1989, Jensen 1995). Red rock crab occur from the lower intertidal zone to depths of at least 91 m (299 ft) (Winn 1985, Carroll and Winn 1989). Juvenile red rock crab inhabiting the intertidal zone survive exposure to the air during low tide by sheltering themselves under rocks and algae (Ricketts et al. 1985). Red rock crab are often collected in bays, estuaries, and sloughs, however, their distribution in these areas is affected by salinity gradients because the species lacks the ability to osmoregulate (Garth and Abbott 1980).

Like the brown rock crab and yellow crab, adult red rock crab are sexually dimorphic, with males attaining a larger size and growing larger, more robust chelae (claws). Male crabs grow to a maximum size (CW) of 200 mm (7.8 in.), while females reach 158 mm (6.2 in.) (Jensen 1995). No estimates of the life span of red rock crab were cited in the literature reviewed.

The size of a female's egg mass is variable and can contain from over one million eggs (Carroll and Winn 1989). No information about the development and subsequent hatching of red rock crab eggs was available in reviewed literature. Trask (1970) found that red rock crab larvae developed to the megalopal stage in 97 days at a temperature of 11° C (52° F), however, none of his laboratory-reared larvae survived to the first crab instar.

Red Rock Crab Results

Red rock crab were collected in very few of the entrainment surveys (Figure 3-60) and comprised less than 1 percent (0.6) of the total number of entrained *Cancer* spp. megalopae (Figure 3-3). Although they are reported as inhabitants of bays and estuaries (Morris et al. 1980) they were most abundant at the Estero Bay station (Station 5) and were never collected from the stations in the interior portions of the bay (stations 3 and 4) during the source water surveys (Figure 3-61). Although their abundances are probably too low to draw any conclusions, they were more abundant on flood tides, which is consistent with their higher Estero Bay abundances (Figure 3-62).

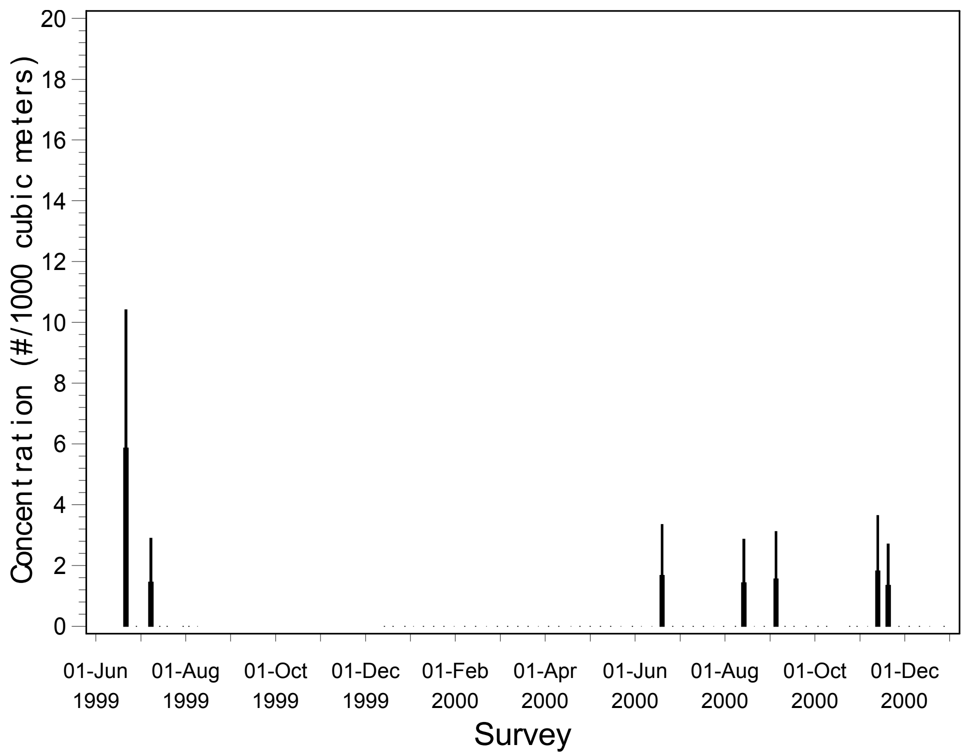


Figure 3-60. Weekly survey mean concentrations of megalopal red rock crab collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

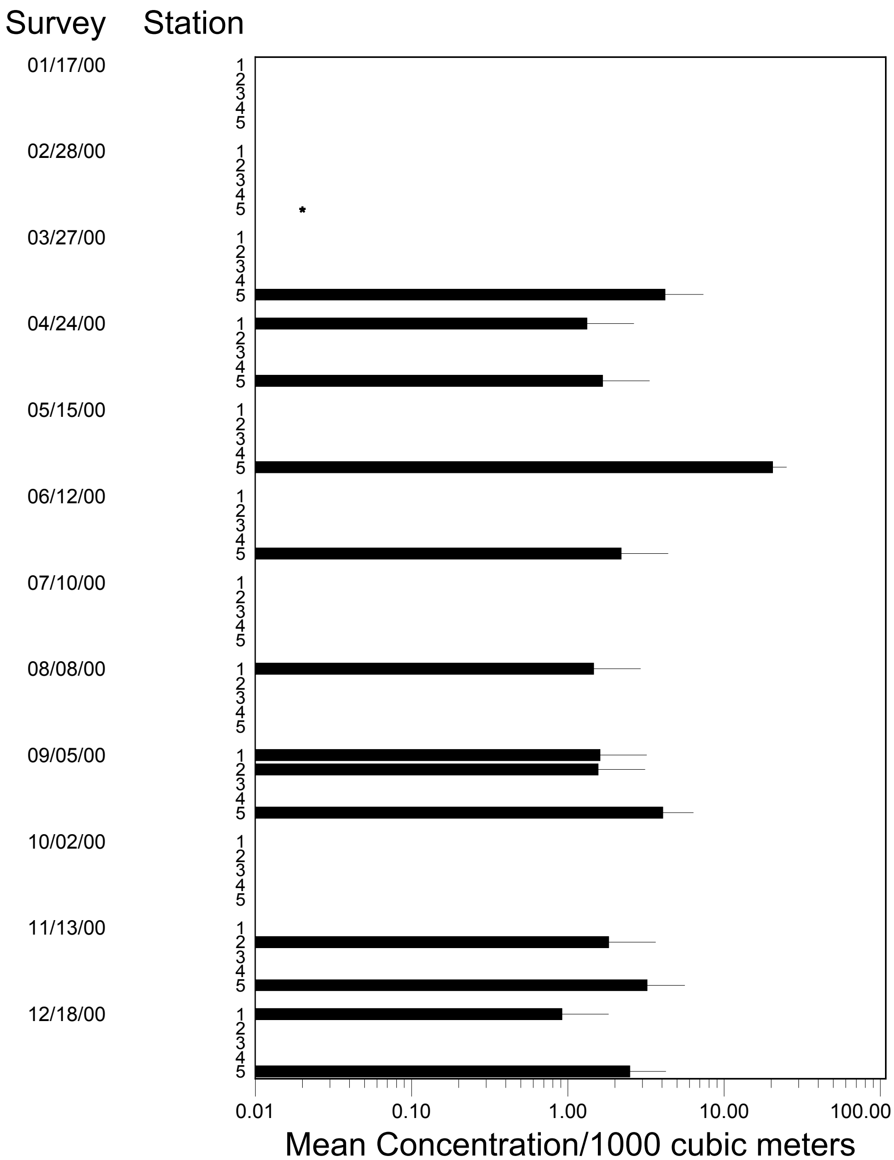


Figure 3-61. Mean megalopal red rock crab concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

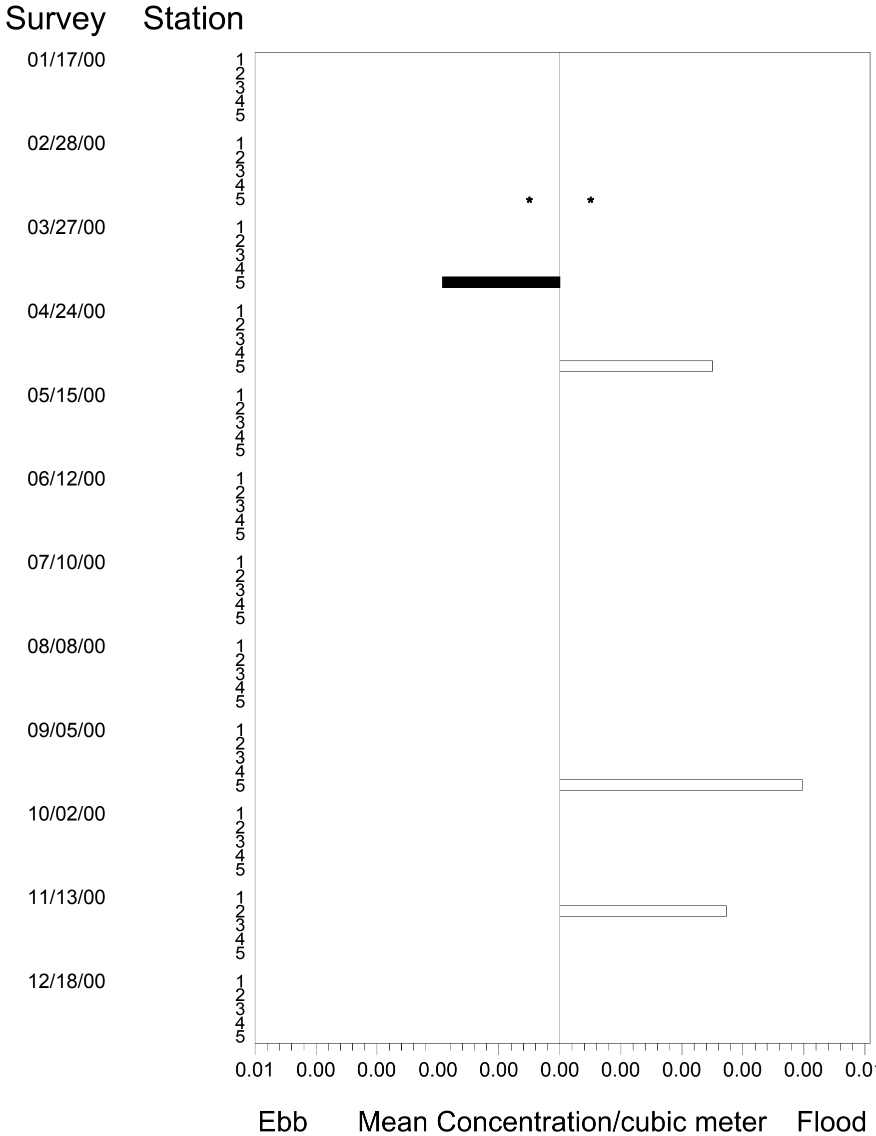
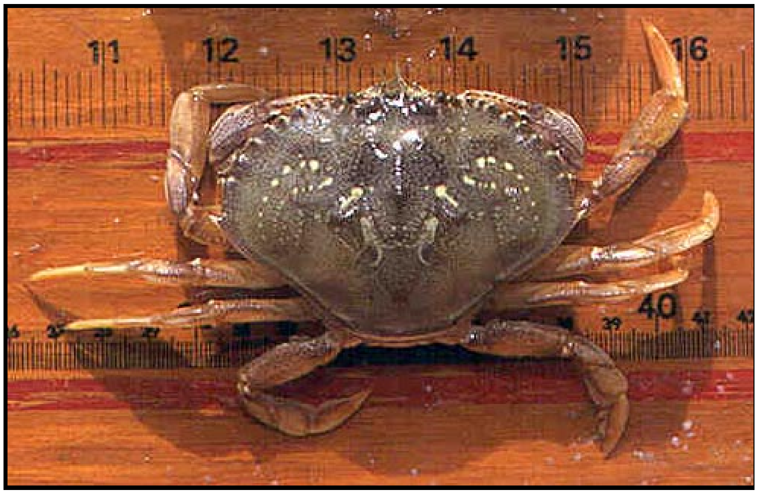


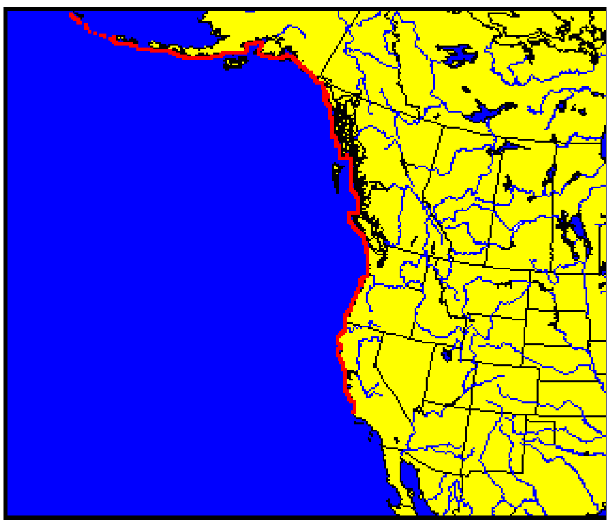
Figure 3-62. Mean concentration of megalopal red rock crab from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.3.11.6 Dungeness Crab *Cancer magister*





Distribution map for adult Dungeness crab

Adult Range: From Pribilof Islands, Alaska to Point Conception, California.

Life History: Size: males to 230 mm (9 in.), females to 165 mm (6.5 in.); Age at maturity: two years; Fecundity: up to 1.3 million eggs, spawns once a year; Life span: to six years.

Adult Habitat: Common sub-tidally to 90 m (295 ft); as deep as 230 m (750 ft).

Adult Fishery: Recreational, large commercial market.

Dungeness crab occur in Pacific coastal waters from Alaska to near Santa Barbara, California (Jensen 1995). They are one of the largest and most commercially important crabs along the Pacific coast. The northern coast of California, including Bodega Bay and the San Francisco area, supports a sizable Dungeness crab population, while smaller populations occur in the Monterey Bay and Morro Bay/Avila Beach area (Dahlstrom and Wild 1983).

Dungeness crab are confined mainly to cold and temperate waters with annual mean temperatures ranging from 4° to 24° C (40° to 75° F) (Garth and Abbott 1980). Adult Dungeness crab commonly occur subtidally to 90 m (295 ft), residing on sandy bottoms and in eelgrass beds, but they may be found as deep as 230 m (750 ft) (Jensen 1995). Estuaries are important to their life cycle, and Dungeness crab are thought to inhabit all estuaries from Morro Bay, California north to Puget Sound, Washington (PSMFC 1999b).

Dungeness crab early life stages are meroplanktonic and, like most crustaceans, consist of a series of molts during these early life stages (Poole 1966, Reed 1969). Dungeness are thought to undergo a brief (10 to 15 minute) pre-zoeal period following hatching (Reilly 1983). The remainder of the planktonic life phase until juvenile settlement at the first instar stage takes approximately four to five months to complete (Lough 1976, Reilly 1983). Dungeness crab may have a larval duration of up to 115 days. This estimate is based on *in situ* development for Dungeness crab showing 80 to 95 days through five zoeal stages and 25 to 30 days for the megalopal stage (Reilly 1983, in Carroll and Winn 1989). The value of 115 days is the average of 105 to 125 days.

Juvenile settlement occurs in estuaries and coastal waters from May to June, occasionally followed by a second smaller pulse later that year (Stevens and Armstrong 1984, Gunderson et al. 1990). Ovigerous (egg-bearing) female Dungeness crab have been found as early as late September in the Gulf of the Farallones, but most spawn in October and November (Reilly 1983). Larvae are released in January to mid-March off of Washington state (McConnaughey et al. 1992) and from December to mid-April in the Gulf of the Farallones (Reilly 1983).

Dungeness Crab Results

Dungeness crab megalopae were collected at the MBPP intake station during the late spring and early summer (Figure 3-63). They were not collected in high concentrations at the MBPP intake station during the course of the study and only occurred in a single source water survey in May 2000 (Figure 3-64). They occurred both inside of Morro Bay and in Estero Bay in approximately equal concentrations. Dungeness crab early life stages are known to move into estuaries and bays as they develop (Carrasco et al. 1985) similar to the abundance distribution observed here.

Dungeness crab megalopae were collected in nearly the same concentrations on ebb and flood tides at Station 2 (Figure 3-65). Samples from stations 3 and 5 in May 2000 were collected on slack tide and therefore data were not graphed.

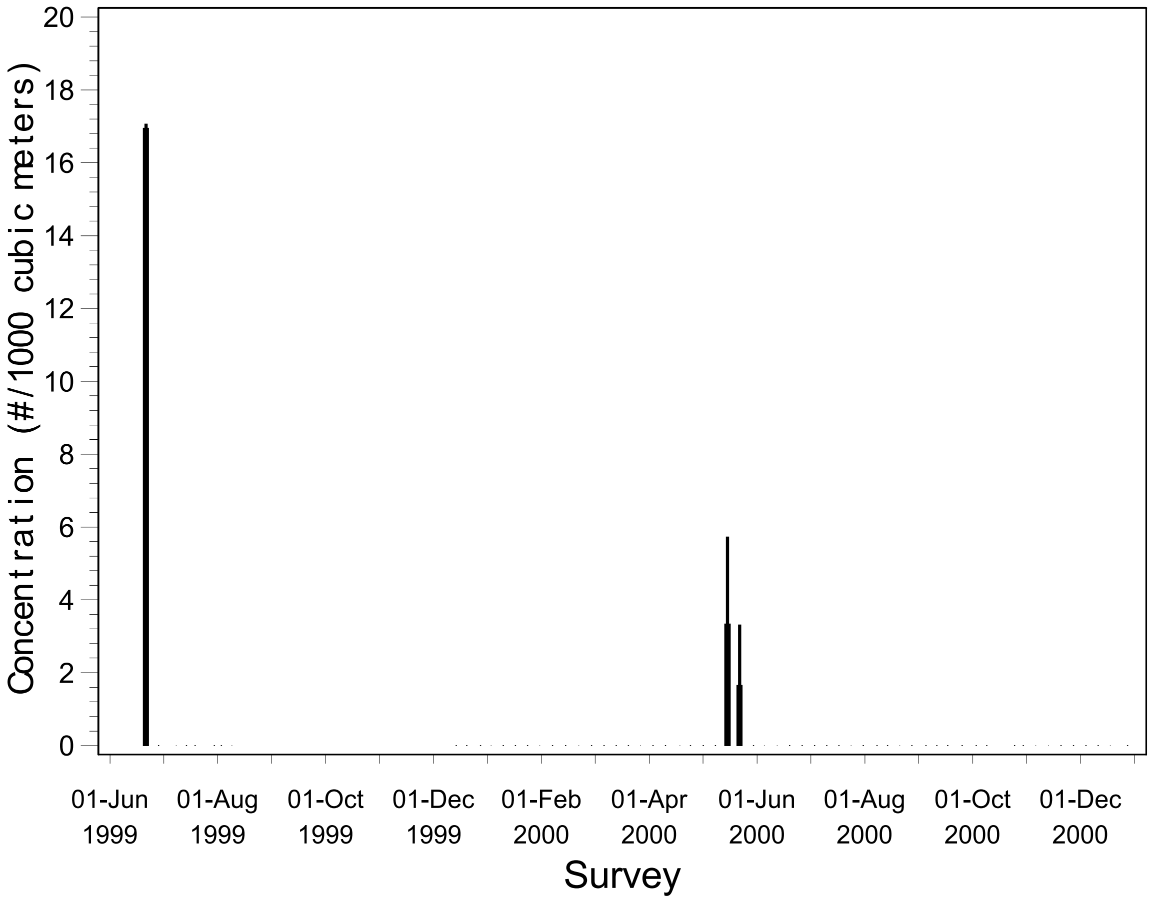


Figure 3-63. Weekly survey mean concentrations of megalopal Dungeness crab collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

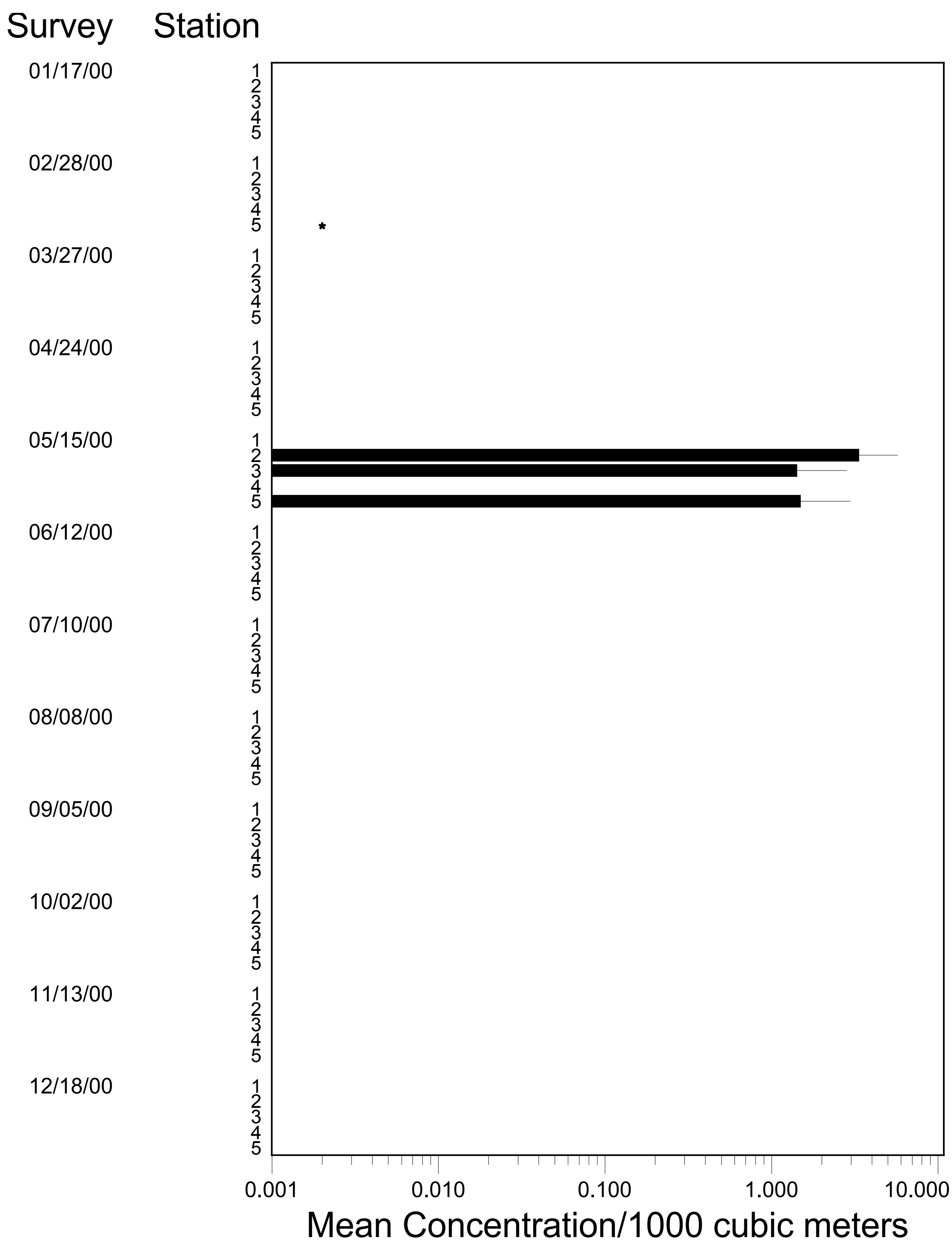


Figure 3-64. Mean megalopal Dungeness crab concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

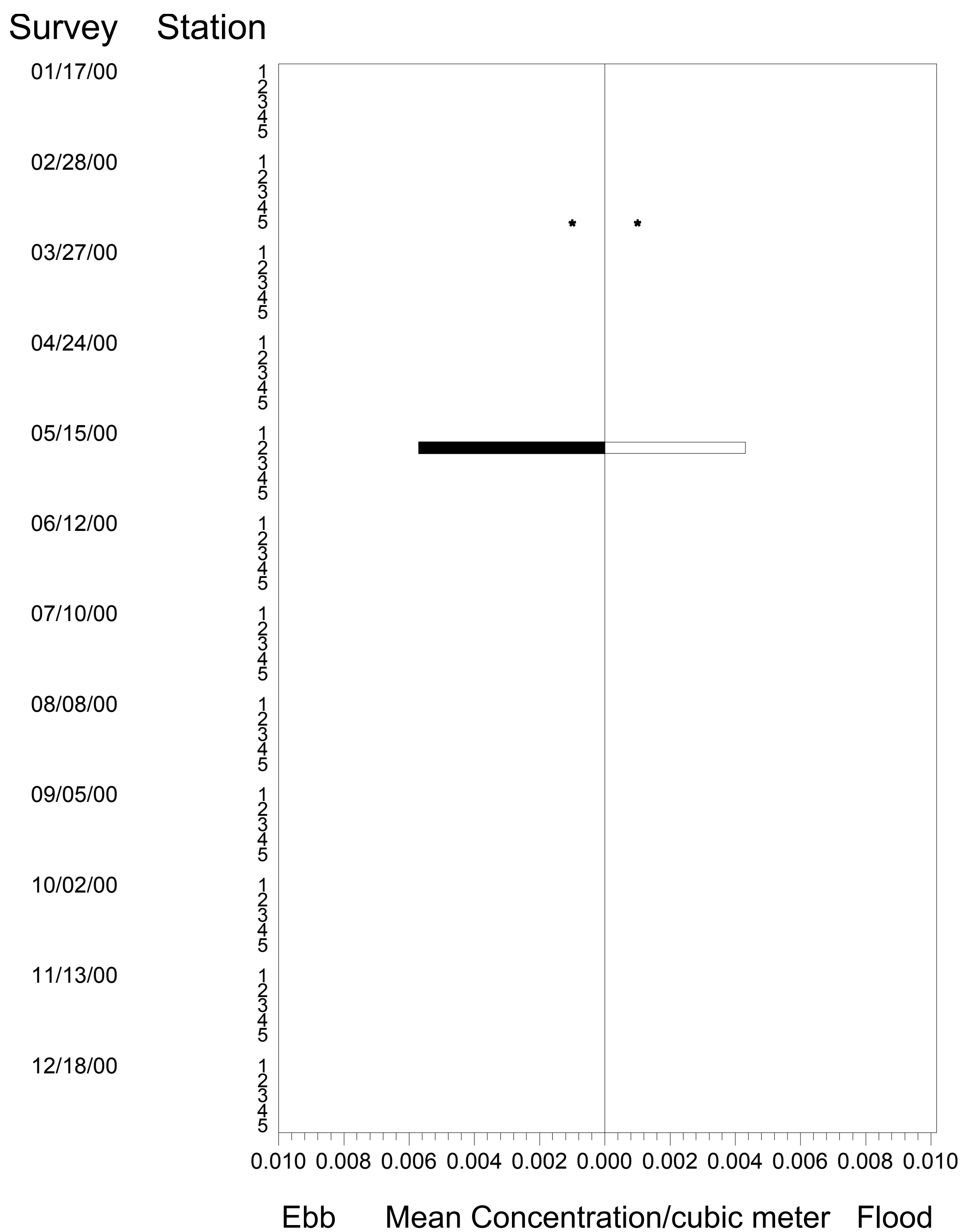


Figure 3-65. Mean concentration of megalopal Dungeness crab from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

3.4 Discussion

The purpose of this study was to describe the composition and abundance of larval fishes and megalopal crabs that were at risk of entrainment in the new combined-cycle MBPP cooling water intake system (CWIS). The new combined-cycle MBPP is designed to reduce the existing power plant entrainment by 38 percent. Even with such a large reduction in entrainment, the remaining losses of fishes and crabs could potentially affect local populations. Previous studies of MBPP entrainment had not been required by resource or regulatory agencies, therefore these entrainment studies were designed and conducted to assess the best technology available for the new plant's CWIS design.

Entrainment studies for the new MBPP CWIS were designed to estimate the number of larval fishes and megalopal cancer crabs entrained in the CWIS over a 12-month period. Source water studies were conducted to characterize the composition and abundance of the larval fishes and cancer crab megalopae that could be entrained by the new MBPP combined-cycle CWIS. The studies demonstrated that larval gobies (i.e., unidentified gobies, shadow goby, bay goby) were the most abundant fishes (nearly 81 percent) collected at the MBPP intake station, and that brown rock crab constituted the majority (71 percent) of the megalopal cancer crabs at the intake station from January through December 2000. Larval gobies were also the most abundant taxa in source water plankton samples, and brown rock crab dominated the number of cancer crab megalopae collected in Morro and Estero bays. The entrainment and source water studies together were designed to gather information on larval and megalopal entrainment losses and potential impacts of these losses on their adult populations.

Five of the seven most abundantly entrained larval fish taxa are commonly associated with nearshore, shallow habitats, such as bays and estuaries (unidentified gobies, shadow goby, Pacific staghorn sculpin, combtooth blennies, and jacksmelt). The northern lampfish is a pelagic, midwater oceanic fish whose adult population is located in deep offshore waters from 59 to 1,980 m (193 to 6,494 ft) (Hart 1973). Thus, northern lampfish larvae transported to these coastal waters are ecologically lost to their source population. Adults of the KGB complex rockfishes collected at the MBPP intake station are more commonly found in giant kelp *Macrocystis pyrifera* forests and along rocky coastlines. The location of Morro Bay situated amidst a wide expanse of sandy beach with a few nearby kelp forests explains their low concentrations in the bay.

Three species of cancrid crab dominated the numbers of megalopae collected in Morro and Estero bays. Brown rock crab megalopae were the most numerous in both entrainment and source water plankton surveys. Their peak abundance during the spring is consistent with spawning periodicity inferred from other central California plankton surveys (Tenera 2000a, b).

While the brown rock crab is reported to spawn only once a year, the fact that they are known to occasionally produce more than one batch per year (Carroll 1982) may account for the earlier peaks in abundance. Megalopae of brown and hairy rock crab were most abundant in Estero Bay, similar to published findings of Carrasco et al. (1985) and other sources (Tenera unpubl. data) indicating offshore gradients in crab early life history stages.

The most abundant group of larval fishes collected at the MBPP intake station and present in the Morro Bay and Estero Bay source waters were larval gobiids in the family Gobiidae. These small, often cryptic fishes do not support any sport or commercial fisheries and consequently there has been little interest in studying their life history. Love (1996) suggests a role in the trophic webs of nearshore ecosystems when he notes that some gobies are common prey of cormorants and sea lions. However, since gobies often burrow into soft sediments found throughout the Morro Bay estuary, their expected abundance may play a yet undefined trophic role in the bay's ecosystem. The burrowing habits of these tiny fishes also modify the mudflat habitat, which may also play some ecological role in the bay's marine sediment community.

The abundance of larval fishes and megalopal *Cancer* spp. crabs at sampling locations in Morro Bay is strongly correlated to tide cycles. Tidal flow carries these planktonic organisms in or out of the estuary depending upon their point of origin. Some larval fish species (e.g., gobies, jacksmelt) are spawned by adult populations residing in Morro Bay and are transported into coastal waters. However, few of the larval fishes spawned in surrounding coastal waters (e.g., rockfishes, lampfish, croakers) appear in the estuary in any great abundance. Source water survey results suggested that both brown and hairy rock crab megalopae spawned in coastal waters move into Morro Bay on tidal currents. Patterns of species composition and abundance found in our study results indicated that there was a net export of larvae originating in Morro Bay to the surrounding coastal waters and little import of coastal larvae into the estuary. This finding is consistent with the fact that Morro Bay is a positive estuary for most of the year with a narrow well-defined ocean entrance. Planktonic coastal larvae could be advected into the estuary during the rainy season when two-layer flows produce counterflowing bottom currents. Hydrodynamic studies of the bay (Tetra Tech 1999) have shown that the bay's shallow geometry would limit these flows and coastal plankton to the lower end of the estuary. During late summer months of the dry season, Morro Bay becomes a negative estuary creating a greater potential for net import and transport of coastal plankton into the bay.

The general transport of fish larvae out of the Morro Bay estuary is also supported by the results of similarity analysis used to compare species composition and abundance among sampling stations. The results of comparing the survey's five sampling locations showed that Station 1 at the harbor mouth is more similar to stations within Morro Bay than to the station in Estero Bay. This result indicated that on average, fish larvae at the entrance to Morro Bay originated from the bay and not the coastal habitat. However, this pattern of net transport certainly varied with the direction, stage, and strength of tidal flow.

3.5 Larval Clam Study

Numerous power plants along the east coast that utilize once-through cooling were queried as to how they address potential plant impacts on clam larvae. The effects of entrainment on larval clams were not an issue at any of the contacted plants except for Seabrook Station Nuclear Power Plant located in Seabrook, New Hampshire.

Bivalve larval monitoring studies were conducted at Seabrook Station to determine the impacts on soft-shell clam *Mya arenaria* larvae. *Mya arenaria* is a soft-shell clam of commercial and recreational importance along the east coast. There was concern that larval entrainment had the potential to affect the benthic life stages of the soft-shell clam, thereby affecting the species population in Hampton Harbor. It was determined, using nine years of monitoring data, that there was no evidence that the operation of Seabrook Station affected the abundance of any of the life stages of the soft-shell clam (Normadeau 1999).

Plankton sampling targeting the collection of larval clams began in Morro Bay in March 2001 and will continue through September 2001. Detailed collection and processing methodologies are discussed in Appendix D. The time period selected for sample collection brackets the major spawning season of most benthic invertebrates and employs an adaptive sampling strategy designed to capture pulses of bivalve recruitment. The targeted species are major prey items for sea otters: the Washington clam, *Saxidomus nuttali*, gaper clam, *Tresus nutalli* and Pismo clam, *Tivela stultorum*. Two other species, *Macoma secta* and *Mytilus galloprovincialis* (also sea otter prey), are likely to be particularly abundant in samples and are also targeted. A strategy for identifying and enumerating larvae that are not among these targeted species, but may be abundant in the samples, was also proposed. Existing sequence detection methods (exonuclease cleavage of reporter dyes from specific probes, also known as Taqman® assay) will be used.

Sampling sites and schedule are the same as for entrainment and source water studies described in Section 3.2, except a weekly sample will be taken to detect the onset of recruitment pulses. Larval density data, in conjunction with plankton sample, entrainment and source water volume estimates, will be used to estimate proportional losses due to entrainment for these clam species during the sampling period.

3.6 Literature Cited

Alderdice, D. F., and A. S. Hourston. 1985. Factors influencing development and survival of Pacific herring (*Clupea harengus pallasii*) eggs and larvae to beginning of exogenous feeding. Can. J. Fish. Aquat. Sci. 42 (Suppl.1): 56-68.

Allen, L. G., M. H. Horn., F. A. Edwards II, and C. A. Usui. 1983. Structure and seasonal dynamics of the fish assemblage in the Cabrillo Beach area of Los Angeles Harbor, California. Bull. So. Calif. Acad. Sci. 82:47-70.

Ally, J. R. R. 1975. A description of the laboratory-reared larvae of *Cancer gracilis* Dana, 1852 (Decapoda, Brachyura). Crustaceana 23:231-246.

Bane, G. W., and A. W. Bane. 1971. Bay fishes of northern California. Mariscos Publications, Hampton Bays, N.Y. 143 pp.

Baruskov, V. V. 1981. A brief review of the subfamily Sebastinae. Journal of Ichthyology. 21:1-26.

Behrens, D. W., and D. C. Somerville. 1982. Impingement studies at the Morro Bay Power Plant. Report 026.22-80.1. Pacific Gas and Electric Company, Dep. Eng. Res., San Ramon, CA.

Bloeser, J. A. 1999. Diminishing returns: The status of west coast rockfish. Pacific Marine Conservation Council. P.O. Box 59, Astoria, OR. 97103. 94 pp.

Brothers, E. B. 1975. The comparative ecology and behavior of three sympatric California gobies. Ph.D. Thesis, University of California, San Diego.

Burge, R. T., and S. A. Schultz. 1973. The marine environment in the vicinity of Diablo Cove, with special reference to abalones and bony fishes. Marine Resources Technical Report No. 19.

California Department of Fish and Game (CDFG). Morro Bay otter trawl survey data. Unpublished. March 1992 – July 1999.

Carroll, J. C. 1982. Seasonal abundance, size composition, and growth of rock crab, *Cancer antennarius* Stimpson, off central California. J. Crust. Biol. 2:549-561.

Carroll, J. C., and R. Winn. 1989. Species Profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) brown rock crab, red rock crab, and yellow crab. U. S. Fish Wildl. Serv. Biol. Rep. 82 (11.117). U.S. Army Corps of Engineers, TR EL-82-4. 16 pp.

Carrasco, K. R., D. A. Armstrong, D. R. Gunderson, and C. Rogers. 1985. Abundance and growth of *Cancer magister* young-of-the-year in the nearshore environment, pp. 171–184. *In:* Melteff, B. E. (ed.) Proceedings of the Symposium on Dungeness Crab Biology and Management. University of Alaska, Fairbanks, Alaska. Alaska SeaGrant Report No. 85-3.

Chen, L. C. 1971. Systematics, variation, distribution, and biology of the subgenus Sebastomus (Pisces, Scorpaenidae, Sebastes). Bulletin, Scripps Institute of Oceanography 18. 115 pp.

Clark, F. N. 1929. The life history of the California jacksmelt, *Atherinopsis californiensis*. Calif. Dept. Fish and Game. Fish Bull No. 16. 22 p.

Cruz-Aguero, J. de la, F. Galvan-Magana, L. A. Abitia-Cardenas, J. Rodriguez-Romero, and F. J. Gutierrez-Sanchez. 1994. Systematic list of marine fishes from Bahía Magdalena, Baja California Sur (Mexico). Cienc. Mar. 20:17-31.

Dahlstrom, W. A., and P. W. Wild. 1983. Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish and Game, Fish. Bull. 172, p. 7.

Digby, P. G. N., and R. A. Kempton. 1987. Multivariate analysis of ecological communities. Chapman and Hall. New York. 206 p. New York.

Eldridge, M. B. 1977. Factors influencing distribution of fish eggs and larvae over eight 24-hr samplings in Richardson Bay, California. Calif. Dept. Fish and Game No. 63(2):101-116.

Eldridge, M., and C. F. Bryan. 1972. Larval fish survey of Humboldt Bay, California. NOAA Tech. Rept., NMFS, SSRF-665:1-8.

Eschmeyer, W. N., E. S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Company, Boston, MA. 336 pp.

Fierstine, H. L., K. F. Kline, and G. R. Garman. 1973. Fishes collected in Morro Bay, California between January, 1968 and December, 1970. Calif. Dept. Fish and Game. No. 59(1): 73-78.

Fitch, J. E., and R. J. Lavenberg. 1971. Marine food and game fishes of California. California Natural History Guides, Vol. 38. University of California Press.

Fitch, J. E., and R. J. Lavenberg. 1975. Tidepool and nearshore fishes of California. University of California Press, Berkeley, 156 pp.

Frey, H. W. (ed.). 1971. California's living marine resources and their utilization. Calif. Dept. Fish and Game. 148 pp.

Fried, S.M., and V.G. Wespestad. 1985. Productivity of Pacific herring (*Clupea harengus pallasi*) in the eastern Bering Sea under various patterns of exploitation. Can. J. Fish. Aquat. Sci. 42 (Suppl. 1):181-191.

Garth, J. S., and D. P. Abbott. 1980. Brachyura: the true crabs *In:* R. H. Morris, D. P. Abbott, and E. C. Haderlie (eds.) Intertidal invertebrates of California. pp 594-630. Stanford University Press, Stanford, CA.

Graham, W. M. 1989. The influence of hydrography on the larval dynamics and recruitment of five Cancer crab species in northern Monterey Bay. M.S. Thesis, University of California, Santa Cruz. 170 pp.

Grosholz, T. 1999. University of California, Davis. Personal communication.

Gunderson, D. R., D. A. Armstrong, Y. Shi, and R. A. McConnaughey. 1990. Patterns of estuarine use by juvenile English sole (*Parophrys vetulus*) and Dungeness crab (*Cancer magister*). Estuaries 13:59-71.

Gunderson, D. R., and P. H. Dygert, 1988. Reproductive effort as a predictor of natural mortality rate. J. Cons. CIEM, 44:200-209.

Haldorson, L., and M. Love. 1991. Maturity and fecundity in the rockfish, *Sebastes* spp., a review. Marine Fishery Review 53(2):25-31.

Hardwick, J. E. 1973. Biomass estimates of spawning herring. *Clupea harengus pallasii*, herring eggs, and associated vegetation in Tomales Bay. Calif. Dept. Fish and Game No. 59(1):36-61.

Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bull. 180: 366-367.

Hay, D.E. 1985. Reproductive biology of Pacific herring (*Clupea harengus pallasi*). Can. J. Fish. Aquat. Sci. 42 (Suppl. l):lll-126.

Hines, A. H. 1991. Fecundity and reproductive output in nine species of cancer crabs (Crustacea, Brachyura, Cancridae). Canadian Journal of Fisheries and Aquatic Sciences 48:267-275.

Horn, M. H. 1980. Diel and seasonal variation in abundance and diversity of shallow water fish populations in Morro Bay, California. Calif. Dept. Fish and Game. Fish. Bull. No. 78(3):759-770.

Hourston, A. S., and C. W. Haegele. 1980. Herring on Canada's Pacific coast, fecundity and growth characteristics of yellow sea herring, *Clupea harengus pallasii*. Can. Spec. Publ. Fish. Aquat. Sci. 48.

Innis, D. 2000. Tenera Environmental. Personal communication.

Jensen, G. C. 1995. Pacific coast crabs and shrimps. Sea Challengers. Monterey, California.

Jones, A. C. 1962. The biology of the euryhaline fish *Leptocottus armatus armatus* Girard (Cottidae). Univ. Calif. Publ. Zool. 67(4):321-367.

Kendall, A. W. Jr., and W. H. Lenarz. 1987. Status of early life history studies of northeast Pacific rockfishes. Proceedings of the International Rockfish Symposium. Univ. Alaska SeaGrant Rept. 87-2. Pp. 99-128.

Laidig, T. E., K. M. Sakuma, and M. M. Nishimoto. 1995. Description of pelagic larval and juvenile stripetail rockfish, *Sebastes saxicola* (family Scorpaenidae), with an examination of larval growth. Fish. Bull. 94:289-299.

Lamb, A., and P. Edgell. 1986. Coastal fishes of the Pacific Northwest. Harbour Publishing Co. Ltd. Canada. 224 pp.

Larson, R. J. 1980. Competition, habitat selection, and the bathymetric segregation of two rockfish (*Sebastes*) species. Ecological Monographs 50(2):221-239.

Leet, W. S., C. M. Dewees, and C. W. Haugen. 1992. California's living marine resources and their utilization. California SeaGrant Extension Publ. 92-12. 257 pp.

Lea, R. N., R. D. McAllister, and D. A. VenTresca. 1999. Biological aspects of nearshore rockfishes of the genus Sebastes from central California. Calif. Dept. Fish and Game Fish. Bull. 177. 107 pp.

Lough, R. G. 1976. Larval dynamics of the Dungeness crab, *Cancer magister*, off the central Oregon coast, 1970-71. Fish. Bull. U. S. 74:353-376.

Love, M. S. 1996. Probably more than you want to know about the fishes of the Pacific coast. (2nd ed.). Really Big Press. pp. 303-304. Santa Barbara, CA.

Love, M. S., and K. Johnson. 1999. Aspects of the life histories of grass rockfish, *Sebastes rastrelliger*, and brown rockfish, *S. auriculatus*, from southern California. Fish. Bull. 97(1):100-109.

Love, M. S., G. E. McGowen, W. Westphal, R. J. Lavenberg, and L. Martin. 1984. Aspects of the life history and fishery of the white croaker, *Genyonemus lineatus* (Sciaenidae), off California. Fish. Bull. 82(1):179-198.

Love, M., S. L. Thorsteinson, C. W. Mecklenburg, and T. A. Mecklenburg. 1996. A checklist of marine and estuarine fishes of the Northeast Pacific, from Alaska to Baja California. National Biological Service. Located at website http://id-www.ucsb.edu/lovelab/home.html.

Matarese, A. C., A. W. Kendall Jr., D. M. Blood, and B. M. Vintner. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. NOAA Tech. Rept. NMFS 80, 652 pp.

McConnaughey, R. A., D. A. Armstrong, B. M. Hickey, and D. R. Gunderson. 1992. Juvenile Dungeness crab (*Cancer magister*) recruitment variability and oceanic transport during the pelagic larval phase. Canadian Journal of Fisheries and Aquatic Sciences 49:2028-2044.

Middaugh, D. P., M. J. Hemmer, J. M. Shenker, and T. Takita. 1990. Laboratory culture of jacksmelt, *Atherinopsis californiensis*, and topsmelt, *Atherinops affinis*, with a description of larvae. Calif. Dept. Fish and Game No. 76:4-13.

Middaugh, D. P., B. S. Anderson, and M. J. Hemmer. 1992. Laboratory spawning of topsmelt, *Atherinops affinis*, with notes on culture and growth of larvae. Env. Tox. and Chem. 11:393-399.

Miller, D. J., and R. N Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish and Game. Fish Bull. No. 157:188. Sacramento, CA.

Miller, D. J., and J. Schmidtke. 1956. Report on the distribution and abundance of Pacific herring (*Clupea pallasi*) along the coast of Central and Southern California. Calif. Dept. Fish and Game 42(3):163-187.

Moreno, G. 1993. Description of early larvae of four northern California species of rockfishes (Scorpaenidae: Sebastes) from rearing studies. NOAA Tech. Rept. NMFS 116, 18 pp.

Morris, R. F., D. P. Abbott, and E. C. Haderlie. 1980. Intertidal invertebrates of California. Stanford University Press. Palo Alto, CA. 690 pp.

Moser, H. G. 1967. Reproduction and development of *Sebastodes paucispinis* and comparison with other rockfishes off southern California. Copeia 1967:773-797.

Moser, H. G. 1996. The early stages of fishes in the California current region. California Cooperative Oceanic Fisheries Investigations, Atlas No. 33; 1214-1226. Allen Press Inc., Lawrence, Kansas.

Moser, H. G., and E. H. Ahlstrom. 1978. Larvae and pelagic juveniles of blackgill rockfish, *Sebastes melanostomus*, taken in midwater trawls off southern California and Baja California. Journal of the Fisheries Research Board of Canada. 35(7):981-996.

Moser, H. G., and J. L. Butler. 1981. Description of reared larvae and early juveniles of the calico rockfish, *Sebastes dallii*. California Cooperative Oceanic Fishery Investigations Report Vol. XXII:88-95.

Moser, H. G., E. H. Ahlstrom, and E. M. Sandknop. 1977. Guide to the identification of scorpionfish larvae (family Scorpaenidae) in the eastern Pacific with comparative notes on species of Sebastes and Helicolenus from other oceans. NOAA Tech. Rept. NMFS Circ. 402. 71 pp.

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley. 405 pp.

Moyle, P. B., and J. J. Cech, Jr. 1988. Fishes: an Introduction to ichthyology. Department of Wildlife and Fisheries Biology, U.C. Davis. Prentice Hall, Englewood Cliffs, New Jersey, 07632. pp. 46, 121, 304, 305, 426.

Murdoch, W. W., R. C. Fay, and B. J. Mechalas. 1989. Final Report of the Marine Review Committee to the California Coastal Commission, MRC Doc. No. 89-02, 346 p.

Nelson, J. S. 1994. Fishes of the world, 3rd Ed. John Wiley and Sons, Inc., New York. 600 pp.

Nishimoto, M. M. In preparation. Identification of Sebastes larvae.

Normandeau Associates. Seabrook Station. 1999. Environmental monitoring in the Hampton-Seabrook area. A characterization of environmental conditions during the operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation.

O'Connell, C. P. 1953. Life history of the cabezon *Scorpaenichthys marmoratus* (Ayres). Calif. Dept. Fish and Game. Fish. Bull. 93, 76 pp.

Orensanz, J.M. and V.F. Gallucci. 1988. Comparative study of postlarval life-history schedules in four sympatric species of Cancer (Decapoda: Brachyura: Cancridae). J. Crust. Biol., 8 (2): 187-220.

Pacific States Marine Fisheries Commission (PSMFC). 1999a. http://www.psmfc.org/habitat/edu_herring_fact.html.

Pacific States Marine Fisheries Commission (PSMFC) 1999b. http://www.psmfc.org/Lifehistory/crab_fact.html.

Page, H. M., J. E. Dugan, D. S. Dugan, J. Richards, and D. Hubbard. 1999. Effects of an offshore oil platform on the distribution and abundance of commercially important crab species. Mar. Ecol. Progr. Ser. 185:47-57.

Parrish, R. H., C. S. Nelson, and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California current. Biological Oceanography 1(2):175-203.

Parrish, R. H., Serra, R., and W. S. Grant 1989. The monotypic sardine, Sardina and Sardinops: Their taxonomy, distribution, stock structure, and zoogeography. Can. J. Fish. Aquat. Sci. 2019-2036.

Pearcy, W. G., and S. S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: nursery ground for marine fishes? Fish. Bull. 72:201-213.

Poole, R. L. 1966. A description of laboratory-reared zoeae of *Cancer magister* Dana and megalopae taken under natural conditions (Decapoda: Brachyura). Crustaceana 11:83-97.

Reed, P. H. 1969. Culture methods and effects of temperature and salinity on survival and growth of the Dungeness crab (*Cancer magister*) larvae in the laboratory. Journal of the Fisheries Research Board of Canada 26:389-397.

Reilly, P. N. 1983. Dynamics of Dungeness crab, *Cancer magister*, larvae off central and northern California, p. 57-84. *In:* P. W. Wild and R. N. Tasto (eds.) life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Calif. Dept. Fish and Game. Fish. Bull. U.S. 81:455-472.

Reilly, P.N. 1988. Growth of young-of-the-year and juvenile Pacific herring from San Francisco Bay, California. Calif. Dept.Fish and Game. Fish. Bull. No. 74 (1). pp. 38-48.

Ricketts, E. F., J. Calvin, J. W. Hedgepeth, and D. W. Phillips. 1985. Between Pacific Tides. 5th ed. Stanford University Press, Stanford, Calif. 652 pp.

Roesijadi, G. 1976. Descriptions of the prezoeae of *Cancer magister* Dana and *Cancer productus* Randall and the larval stages of *Cancer antennarius* Stimpson (Decapoda, Brachyura). Crustaceana 31:275-295.

Shanks, A. L. 1985. Behavioral basis of internal-wave-induced shoreward transport of megalopae of the crab *Pachygrapsus crassipes*. Marine Ecology Progress Series 24:289-295.

Skogsberg, T. 1939. The fishes of the family Sciaenidae (croakers) of California. Calif. Dept. Fish and Game. Fish. Bull. No. 54, 62 pp.

Smith, P. E., and S. L. Richardson. 1977. Standard techniques for pelagic fish egg and larva surveys. FAO Fisheries Technical Paper 175:1-100.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. Iowa State University Press, Iowa. 593 pp.

Snyder, H. G. 1965. Some larval fishes of Mission Bay, San Diego County, California. Master's Thesis. San Diego State College.

Starr, R. M., K. A. Johnson, E. A. Laman, and G. M. Cailliet. 1998. Fishery resources of the Monterey Bay National Marine Sanctuary. Publ. No. T-042. California SeaGrant College System, University of California, La Jolla, CA. 102 pp.

Steele, M. A. 1997. Population regulation by post-settlement mortality in two temperate reef fishes. Oecologia. 112:64-73.

Stephens, J. S., Jr., R. K. Johnson, G. S. Key, and J. E. McCosker. 1970. The comparative ecology of three sympatric species of California blennies of the genus *Hypsoblennius* Gill (Teleostomi, Blenniidae). Ecol. Monogr. 40(2):213-233.

Stevens, B. G., and D. A. Armstrong. 1984. Distribution, abundance, and growth of juvenile Dungeness crabs, *Cancer magister*, in Grays Harbor estuary, Washington. Fishery Bulletin U.S. 82:469-483.

Stevenson, J. C. 1962. Distribution and survival of herring larvae (*Clupea pallasii* Valenciennes) in British Columbia waters. Journal of the Fisheries Research Board of Canada 19: 735-810.

Stocker, M., V. Haist, and D. Fournier. 1985. Environmental variation and recruitment of Pacific herring (*Clupea harengus pallasi*) in the Strait of Georgia. Can. J. Fish. Aquat. Sci. 42 (Suppl. 1):174-180.

Streamnet. 1999. http://www.streamnet.org/ff/Lifehistory/html.

Tasto, R. N. 1975. Aspects of the biology of Pacific staghorn sculpin, *Leptocottus armatus* Girard, in Anaheim Bay. *In*: Lane, E. D., and C. W. Hill (eds.) The Marine Resources of Anaheim Bay. pp. 123-135. Calif. Dept. Fish and Game. Fish. Bull. No. 165.

Tenera Environmental. 2000 (a). Diablo Canyon Power Plant final 316(b) demonstration report. Prepared for Pacific Gas and Electric Company. San Francisco, CA.

Tenera Environmental. 2000. (b). Draft Moss Landing Power Plant modernization project 316(b) resource assessment dated April 28, 2000. Final Draft. Prepared for Duke Energy. Oakland, CA.

Tenera. 1999. unpublished data from field studies at the Moss Landing Power Plant. Moss Landing, California.

Tetra Tech, Inc. 1999. Morro Bay National Estuary Program hydrodynamic circulation model, Lafayette, CA, various pages.

Trask, T. 1970. A description of laboratory-reared larvae of *C. productus* and comparison to larvae *of C. magister*. Crustaceana 18:133-147.

Trumble R.J., and R.D. Humphreys. 1985. Management of Pacific herring (*Clupea harengus pallasi*) in the eastern Pacific Ocean. Can. J. Fish. Aquat. Sci. 42 (Suppl. 1):230-244.

Vetter, R. D., and J. Stannard. 1999. Molecular identification of rockfish (*Sebastes* spp.) larvae. NMFS, NOAA, Southwest Fishery Science Center. La Jolla, California. 1999. *In*: Tenera. Diablo Canyon Power Plant Final 316(b) Demonstration Report. Prepared for Pacific Gas and Electric Company. San Francisco, CA.

Wang, J. C. S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life stages. Tech. Rept. 9, January 1986.

Watson, W. 1982. Development of eggs and larvae of the white croaker, *Genyonemus lineatus* Ayres (Pisces: Sciaenidae), off the southern California coast. Fish. Bull. No. 80(3):403-417.

Winn, R. N. 1985. Comparative ecology of three cancrid crab species (*Cancer anthonyi*, *C. antennarius*, *C. productus*) in marine subtidal habitats in southern California. Ph.D. Dissertation, Univ. So. Calif. 235 pp.

Woodbury, D. 1999. NOAA, Tiburon Laboratories. Personal communication.

Wyllie Echeverria, T. 1987. Thirty-four species of California rockfishes: maturity and seasonality of reproduction. Fish. Bull. 85(2):229-250.

Yamanaka, K. L., and A. R. Kronlund. 1997. Inshore rockfish assessment for the west coast of Canada in 1996 and recommended yields for 1997. Canadian Technical Reports on Fisheries and Aquatic Sciences No. 2175. Fisheries and Oceans Canada, Science Branch, Pacific Region, Pacific Biological Station, Nanaimo, British Columbia V9R 5K6. 80 pp.

Yoklavich, M. M., V. J. Loeb, M. Nishimoto, and B. Daly. 1996. Nearshore assemblages of larval rockfishes and their physical environment off central California during an extended El Niño event, 1991-1993. Fish. Bull. No. 94:766-782.