
Diablo Canyon Power Plant

316(b) Demonstration Report

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GLOSSARY OF TERMS AND ABBREVIATIONS

AEI	Adverse Environmental Impact: According to USEPA (1977), “adverse aquatic environmental impacts occur whenever there will be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure. The critical question is the magnitude of any adverse impact.”
<i>AEL</i>	Adult Equivalent Loss: Forecasts the number of adults that would have resulted from the number of entrained larvae, had they survived entrainment. Calculated using estimates of natural mortality rates applied to various life stages.
ambient	Describes the conditions and factors that are present in the natural environment.
ASW	Auxiliary seawater pump supply cooling water to the safety related component cooling water heat exchangers that maintain the operating temperature of vital plant equipment.
BTA	Best Technology Available: In USEPA regulations, refers to intake technology that is the best available to minimize AEI.
°C	Degrees Centigrade (or Celsius)
CalCOFI	California Cooperative Oceanic Fisheries Investigations
compensation	The ability of a [fish] population to offset, in whole or part, reductions in numbers caused by impacts from natural and/or man-induced stresses.
CV	Coefficient of variation: A statistical quantity computed as the standard error of a sample divided by the mean.
CTD	A data recording instrument used to measure ocean water conductivity [salinity] and temperature as a function of depth.
CWP	Circulating water pumps supply cooling water from the Pacific Ocean to the condensers to condense exhaust steam from the low pressure turbines.
CWS	Cooling water system: Includes portions of the DCCP intake structure, circulating water pumps, conduit tunnels, condensers, and discharge structure.
Davidson Current	Northward flowing current along the western US coast, usually during the fall and winter.
deme	A local population of organisms which is geographically isolated but not genetically isolated (i.e., through larval dispersal).
demography	The study of population statistics; specifically density, distribution, and vital rates of a population of organisms.
density dependence	Adjustment of vital rates (e.g., fecundity, mortality, somatic growth) in response to changes in population density; see <i>compensation</i> .

GLOSSARY (continued)

ENSO	El Niño–Southern Oscillation: Naturally occurring climatologic and oceanographic condition consisting of anomalous cooling and warming events.
El Niño	Ocean warming condition in the eastern Pacific that occurs when trade winds weaken over the central and western Pacific. Coastal upwelling is reduced resulting in widespread declines in nearshore productivity; an extreme phase of the ENSO phenomenon.
entrainment	Passage of small planktonic marine life through the power plant CWS.
<i>ETM</i>	Empirical Transport Model: A mathematical model that estimates the total annual probability of mortality (P_M) associated with entrainment using PE estimates.
ETWG	Entrainment Technical Work Group
<i>FH</i>	Fecundity Hindcasting: The number of larvae entrained are hindcast to the number of eggs by applying mortality estimates; the number of eggs is then used to estimate the number of adult females that would have produced that quantity of eggs.
gpm	Gallons per minute (0.0038 m ³ /min)
growth overfishing	Fishing pressure that eliminates young fishes before they can spawn, as in the live-fish fishery.
impingement	Entrapment of macroscopic organisms on the intake traveling screens.
km	Kilometer (0.62 miles)
La Niña	An oceanographic phenomenon that occurs when trade winds strengthen over the tropical Pacific, increasing the amount of cold, nutrient rich water brought to the surface in upwelling currents; generally results in high primary productivity; an extreme phase of the ENSO.
m	Meter (3.28 feet)
m ³ /d	Cubic meters per day (measure of flow rate; 264 gallons/ m ³)
MLLW	Mean lower low water; the elevation defined as 0.0 m (ft)
MT	Metric ton; (1,000 kg; 2,205 pounds)
North Pacific Gyre	Clockwise gyre in the, north Pacific Ocean that creates a southward movement of water along the western coast of the United States (i.e., California Current).
NPDES	National Pollutant Discharge Elimination System
NPV	Net Present Value of cash flow: The economic measure of evaluating proposed projects including capital and maintenance costs, and the cumulative lost revenue, discounted to a present value using an after-tax discount rate.

GLOSSARY (continued)

#/m ³	Number of organisms per cubic meter of water (density of organisms)
<i>PE</i>	Proportional Entrainment: A mathematical value comparing the number of larvae entrained to the number of larvae available in the source water body.
<i>P_M</i>	Total annual mortality probability due to entrainment
population	The individuals of a given species or taxon within a defined geographical area.
<i>P_s</i>	The proportion of the population of inference represented by the number of larvae in the study grid, (i.e., number of larvae at risk in the study grid) / (number of larvae in the population of inference).
<i>r</i>	Instantaneous rate of increase
recruitment overfishing	Fishing pressure that limits the amount of larvae a population produces by taking primarily older, more fecund adults and leaving behind young, less fecund individuals.
RWQCB	Regional Water Quality Control Board (Central Coast)
species	A group of similar organisms that produce fertile offspring.
SST	Sea surface temperature
stock	A managed unit of a fish subpopulation available to a fishery.
subpopulation	A group of individuals of a species which interbreeds but is reproductively isolated from other such groups.
surplus production	In fisheries biology, production above and beyond an equilibrium level that can be harvested without substantially depleting a population; a population in equilibrium occurs when recruitment (or emigration) balances mortality (or immigration); see <i>compensation</i> .
traveling screens	A series of rotating meshed baskets at the intake structure designed to remove material and debris in the cooling water flow.
USEPA	United States Environmental Protection Agency
upwelling	Offshore transport of surface waters that results from steady northwest winds and causes cold, deep, nutrient-rich water to rise to the surface.
<i>Z</i>	Instantaneous mortality rate

1.0 EXECUTIVE SUMMARY

Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act) requires that Diablo Canyon Power Plant (DCPP) cooling water intake structure represents the best technology available (BTA) to minimize adverse environmental impacts (AEI) as defined by the USEPA. This report provides information to the Central Coast Regional Water Quality Control Board (RWQCB) in response to the requirements in Section 316(b). The report follows previous reports that described the sampling design and methods of the study, selection of target taxa, and formulations of the three assessment approaches (Tenera 1997a and b; Tenera 1998a) for approval by the RWQCB. PG&E also submitted two preliminary assessment reports to the Central Coast RWQCB, USEPA, and the ETWG (Tenera 1999a and b) that provide a comprehensive application of the three assessment approaches to entrainment effects on the selected target taxa.

Entrainment Technical Work Group

The Entrainment Technical Work Group (ETWG) was assembled by the RWQCB to assist their staff in reviewing the design and implementation of the 316(b) demonstration at DCPP. The ETWG was composed of PG&E and their consultants, RWQCB and their consultants, a consultant to the League for Coastal Protection, the California Department of Fish and Game, and USEPA. The ETWG assisted in developing criteria to assess the effects of the DCPP intake.

Impingement

The cooling water intake system at DCPP entrains and impinges larval, juvenile, and adult fishes and invertebrates. Entrainment occurs when organisms smaller than the 0.95 cm mesh of the traveling screens pass through the screens and enter the cooling water system. Impingement occurs when organisms too large to pass through the mesh are held against the screens by the water pumped through the plant. Once entrained, larval mortality was assumed to be 100%. Estimates of impingement were very low based on a review of the 1985–86 DCPP impingement

study (Tenera 1988a). The ETWG determined that additional impingement studies were not required at DCPD because of the low levels of impingement.

Assessment Approaches

Pacific Gas and Electric (PG&E) and its consultants, in cooperation with other members of the ETWG, employed three population assessment approaches to determine the entrainment and impingement effects of the DCPD intake. Estimates of entrainment loss, and the demographic data collected from the scientific literature, were used to parameterize two demographic approaches to estimating entrainment effects: Adult Equivalent Loss (*AEL*) and Fecundity Hindcasting (*FH*). The *AEL* method forecasts the number of adults that would have survived from the estimated number of entrained larvae, as if they had survived entrainment, using knowledge of mortality rates other than from entrainment by the power plant (i.e., natural mortality). The *FH* method is similar except that the number of larvae entrained are hindcast to the number of eggs, and the number of eggs is then used to estimate the number of female adults that would have produced them.

A third method, the Empirical Transport Model (*ETM*), estimates an average annual larval mortality due to entrainment per individual taxon, using estimates of proportional entrainment (*PE*) that compare the number of larvae entrained in one day to the number of available larvae in the source water body. Larval mortality is calculated after *PE* is weighted by the estimated fraction of the total population affected and compounded by the time larvae are susceptible to entrainment. Data collected during the study period from a current meter located offshore of DCPD was used to estimate this fraction (P_s) using either alongshore currents (for nearshore species) or both alongshore and onshore currents (for those more widely distributed species).

Target Organism Selection

The ETWG selected the organisms targeted for study: larval fishes, *Cancer* spp. crab zoea and megalops larvae, and metamorphosing larval and juvenile *Strongylocentrotus* spp. sea urchins. The individual taxa were chosen based on a set of criteria following USEPA Draft Guidelines

(USEPA 1977) and described in Tenera (1997b), that included constraints imposed by the availability of data to estimate population-level effects.

Sixteen target taxa were identified for assessment of entrainment effects using criteria based on USEPA guidance on 316(b) studies, and recommendations of the ETWG and other experts:

- Brown rock crab
- Slender crab
- Pacific sardine
- Northern anchovy
- Blue rockfish complex
- KGB rockfish complex
- Painted greenling
- Smoothhead sculpin
- Snubnose sculpin
- Cabezon
- White croaker
- Monkeyface prickleback
- Clinid kelpfishes
- Blackeye goby
- Sanddabs
- California halibut

Sampling

Entrainment and study grid sampling provided data for estimating entrainment abundance and abundance in the nearshore area defined by a study grid centered on the DCP intake. Collection of the DCP entrainment samples took place once per week from four permanently moored sampling stations located directly in front of the intake structure. The study grid contained 64 sampling cells in an eight cell by eight cell pattern and extended a distance of 17.4 km alongshore (8.7 km to the north and south) and an average distance of 3.0 km offshore.

The sampling surveys were conducted during 1996–1999 and divided into annual periods for analyses. Where it was possible, the estimates of annual entrainment were scaled to better represent long-term trends for a taxon by using data from surface plankton tows collected at the mouth of the DCP Intake Cove starting in 1990. The analysis periods provided two annual estimates for comparing *FH* and *AEL* and two years of paired entrainment and study grid survey for comparing annual estimates of larval mortality \widehat{P}_M using *ETM*.

Results of Assessment

Variation of *FH* and *AEL* estimates between the years 1996–97 and 1997–98 appeared to be taxon-specific, but was likely also influenced by the El Niño event that occurred along the central California coast during the fall, winter, and spring seasons of 1997–98. For example, estimates of *FH* and *AEL* for both Pacific sardine and northern anchovy increased markedly between the first and second year of the study. The spawning biomass for both of these species is typically centered south of Point Conception, and was likely displaced northward with the north-flowing El Niño currents present in the second year. White croaker *FH* and *AEL* also appeared to increase slightly, which may also be due to additional transport northward during the El Niño year. Other species appeared to be somewhat less affected by El Niño-related transport since *FH* and *AEL* remained relatively constant or changed only slightly between years (e.g., KGB rockfishes, blue rockfish complex, blackeye goby, and sanddabs). These fishes probably have more localized spawning populations that were less affected by the El Niño event.

For some taxa, multiple assessment methods were applied to a known reference population or to fishery harvest data. For other taxa, assessment of impacts was limited to reporting the number of individuals lost to the population, or to a mortality estimate that was specific to an area where there is little knowledge of the adult population size. For example, demographic data on egg and larval mortality for blackeye goby allowed the application of multiple assessment approaches, but the absence of a stock assessment or fishery data precluded a context for the estimates.

For taxa where all three assessment methods were completed, comparison among the results illustrated the usefulness of the multiple assessment approach. While the range and variance of life history parameters and population estimates were sources of uncertainty in our estimates, we determined our areas of uncertainty through model comparison. Where both *FH* and *AEL* estimates exist, assuming a 50:50 sex ratio and aligning the ages of recruitment and maturation, the models were compared directly using the relationship $AEL \equiv 2FH$ presented in previous assessment reports (Tenera 1999a, b). The results from the demographic approaches were in similar units of either adult females (*FH*) or adults (*AEL*).

The *FH* and *AEL* model estimates, when ages were aligned, were in close agreement for northern anchovy and the blue rockfish complex. Results for these taxa provided assurance that the parameters used in the models (and thus the assessments) for these two taxa are reasonably accurate for central California populations. In the example of the blue rockfish, the *FH* and *AEL* estimates were used to extrapolate population-level effects and then were compared to local fishery landings. Applying the range of P_M estimates for this taxon (0.001–0.02) calculated using alongshore currents and extrapolating density offshore to these same fishery data provided an estimate of loss to the fishery of 15–292 kg of whole fish. Using an estimate of approximately 0.5 kilogram per live fish, the percentage catch equaled 29–584 adult fish. This estimate also agreed with aligned estimates of *2FH* (114–273) and *AEL* (142–353).

Age at assessment needed to be considered when interpreting the large *FH* estimate for brown rock crab. The estimated number of reproductive adults using the *FH* model was extrapolated to known fishery-sized animals using estimates of adult mortality because females are reproductive before they enter the fishery. This reduced the *FH* estimate by an order of magnitude.

Assessments of entrainment effects on taxa that had very little demographic information were limited to *ETM* estimates. However, the availability of data on populations from sport or commercial fisheries provided context for assessments on some of these taxa (e.g., California halibut, cabezon, and monkeyface prickleback). The absence of catch data or stock assessments for other taxa limited the ability to assess entrainment effects on their populations with any methodology. Limited species' life history information imposed limitations on which methods could be used to assess entrainment effects on a particular taxon.

Taxa that are not commercially or recreationally harvested were primarily small, nearshore fishes. As might be expected due to the shallow water, shoreline location of the DCP intake structure, several of these taxa were entrained in relatively high numbers, resulting in large P_M estimates. For example, adult kelpfishes that occur in rocky, nearshore habitat had one of the highest P_M estimates (ca. 30–40%). Other taxa with nearshore distributions, including smoothhead sculpin, snubnose sculpin, and monkeyface prickleback, also had relatively large

P_M estimates. Their greatest larval abundance occurred in the cells closest to shore in the study grid; a distribution that was consistent with their adult distributions.

Estimates of P_M for some of the species that have broader adult distributions (e.g., blackeye goby and California halibut) were also high. Blackeye goby larvae (P_M ca. 20%), distributed throughout the survey grid, also occurred as adults from the intertidal zone out to depths of 30m. The high P_M for blackeye goby, in part, may have resulted from the high density of adults directly in front of the intake structure. Although California halibut P_M estimates were high, particularly during the July 1998–June 1999 period, the estimates are based on a limited number of larvae. Although low in abundance in entrainment California halibut was included in the list of target taxa because of its sport and commercial fishery importance.

Estimates of P_M for species with more widespread, pelagic larvae (e.g., Pacific sardine and northern anchovy) were low. Impacts on commercially and recreationally harvested species with subtidal or pelagic distributions were minimal. For cases where all three assessment approaches were applied, the effects detected were relatively small, appeared to be localized, and thus would not affect the overall adult populations. These conclusions were supported by results for taxa such as KGB rockfishes where the estimated low levels of entrainment effects were corroborated by corollary data that showed no consequent adult abundance or larval production decreases.

Several small, nearshore fishes were included in the assessment because of their high abundance in entrainment samples. There was very little available information describing the demography of these taxa which limited the applicable assessment approaches to *ETM*. The *ETM* results showed that entrainment could remove over 10% of the annual larval production of several of these nearshore and intertidal taxa in an area from one to eight times the study grid area (52 km²). In some of these cases, corollary data indicated that entrainment only removed surplus production since there were no apparent long-term declines in local adult populations, or in the weekly intake cove plankton tows conducted since 1990. For those nearshore taxa that did not display decreasing adult abundance, it was apparent from their length-frequency distributions that they were exposed to entrainment mortality for only a brief portion of their early

development. In contrast, for kelpfish and snubnose sculpin, whose adult abundance appeared to be decreasing, the length-frequency distributions indicated a longer exposure to entrainment. The combination of length-frequency analyses, *ETM* estimates, and other corroborating data support the conclusion that the local subpopulations of most nearshore taxa are not experiencing long-term declines in abundance due to entrainment.

Conclusion

United States Environmental Protection Agency (USEPA) criteria for determining the extent of adverse environmental impacts (AEI) focus on population-level effects. The results presented in this 316(b) study provide the necessary assurance that the DCPD cooling water intake system is not causing widespread or long-term population-level effects on the target taxa. Since DCPD is not causing population-level effects, no consideration of alternative cooling water intake structure technologies for minimizing AEI is necessary. However, this report does include an assessment of alternative technologies in response to a requirement by the Central Coast RWQCB. The conclusion of this alternative technologies assessment is that the existing cooling water intake structure is the best technology available for DCPD.

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2.0 INTRODUCTION

The purpose of this study is to determine if the Diablo Canyon Power Plant (DCPP) intake is causing an adverse environmental impact and, if so, what type of intake structure represents the best technology available to minimize that impact. The results will also be used to project the long-range effects on taxa where estimates of their populations are available. The estimates of entrainment and impingement effects on target taxa presented in this report will be used in recommending any action that may be required to comply with Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act).

2.1 USEPA Section 316(b) Background

Section 316(b) of the Clean Water Act regulates cooling water intake structures and requires that “the location, design, construction, and capacity of cooling water intake structures reflect the best technology available [BTA] for minimizing adverse environmental impact [AEI].” Although the EPA attempted to establish regulations in the mid-1970s, these rules were set aside by the courts on procedural grounds. As a result there are currently no regulations in effect for implementing Section 316(b).

To date, USEPA has not reissued Section 316(b) regulations and, instead, has allowed state and federal permit writers to implement Section 316(b) on a case-by-case basis. To make Section 316(b) decisions, permit writers have relied on other cases and on USEPA’s (1977) informal draft “Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500.”

In California, the State Water Resources Control Board (SWRCB) and the Regional Water Quality Control Boards (RWQCB) are authorized to implement the Section 316(b) requirement. In the case of DCPP, the permit applicant is obligated to provide the Central Coast RWQCB with

the “best information reasonably available”¹ to assist it in fulfilling its decision-making responsibility.

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

1. Whether or not an AEI is caused by the intake and, if so,
2. What intake structure represents BTA to minimize that impact.

The usual approach for a 316(b) demonstration is to consider the question of BTA only if a determination has been made that a facility is causing an AEI. However, in response to a requirement from the Central Coast RWQCB, PG&E is providing an alternative technology assessment as a part of this demonstration report (**Section 6**) and discusses BTA in **Section 7** of this report, even though a determination of AEI has not been made.

2.1.1 Adverse Environmental Impact (AEI) Standard

Since there are no regulations defining AEI, permit decisions must be based on the USEPA’s long-standing AEI interpretations and previous 316(b) decisions. In several guidance documents issued since the 1970’s, the USEPA has indicated that assessment of AEI should be based on an evaluation of population level effects, not just losses of individual organisms. In its 1975 Draft BTA Guidelines, the USEPA stated that “[a]dverse environmental impacts occur when the ecological function of the organism(s) of concern is impaired or reduced to a level which precludes maintenance of existing populations....”² Additionally, in the 1976 Development Document, released in conjunction with the EPA’s previous Section 316(b) rules, the USEPA said that “[t]he major impacts related to cooling water use are those affecting the aquatic ecosystems. Serious concerns are with population effects that...may interfere with the

¹ Boston Edison Company (Pilgrim Station), Case No. 78-7 (May 3 1978).

² USEPA, Draft Guidelines to Determine Best Available Technology for the Location, Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact Section 316(b) P.L. 92-500 (December 5, 1975), p 8.

maintenance or establishment of optimum yields to sport or commercial fish and shellfish, decrease populations of endangered organisms, and seriously disrupt sensitive ecosystems.”³ The EPA has looked to population level effects in evaluating AEI in specific permit decisions. One such example was in a decision on Seabrook Power Station in New Hampshire. In Seabrook I, the Administrator determined that the estimated loss of 100 billion *Mya* clam larvae through entrainment would not have a “significant effect” on the local clam population.⁴ On remand, the USEPA Administrator in Seabrook II determined that entrainment mortality would not have an adverse impact on abundance and distribution of plankton “even though the total biomass...killed may amount to hundreds or thousands of tons per year.” He cited the ability of clams to reproduce rapidly, their wide distribution in the area beyond the immediate vicinity of the plant, and their transient nature.⁵ Upon review of the Seabrook II decision, a circuit court upheld the Administrator’s decision and indicated that the issue in assessing AEI is whether intake losses would “affect the ability [of fish species] to propagate and survive.”⁶

2.1.2 Best Technology Available (BTA) Standard

The second issue to be considered in making a Section 316(b) decision is whether the existing intake structure represents BTA to minimize adverse environmental impacts if they are occurring. Determination of BTA for any cooling water intake requires

- consideration of the technical and engineering feasibility of alternative intake technologies,

³ Development Document for Best Technology Available for the Location, Design, Construction, and Capacity of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b). (1976 Development Document) USEPA Effluent Guidelines Division, Office of Water and Hazards Materials, April 1976.

⁴ In the Matter of Public Service Co. of New Hampshire: Seabrook Station I and II, NPDES Appeal No. 76-7 (Decision of the Administrator, June 10, 1977) (Seabrook I).

⁵ In the Matter of Public Service Co. of New Hampshire, et al.: Seabrook I and II. NPDES Permit Application No. NH0020338 Case No. 76-7 (Decision on Remand August 4, 1978 Seabrook II).

⁶ Seacoast Anti-Pollution League v. Costle, 597 F.2d 306,309,311 (1st Cir. 1979).

- the potential for an intake technology to reduce or eliminate the “adverse environmental impact,”
- the potential for the technology to produce other environmental impacts reducing its net benefit, and
- the cost of the technology in relation to its potential environmental benefits.

Although no reference to cost is made in Section 316(b), legislative history suggests that Congress intended that costs be considered in 316(b) determinations. Specifically, a statement by the spokesman for the House Conferees indicates that Congress intended the “best technology available” to be interpreted to mean the “best technology available commercially at an economically practicable cost.”⁷ Additionally, in responding to comments during the drafting of its 1977 Draft Guidance, the USEPA said that BTA is the technology or group of technologies that minimize adverse impacts to the greatest possible degree at a cost that is not “wholly disproportionate” to the environmental benefits. This standard was also applied by the USEPA Regional Administrator in the Pilgrim decision that states, “a decision regarding the required degree of minimization calls for a determination that the costs involved are not wholly out of proportion to the adverse environmental impact being avoided.”⁸

2.1.3 Status of Future 316(b) Regulations

Currently, the USEPA is developing regulations for implementing Section 316(b) of the Clean Water Act. This effort is the result of a 1993 lawsuit brought by the Hudson Riverkeeper and several environmental groups alleging that the USEPA had failed to perform a “non-discretionary duty” to promulgate Section 316(b) regulations.⁹ In its effort to draft these

⁷ 188 Cong. Rec. H 9130 (daily ed. Oct. 4, 1972) (remarks of Congressman Clausen).

⁸ “Determination Regarding Issuance of Proposed NPDES Permit No. MA 0025135”, dated March 11, 1977, regarding Boston Edison’s Pilgrim Units 1 and 2.

⁹ Cronin v. Browner, 898 F. Supp. 1052, 1063 (S.D.N.Y. 1995).

regulations, the USEPA has held several public meetings to obtain input from interested parties and has also requested some facilities to respond to questionnaires to provide data that the USEPA deems relevant. As a result of a settlement agreement reached by the USEPA and the Hudson Riverkeeper plaintiffs, the USEPA will issue final 316(b) regulations by August 2001. However, the USEPA recently requested from the court that they be given a time extension and allowed to bifurcate the regulations. If the request is granted, the USEPA would issue final regulations for new facilities by May 2002 and presumably less stringent regulations for existing facilities by April 2004.

2.2 DCPD Study Development Process

The Central Coast RWQCB assembled a team of experts to assist their staff in reviewing the design and implementation of the 316(b) demonstration at DCPD. This team, the Entrainment Technical Work Group (ETWG), has met periodically since 1996 to discuss topics relevant to assessing entrainment and impingement effects at DCPD. The ETWG approved the design for the DCPD 316(b) demonstration, including the selection of the organisms targeted for study (larval fishes, *Cancer* spp. crabs, and metamorphosing and juvenile *Strongylocentrotus* spp. sea urchins). The individual taxa were chosen by the ETWG for assessment based on criteria agreed to and described by Tenera (1997b) that included the statistical qualities of the data for a taxa and the availability of suitable life-history information to meet assessment model requirements. These criteria were, in turn, based on criteria described in USEPA Draft Guidelines (USEPA 1977). The ETWG and the RWQCB's consultants will present their final recommendations regarding the 316(b) demonstration study for consideration by the Central Coast RWQCB at their July 14, 2000 meeting.

Several approaches to assessment were developed by PG&E, its consultants, and additional members of the Entrainment Technical Work Group (ETWG). These assessment approaches are fecundity hindcasting (*FH*: Alec MacCall, NOAA/NMFS, Tiburon Laboratory, pers. comm.; Tenera 1998a), adult equivalent loss (*AEL*: Horst 1975; Goodyear 1978), and empirical transport modeling (*ETM*: Boreman et al. 1978, 1981). Previous reports submitted to the ETWG for

review and approval detailed the sampling design and methods of the study, selection of target taxa, and formulations of the three assessment methods (Tenera 1997a; Tenera 1997b; Tenera 1998a). Two preliminary assessment reports were also presented using these three approaches. The first (Tenera 1999a) presented an assessment for three of the target fish taxa for the period July 1997 through June 1998, while the second presented results for all 16 target taxa (crabs and fishes) for the same one year period (Tenera 1999b). Results in these reports demonstrated how available life history information could be incorporated into assessment calculations, what influence life history information would have on results, and how results of the three approaches could be interpreted together. In this report, the methods are described, the principles embodied in these methods are summarized, and the results are presented using one or more of these assessment approaches, as appropriate, for the 16 target taxa studied.

2.3 Standards for Assessment

The USEPA (1977) draft guidelines acknowledge that the determination of the extent of AEI when it is occurring is difficult to assess. They state:

Adverse aquatic environmental impacts occur whenever there will be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure. The critical question is the magnitude of any adverse impact. The exact point at which adverse aquatic impact occurs at any given plant site or water body segment is highly speculative and can only be estimated on a case-by-case basis...

In light of these obvious difficulties, the document (USEPA 1977) also provides some general guidelines for determining the extent of AEI. These involve determining the “relative biological value of the source water body zone of influence for selected species and determining the potential for damage by the intake structure” based on the following considerations of the value of a given area to a particular species:

- principal spawning (breeding) ground,
- migratory pathways,
- nursery or feeding areas,
- numbers of individuals present, and

- other functions critical during the life history.

Following this general approach provided by the USEPA (1977), additional criteria can be evaluated that are specific to the marine environment around Diablo Canyon, unique to marine aquatic animals, and directly applicable to the present 316(b) entrainment study:

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

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

2.4 Report Organization

Section 3 of this report presents a background on the power plant and its environmental setting. Methods used for data collection and the formulation of each assessment models are contained in **Section 4**. **Section 5** presents the results of the study, including assessments for each of the target taxa as separate subsections. Taxa are organized in phylogenetic order from the most primitive to the more evolutionarily advanced species, a standard form of organization in scientific publications. Each taxon's subsection provides a summary of its demography, entrainment estimates, and assessment results. An evaluation of alternative intake technologies available to minimize entrainment and impingement is presented in **Section 6**. A summary discussion of all results and their interpretations is provided in **Section 7**, which is followed by **Section 8: Conclusions**. A listing of the literature cited is presented in **Section 9**. Fourteen

appendices present previous reports, results summary tables, and other supporting information.

These appendices are as follows:

- Appendix A:** DCP 316(b) Demonstration Study: Phase 1-Entrainment Study Design, I. Sampling Location
- Appendix B:** DCP 316(b) Demonstration Study: Phase 1-Entrainment Study Design, II. Selection of Target Organisms, Sampling Methods, and Gear Testing
- Appendix C:** DCP 316(b) Study: Phase 3-Sampling Plan and Modelling Evaluation
- Appendix D:** DCP 316(b) Entrainment Study, Field and Laboratory Procedures
- Appendix E:** DCP 316(b) Study: Comparison of Entrainment Larval Density in Paired Samples: One-vs. Two-nets
- Appendix F:** Estimating Total Entrainment Mortality using the Delta method
- Appendix G:** Number of Samples Collected and Laboratory Processed
- Appendix H:** Estimated Mean Density of Larvae Collected at DCP
- Appendix I:** Estimated Number of Target Taxa Larvae Entrained per Week
- Appendix J:** Results of t-tests and Kolmogorov-Smirnov tests on length frequency data from paired entrainment and study grid samples
- Appendix K:** DNA Analysis of Larval *Sebastes* spp.
- Appendix L:** Technologies that do not have demonstrated commercial operability or reliability at power plants of a scale similar to DCP
- Appendix M:** Technologies that are currently available but would not reduce impingement or entrainment to levels lower than observed at DCP
- Appendix N:** Technologies and methods currently available and proven effective at facilities of the same size as DCP but determined to not be effective at DCP

3.0 BACKGROUND

Diablo Canyon Power Plant, owned and operated by Pacific Gas and Electric Company (PG&E), is a nuclear-powered, steam-turbine power plant with a rated output of 2,200 megawatts of electricity. Commercial operation of Unit 1 began in May 1985, Unit 2 in March 1986. DCP is located on a coastal terrace midway between the communities of Morro Bay and Avila Beach on the central California coast (Figure 3-1). The local coast is a steep and rugged rocky shoreline that is exposed to heavy wave activity. The study area supports a rich community of marine life that is a biogeographical extension of similar marine communities extending many hundreds of miles to the north. Except for the DCP, the coast is largely uninhabited and undeveloped along the 16 km (10 mi) between the cities of Morro Bay and Avila Beach.

The power plant draws in seawater from a constructed intake cove through a cooling water system (CWS) to provide cooling for power plant operations. The intake structure was sited behind breakwater structures to mitigate the effect of wave action. Use of the breakwater structures reduced the rise and fall of pump suction levels due to wave action by 75% and reduced the potential of storm-uprooted kelp and suspended sands entering the intake. The common unit 1 and unit 2 intake structure was sited at the north end of the cove created by the breakwaters to accommodate the potential addition of units 3 through 6 (Lillevang 1969).

As the water passes through the plant's condensers, it causes the steam contained within the secondary reactor loop to recondense. After passing through the plant's CWS, the heated water is discharged into Diablo Cove. The discharge is approximately 11°C (20°F) warmer than ambient ocean waters under normal operating conditions.

3.1 DCP Circulating Water System Description

The DCP intake structure entrains and impinges larval, juvenile, and adult fishes and invertebrates. Entrainment occurs when organisms smaller than the 0.95 cm mesh of the traveling screens pass through the screens and enter the cooling water system. Impingement

occurs when organisms too large to pass through the mesh are held against the screens by the velocity of the water pumped through the plant's intake structure.

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

Each CWP has a manufacturer's estimated average pumping flow rate of 1,641 m³/min (PG&E 1998a). The calculated DCPD total daily intake volume is 9.45 million m³/d when all four CWPs (two per unit) are operating. The flow rates of the ASW pumps are 240,000 m³/d. The volume of cooling water can vary daily due to a variety of factors that include changes in tidal and swell height, as well as resistance caused by occlusion of condenser tubes. During the period June 1996 through June 1999, pumping stopped during three refueling outages and other shorter periods of time when one or more of the DCPD CWPs were not in operation (**Figure 3-3**).

The traveling screen assemblies are equipped with a high pressure seawater wash system, and screens are rotated either automatically or manually. When the screens rotate, impinged debris, fishes, and invertebrates are rinsed from the screens into a trough that slopes to a central refuse sump area (**Figure 3-4**). In Fall 1997, a grinder system was installed to decrease the size of all material before it entered the sump. All material in the sump is then pumped back to the ocean at the landward end of the west breakwater. Automatic operation of the screens occurs in one of two ways: by timed cycles or by hydrostatic pressure. Timers are typically set to initiate a 40-minute screen wash once every four hours. The screens also rotate automatically when a height differential of approximately 20 cm across the screen surface is detected. Manual operation of the traveling screens occurs whenever necessary, especially when heavy accumulations of kelp threaten the safe operation of the intake system. During these times continuous screen washing is usually necessary.

3.2 Environmental Setting

3.2.1 Bathymetry

The bathymetry of the nearshore region between Point Buchon and Point San Luis is characterized by sloping bedrock and soft-bottom flats, with steeper relief generally increasing from the south to the north (**Figure 3-5**). The majority of the nearshore region near Pt. San Luis, from the shoreline to ~2 km offshore, is less than 40 m in depth, while the corresponding nearshore region off Point Buchon is 60–80 m in depth. Rocky pinnacles are relatively common out to the 40 m contour, in contrast to the relatively flat bottom typical of the 40–100 m region. Within the geographic area bounded by Point Buchon and Point San Luis, several prominent rocky ridges extend from the shoreline out to about the 20 m contour, especially noticeable at Point Buchon, Lion Rock, and Pecho Rock.

3.2.2 Ocean Current Patterns

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

The following paragraphs discuss the mechanics of the constant and smoothed current components summarized in Safaie (1986). The residual current component was not discussed as completely in Safaie (1986), presumably because the magnitude and duration of this current is relatively minor compared to that of the constant and smoothed currents. In addition to these regularly-occurring currents, the mechanics of periodic El Niño and La Niña oceanographic events are described. Finally, the hydrology and water chemistry of the nearshore region of Diablo Canyon during the study period October 1996–June 1999 are summarized.

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

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

The California Current ecosystem is characterized by seasonally high levels of primary production when northwesterly winds predominate and cause coastal upwelling to occur, typically in the spring and summer of each year. Upwelling occurs because the northwesterly winds generate Ekman transport of surface waters due to the Coriolis Force, resulting in a net movement of surface waters perpendicular to the wind direction: to the right in the northern hemisphere and offshore relative to the California coast.

3.2.3 El Niño Southern Oscillation and Ocean Water Temperatures

The El Niño Southern Oscillation (ENSO) in the eastern Pacific Ocean typically consists of a warm water El Niño phase followed by cooler water temperatures during a subsequent La Niña. However, the effects of the ENSO are not limited to ocean waters as they also affect the atmospheric/oceanic circulation (Rasmusson and Wallace 1983). Much of the interannual ocean variability on decadal and sub-decadal time scales can be attributed to El Niño events that have significant impacts on the global ocean's heat budget and ecosystems (Barber and Chavez 1986; Cane et al. 1986). Its global impacts (Rasmusson and Wallace 1983) are most apparent in the eastern Pacific (Barber and Chavez 1983) where the influence of El Niño can be detected from the southern tip of Chile to Alaska (Enfield and Allen 1980). It remains unclear whether the primary impacts of the ENSO arrive via ocean or atmospheric circulation, but the fact remains that these impacts are significant in the coastal waters of Central California (e.g., Lenarz et al. 1995; Chavez 1996; Schwing et al. 1997; Lynn et al. 1998).

Moderate to weak La Niña conditions prevailed along the central California coast from 1995 through early 1997 (Schwing et al. 1997) when one of the strongest El Niño events recorded this

century began to develop (Lynn et al. 1998). During the first year of field sampling conducted at DCP (October 1996–September 1997), this weak La Niña may have, atypically, contributed to higher than normal sea surface temperatures (SST) observed off California and Mexico as the result of anomalous wind relaxation events (Schwing et al. 1997). The El Niño that had been developing in the western tropical Pacific since early Spring 1997 arrived along the coast of California in Fall 1997, bringing higher than normal SST and suppressing upwelling activity along the length of the coast. This El Niño event continued into the summer of 1998 (Lynn et al. 1998) and was followed by another La Niña beginning in Fall 1998 and extending at least to the end of the field sampling operations at DCP in June 1999.

The continuing cycle of ENSO events has also had dramatic effects on the primary and secondary production of the California Current ecosystem. Primary production, measured as chlorophyll concentration, decreased during warmer El Niño years—1992 and 1997—and rose in the cooler La Niña years—1991 and 1995 (Chavez 1999). Total phytoplankton biomass demonstrated similar trends: declining in 1992 and 1997 and rising in 1995 when the average temperature was close to the climatological mean, 13.5°C. Chavez (1999) also notes that over the 10-year period 1988–1998, SST have gradually risen while levels of nitrate, chlorophyll, primary production, and certain phytoplankters (e.g., centric diatoms) have declined, effectively reducing the overall productivity of the California Current ecosystem. The changes to the ecosystem at these fundamental levels may have dramatic consequences for the remainder of the ecosystem, which supports a diverse assemblage of marine birds, mammals, and fishes. Lynn et al. (1998) also notes that “mean macrozooplankton abundance during the spring of 1998 was the lowest in the 50-year CalCOFI time series,” further confirming the findings of Chavez and MBARI.

3.2.4 Ocean Currents and Temperatures during the Entrainment Study Period (October 1996 – June 1999)

The DCP 316(b) study period was characterized by a series of climatological and meteorological ENSO events (**Table 3-1**) that are known to have dramatic effects on ocean ecosystems, oceanic and atmospheric currents, and on productivity in the California Current.

Field sampling was initiated during an anomalously warm La Niña event that occurred during the fall of 1996 and continued through the fall of 1997 (Schwing et al. 1997). In the fall of 1997, one of the strongest El Niño events recorded this century occurred along the California coast and continued through the summer of 1998 (Lynn et al. 1998). The fall and winter of 1998–99 were subject to a more typical cold water La Niña phase that continued through the end of field sampling operations in June 1999.

Data collected during the study period from the single current meter and meteorological observation station at DCPD showed that nearshore currents were largely controlled by prevailing wind conditions (**Figure 3-6**). During those infrequent periods when wind speeds were negligible (i.e., less than 2 nautical miles per hour), longshore constant currents predominated.

Mean monthly water temperatures near DCPD during the study period October 1996 through June 1999 ranged from 17.5°C in November 1997 to 10.5°C in April 1999 (**Figure 3-7**). While maximum temperatures occurred at various times throughout the year (e.g., November 1997 and August/September 1998), annual temperature minimums were consistently present during the month of April. These temperature minimums generally corresponded to seasonal offshore winds and consequent coastal upwelling. The continuing influence of the ENSO throughout the study period may explain the inconsistent interannual timing of recorded maximum temperatures. Overall, nearshore seawater temperatures during the study period deviated appreciably from long-term patterns. The mean seawater temperature recorded for November 1997 was the warmest since records began in 1976 (Figure 3-7). This was rivaled only by temperatures recorded in the summer/fall of 1983 and 1984, another strong El Niño event.

Table 3-1. Presence and relative magnitude of El Niño (W) and La Niña (C) events from 1996 through 1999 in the tropical Pacific: relatively strong events are noted with (+), relatively weak events with (-), and C* denotes anomalously warm La Niña conditions postulated by Schwing et al. (1997). Blank cell in 4th quarter of 1999 represents non-ENSO (= normal) period. Table combines data from Schwing et al. (1997) and the NOAA ensoyears.html page at www.noaa.gov.

Year	1 st Quarter	2 nd Quarter	3 rd Quarter	4 th Quarter
1996	C*	C*	C*	C*
1997	C*	W	W+	W+
1998	W+	W	C-	C
1999	C+	C	C-	

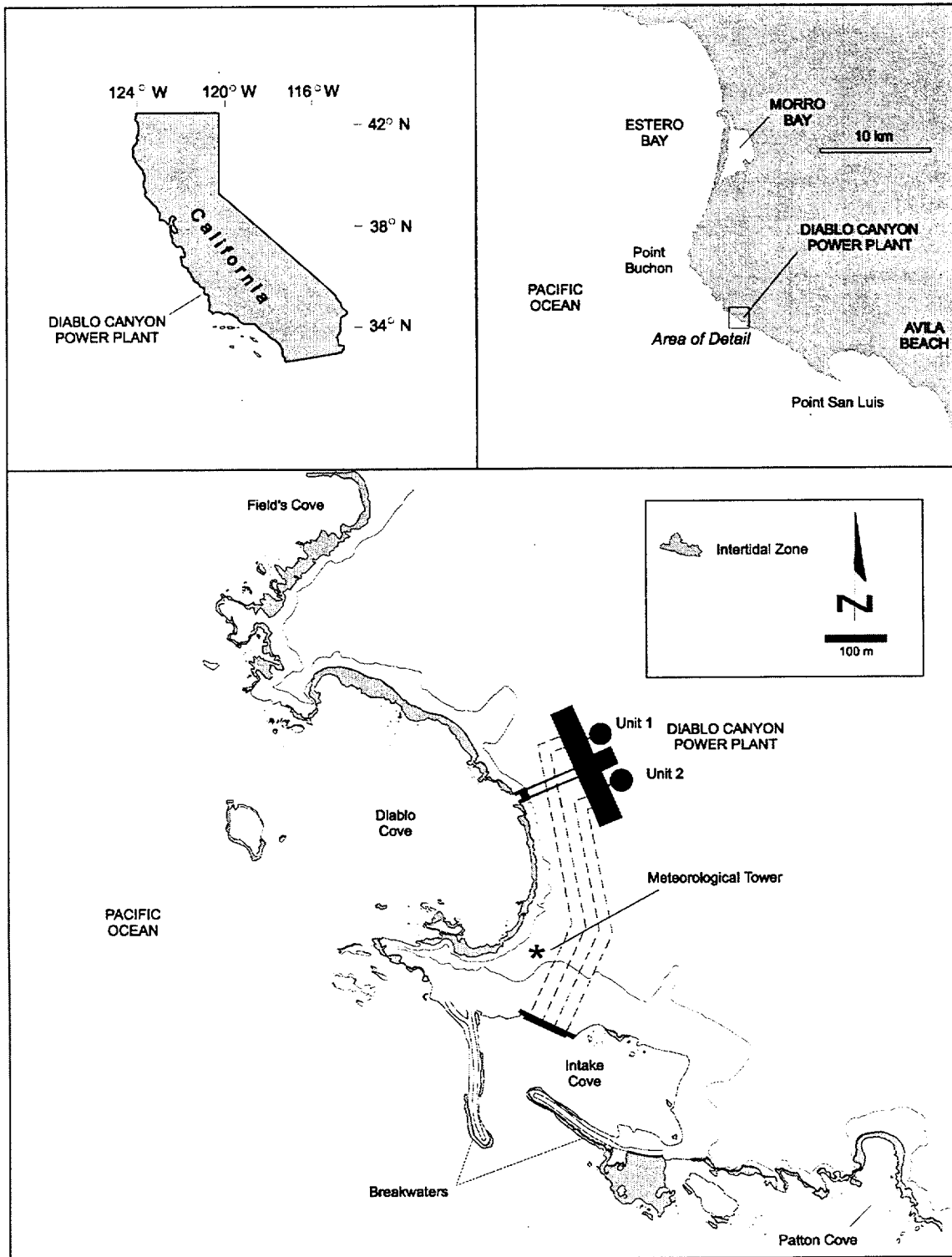


Figure 3-1. Location of Diablo Canyon Power Plant.

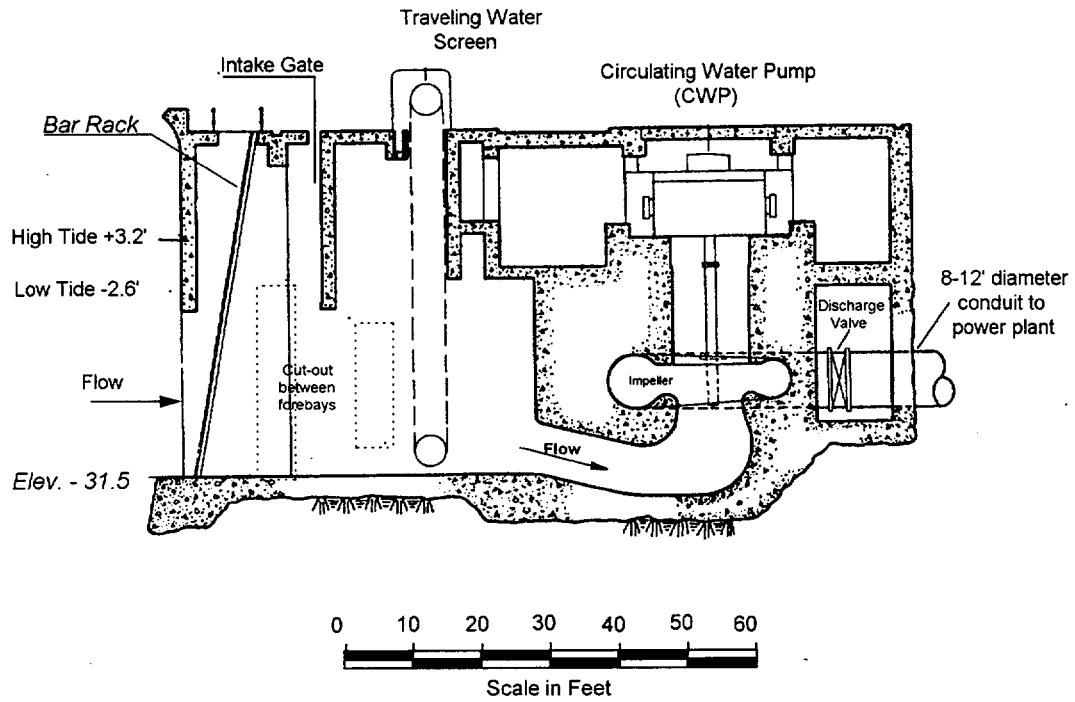


Figure 3-2. Cross-section diagram of DCP intake structure showing water flow path. Elevations are based on mean sea level (modified from PG&E 1988a).

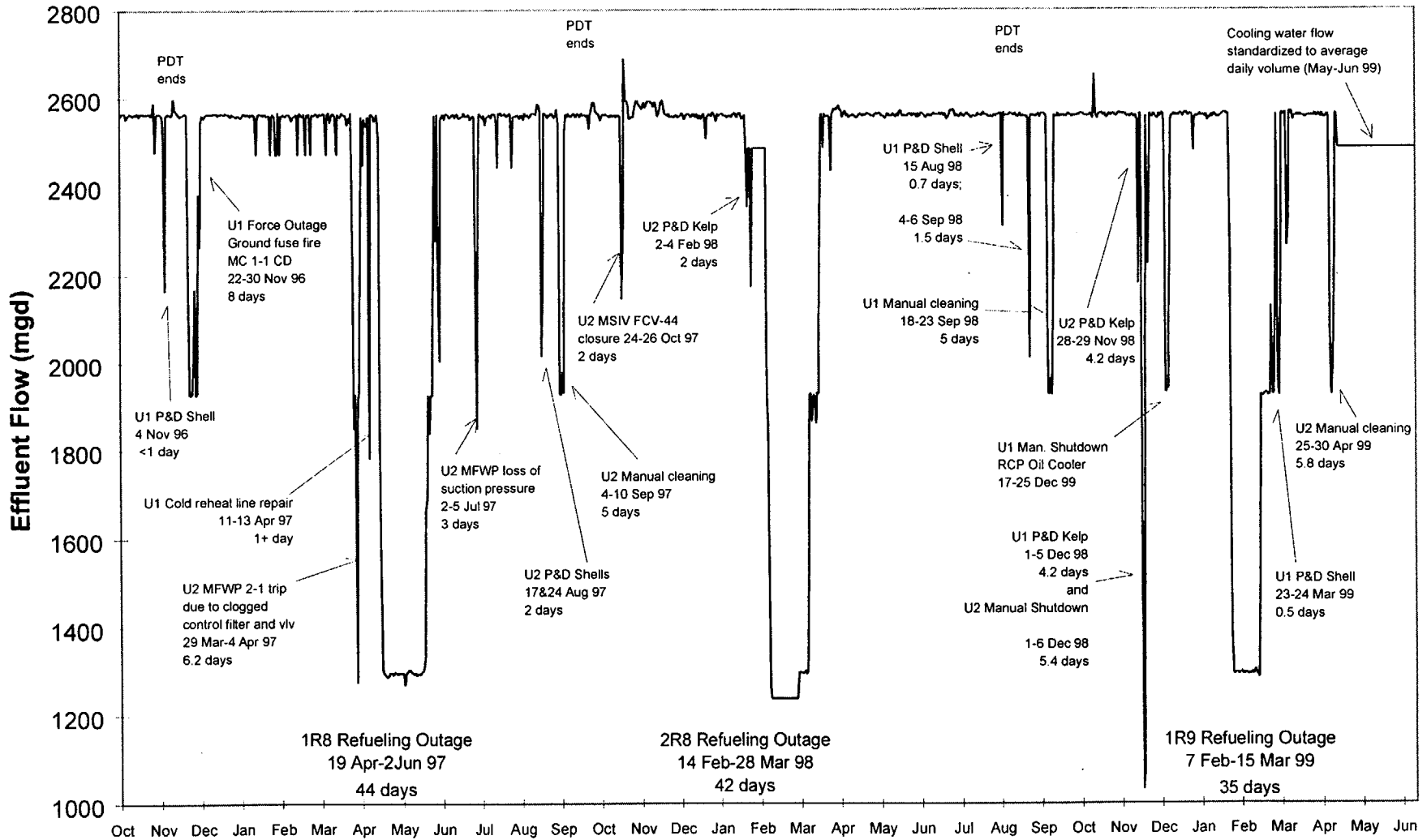
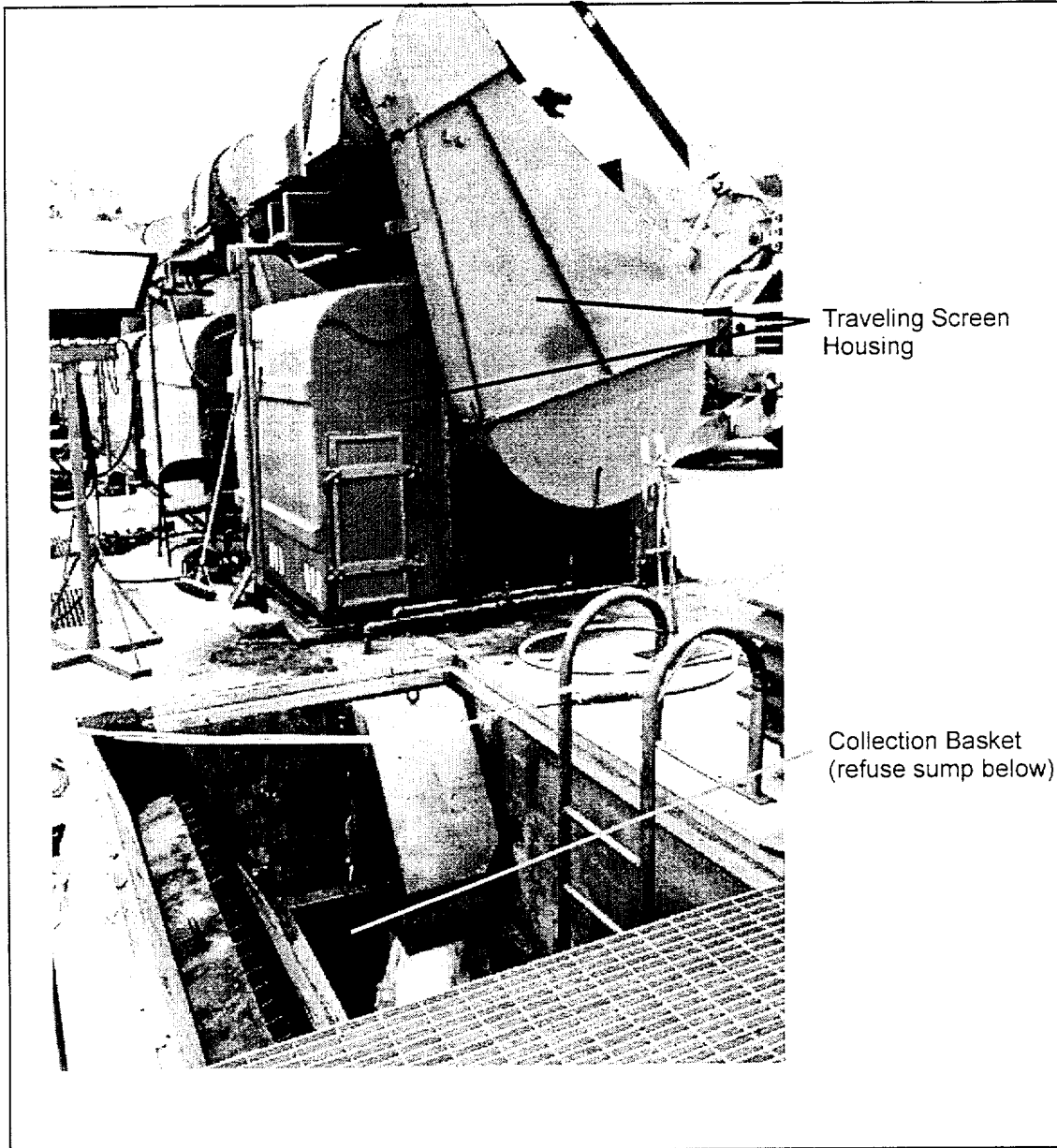


Figure 3-3. DCPD daily cooling water flow - October 1996-June 1999.

Figure 3-4. Unit 1 traveling screen assemblies photographed in 1985 during an impingement collection.



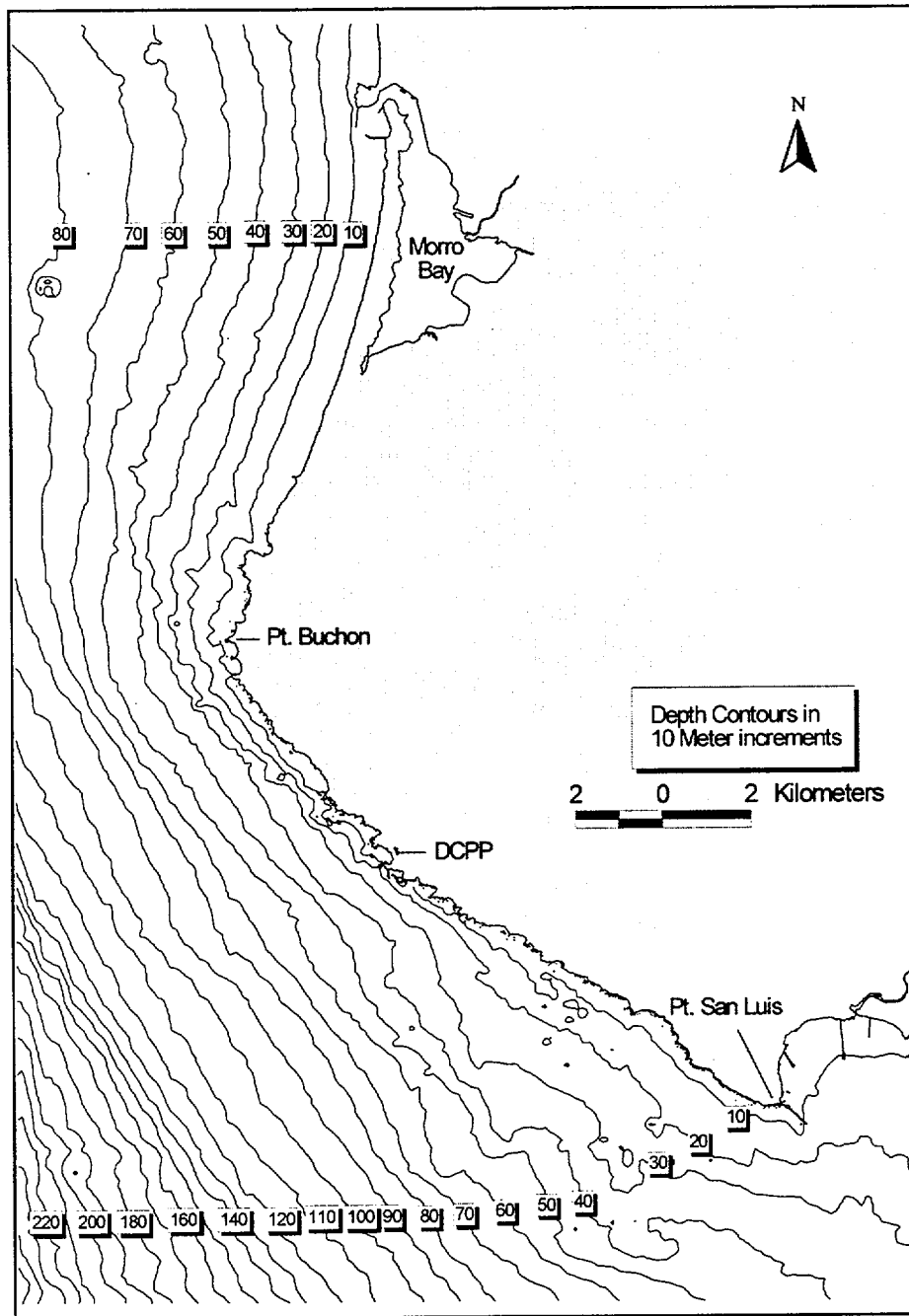


Figure 3-5. Bathymetry of nearshore region between Point Buchon and Point San Luis.

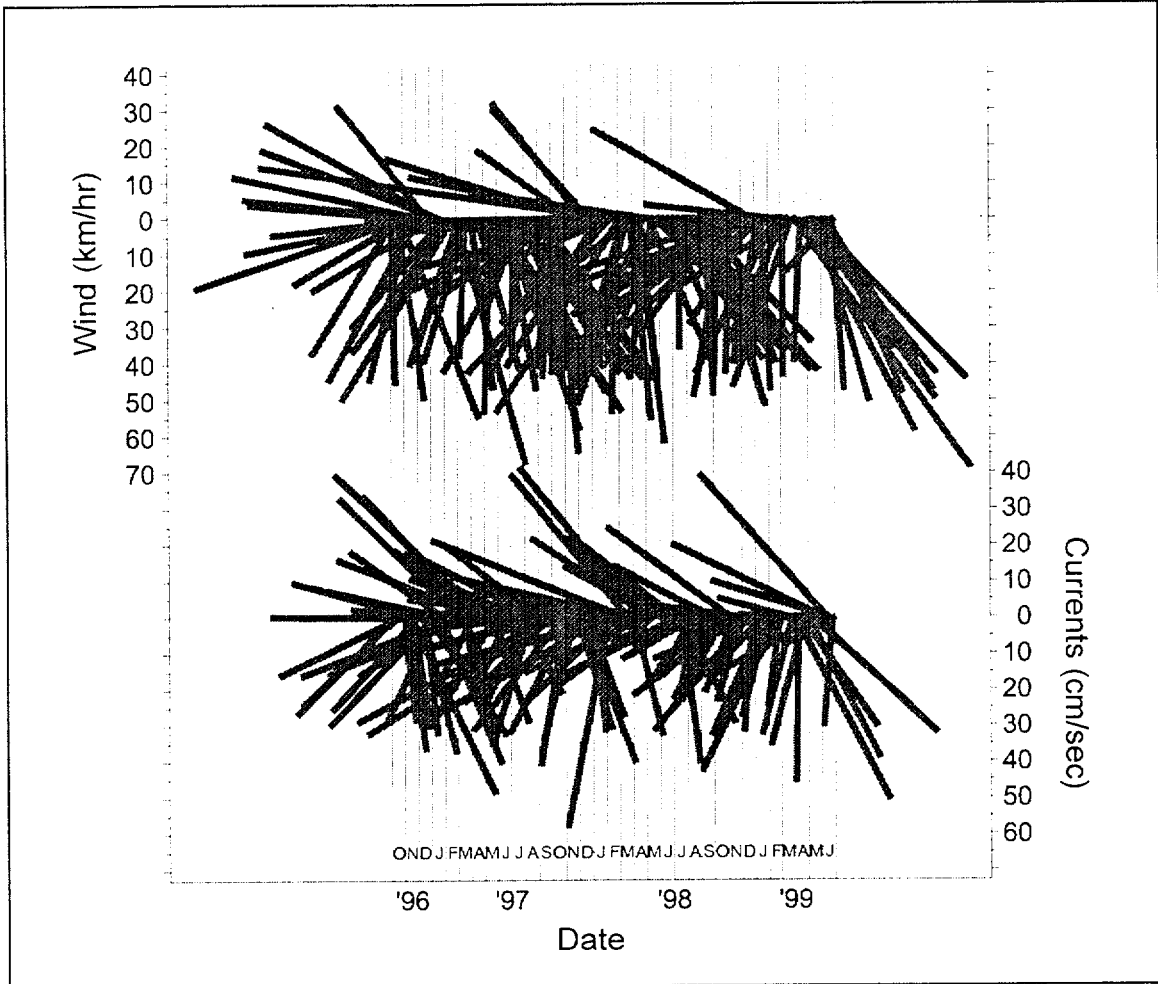


Figure 3-6. DCP wind and water current patterns October 1996 through June 1999.

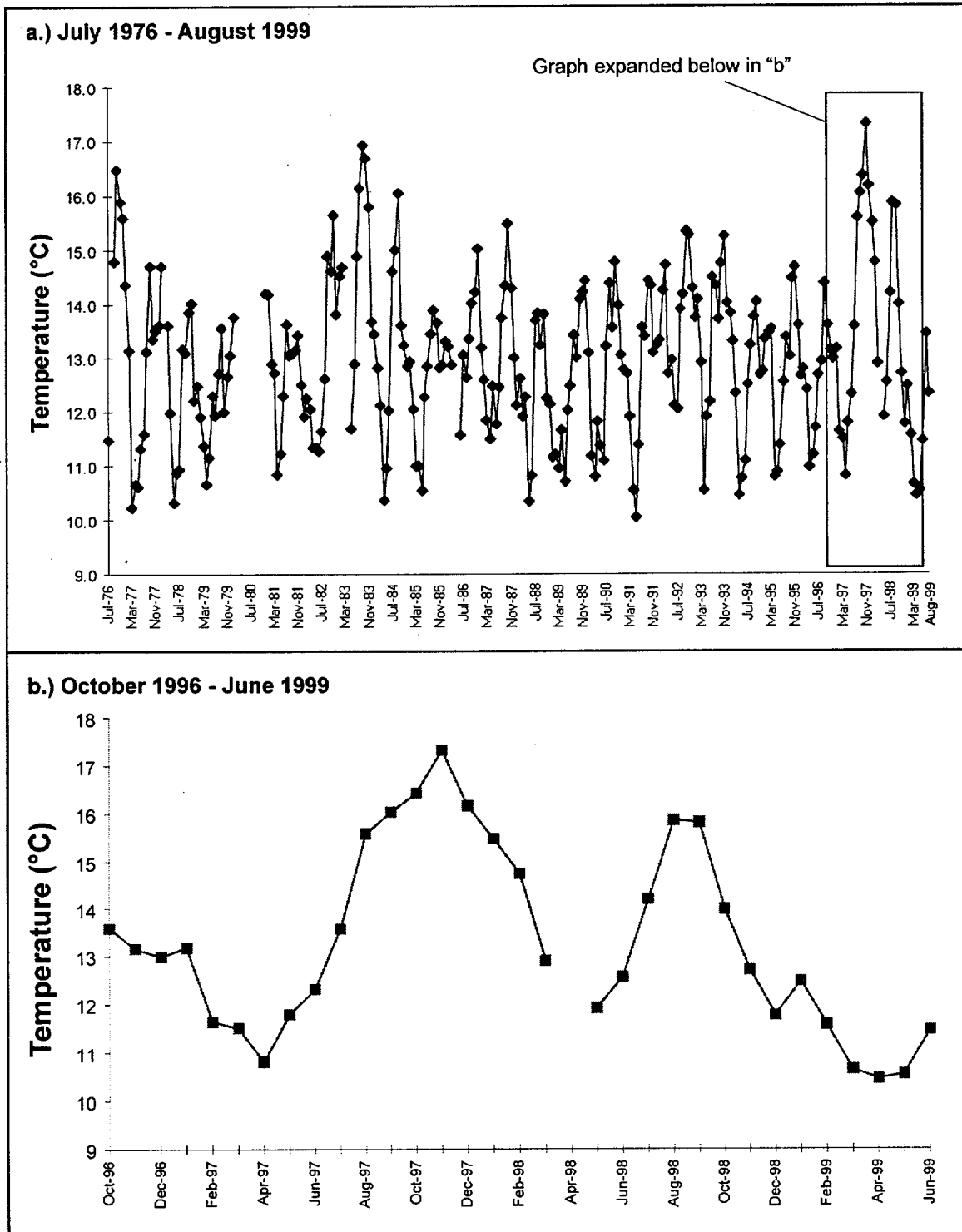


Figure 3-7. Mean monthly seawater temperatures near DCP.

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4.0 METHODS

The Environmental Protection Agency EPA guidance on Section 316(b) demonstrations recognizes that it is not practical to analyze the impacts on all organisms that may be entrained by cooling water intake operations (USEPA 1977). Generally only some groups or species of organisms in the vicinity of a facility are targeted for collection and analysis. Target organisms are those having certain characteristics that make them suitable for detecting or forecasting impacts to an ecosystem under investigation (Cairns and Pratt 1989; Jones and Kaly 1996).

4.1 Criteria for Selection of Target Organisms

The initial criteria used to select appropriate target organisms at DCPD were developed by the Environmental Protection Agency (USEPA 1977). Discussions with the DCPD Entrainment Technical Working Group (ETWG) were instrumental in guiding the use of the criteria at DCPD. Meetings with the ETWG and other invited experts at the Tiburon Impact Assessment Colloquia (October 1996 and October 1998) also helped refine these criteria for application at DCPD. USEPA guidance on 316(b) defines target organisms as those that meet at least one or more of the following criteria:

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

The DCPPE ETWG added three additional criteria for selecting target organisms for the entrainment study at DCPPE:

8. identifiable to the species level;
9. entrained in sufficient abundance to allow for impact assessment, i.e. allowing the model(s) constraints to be met and confidence intervals to be calculated; and
10. having local adult and larval populations (i.e., source not sink species). For example, northern lampfish (*Stenobranchius leucopsarus*), relatively abundant as entrained larvae, is a sink species because it is an offshore and deep water species whose larvae become widely separated from their viable environment and enter coastal waters.

Target organisms meeting these criteria included larval fishes, larval *Cancer* spp. crabs, and larval sea urchin. The final list of target organism taxa (Table 4-1) was determined by the ETWG (May 1999) based mainly on the data collected during this study and the above listed criteria.

Other potential target organism groups reviewed by the ETWG for possible inclusion in this study but subsequently rejected by the ETWG included kelp spores, fish eggs, abalone larvae, squid, and Pismo clams. The risk of a significant impact on adult kelp populations by entrainment of kelp spores was determined to be negligible due to the large number of spores produced along the coast. Additionally, it is not possible to identify the species of kelp based on gametes or spores. Fish eggs were not included because they are difficult to identify and most of the taxa included in the final entrainment evaluation have egg stages that are not likely to be entrained: they either have demersal/adhesive eggs or are internally fertilized and extrude free-swimming larvae. Abalone larvae were not included because they are at low risk from entrainment and cannot be effectively sampled or identified during early life stages when they would be susceptible to entrainment (Tenera 1997b). Young squid are also unlikely to be entrained because they are competent swimmers immediately after hatching. Pismo clam larvae were not included because there is no suitable substrate for settlement in the vicinity of DCPPE, and the duration of their pelagic phase is too short to enable them to reach appropriate settling habitat in significant numbers after spawning in the Diablo Canyon region (Sandra Owen, CDF&G, Long Beach, CA, pers. comm.).

4.2 Entrainment

This section presents a summary of the sample collection and laboratory processing methods. A more detailed presentation of the entrainment and study grid collection methods can be found in

- Appendix A—DCPP 316(b) Demonstration Study: Phase 1, Entrainment Study Design, I. Sampling Location
- Appendix B—DCPP 316(b) Demonstration Study: Phase 1, Entrainment Study Design, II. Selection of Target Organisms, Sampling Methods, and Gear Testing
- Appendix C—DCPP 316(b) Demonstration Study: Phase 3, Sampling Plan and Modelling Evaluation
- Appendix D—DCPP 316(b) Entrainment Study, Field and Laboratory Procedures

Sea urchin larvae were originally chosen by the ETWG as a target organism, but laboratory experiments showed that the early stages of larval urchins are small enough to pass through the 335 μm net mesh. The only urchin developmental stage that appeared to be effectively captured during sampling were metamorphosing and recently metamorphosed individuals. Therefore, the results of the entrainment sampling are presented for metamorphosing and recently metamorphosed sea urchins, but no assessment on the effects to the population is made based on agreement with the ETWG.

4.2.1 Sample Collection

Entrainment and study grid sampling provided data for estimating entrainment abundances and abundances in the nearshore area defined by the study grid. The sampling plans were tailored to the methodology chosen for estimating future adult loss and population mortality. Three methods were chosen, developed fully in **Section 4.4**, and briefly described below.

The estimate of entrainment loss and demographic data, collected from the scientific literature, was used to parameterize two demographic models of entrainment effects: Adult Equivalent Loss (*AEL*) and Fecundity Hindcasting (*FH*). The *AEL* method forecasts the number of adult survivors from the estimated number of entrained larvae, as if they had survived entrainment, using knowledge of mortality rates other than from entrainment by the power plant (i.e., natural

mortality). The *FH* method is similar except that the number of larvae entrained are hindcast to number of eggs, and the number of eggs is then used to estimate the number of female adults that would have produced them. A third method, the Empirical Transport Model (*ETM*), estimates an average annual larval mortality per individual due to entrainment, using estimates of Proportional Entrainment (*PE*), which compares the number of larvae entrained in one day to the number of available larvae in the source water body. A larval mortality is calculated after *PE* is weighted by an estimated fraction of the total population affected and compounded by the time larvae are susceptible to entrainment. The Phase 3 Sampling Plan (Table 2-1 in Tenera 1998a) describes the data required for *AEL*, *FH*, and *PE*.

4.2.1.1 Entrainment Sampling

Collection of the DCPD entrainment samples took place once per week from four permanently moored sampling stations located directly in front of the intake structure (Figures 4-1 and 4-2). Entrainment sampling occurred from October 1996 through June 1999, with details about the number of samples collected per survey presented in Appendix G. Surveys 01 and 02 were not processed because they were used to finalize sampling protocols and only 8 and 34 subsamples were collected, respectively. Therefore, the first complete survey was conducted on October 23, 1996. The four fixed stations were sampled in a random order during each 3-hour survey cycle. Samples were collected over a 24-hour period from a boat moored approximately 10 m from the intake structure using a 0.71 m diameter bongo frame with two 1.8 m long, 335 μm white Nitex™ mesh nets similar to the nets used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). The first 9 surveys were collected with 505 μm , but due to possible extrusion of larval fishes observed in Surveys 8 and 9, subsequent surveys were collected with 335 μm mesh (Tenera 1997b). Surveys 9 and 10 were completed on consecutive days, but only the data from Survey 10 was used in the analyses because samples were collected using the smaller mesh size. The bongo frame and nets were fished from the top to the bottom and back to the surface a total of eight times to filter approximately 40–50 m^3 per net. At the surface, the net was turned as the upper portion of the frame hit the surface and was turned within approximately 13–25 cm of the bottom. The upward vertical lift speed of the nets was held constant at approximately 0.3 m/s

(~0.6 knots) using an electric winch. The downward speed of the nets (0.3–0.45 m/s) was determined primarily by gravity acting on the mass of the bongo frame and the drag resistance of the nets. Each 24-hour sample period was divided into eight 3-hour sampling cycles, with each station being sampled once per cycle. The sample contents of each net were initially preserved separately in either a solution of 5% buffered formalin or 70–80% ethanol. All samples were later transferred to ethanol before laboratory processing. A total of 64 subsamples (32 samples) was collected per day with a total of approximately 2,560–3,200 m³ of water filtered per 24-hour survey period.

4.2.1.2 Study Grid Sampling

Sampling of the study grid was designed to provide the information on abundance and distribution of target organisms in the vicinity of DCPD that is used in the *ETM* assessment. The data from each study grid survey were paired with the corresponding entrainment survey to estimate an index of entrainment loss (*PE*): the ratio between the number of larvae entrained in one day to the number estimated in the study grid over a three day period. The boundaries and shape of the study grid were chosen based on the following criteria:

- the grid would be large enough to characterize the larvae from the target groups potentially influenced by DCPD's cooling water intake operations, and
- the grid would include a representative variety of local nearshore habitats.

In establishing the study grid, the ETWG also considered that ocean currents in the area generally move both up and down the coast past DCPD. Currents also show inshore/offshore oscillations, but these occur less frequently and generally at a lower magnitude (Section 3.2.2). The study grid contained 64 cells in an eight cell by eight cell pattern (Figure 4-3) and was centered on the Intake Cove at DCPD. The northern extent of the grid was near Point Buchon and the southern half, a mirror image of the northern portion, extended to Point San Luis. The coastline between Point Buchon and Point San Luis makes a slight bend (approximately 20°) northward at DCPD. Tangents along the coastline from the tip of the west breakwater at DCPD defined the inshore margins of the study grid at 321° True (NW) and 121° True (ESE). The grid extends a distance of

8.7 km to both the north and south at an average distance of 3 km offshore. Lines dividing the study grid into eight partitions ran SSW (221° True) to a distance of 2.7 km offshore of the inshore margin. Regions inshore of the study grid dimensions were in shallow water with partially submerged rocks, making the areas unsafe for boat operations and sampling.

The study grid was sampled monthly from July 1997 through June 1999. Two randomly positioned stations within each of the 64 cells of the grid were sampled using a 0.71 m diameter standard CalCOFI-style bongo frame with two 3.3 m long, 335 μm white Nitex™ mesh nets. The study grid was sampled continuously over 72 hours using a “ping-pong” transect to limit temporal and spatial biases in the sampling pattern and to optimize shipboard time (**Figure 4-4**). The starting cell (constrained to the 28 cells on the perimeter of the grid) and the initial direction of the transect (constrained to the two cells diagonally, adjacent to the starting cell) were selected at random. When the adjacent diagonal cell had previously been sampled (e.g., cell D1 in **Figure 4-4**), one of the two adjacent cells in the direction of travel (E1 or E3) was randomly selected to be sampled next.

Nets were fished in an oblique fashion following CalCOFI protocol (Smith and Richardson 1977). The sampling depth was limited to within 3 m of the bottom depth to avoid damage or loss of sampling equipment and for safe operation of the vessel. Had larval fishes been concentrated in the 3 m near bottom, this sampling method would not detect them leading to underestimates of larval density that would increase estimates of *PE*. Two stations were sampled per grid cell with the station locations for each monthly survey being randomly-positioned, latitude/longitude coordinates within each cell. The random position of latitude and longitude for each grid cell station was generated using Microsoft Excel™ macro code, designed to randomly select polar coordinates and to convert these coordinates to a Mercator Projection system used for navigational purposes. Latitude and longitude positions were located in the field using a Micrologic™ Global Positioning System (GPS) plotter.

A total of 256 subsamples was collected during each 72-hr survey. At the end of each haul, the material collected in one bongo net was fixed in 5% buffered formalin for abundance and

composition analyses. The material in the second net was fixed in about 70–80% ethanol (ETOH) to be archived for possible future use in larval fish age and growth analyses. To minimize temporal variation between entrainment and study grid sampling, grid surveys were scheduled to bracket the 24-hour entrainment survey, overlapping by one day before and after the collection of entrainment samples. The paired sampling from July 1997 was an exception to this design, i.e. entrainment sampling occurred during the first 24 hours of the 72-hour grid survey.

4.2.1.3 Intake Cove Surface Plankton Tow Sampling

Weekly plankton samples were collected in the DCPD Intake Cove during the following periods: February 1990 through June 1990, January 1991 through June 1991, and then continuously from September 13, 1991 to the present. Three samples were collected at dawn once per week by towing a 0.5 m diameter, 335 μm mesh standard plankton net in front of the intake structure to a location approximately even with the outer end of the west breakwater (Figure 4-5). The net was towed at a depth of about 1 m below the surface. Water flowing into the net was measured by a calibrated flowmeter. Approximately 40–50 m^3 of water was filtered per tow. The samples were preserved in 5% buffered formalin and later transferred to 80% ethanol. These samples were only processed for larval fishes.

4.2.2 Laboratory Processing

Laboratory sample processing procedures used during this study are presented in Appendix D. All larval fishes and the megalopal stages of *Cancer* spp. were sorted from either 32 or 64 subsamples (four to eight per cycle) from each entrainment survey and from the formalin-preserved grid survey samples (two per cell). One of the two paired bongo nets represents a dependent subsample such that both to the paired nets comprise the complete sample or tow. The estimate of the mean larval density calculated after processing only 32 subsamples was on average similar to the estimate for all 64 subsamples (Tenera 1998b: Appendix E). All *Cancer* zoeal stages and juvenile urchins were sorted from one randomly selected entrainment sample from each of the 3-hour cycles, resulting in eight samples processed per sampling day. The zoea

and urchins, sorted from the samples collected in the grid, were processed from one sample per cell for only two of the total number of surveys performed in the grid.

Due to the large number of zoea and urchins, most samples were split before processing. Density estimates were calculated for each sample based on the number of individuals of each taxon and the volume of water filtered. For split samples, the density was mathematically adjusted for the level of splitting. For example, when a sample was divided into eight parts and one part was sorted, the number of each of the larval stages identified and enumerated was multiplied by eight to estimate the number in the sample.

Not all of the target organism groups were sorted from all of the entrainment and grid survey samples, per agreement with the ETWG (**Figure 4-6**). Larval fishes were sorted from weekly entrainment samples from surveys collected from October 1996 through September 1998 and from surveys that paired with the grid surveys for the period of October 1998 through June 1999. *Cancer* crab megalops were sorted from entrainment samples collected from October 1996 through June 1999. *Cancer* crab zoea and metamorphosing and recently metamorphosed sea urchins were sorted from entrainment surveys collected from December 1996 through June 1998. Samples during October and November 1996 were not sorted for zoea and urchins because these samples were collected with 505 μm mesh nets and these organisms could possibly have been extruded through the mesh, resulting in underestimates of their density. These samples were used for larval fish and megalops because their generally larger size would lessen the chance of extrusion. Larval fishes and *Cancer* crab megalops were processed from two samples per cell during all of the grid surveys. As previously mentioned, *Cancer* crab zoea and metamorphosing and recently metamorphosed sea urchins were processed only from one sample per cell during surveys collected in March and April 1998.

An on-site quality control program ensured that each of the sorters maintained a high level of accuracy in identifying target taxa in the samples. This program employed both on-site and off-site personnel to verify the identification and enumeration of the collected organisms. All data pertaining to the collection and laboratory processing of each of the samples were tracked using a

computer database. The procedures used in laboratory processing, identification, and quality control are included in **Appendix D**.

A variety of general and specific references were used to identify the collected individuals. The larvae of several species in the DCPD area are at present poorly known or undescribed. Larvae for several taxa could only be identified into higher taxonomic categories, such as genus (e.g. *Gibbonsia* spp.) or family (e.g. Cottidae). Identification for larvae of the rockfishes (genus *Sebastes*) was especially troublesome. At least 72 species and 11 subgenera of rockfish live along the eastern Pacific coast of North America (Moreno 1993). Because of relatively recent speciation in this genus, many larval characteristics are shared over a wide range of species, making identification within this genus problematic (Moser et al. 1977; Moser and Ahlstrom 1978; Baruskov 1981; Kendall and Lenarz 1987; Moreno 1990; Nishimoto in prep.).

Identification of larval rockfish to the species level relies heavily on pigment patterns that change as the larvae develop. Currently, at least 5 of these 72 species can be reliably identified to the species level at larval developmental stages. They are the blue rockfish (*Sebastes mystinus*), shortbelly rockfish (*S. jordani*), cowcod (*S. levis*), bocaccio (*S. paucispinis*; Yoklavich et al. 1996), and striptail rockfish (*S. saxicola*; Laidig et al. 1995). Other species within this genus can only be resolved to broad sub-generic groupings based on pigment patterns (Nishimoto in prep.). **Table 4-2** presents the rockfish pigment groups used in this study and the species reported in each group.

Crab larvae also are sometimes difficult to separate to species. The first zoeal stage of brown rock crab (*C. antennarius*), yellow crab (*C. anthonyi*), and slender crab (*C. gracilis*) is similar in appearance; consequently, these species could not be separated at this stage. When these species metamorphose to the second zoeal stage, however, individual characteristics develop that allow their correct classification. Therefore, in calculating *FH* models for the two species of *Cancer* crabs, the proportion of the two species for zoeal stage II was assumed to be the same for the first zoeal stage. This ratio was used to estimate the numbers of zoeal stage I larvae for the two species. The species of a few individual megalops and zoea could not be determined; therefore, identification of these individuals was left at the genus level, *Cancer* spp.

Lengths of the larval fish target taxa were measured using a computer imaging system. A quality assurance program for the operators of the system was conducted. Larvae from both entrainment and study grid samples were measured.

4.3 Impingement

An impingement study at DCPD was conducted from February 1985 through March 1986 to provide information on

- taxonomic composition and abundance of impinged organisms
- size of impinged fishes and selected macroinvertebrates
- diel and seasonal patterns of impinged organisms, and
- sex ratio and degree of gonadal maturity of selected impinged species.

Impingement samples were collected once per week for a continuous 24-hr period. A requirement for sampling was that at least one of the two cooling water pumps (CWP) per unit be operating for the entire 24 hr. At times, collections were postponed because of equipment testing or maintenance that may have prevented the collection of a complete 24-hr period. When possible, the sampling was re-scheduled for later the same week. Samples were not collected when kelp accumulation caused the collection baskets to overflow, potentially leading to a loss of organisms and inaccurate estimates of impingement rates.

On a collection day, the traveling screens were rotated initially to ensure that they were clean before the sampling began. The troughs were also cleaned of all accumulated debris and organisms. The screens remained stationary for approximately 3.75 hr and then rotated and rinsed for 15 min. The impinged material was rinsed into the troughs and collected in metal baskets made of 0.635 cm steel mesh. All impinged material was removed from the baskets after each of these 4-hr periods (cycles), except during times of heavy kelp accumulation when the screens operated continuously. During continuous screen rotation the screen wash system was stopped, when possible, for 15 min per cycle to allow for the removal of the samples from the baskets. The

impinged material from each unit was kept separate. All organisms were removed from the impinged material and returned to the laboratory for processing. A quality control program verified that all organisms were removed during the sorting process.

All fishes and selected invertebrates were identified to the lowest practical taxonomic category, counted, measured, and weighed. Invertebrates that were measured and weighed included caridean shrimps, decapod and pelagic red crabs, cephalopod molluscs, rock scallops, and sea urchins. All other invertebrates were recorded as either individual counts or as present and were not measured nor weighed. A quality control program ensured the accuracy of the data.

It was assumed that all impinged organisms would not survive. Studies at other power plants where impingement losses are high normally combine impingement losses for a taxon with other projected adult losses from estimated entrainment. We did not combine impingement with estimates of projected entrainment losses because of the low impingement rate at DCPD and the time difference between the two studies. The results of the impingement study are included in the DCPD 316(b) Study Phase 3: Sampling Plan and Modelling Evaluation (Tenera, 1998a; Appendix C), and impingement methodology is not described further.

4.4 Description of Entrainment Analytical Methods

The entrainment and study grid surveys were divided into annual periods for analysis (Figure 4-6). The entrainment surveys were divided into three analysis periods:

- Period 1—October 23, 1996 through September 30, 1997
- Period 2—October 1, 1997 through September 30, 1998
- Period 3—July 1, 1997 through June 30, 1998

Data for Period 3 were previously analyzed by Tenera (1999b), Preliminary Assessment of Entrainment Effects on Target Fish and Crab Taxa (July 1, 1997–June 30, 1998). Analysis Period 3 overlaps Periods 1 and 2. It is presented here as the entrainment data for this time interval is used in the calculation of *PE* which is used in the *ETM*, which allows a comparison of *FH*, *AEL*

and *ETM* calculations for the same 12 month time interval. Analysis for zoea for Period 1 was adjusted to December 1, 1996 through November 30, 1997 because the samples from October and November 1996 were collected with a larger mesh net and not analyzed for crab larvae.

Larval densities from samples collected during Periods 1, 2, and 3 were used to calculate the total number of larvae entrained and project adult losses using *FH* and *AEL* methodology. The grid surveys were divided into two analysis periods for the purpose of providing two annual estimates of larval mortality based on the *ETM* methodology. The monthly grid and paired entrainment surveys for these 2 analysis periods are as follows:

- Period 3—July 1, 1997 through June 30, 1998
- Period 4—July 1, 1998 through June 30, 1999

The Intake Cove surface plankton tows were processed only for the consecutive seven month period of December through June, per agreement with the ETWG (**Figure 4-6**), as the peak in larval ichthyoplankton is generally during these months. These samples were processed only for larval fishes. These data were used to adjust the number of larvae entrained during a year to a long-term average that was more likely to represent average effects.

4.4.1 Total Annual Entrainment

The density of each of the target organisms in the entrainment samples was used to estimate the total annual larval entrainment for each taxa (\widehat{E}_T). Daily entrainment estimates and their variances were derived from the mean density of larvae (number of larvae per cubic meter of water filtered) and calculated from the 32 samples collected during each 24-hr entrainment survey, using the methods described in the Phase 3 report (Tenera 1998a). In the few instances where the measured volumes in each paired net differed by more than 20%, the higher value was used under the assumption that one of the paired flowmeters had slowed due to kelp fouling, improper lubrication, or misalignment. Density estimates were multiplied by the DCPD daily intake flow volume to obtain the number of larvae entrained per day. The daily intake flow volume was calculated by multiplying the number of hours of operation of each of the pumps by

their rated design flow rate. One hundred percent mortality was assumed for all entrained organisms. To estimate weekly entrainment, the number of days that each sampling event represented was determined by setting the sampling date at the mid-point between sample collections. The daily cooling water intake volumes were then used to calculate entrainment for the period by summing the product of the entrainment estimates and the daily intake volumes for each approximate weekly period. These weekly estimates and their associated variances were then added to obtain annual estimates of entrainment and variance for each taxa.

The annual estimate of entrainment (\widehat{E}_T) was calculated by adding a weekly entrainment estimate that was the daily entrainment estimate multiplied by the weekly volume of intake cooling water:

$$\widehat{E}_T = \sum_{i=1}^{52} \left(\frac{V_i}{v_i} \right) \widehat{E}_i \quad (1)$$

where

v_i = intake volume on the survey day of the i th weekly period ($i=1, \dots, 52$)

V_i = total intake volume for the i th weekly period ($i=1, \dots, 52$)

\widehat{E}_i = the estimate of daily entrainment during the entrainment survey of the i th weekly period.

The variance of \widehat{E}_T was estimated as

$$\widehat{Var}(\widehat{E}_T) = \sum_{i=1}^{52} \left(\frac{V_i}{v_i} \right)^2 \widehat{Var}(\widehat{E}_i), \quad (2)$$

using the sampling variances of entrainment on the survey day of the i th weekly period, $\widehat{Var}(\widehat{E}_i)$.

Equation 2 will underestimate the true variance because it does not incorporate the variance associated with the within-week ratio estimator

$$\frac{V_i}{v_i} = \frac{\widehat{E}_{T_i}}{\widehat{E}_i},$$

where \widehat{E}_T is the estimated total entrainment for the i th week. It also does not incorporate daily variations in intake flow due to waves, tide, and other factors not measured by the power plant.

As recommended by the ETWG, the estimates of annual entrainment were scaled to better represent long-term trends for a taxa by using data from Intake Cove surface plankton tows collected at DCP, starting in 1990. These data provide an index of annual trends in larval abundance for the period of 1990–1998. This multi-year annualized index consists of five months (February–June) of larval fish density estimates in 1990, six months (January–June) in 1991, and seven months (December–June) in all subsequent years. The estimated annual entrainment was adjusted to the long-term average by the equation

$$\hat{E}_{Adj-T} = \widehat{E}_T \cdot \left(\frac{\bar{I}}{I_i} \right) \quad (3)$$

where

\hat{E}_{Adj-T} = adjusted estimate of total annual entrainment to a long-term average, 1990–1998,

I_i = index value from DCP Intake Cove surface plankton tows in the i th year, and

\bar{I} = average index value from DCP Intake Cove surface plankton tows, 1990–1998.

The variance for adjusted annual entrainment can then be expressed as

$$\widehat{Var}(\hat{E}_{Adj-T}) = \widehat{Var}(\widehat{E}_T) \cdot \left(\frac{\bar{I}}{I_i} \right)^2, \quad (4)$$

assuming the indices are sampled without error. Ignoring the sampling error of the indices will underestimate the true variance, but Equation 4 will account for the change in scale associated with multiplying the annual entrainment estimate by a scalar. The variance of \hat{E}_{Adj-T} , however, does not take into account the between-day, within-stratum variance, interannual variation, nor the variance associated with the indices used in the adjustment. Hence, the actual variance of the \hat{E}_{Adj-T} estimate is greater than the value expressed above.

The Intake Cove surface tow index was assumed to have the relationship

$$E(I_i) = C \cdot E_i$$

where

$E(I_i)$ = expected value of the index for the i th year,
 E_i = entrainment for the i th year, and
 C = proportionality coefficient.

If this relationship holds true, then the interannual variance in the index has the relationship

$$\text{Var}(I_i) = C^2 \text{Var}(E_i).$$

Therefore, the coefficients of variation (CV) for \bar{I} and \bar{E} across n years have the relationship

$$CV(\bar{I}) = \frac{\sqrt{\frac{\text{Var}(I)}{n}}}{\bar{I}} = \frac{\sqrt{\frac{C^2 \text{Var}(E)}{n}}}{C\bar{E}} = CV(\bar{E}).$$

Hence, the CV for the Intake Cove surface tow index should be a measure of the CV for entrainment across years. In the case of estimates of \hat{E}_i and \hat{I}_i , the variances include sampling errors that may not be equal. Therefore, the CV of \hat{I} was used to express the possible variation in entrainment across years.

The use of adjusted entrainment in the *FH* and *AEL* models provides results that represent average long-term effects. The CV for \hat{I} was used in propagating the variances of the entrainment effects and calculating the ranges of possible values for *FH* and *AEL* in sensitivity analyses. Sensitivity analyses were used to examine the effects of different input parameters on model results.

Adjusted entrainment values were not used in calculating *ETM* results because the computation of *ETM* relies on a proportional entrainment (*PE*) ratio using estimates from paired entrainment and nearshore larval sampling. Moreover, if the assumptions of the *ETM* are valid, then the estimate already represents average long-term entrainment effects. Using adjusted entrainment in the *FH* and *AEL* models provides a better basis to compare results from all three models when

they are converted into a common currency through the use of population or fishery stock assessments.

The length frequency distributions for the measured larvae from the paired entrainment and study grid surveys were tested for differences using a Kolmogorov-Smirnov 2 sample test (Zar 1984). Large differences between the two distributions may indicate that the age distribution of entrained larvae is significantly different from the source population in the study grid. The mean larval lengths from the two distributions were tested for differences using a two-sample *t*-test. When variances were unequal between the two groups, Satterthwaite-adjusted degrees of freedom were used in the test (SAS Institute 1990). The statistical power of these tests to detect very small differences between the two groups will be very high because of the large sample sizes (Zar 1984).

4.4.2 Fecundity Hindcasting (FH)

The *FH* approach combines larval entrainment losses with adult fecundity to estimate the amount of adult female reproductive output eliminated by entrainment, assuming no compensatory reserve of the population. The loss of reproductive output (i.e., numbers of larvae) was used to hindcast the numbers of adult females possibly removed from the reproductively active population. These *FH* estimates require data on age-specific mortality from the egg and early larval stages up to entrainment. The fact that *FH* requires survivorship from a relatively short period of time (i.e., egg to larva) is an advantage of this approach. Fecundity and mortality from sources other than entrainment are integrated into an estimate of loss by converting the estimated number of entrained larvae backwards to reproductively active females (i.e., hindcasting). *FH* does not require additional sampling other than from the entrainment intake water, for estimates of larval abundance. These advantages may be offset by the need to (1) obtain or model age-specific mortality rates and total lifetime fecundities to predict the adult losses, and (2) secure information on the size of the adult population of interest to estimate population-level effects (i.e., relative losses). Therefore, the method was only used for those taxa where the minimal data of item (1), above, were available. With the broad generalization of ignoring any population

reserve (compensation), entrainment losses can be interpreted as population level impacts when *FH* estimates are applied as direct losses to an inferred population.

4.4.2.1 Formulation

The estimated total larval entrainment for a species (\widehat{E}_T) was used to estimate the number of breeding females needed to produce the number of larvae entrained. The estimated number of breeding females (\widehat{FH}) whose fecundity was equal to the estimated total loss of entrained larvae is calculated as follows:

$$\widehat{FH} = \frac{1}{\widehat{F}_T} \sum_{i=1}^w \frac{\widehat{E}_{T_i}}{S_i} \quad (5)$$

where

- w = number of weeks the larvae are vulnerable to entrainment,
- \widehat{E}_{T_i} = estimated total entrainment for the i th weekly survey period ($i = 1, \dots, w$),
- S_i = survival rate from eggs to larvae of the stage present in the i th weekly survey period, and
- \widehat{F}_T = average total life time fecundity for females, equivalent to the average number of eggs spawned per female over their reproductive years.

Equation 5 is based on the simplified case of a single synchronized spawning by a species. For species with overlapping or continuous spawning, larval abundance would have to be specified by week and age class (i.e., \widehat{E}_{ij}). However, we used the mean size of all larvae entrained at DCPD to estimate a representative age of larvae, and then estimated a survival rate to this representative age. Two input parameters in Equation 5 that may not be available for many species, and thus may limit the method, are average fecundity (\widehat{F}_T) and survival rates (S_i) from spawning to entrainment.

Larval age (duration from release or hatching to entrainment), needed for estimating survival, was calculated from growth rates and the minimum and mean size at entrainment. Estimates of growth rate appear in **Table 4-3**, and their use in survival estimation is discussed further when applied to specific taxa.

Adjusted annual entrainment can be incorporated in the FH method (Equation 5), assuming that average rates of survival are the same among years and study periods:

$$\widehat{FH} = \frac{\widehat{E}_{Adj-T}}{\prod_{j=1}^n \widehat{S}_j \cdot \widehat{F}_T} \quad (6)$$

where

\widehat{S}_j = age specific survival of eggs and larvae for the j th age class ($j = 1, \dots, n$) and

\widehat{F}_T = expected number of eggs produced in a reproductive lifetime.

In practice, survival was estimated by either one or several age classes, depending on the data source, to the estimated age at entrainment. The expected total lifetime fecundity \widehat{F}_T was approximated by the expression

$$\begin{aligned} \widehat{F}_T &= \text{Average eggs/year} \cdot \text{Average number of years of reproductive life} \\ &= \text{Average eggs/year} \cdot \left(\frac{\text{Longevity} - \text{Age at maturation}}{2} \right). \end{aligned} \quad (7)$$

The expected length of reproductive life was approximated as the midpoint between the times of maturation and longevity. This approximation was based on the assumption of a linear survivorship curve between these events (i.e., uniform survival). For exploited species such as northern anchovy and sardine, the expected number of years of reproductive life may be much less than predicted using this assumption. Therefore, the estimated longevity was based on the oldest observed individual caught by the fishery, rather than by the oldest recorded fish. Simulation, comparing exponential survival, shows that the calculation of \widehat{F}_T will be negatively biased for species with short reproductive lifespans, and positively biased for those with longer durations.

The variance of \widehat{FH} was approximated by the Delta method (Seber 1982):

$$\widehat{Var}(\widehat{FH}) = (\widehat{FH})^2 \left[CV^2(\widehat{E}_{Adj-T}) + \sum_{j=1}^n CV^2(\widehat{S}_j) + CV^2(\widehat{F}) + \left(\frac{\widehat{Var}(A_L) + \widehat{Var}(A_M)}{(A_L - A_M)^2} \right) \right]$$

where

$CV(\widehat{E}_{Adj-T})$ = CV of adjusted estimated entrainment (estimated by $CV(\widehat{I})$ when available),

$CV(\widehat{S}_j)$ = CV of estimated survival of eggs and larvae up to entrainment,

$CV(\widehat{F})$ = CV of estimated average annual fecundity,

A_M = age at maturation, and

A_L = age at maturity.

The behavior of estimator 7 for FH appears log-linear, suggesting that an approximate confidence interval can be based on the assumptions that $\ln(\widehat{FH})$ is normally distributed and uses the pivotal quantity

$$Z = \frac{\ln \widehat{FH} - \ln FH}{\sqrt{\frac{\widehat{Var}(FH)}{\widehat{FH}^2}}}$$

A 90% confidence interval for FH was estimated by solving for FH and setting Z equal to ± 1.645 , i.e.

$$\widehat{FH} \cdot e^{-1.645 \sqrt{\frac{\widehat{Var}(FH)}{\widehat{FH}^2}}} \text{ to } \widehat{FH} \cdot e^{+1.645 \sqrt{\frac{\widehat{Var}(FH)}{\widehat{FH}^2}}}$$

4.4.2.2 Sensitivity Analysis

In addition to calculating a confidence interval, a sensitivity analysis was performed where \widehat{FH} was recomputed by varying each input parameter ($\hat{\theta}$) and using an additive error model for the entrainment parameter (\widehat{E}_T or \widehat{E}_{Adj-T}) of $\pm 1.645 \widehat{SE}(\theta)$ and using a multiplicative error model for the remaining parameters. The CV for \widehat{I} (i.e. the average surface tow index across years) was used in propagating the variances of the adjusted entrainment estimate for calculating the ranges of possible values for \widehat{FH} in the sensitivity analyses. An assumed CV of 1.0 (100%) was used in

calculating the other parameter estimates as $\hat{\theta} e^{\pm 1.645 CV(\hat{\theta})}$. This approach helps to identify how the parameters' variability influences \widehat{FH} . In addition, the following constraints to the modified parameter estimates were applied to assure reasonable ranges:

- Survival ≤ 1
- Age at maturity \geq one-half the original estimate of age at maturity
- Age at maturity \leq the age half way between the original estimates of age at maturity and longevity
- Longevity \geq the age half way between the original estimates of age at maturity and longevity
- Longevity \leq twice the original estimated longevity

4.4.2.3 Assumptions

Fecundity hindcasting calculations assume the following:

- Values of parameters from the literature represent the population parameters for the years and location of the Diablo Canyon study.
- No population reserve or compensation counters entrainment mortality.
- Reported values of egg mass are lifetime averages in order to calculate an unbiased estimate of lifetime fecundity.
- Reproductive life expectancy can be accurately calculated by assuming that time of death is uniformly distributed between age-at-maturation and age-of-longevity.
- Juvenile and egg survival rates are constant over time.
- The loss of the reproductive potential of one female is equivalent to the loss of an adult female.

4.4.3 Adult Equivalent Loss (AEL)

The *AEL* approach uses estimates of the abundance of entrained or impinged organisms to forecast the loss of equivalent numbers of adults. The approach requires survival estimates (had the larvae not been entrained) from entrainment to an age at recruitment to the adult population. This model and the *FH* model both translate larval entrainment mortality into adult fish losses, which are familiar units to resource managers. Although *AEL* methodology does not require estimates of larval abundance in water volumes other than at the power plant intake, this advantage may be offset by (1) the need to obtain or model age-specific survival rates to predict

the adult equivalent losses and by (2) the need for information on the size of the adult population of interest to estimate relative population effects. Similar to *FH* methodology, with an assumption that any population reserve (compensation) that could account for the entrainment loss is lacking, entrainment losses yield population level impacts when *AEL* estimates are interpreted as direct losses to an inferred population.

4.4.3.1 Formulation

Starting with the number of age class j larvae entrained (\widehat{E}_j), it is conceptually easy to convert these numbers to an equivalent number of adults lost (\widehat{AEL}) at some specified age class from the formula:

$$\widehat{AEL} = \sum_{j=1}^n \widehat{E}_j \widehat{S}_j \quad (8)$$

where

n = number of age classes,

\widehat{E}_j = estimated number of larvae lost in age class j , and

\widehat{S}_j = survival rate for the j th age class to adulthood (Goodyear 1978).

Age-specific survival rates from larval stage to recruitment into the fishery (through juvenile and early adult stages) must be included in this assessment method. For some commercial species, survival rates are known for adults in the fishery; but for most species, age-specific larval survivorship has not been well described.

When age-specific survival rates from larval stage to recruitment into the fishery were available, *AEL* was calculated using survival from a representative age of the entrained larvae at DCP. This age was calculated by dividing the average larval length at entrainment (minus hatch length) by a literature-based growth rate (Table 4-3). Age-specific survivorship for any interval of time (t) was then calculated following the formula (Ricker 1975)

$$\frac{N_t}{N_0} = e^{-Zt}$$

where

- N_t = number of animals in the population at time t ,
- N_0 = number of animals in the population at time $t = 0$,
- $\frac{N_t}{N_0} = S$ (finite survivorship to time t),
- $e = 2.71828\dots$ (base of the natural log), and
- Z = instantaneous mortality rate.

Survivorship to recruitment, to an adult age, was apportioned into several age stages, and AEL was calculated using the adjusted entrainment as

$$\widehat{AEL} = \hat{E}_{Adj-T} \prod_{j=1}^n \widehat{S}_j \quad (9)$$

where

- n = number of age classes from entrainment to recruitment and
- \widehat{S}_j = survival rate from the beginning to end of the j th age class.

The variance of \widehat{AEL} can be estimated using a Taylor series approximation (Delta method of Seber 1982) as

$$\widehat{Var}(\widehat{AEL}) = \widehat{AEL}^2 \left(CV^2(\hat{E}_{Adj-T}) + \sum_{j=1}^n CV^2(\widehat{S}_j) \right). \quad (10)$$

An alternative analysis would be to compare \widehat{AEL} with the size of the adult population of interest or with fishery harvest data. This method converts numbers of adult losses into fractional loss of the population of interest (e.g., stock assessment). However, information describing adult stocks is limited for many species, and independent field estimates of survival from time of entrainment to adulthood are not available for some species. For some species where such information is unavailable, we can estimate this parameter by assuming a stationary population where an adult

female must produce two adults (i.e., one male and one female). Overall survival (S_T) can then be estimated from total lifetime fecundity (\widehat{F}_T) by the quantity

$$\widehat{S}_T = \frac{2}{\widehat{F}_T} = \widehat{S}_{egg} \cdot \widehat{S}_{larvae} \cdot \widehat{S}_{adult},$$

which leads to

$$\widehat{S}_{adult} = \frac{2}{\widehat{F}_T \cdot \widehat{S}_{egg} \cdot \widehat{S}_{larvae}}. \quad (11)$$

Substituting Equation 11 into the overall form of the *AEL* equation where

$$\widehat{AEL} = \widehat{E}_{Adj-T} \cdot \widehat{S}_{adult} \quad (12)$$

yields

$$\widehat{AEL} = \frac{2(\widehat{E}_{Adj-T})}{\widehat{S}_{egg} \cdot \widehat{S}_{larvae} \cdot \widehat{F}_T}$$

where

$$\widehat{AEL} \equiv 2\widehat{FH}. \quad (13)$$

Without independent adult survival rates and assuming a 50:50 sex ratio, \widehat{AEL} and \widehat{FH} are deterministically related according to Equation 13, with an associated standard error of $\widehat{SE}(\widehat{AEL}) = 2\widehat{SE}(\widehat{FH})$. Equation 13 should be aligned so that the average female age is also the age of recruitment used in computing \widehat{AEL} . This alignment is accomplished by solving the simple exponential survival equation (Ricker 1975)

$$N_t = N_0 \cdot e^{-Z(t-t_0)}$$

by substituting numbers of either equivalent adults or hindcast females, their associated ages, and mortality rates into the equation where,

- N_t = number of adults at time t ,
 N_0 = number of adults at time t_0 ,
 Z = instantaneous rate of natural mortality, and
 t = age of hindcast animals (FH) or extrapolated age of animals (AEL).

This allows for the alignment of ages in either direction such that $2FH \equiv AEL$ since they are either hindcast or extrapolated to the same age.

The estimates of mortality calculated from the AEL and FH approaches can be compared for the same time periods for taxa where independent estimates are available for (1) survival from entrainment to recruitment into the fishery and (2) entrainment back to hatching. These comparisons serve as a method of cross-validation for the demographic approaches to impact assessment.

4.4.3.2 Sensitivity Analysis

A sensitivity analysis for \widehat{AEL} was computed in order to identify which parameters' estimates could be improved to increase the reliability of the estimate of adult losses. The analysis varied each input parameter ($\hat{\theta}$), using (1) an additive error model for the entrainment parameter (\widehat{E}_T or \hat{E}_{Adj-T}) by $\pm 1.645 \widehat{SE}(\hat{\theta})$ and (2) a multiplicative error model ($\hat{\theta} e^{\pm 1.645 CV(\hat{\theta})}$) for survival parameters. These survival estimates used an assumed CV of 1.0 (100%) and were constrained ≤ 1 . When estimates of survival to adult are unavailable, the sensitivity analysis performed for \widehat{FH} was applicable. The CV for \hat{T} was used in propagating the variances of the adjusted entrainment estimate for calculating the ranges of possible values for \widehat{AEL} in the sensitivity analyses. This approach helps to identify how a parameter's variability influences \widehat{AEL} .

4.4.3.3 Assumptions

Calculations of AEL using data on survivorship from entrainment to recruitment into the fishery assume the following:

- Values in the literature on life history parameters represent the fish population in the years and location of the Diablo Canyon study.

- If survivorship values from the literature are limited to single observations, values are assumed constant over time or representative of the mean.
- No population reserve or compensation counters entrainment mortality.
- Survival rates used in the calculations represent the life stage of the larvae or fish.

In some cases, survival rates estimated for a similar fish species were used. Should survivorship data from one species be substituted for another, there is the additional assumption that:

- Values of survivorship for the two species are the same.

For fish species where larval survival data are missing, expected survival could be estimated from fecundity and juvenile and adult survival data. However, in those cases where fecundity data were available, we did not have juvenile and adult survival estimates. To use fecundity data in calculating survival rates, there is the additional assumption that

- The fish population is stationary in size such that each adult female contributes two new offspring to the population of adults during its lifetime.

4.4.4 Empirical Transport Model (*ETM*)

The *ETM* estimates the total annual probability of mortality (P_M) associated with entrainment and requires an estimate of proportional entrainment (*PE*) as an input. Proportional entrainment estimates daily mortality imposed by DCPD on local larval populations (i.e., in the study grid), assuming no other types of mortality exist. In this context, *PE* is called conditional mortality (Ricker 1975). *PE* was calculated using the ratio based on intake samples and study grid samples. In previous entrainment studies using the *ETM* method, intake densities were assumed from weighted population concentrations (Boreman et al. 1981). The *PE* index is used in the *ETM* to estimate mortality rates resulting from cooling water withdrawals. As proposed by the U.S. Fish and Wildlife Service (Boreman et al. 1978, 1981), *ETM* has been used to assess entrainment effects at the Salem Nuclear Generating Station in Delaware Bay, New Jersey and at other power stations along the east coast of the United States (Boreman et al. 1978, 1981; PSE&G 1993). Variations of this model have been discussed in MacCall et al. (1983) and used to assess impacts at the San Onofre Nuclear Generating Station (SONGS; Parker and DeMartini 1989).

The *ETM* estimates annual, conditional mortality due to entrainment, while accounting for the spatial and temporal variability in distribution and vulnerability of each life stage to cooling water withdrawals. The generalized form of the *ETM* incorporates many time-, space-, and age-specific estimates of mortality as well as information regarding spawning periodicity and larval duration. Most of this information is limited or unknown for the taxa being investigated at DCP. Thus, the applicability of the *ETM* to the study at DCP will be limited by the absence of empirically derived or reported demographic parameters needed as input to the model. Specifically, the length of time a larva is susceptible to entrainment must be estimated. However, the concept of summarizing *PE* over time with the *ETM* can be used to estimate entrainment effects over appropriate temporal scales, either by modeling or making assumptions about species-specific life histories. At DCP, we employ a *PE* approach similar to the method described by MacCall et al. (1983) and used by Murdoch et al. (1989) in (Parker and DeMartini 1989) their final Marine Review Committee (MRC) report to the California Coastal Commission for SONGS. The annual estimate of *ETM* is formed from the weighted average of 12 approximately monthly surveys which pair entrainment and study grid larval samples.

4.4.4.1 Formulation of *PE* and *ETM*

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

$$\widehat{PE} = \frac{\widehat{N}_E}{\widehat{N}_G}$$

where

\widehat{N}_E = estimated number of larvae entrained during the day, calculated as
(estimated density of larvae in the water entrained that day) × (design specified daily cooling water intake volume),

\widehat{N}_G = estimated number of larvae in the study grid that day, calculated as
 $\sum_{i=1}^{64} [(\text{estimated average density of larvae per cell}) \cdot (\text{cell volume})]$ for $i = 1, \dots, 64$ grid cells

where the estimated cell densities are obtained from the 72-hour grid survey that contains the 24-hour entrainment sampling period.

The *PE* estimate for days when grid surveys were not done is the estimate for the nearest day to the monthly survey. In addition, an adjustment was made to the estimated number of larvae in the row 1 cells of the study grid to help compensate for the inability to safely collect samples inshore of the grid (Figure 4-3). The estimated volume of the water directly inshore of the study grid was multiplied by the density of larvae collected in the row 1 cells, except for cells A1, D1, and E1.

Cell A1 is more offshore than the rest of the cells in row 1, due to the bend in the coastline at Point Buchon. An adjustment was not done for the volume of water inshore of cell A1 because a substantial volume would be added and the composition and abundance sampled in cell A1 would not adequately represent inshore volumes. Columns D and E are directly offshore from the Intake Cove where entrainment samples were collected. The density estimate from entrainment sampling was used for the areas inshore of cells D1 and E1. This estimated number of larvae inshore of the grid was added to the grid abundance number estimated for the cells in row 1 before *PE* and *ETM* calculations were done.

The ETWG recommended using entrainment samples in adjusting only the volumes inshore of cells D1 and E1. The estimated number of larvae inshore of the grid cells D1 and E1 was somewhat larger than the estimated entrainment numbers used in *PE* because the sum of water volumes inshore of D1 and E1 (4.90 and 5.95 million m³, respectively) is slightly greater than the daily flow through the power plant (9.60 million m³). However, the estimated entrainment density could be used to represent the remaining inshore volumes (total inshore volume excluding A1 is 38.2 million m³), in which case the *PE* value (and therefore estimated mortality) would decrease especially for those nearshore species not found commonly in the study grid. While not appropriate for taxa with larvae dispersed throughout the study grid, an adjustment to the unsampled inshore volumes may be reasonable for some nearshore species whose larvae are potentially more abundant closer to shore.

The *PE* value represents the effects of a number of processes operating over a day and is estimated in two year groups, each year having 12 approximately monthly surveys. Proportional entrainment was calculated for the 12 paired nearshore study grid and entrainment surveys conducted between July 1, 1997 and June 30, 1998, and for another 12 pairs from July 1, 1998 to June 30, 1999. To estimate specific *PE* ratios, each 24-hour entrainment abundance estimate was temporally paired with the abundance estimate from the 72-hour nearshore grid survey.

The purpose of the DCPD study is to estimate entrainment effects within the study grid and attempt to extrapolate those effects to a population of inference. Boreman et al. (1981) point out that if any members of the population are located outside the study grid area, then the *ETM* will overestimate the conditional entrainment mortality for the entire population. In their study of entrainment by SONGS, Parker and DeMartini (1989) incorporated the inference population (which was an extrapolation to the entire Southern California Bight, an area extending about 500 km) directly into their estimate of *PE*. In the following *ETM* analyses, *PE* is multiplied by the fraction of the population in the study grid area. Let $P_S = (\text{number of larvae at risk in the study grid}) / (\text{number of larvae in the population of inference})$. The fraction of larva being entrained from the population of inference on a given day is then the product

$$PE_i \cdot P_S .$$

The boundaries of the population affected by entrainment could vary from local (e.g., a subarea of the study grid) to regional (e.g., fishery management units, zoogeographic range). For some species the area of the study grid may represent the population of inference and, in these cases, $P_S = 1$. For other species, the population of inference will likely be larger than the study grid. In fact, the population of inference depends both on the species and on what appeals usefully to intuition. Therefore, *ETM* is computed over a range of values of P_S for each of the target taxa. The curves from these functions can be used to determine the *ETM* at any value of P_S . The curves can also be interpreted as a continuous probability function representing the risk of entrainment to the larvae at different values of P_S . This representation replaces the need for sensitivity analysis for P_M to the population of inference implied by P_S . Several approaches will be used to define the proportion of the population of inference for the different taxa groups.

These point estimates of P_S (and their ranges) will also be represented on the curves for each of the target taxa. This representation of the population at risk is more biologically meaningful than sensitivity analyses using confidence intervals around a single estimate of P_M .

If larval entrainment mortality is constant throughout the period and a larva is susceptible to entrainment over d days, then the proportion of larvae that escape entrainment in survey i is:

$$(1 - \widehat{PE}_i \cdot \widehat{P}_S)^d .$$

Larval duration from hatching to entrainment was calculated from growth rates using either the mean or maximum size at entrainment. The value for d was computed by dividing an estimate of growth rate into the change in length based on either the mean or maximum size at entrainment (Tables 4-3 and 4-4). Although the maximum larval size produces the longest duration of susceptibility, larval entrainment probabilities may be age dependent. The mean size is used to illustrate the sensitivity of the estimate of population-wide mortality to larval duration of susceptibility. The mean length of target taxa larvae from all entrainment samples was calculated, and length-frequency histograms were used to determine the central 98% of the distribution. The minimum and maximum sizes used for analyses were determined after removing the largest and smallest 1% of the values. This procedure helped account for 1) outliers that were the result of larger post-larval fishes, 2) inadvertently measured larval fish fragments from the samples, 3) shrinkage in preservation fluid, and 4) variations in hatch length. As a result, the larval lengths that were used to estimate ages were the 98% center interval of all the lengths.

It is possible that aging was biased, even though standard lengths of larval fishes (i.e., measurements of minimum, mean and maximum), and larval growth rates were applied to estimate the ages of the entrained larvae. It was assumed that larvae shorter than the minimum length of the central 98% of the distribution were just hatched and aged zero days. Subsequent ages were estimated using this length. Other reported data for various species suggests that hatching length can be either smaller or larger than estimated from DCPP samples, and indicates that the smallest observed larvae represent either natural variation in hatch lengths within the population or the phenomenon of shrinkage following preservation (Theilacker 1980). The

possibility remains that all larvae from the observed minimum length to the greatest reported hatching length (or to some other size) could have just hatched, leading to overestimation of ages for all larvae. Both *FH* and *AEL* estimation use the mean and minimum sizes to estimate age at entrainment and are subject to similar biases.

Twelve monthly survey periods were used to estimate larval mortality (P_M) due to entrainment for 2 one-year study periods. P_M was estimated by the equation

$$\widehat{P}_M = 1 - \sum_{i=1}^{12} \widehat{f}_i (1 - \widehat{PE}_i \cdot \widehat{P}_S)^{\widehat{d}} \quad (15)$$

where

\widehat{PE}_i = estimate of proportional entrainment for the i th monthly survey ($i = 1, \dots, 12$),

\widehat{P}_S = estimated proportion of the fish population in the study grid,

\widehat{f}_i = annual proportion of the total larvae hatched during the i th monthly survey, and

\widehat{d} = the estimated number of days of larval life.

To establish independent survey estimates, it is assumed that during each survey a new and distinct cohort of larvae is subject to entrainment. Each of the twelve surveys was weighted by \widehat{f}_i and estimated as the proportions of the yearly entrainment in all the days of the i th survey period. The survey dates (from July 1997 through June 1998 and July 1998 through June 1999) of the paired entrainment samples and number of days in the survey periods are found in **Table 4-5**. For each of the two years, the sum of the proportions equals one:

$$\widehat{f}_i = \frac{\widehat{E}_i}{\sum_{j=1}^{12} \widehat{E}_j} \quad \text{and} \quad \sum_{i=1}^{12} \widehat{f}_i = 1.$$

The variance of P_M was estimated using the Delta method (Seber 1982), and its formulation is presented in **Appendix F**.

The estimate of the population-wide probability of entrainment ($\widehat{PE}_i \cdot \widehat{P}_S$) is the central feature of the *ETM* approach (Boreman et al. 1981; MacCall et al. 1983). If a population is stable and

stationary, then \widehat{P}_M also estimates the effects on the fully-recruited adult age classes when uncompensated natural mortality from larva to adult is assumed.

4.4.4.2 Formulation of \widehat{P}_S

The relationship between \widehat{P}_M and \widehat{P}_S is represented by the sets of curves presented for each of the target taxa. Discrete values of \widehat{P}_S are also presented for each of the target taxa. These values are computed differently for three groups of taxa identified by the distribution of adults:

- Offshore - Pacific sardine and northern anchovy
- Subtidal - rockfishes, flatfishes, crabs, cabezon, white croakers, and blackeye gobies
- Intertidal and shallow subtidal or nearshore sculpins, kelpfishes, pricklebacks, and greenlings

The incorporation of P_S into the *ETM* is typically defined by the ratio of the area or volume of the study grid to a larger area or volume containing the population of inference (Parker and DeMartini 1989). If an estimate of the larval (or adult) population in the larger area is available, \widehat{P}_S can also be computed using the estimate of the larval or adult population in the study grid, defined by Ricker (1975) as the proportion of the parental stock. If the distribution in the larger area is assumed to be uniform, then the value of \widehat{P}_S for the proportion of the population will be the same as the value computed using area or volume. For offshore and subtidal target taxa whose larval distribution extends to the offshore edge of the study grid, \widehat{P}_S will be calculated as the ratio

$$P_S = N_G / N_p$$

where N_G is the number of larvae in the study grid, and N_p is the number of larvae in the population of inference. The numerator N_G is presented in section 4.4.4.1 in the calculation of *PE*, i.e.

$$\widehat{N}_{G_i} = \sum_{k=1}^{64} A_{G_k} \cdot \bar{D}_k \cdot \rho_{i,k}$$

where

A_{G_k} = area of grid (G) cell k,

\bar{D}_k = average depth of the kth grid cell, and

$\rho_{i,k}$ = density (per m³) of larvae in kth grid cell during survey i.

N_p was estimated by an offshore and alongshore extrapolation of the study grid densities, using water current measurements. First, a conceptual model was formulated to extrapolate larval densities (per m³) offshore of the grid

$$\widehat{P}_S = \frac{\widehat{N}_G}{\widehat{N}_P} = \frac{\sum_{j=1}^{K_G} L_{G_j} \cdot W_j \cdot \bar{D}_j \cdot \overline{\text{density}}_j}{\sum_{j=1}^{K_P} L_{P_j} \cdot W_j \cdot \bar{D}_j \cdot \overline{\text{density}}_j} \quad (16)$$

where

L_{G_j} = alongshore length of grid in the jth stratum,

W_j = width of jth stratum,

L_{P_j} = alongshore length of the population in the jth stratum based on current data,

\bar{D}_j = average depth of the jth stratum, and

$\overline{\text{density}}_j$ = average density of larvae in jth stratum.

For this model, the grid was subdivided into K_G alongshore strata (i.e., $K_G = 8$ rows in the grid) and the population into $K_P > K_G$ alongshore strata.

Formula (16) above describes discrete values in intervals of a continuous function. Therefore, to ease implementation, an essentially equivalent formula incorporates the use of grid cell densities during the i th sampling period, $\rho_{i,k}$, and integrates a linear extrapolation of density (per m² calculated by multiplying $\rho_{i,k}$ by the cell depth) as a function of offshore distance, w :

$$\widehat{P}_{S_i} = \frac{\widehat{N}_{G_i}}{\widehat{N}_{P_i}} = \frac{\widehat{N}_{G_i}}{\widehat{N}_{G_i} \left(\frac{L_{P_i}}{L_G} \right) + L_{P_i} \cdot \int_{w_0}^{w_{\max}} \rho(w) dw}$$

where

L_{P_i} = alongshore length of the population (P) in the i th study period based on current data.

The limits of integration are from the offshore margin of the study grid, W_o , to a point estimated by the onshore movement of currents or where the density is zero or biologically limited, W_{max} . Note that this point can occur outside the study grid area.

Note that the population number, N_p , is composed of two components that represent the alongshore extrapolation of the grid population and the offshore extrapolation of the alongshore grid population (**Figure 4-7**).

The alongshore and onshore current velocities were measured at a current meter positioned approximately 1 km west of the DCPPI intake at a depth of approximately 6 m (**Figure 4-3**). The direction in degrees true from north and speed in cm/s were estimated for each hour of the nearshore study grid survey periods. **Figure 4-8** shows the results of current meter analysis in which hourly current vectors were first rotated orthogonal to the coast by 49 degrees west of north (average of two tangents, **Section 4.2.1.2**). The movement of water was then tracked during the period from April 1997 through June 1999. A total alongshore length or displacement in kilometers can be calculated from these data using the range of both upcoast and downcoast movement over the larval duration period prior to each survey period. The maximum upcoast and downcoast current vectors measured during each survey period were added together to obtain an estimate of total alongshore movement. Onshore movement used to extrapolate densities offshore can also be calculated from this graph by excluding periods of offshore movement. Within this scenario, there are two subclasses:

1. For species where the regression of density versus offshore distance has a negative slope, the offshore distance predicted where density is zero (i.e., integral of zero) will be calculated. The alongshore distance would be calculated from the water current data.
2. For species where the regression of density versus offshore distance has a slope of ≥ 0 , either the offshore distance from the water current data or an average distance based on the depth distribution of the adults offshore will be used. Literature values (e.g., CalCOFI) will be used to place a ceiling on both the distance and density values used in the offshore extrapolation.

Parameter values needed in performing the extrapolation were obtained by using analysis of covariance based on all of the data from the surveys within the period July 1997 through June

1998. Another set of parameter values was calculated for the period July 1998 through June 1999. A quadratic model was tested in the analysis

$$\delta_{ij} = \alpha_i + \beta w_{ij} + \gamma w_{ij}^2 + \varepsilon_{ij}$$

where

ε_{ij} = normally distributed error term with mean of zero,

w_{ij} = distance for the i th observation in the j th survey,

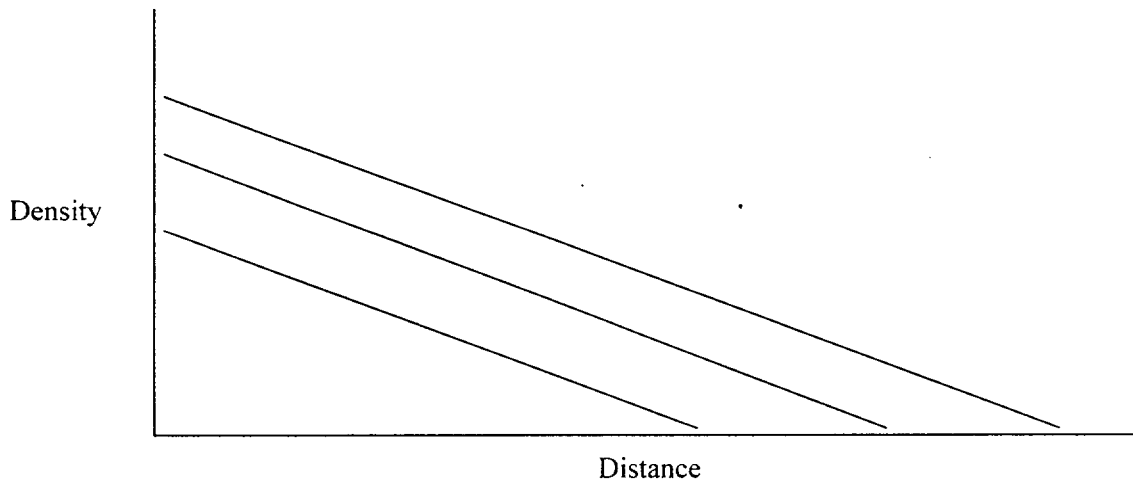
δ_{ij} = larval density for the i th observation in the j th survey and

α_i, β, γ = regression coefficients.

A linear model produced a better fit in all cases:

$$\delta_{ij} = \alpha_i + \beta w_{ij} + \varepsilon_{ij}.$$

A common slope, β , for all surveys and unique intercepts, α_i , for each survey were derived from the model. It is reasonable to assume a common slope, but differences in abundance between surveys required fitting different intercepts. The illustration below depicts three hypothetical survey periods.



Note that unique distances (i.e., intercepts) are used from each survey period when calculating N_p . The value of P_s computed using this method to extrapolate increasing or decreasing densities offshore will result in non-uniform densities over the extrapolated area of inference.

Therefore, this value would not be equal to a P_S that is computed using the ratio of area or volume from the grid and the population of inference. The estimate of P_M obtained using the extrapolated value of P_S will be compared for the Pacific sardine and northern anchovy to their fishery management areas and existing biomass estimates. The ratio of the extrapolated area to the fishery management area will be used to estimate the effects of entrainment on these populations.

A P_S for nearshore taxa will be calculated using the alongshore length of the sampling grid, L_G , and the total alongshore displacement, L_P , to predict a coastwise fraction of the population of inference (**Figure 4-7**). The total alongshore displacement in the i th survey, L_{P_i} , includes both upcoast and downcoast movement calculated during a period equal to the larval duration before each survey. No onshore or offshore current movement was incorporated in the calculated population fraction:

$$\widehat{P}_S = \frac{L_G}{\frac{1}{n} \sum_{i=1}^n L_{P_i}} = \frac{L_G}{L_P} .$$

4.4.4.3 Assumptions

Assumptions associated with the estimation of P_M include the following:

- The samples at each survey period represent a new and independent cohort of larvae.
- The monthly estimates of larval abundance represent a proportion of total annual larval production during that month.
- The conditional probability of entrainment (PE_i) is constant within monthly survey periods.
- P_S accurately characterizes the fraction of the target population represented by the sampling grid.
- Lengths and applied growth rates of larvae accurately estimate larval duration

Table 4-1. List of target taxa for assessment in DCP 316(b) Demonstration. Target taxa, listed in phylogenetic order, were selected at the May 7, 1999 ETWG meeting.

Common Name	Scientific Name
Brown rock crab	<i>Cancer antennarius</i>
Slender crab	<i>Cancer gracilis</i>
Pacific sardine	<i>Sardinops sagax</i>
Northern anchovy	<i>Engraulis mordax</i>
Blue rockfish complex	† <i>Sebastes</i> spp. V / <i>S. mystinus</i>
KGB rockfish complex	† <i>Sebastes</i> spp. V_De/V_D_
Painted greenling	<i>Oxylebius pictus</i>
Smoothhead sculpin	<i>Artedius lateralis</i>
Snubnose sculpin	<i>Orthonopias triacis</i>
Cabezon	<i>Scorpaenichthys marmoratus</i>
White croaker	<i>Genyonemus lineatus</i>
Monkeyface prickleback	<i>Cebidichthys violaceus</i>
Clinid kelpfishes	<i>Gibbonsia</i> spp.
Blackeye goby	<i>Coryphopterus nicholsi</i>
Sanddab	<i>Citharichthys</i> spp.
California halibut	<i>Paralichthys californicus</i>

† *Sebastes* spp. V/ *S. mystinus*, and *Sebastes* spp. V_De/V_D_ refer to pigmentation groups within the larval rockfish complex that were used as a taxonomic group in this study.

Table 4-2. Pigment groups, parturition peak periods (PPM), and seasonality of preflexion rockfish larvae from Nishimoto (in prep.).

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	SUBGENUS	'77-'84 PPM	Parturition period N and C CA (Wyllie Echeverria 1987)
V_P	Long ventral series, no dorsal, pectoral pigment				
	<i>S. chlorostictus</i>	greenspotted	Sebastomus	?	Apr-Sep
	<i>S. ensifer</i>	swordspine	Sebastomus	?	Uncommon in central CA (Miller and Lea 1972)
V_D	Long ventral series, short dorsal series, no pectoral pigment				
	<i>S. saxicola</i>	stripetail	Allosebastes	Jan	Jan-Mar (Nov-Mar, Phillips 1964)
V_D_	Long ventral series, short dorsal series, no pectoral pigment				
	<i>S. atrovirens</i>	kelp	Mebarus	ND	ND
	<i>S. chrysomelas</i>	black and yellow	Pteropodus	Feb	Feb-Mar (Jan-May (Larson 1980))
	<i>S. maliger</i>	quillback	Pteropodus	Apr	Apr-Jul
	<i>S. nebulosus</i>	China	Pteropodus	?	?
	<i>S. semicinctus</i>	halfbanded	Allosebastes	ND	Jan-Apr for southern CA (Love et al. 1990)
V_De	Long ventral series, elongating dorsal series, pectoral pigment				
or	<i>S. auriculatus</i>	brown	Auctospina	June	Dec-Jan, principally May-Jul (May, Larson 1980)
V_DeP	<i>S. carnatus</i>	gopher	Pteropodus	Mar	Mar-May (May, Larson 1980)
or	<i>S. caurinus</i>	copper	Pteropodus	Feb	Feb
V_dep	<i>S. dalli</i>	calico	Allosebastes	?	Uncommon in central CA (Miller and Lea 1972)
	<i>S. rastrelliger</i>	grass	Pteropodus	ND	ND

Table 4-2. (continued). Pigment groups, parturition peak periods (PPM), and seasonality of preflexion *Sebastes* spp. larvae from Nishimoto (in prep.).

LETTER CODE	SPECIES	COMMON NAME	SUBGENUS	'77-'84 PPM	Parturition period N and C CA (Wyllie Echeverria 1987)
V	Short ventral series, no dorsal series, no pectoral				
	<i>S. aleutianus</i>	rougheyeye	Zalopyr	ND	
	<i>S. alutus</i>	POP	Acutomentum	Mar	Jan-Mar (?)
	<i>S. brevispinis</i>	silvergrey	Acutomentum	ND	
	<i>S. crameri</i>	darkblotched	Eosebastes	Jan	Nov-Mar (Nov-Mar, Larson 1980)
	<i>S. diploproa</i>	splitnose	Allosebastes	Jul	Jan-Sep (Feb-Jul, Phillips 1964)
	<i>S. elongatus</i>	greenstriped	Hispaniscus	May	May-Jul
	<i>S. macdonaldi</i>	Mexican	Acutomentum	ND	
	<i>S. miniatus</i>	vermilion	Rosicola	Sep	Sep (Nov, Moser 1967; Nov-Mar, Phillips 1964)
	<i>S. nigrocinctus</i>	tiger	Sebastichtys	ND	
	<i>S. proriger</i>	redstripe	Allosebastes	?	Jul-Aug
	<i>S. rosaceus</i>	rosy	Sebastomus	Jun	Apr-Jul
	<i>S. ruberrimus</i>	yelloweye	Sebastopyr	Jun	Apr-Jul (?)
	<i>S. serriceps</i>	treefish	Sebastocarus	ND	
	<i>S. umbrosus</i>	honeycomb	Sebastomus	ND	ND
	<i>S. wilsoni</i>	pygmy	Acutomentum	ND	
	<i>S. zacentrus</i>	sharpchin	Allosebastes	?	May-Jun
VP	Short ventral series, no dorsal series, various patterns of pectoral pigmentation (At smaller size might fit into group V above)				
	<i>S. constellatus</i>	starry	Sebastodes	Apr	Apr-May
	<i>S. eos</i>	pink	Sebastomus	ND	ND
	<i>S. goodei</i>	chilipepper	Sebastodes	Jan	Nov-Jun (Nov-Mar, Phillips 1964)
	<i>S. helvomaculatus</i>	rosethorn	Sebastomus	?	May-Jun
	<i>S. levis</i>	cowcod	Hispaniscus	Dec	Dec-Feb
	<i>S. melanostomus</i>	blackgill	Eosebastes	Feb	Feb-Apr
	<i>S. paucispinis</i>	bocaccio	Sebastodes	Feb	Jan-May (Nov-Mar, Moser 1967)
	<i>S. rosenblatti</i>	greenblotched	Sebastomus	ND	ND
	<i>S. rubrivinctus</i>	flag	Hispaniscus	?	Jul
Vdp	Short ventral series, develops dorsal series, develops various patterns of pectoral pigmentation (At stage 1-2 can confuse with V above due to lack of dorsal and pectoral pigmentation.)				
	<i>S. entomelas</i>	widow	Acutomentum	Feb	Dec-Apr (Nov-Mar, Phillips 1964)
	<i>S. flavidus</i>	yellowtail	Sebastosomus	Feb	Jan-Jul (Nov-Mar, Phillips 1964)
	<i>S. melanops</i>	black	Sebastosomus	Feb	Jan-May
	<i>S. mystinus</i>	blue	Sebastosomus	Jan	Nov-Jan (Nov-Jan, Wales 1952)
	<i>S. rufus</i>	bank	Acutomentum	Feb	Dec-May
	<i>S. serranoides</i>	olive	Sebastosomus	Feb	Jan-Mar
VD	Short ventral series, short dorsal series				
	<i>S. aurora</i>	aurora	Eosebastes	Apr	Mar-May
	<i>S. babcocki</i>	redbanded	Rosicola	May	May
	<i>S. gilli</i>	bronzespotted	Sebastosomus	?	Uncommon in central CA (Miller and Lea 1972)
	<i>S. hopkinsi</i>	squarespot	Acutomentum	Mar	Feb-Mar
	<i>S. jordani</i>	shortbelly	Sebastodes	Feb	Feb-Apr (Nov-Apr, Phillips 1964)
	<i>S. ovalis</i>	speckled	Acutomentum	May	May
	<i>S. pinniger</i>	canary	Rosicola	Dec	Dec-Mar (Nov-Mar, Moser 1967)
Species without descriptions or illustrations					
	<i>S. phillipsi</i>	chameleon	?	?	Uncommon in central CA (Miller and

Table 4-3. Larval growth estimates for entrainable fish larvae at DCPD based on literature citations. Growth estimates are used to estimate larval durations in **Table 4-4**. Growth rates are not listed for *Cancer* crabs because of step-wise growth increments between larval stages. Larval durations for crabs were taken directly from laboratory studies and are listed in **Table 4-4**.

Family <i>Species</i>	Larval Growth Rate (mm/d)	Reference
Canceridae		
<i>Cancer antennarius</i>	—	Roesijadi 1976
<i>Cancer gracilis</i>	—	Ally 1975
Clupeidae		
<i>Sardinops sagax</i>	0.238	Miller 1952
Engraulidae		
<i>Engraulis mordax</i>	0.445	Methot and Kramer 1979
Scorpaenidae		
<i>Sebastes</i> spp. KGB	0.140	Love and Johnson 1999 and Yoklavich pers. comm.
<i>Sebastes</i> spp. V/S. <i>mystinus</i>	0.140	Yoklavich et al. 1996 and Yoklavich pers. comm.
Hexagrammidae		
<i>Oxylebius pictus</i>	0.083	Freeman et al. 1985
Cottidae		
<i>Artedius lateralis</i>	0.083	Freeman et al. 1985
<i>Orthonopias triacis</i>	0.083	Freeman et al. 1985
<i>Scorpaenichthys marmoratus</i>	0.300	O'Connell 1953; Moser 1996
Sciaenidae		
<i>Genyonemus lineatus</i>	0.200	Murdoch et al. 1989
Stichaeidae		
<i>Cebidichthys violaceus</i>	0.248	Stepien 1986
Clinidae		
<i>Gibbonsia</i> spp.	0.248	Stepien 1986
Gobiidae		
<i>Coryphopterus nicholsi</i>	0.273	Steele 1997
Paralichthyidae		
<i>Citharichthys</i> spp.	0.200	Kendall 1992; Sakuma 1995
<i>Paralichthys californicus</i>	0.280	Allen et al. 1990

Table 4-4. Mean and maximum larval stage durations in days from hatching to entrainment estimated for fish larvae collected at DCP. Maximum duration is based on the central 98% of the length frequency distribution and growth rates from the scientific literature (Table 4-3). Crab megalopal duration estimated from Roesijadi 1976 and Ally 1975.

Family <i>Genus and Species</i>	Shortest larva entrained (mm)	Mean larva entrained (mm)	Longest larva entrained (mm)	Estimated larval durations Mean-Max (d)
Cancridae				
<i>Cancer antennarius</i> (megalops)	—		—	42.7
<i>Cancer gracilis</i> (megalops)	—		—	41.6
Clupeidae				
<i>Sardinops sagax</i>	2.4	5.5	19.1	13.3–70.6
Engraulididae				
<i>Engraulis mordax</i>	2.1	6.1	24.9	9.0–51.2
Scorpaenidae				
<i>Sebastes</i> spp. KGB	3.3	4.2	5.6	6.2–16.4
<i>Sebastes</i> spp. V / <i>S. mystinus</i>	2.7	3.6	4.5	6.4–12.9
Hexagrammidae				
<i>Oxylebius pictus</i>	3.2	4.1	5.2	10.4–24.1
Cottidae				
<i>Artedius lateralis</i>	2.4	3.1	5.3	8.9–34.9
<i>Orthonopias triacis</i>	2.6	3.6	6.1	11.4–42.2
<i>Scorpaenichthys marmoratus</i>	3.7	4.8	6.1	3.6–8.0
Sciaenidae				
<i>Genyonemus lineatus</i>	1.1	2.4	5.5	6.7–22.0
Stichaeidae				
<i>Cebidichthys violaceus</i>	5.7	2.6	12.0	6.6–25.4
Clinidae				
<i>Gibbonsia</i> spp.	4.1	6.4	12.0	9.0–31.6
Gobiidae				
<i>Coryphopterus nicholsi</i>	2.0	2.6	3.4	2.2–5.2
Paralichthyidae				
<i>Citharichthys</i> spp.	1.3	2.6	3.5	6.7–11.0
<i>Paralichthys californicus</i>	1.6	3.3	7.8	6.0–22.1

Table 4-5. Study grid survey start dates and the period of days used in calculations for each survey, for two sampling periods: June 1997 through July 1998, and June 1998 through July 1999. The start date of the entrainment surveys that paired with the grid surveys generally started 24 hours after the beginning of each 72-hour grid survey.

	Survey Start Date	Period Start	Period End	Days
Analysis Period 3				
Surveys	Jul 21, 1997	Jul 4, 1997	Aug 7, 1997	35
	Aug 25, 1997	Aug 8, 1997	Sep 11, 1997	35
	Sep 29, 1997	Sep 12, 1997	Oct 9, 1997	28
	Oct 20, 1997	Oct 10, 1997	Nov 2, 1997	24
	Nov 17, 1997	Nov 3, 1997	Nov 28, 1997	26
	Dec 10, 1997	Nov 29, 1997	Dec 31, 1997	33
	Jan 22, 1998	Jan 1, 1998	Feb 8, 1998	39
	Feb 26, 1998	Feb 9, 1998	Mar 7, 1998	27
	Mar 18, 1998	Mar 8, 1998	Mar 31, 1998	24
	Apr 15, 1998	Apr 1, 1998	May 1, 1998	31
	May 18, 1998	May 2, 1998	May 28, 1998	27
	Jun 8, 1998	May 29, 1998	Jul 3, 1998	36
Analysis Period 4				
Surveys	Jul 21, 1998	Jul 3, 1998	Aug 7, 1998	36
	Aug 26, 1998	Aug 8, 1998	Sep 5, 1998	29
	Sep 16, 1998	Sep 6, 1998	Sep 25, 1998	20
	Oct 6, 1998	Sep 26, 1998	Oct 23, 1998	28
	Nov 11, 1998	Oct 24, 1998	Nov 24, 1998	32
	Dec 9, 1998	Nov 25, 1998	Dec 25, 1998	31
	Jan 12, 1999	Dec 26, 1998	Jan 22, 1999	28
	Feb 3, 1999	Jan 23, 1999	Feb 23, 1999	32
	Mar 17, 1999	Feb 24, 1999	Mar 30, 1999	35
	Apr 14, 1999	Mar 31, 1999	May 3, 1999	34
	May 24, 1999	May 4, 1999	Jun 7, 1999	35
	Jun 23, 1999	Jun 8, 1999	Jul 2, 1999	25

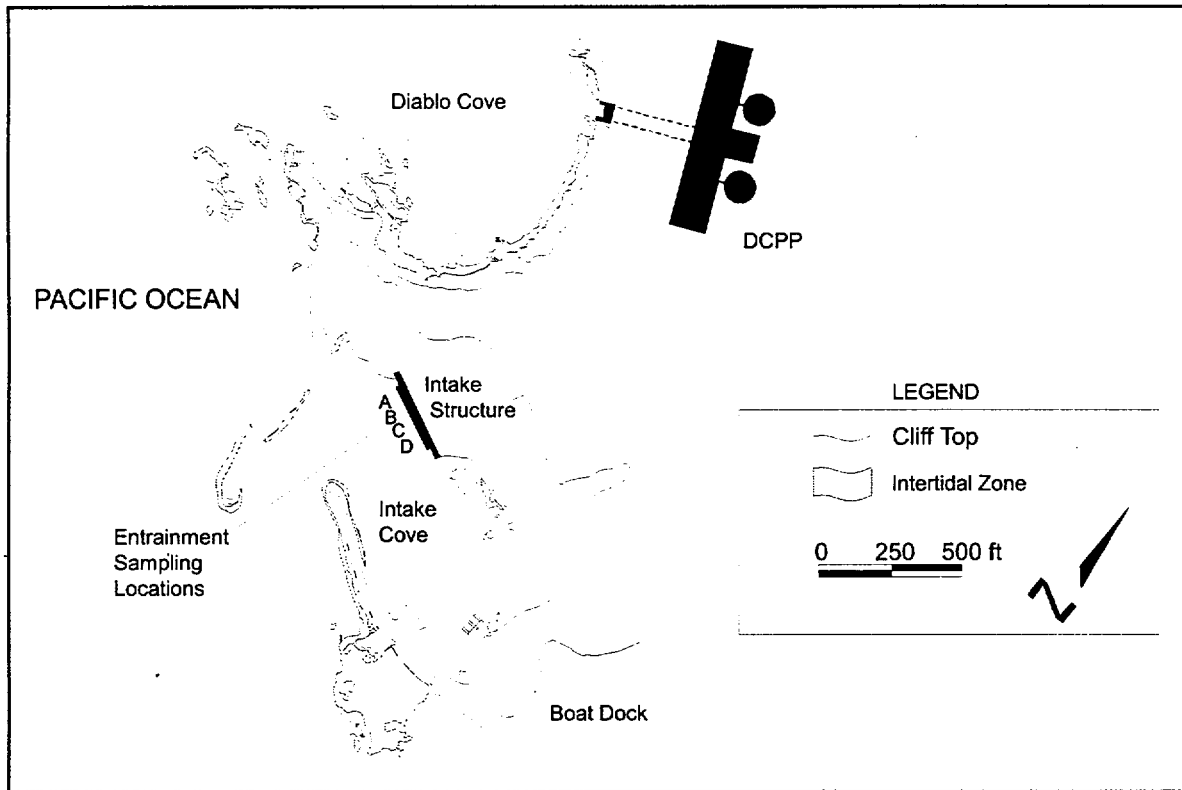


Figure 4-1. Diagram of DCP Power Plant, Intake Cove and Entrainment Sampling Locations.

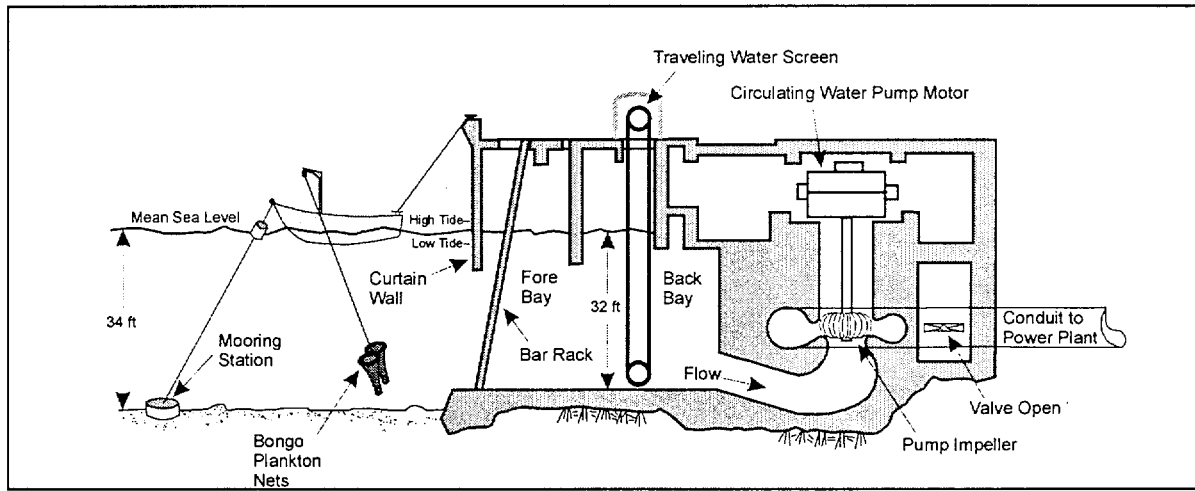


Figure 4-2. Cross-section view of the DCCP intake structure illustrating the location of the entrainment sampling sites.

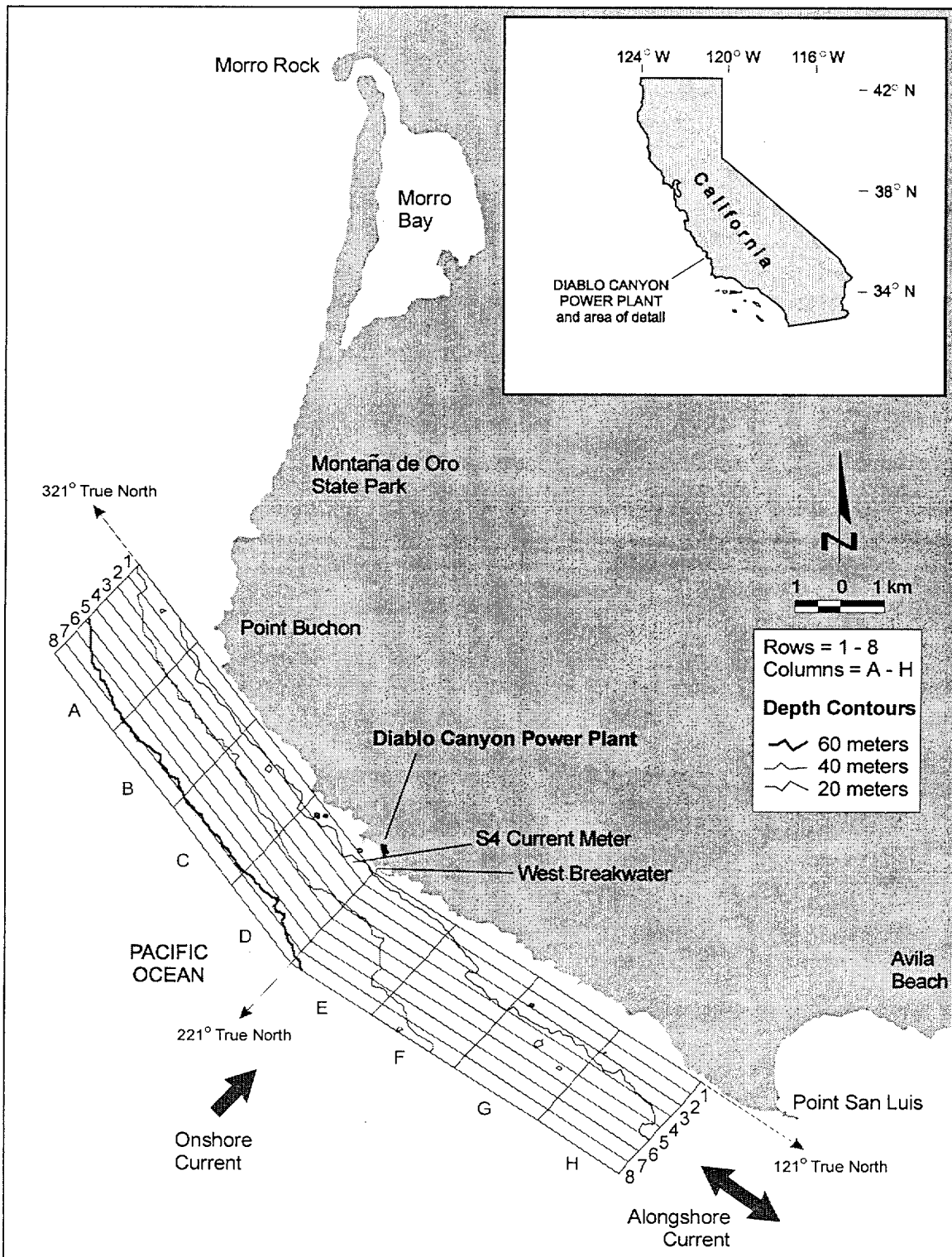


Figure 4-3. DCPD 316(b) study grid and depth contours.

H	G	F	E	D	C	B	A
8	8	8	8	8	8	8	8
7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6
5	5	5	5	5	5	5	5
4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1

DCPP Intake
Cove

Figure 4-4. An example of the “ping-pong” sampling track employed in grid cell sampling; the starting cell (F1) and the initial southward direction of the transect were randomly selected. All 64 cells are sampled during the 72-hour survey period, weather permitting. DCPD’s Intake Cove is located east of the juncture between cells E1 and D1.

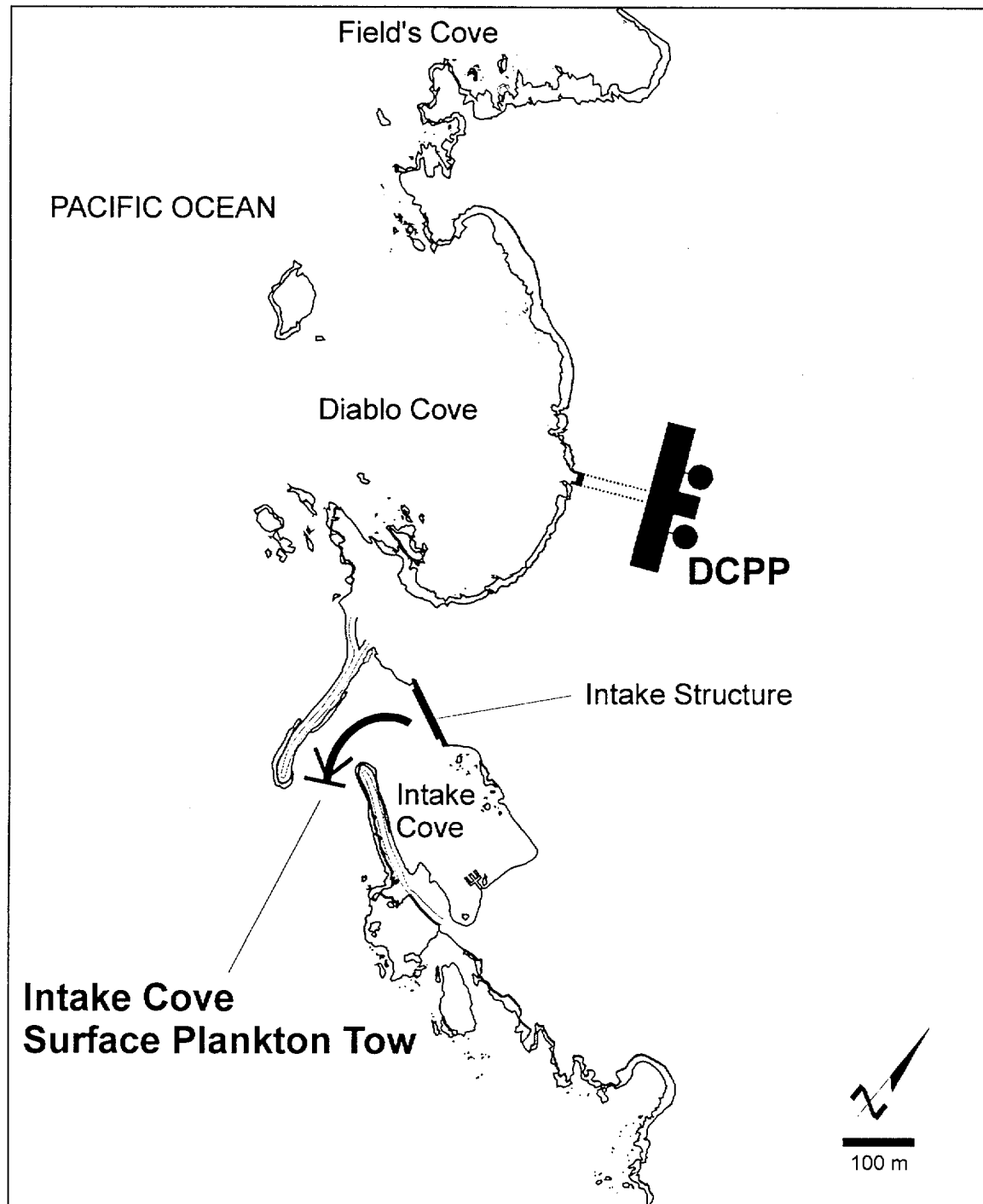
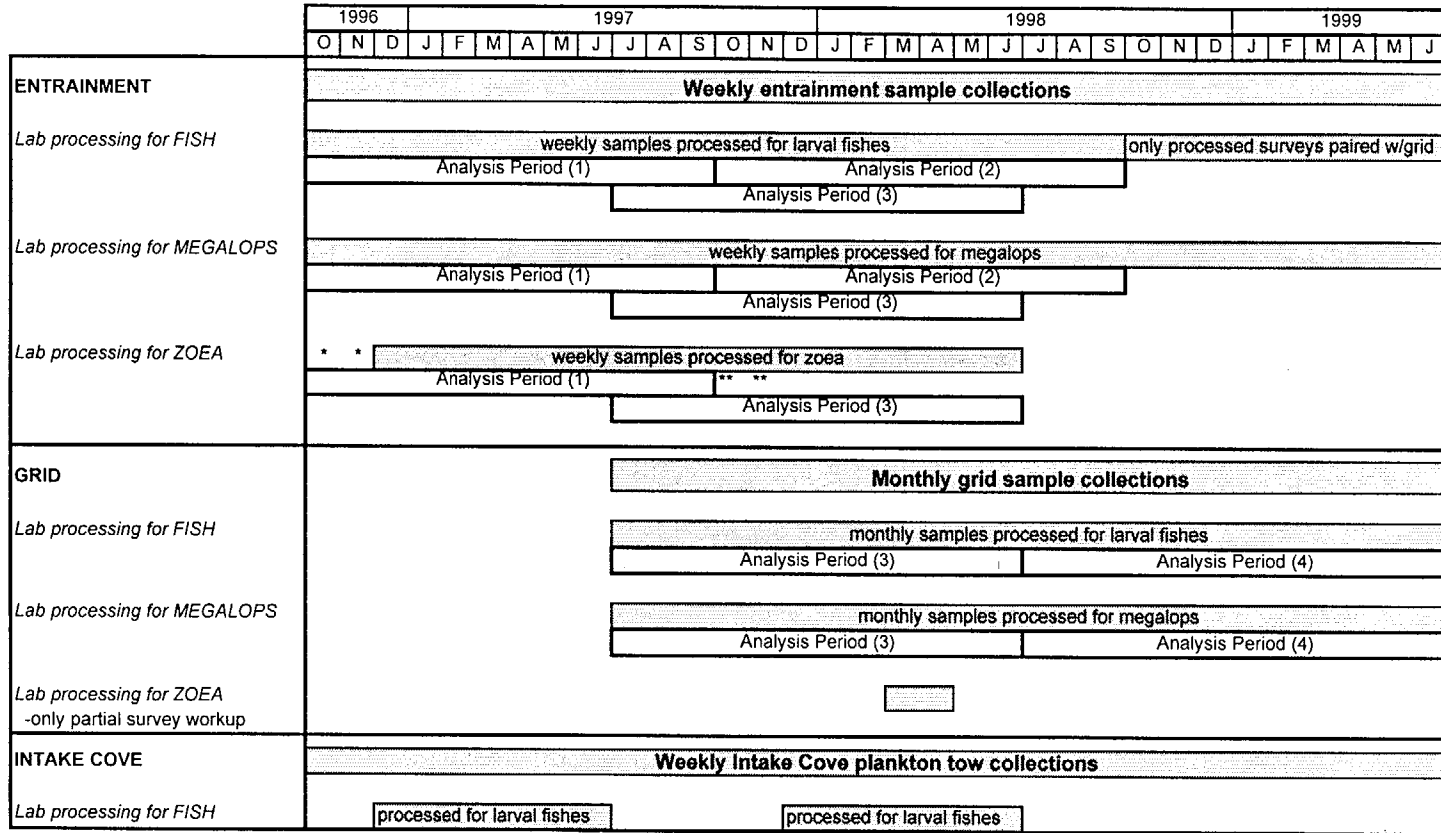


Figure 4-5. Diagram of DCPD Intake Cove surface plankton tow sampling location.



* zoea not removed from these samples.

** zoea density substituted for October and November 1996

Analysis Period (1): October 23, 1996 - September 30, 1997

Analysis Period (2): October 1, 1997 - September 30, 1998

Analysis Period (3): July 1, 1997 - June 30, 1998

Analysis Period (4): July 1, 1998 - June 30, 1999

Figure 4-6. Summary of entrainment, study grid, and Intake Cove surface plankton tow sample collection, laboratory processing, and analysis periods.

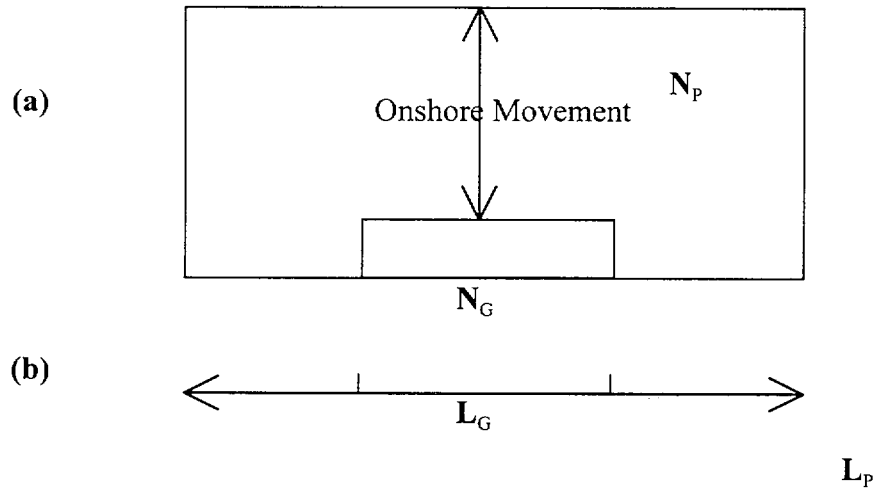


Figure 4-7. Two approaches for calculating \hat{P}_s based upon water current measurements: (a) For species dispersed throughout the sampling grid (small rectangle), both alongshore and onshore components are used to calculate $\hat{P}_s = \frac{\hat{N}_G}{\hat{N}_p}$, where \hat{N}_G is the larval population estimate of the offshore grid and \hat{N}_p is the estimate of larval abundance of the population of inference; (b) For nearshore species, only the alongshore component is used to calculate $\hat{P}_s = \frac{L_G}{L_p}$, where L_G is the length of the offshore grid and L_p is the estimated alongshore movement through the offshore grid.

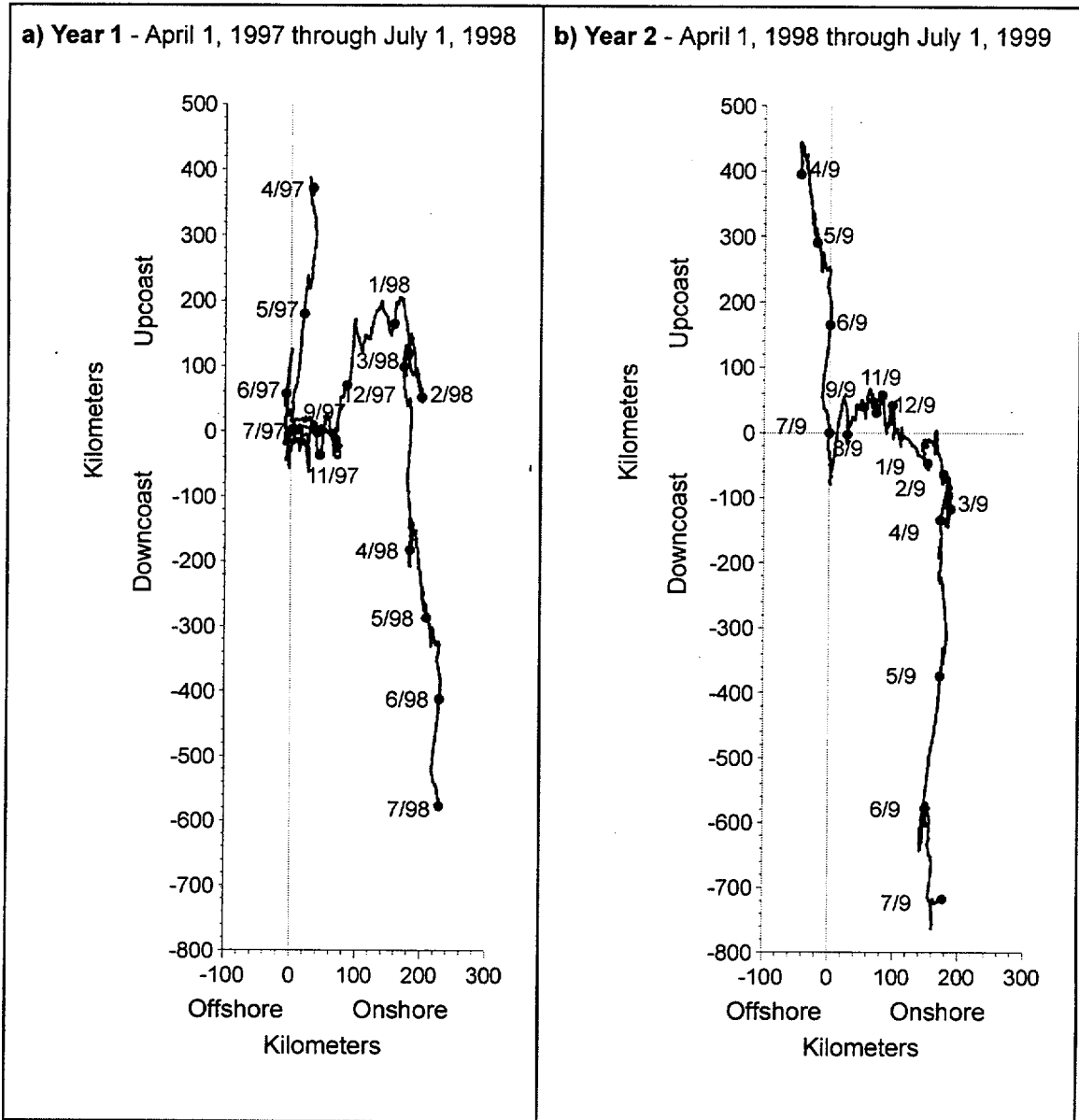


Figure 4-8. Cumulative upcoast/downcoast and onshore/offshore movement of water at the Diablo Canyon current meter station (current meter station is located at the cross-hairs).

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5.0 RESULTS

This section is divided into a general overview of the data collected during the entrainment and impingement studies at DCP, results of various modeling analyses on selected target taxa, and a summary of the taxa assessments.

5.1 Overview

The following is a general overview of the data collected and analyzed for the DCP Section 316(b) Demonstration. Density estimates of target organisms were determined from plankton collections at the intake structure, in the Intake Cove, and in the study grid. The sections that follow present and discuss the results of analyses of individual target taxa chosen by the ETWG.

5.1.1 Entrainment

Entrainment is defined as the capture and inclusion of organisms in the cooling water of power plants (Schubel and Marcy 1978). Organisms become entrained in the cooling water system at DCP once they pass through the traveling screens and cannot escape. Larval stages of fish and invertebrates are usually weak swimmers and generally enter the flow passively.

5.1.1.1 Weekly Abundance Estimates of Entrainment

There were 8,804 subsamples collected at the entrainment sampling location from October 23, 1996 through June 1999. In accordance with the ETWG agreement, larval fishes, *Cancer* crab larvae, and sea urchin larvae were identified and enumerated from a portion of these subsamples. *Cancer* crab megalops were processed from 5,524 subsamples, larval fish from 4,693 subsamples, and *Cancer* crab zoea and stronglylocentrotid sea urchins from 636 subsamples during laboratory processing. The data for sea urchins were collected for informational purposes only and were not used in assessing entrainment effects per agreement with the ETWG.

Cancer spp. crabs

Zoal stages of *Cancer antennarius*, *C. anthonyi*, *C. gracilis*, *C. productus*, and two *Cancer* spp. identifications left at the generic level were found in the entrainment subsamples. One unidentified *Cancer* species (sp. A) was confirmed late in the study to be *Cancer jordani* (P. Reilly, CDF&G, Monterey, CA). There were 96,295 zoeae identified and enumerated from the 636 entrainment subsamples processed. The mean density of each stage by species is presented in **Appendix H**. In general, zoeal stage 1 individuals were most abundant, and zoeal stage 5 individuals were least abundant.

The megalopal stage of *Cancer* spp. crabs was also identified and enumerated from entrainment subsamples. Megalops of *Cancer antennarius*, *C. anthonyi*, *C. gracilis*, *C. magister*, *C. productus*, and at least two generic identifications of *Cancer* spp. and *C. jordani* were recorded. In the 5,524 entrainment subsamples processed for megalops, 4,887 individuals were identified and enumerated. *Cancer antennarius* and *C. gracilis* megalops were more abundant than other *Cancer* species megalops (**Appendix H**).

The species chosen by the ETWG for analysis were *Cancer antennarius* and *C. gracilis* (Tenera 1997b). Additional information on the demography and results of the three assessment models for these two species is presented in **Section 5.2.1**.

Fishes

There were 98,593 larval fishes identified and enumerated from 4,693 entrainment subsamples (**Appendix H**). Of these, ~98% were placed into 178 different taxonomic categories ranging from ordinal to specific classifications (**Table 5.1-1**) while the remaining ~2% were placed into one of three categories: unidentified larval fish (0.4%), unidentified damaged larval fish (0.2%), or unidentified larval fish fragment (1%). Adults of these taxa live in a variety of habitats, from intertidal and shallow subtidal to deep-water and pelagic habitats. The taxa in highest abundance were those whose adults were generally found close to shore, in shallow water. One exception was the thirteenth most abundant taxon, the northern lampfish (*Stenobranchius leucopsarus*), whose adults are found to depths of 3,000 m (Miller and Lea 1972).

The ETWG chose 14 larval fish taxa (**Table 4-1**) for detailed assessment using the *FH*, *AEL*, and *ETM* approaches. Results of these analyses are presented separately in subsequent sections.

Sea Urchins

The ETWG agreed that only metamorphosing and recently metamorphosed juvenile sea urchins would be removed, identified, and enumerated from the entrainment subsamples, but that no assessment of entrainment effects would be made. Due to the small size of the echinopluteus larvae, it was assumed that many would be extruded through the net mesh used, resulting in an underestimate of their abundance.

A total of 5,966 sea urchin larvae was found in the 636 subsamples processed. The weekly mean density of *Strongylocentrotus fransicanus* and *S. purpuratus* individuals collected at the intake during the period October 1996 through June 1998 is presented in **Figure 5.1-1**. The density of *S. purpuratus* was greater than *S. fransicanus* during most surveys where individuals of both species were present. Both species were most abundant during the spring and summer, with highest densities of *S. fransicanus* present in March 1997 and *S. purpuratus* peak densities observed during June 1997. A greater density of both species occurred during 1997 than in 1998. Generally, only a few individuals were collected during the fall or winter. A summary of the data for all entrainment surveys is presented in **Appendix H**.

5.1.1.2 Monthly Abundance Estimates in the Study Grid

A total of 6,141 subsamples was collected during the monthly study grid surveys conducted from July 1997 through June 1999. As agreed with the ETWG, larval fish were identified and enumerated from 3,061 subsamples, megalops were identified and enumerated from 3,066 subsamples, and zoea and urchins were identified and enumerated from 128 subsamples during laboratory processing (**Appendix G**).

Cancer spp. crabs

The five *Cancer* crab zoeal stages were removed from the half of the subsamples preserved in formalin and collected during the March and April 1998 grid surveys. The ETWG decided not to require that zoea be removed from the remainder of the grid subsamples collected during this study.

Zoeal stages of *Cancer antennarius*, *C. gracilis*, *C. anthonyi*, *C. productus*, *C. jordani*, and at least one unidentified *Cancer* spp. were found in the subsamples from the two study grid surveys that were processed. A total of 27,270 zoea was removed and identified from the 128 grid samples processed. The mean density of each stage by species is presented in **Appendix H**. Generally, recently hatched stage 1 zoea were the most abundant and older stage 5 zoea were least abundant.

The megalops stage of *Cancer antennarius*, *C. gracilis*, *C. anthonyi*, *C. productus*, *C. magister*, *C. jordani*, and at least one unidentified *Cancer* spp. were found in the study grid samples. In the 3,066 grid samples processed for megalops, 6,599 individuals were removed and identified. The mean density of megalops by species for each survey is presented in **Appendix H**. *Cancer antennarius* and *C. gracilis* megalops were more abundant than the megalops of other *Cancer* species. The *ETM* assessment of these two species only uses megalops data because zoea were not processed from all of the paired study grid surveys per agreement by the ETWG.

Fishes

There were 43,785 larval fishes identified and enumerated from the 3,163 study grid subsamples that comprised 175 different taxa ranging from ordinal to specific levels of classification. Adults of these taxa live in a variety of habitats, from intertidal and shallow subtidal to deep-water and pelagic habitats. The taxa in highest abundance in the grid subsamples were those whose adults were typically pelagic or subtidal; more intertidally or nearshore distributed species were found in lower abundance in the study grid.

Sea Urchins

Sea urchins were identified from the half of the subsamples preserved in formalin during only the March and April 1998 study grid surveys. The ETWG decided not to require that sea urchins be sorted from the remainder of the study grid subsamples and agreed that the data would not be assessed using a mathematical modeling approach (Tenera 1997b). There were 764 *Strongylocentrotus* spp. found in the 128 subsamples processed. The mean density of *S. purpuratus* in March and April of 1998 appeared to be greater than *S. fransicanus* during those months (**Appendix H**).

5.1.1.3 Weekly Intake Cove Surface Tows

There were 27,062 larval fishes identified and enumerated from 660 Intake Cove surface plankton tow samples collected between 1990 and 1998. The ETWG agreed that only the samples from the 7 mo period of December through June of each year would be processed and analyzed for each year because these months are generally the period of peak larval abundance for most species. The taxa present in these samples were similar to those found in the entrainment and study grid samples (**Appendix H**). As mentioned previously, these data were used to generate a nine-year average of larval abundance. This index calculated from this long-term average was then used to scale the estimates of annual entrainment for each taxon.

5.1.2 Impingement

There were 66 taxa representing 29 families of bony fishes, sharks, rays, and eels identified from impinged material collected during the 1985–86 DCP study (**Table 5.1-1**). Some taxa, such as thornback rays, were collected in higher numbers and biomass at Unit 2 despite more frequent sampling at Unit 1. The densities of impinged fishes for Units 1 and 2 were compared during a 10 d period when pump and traveling screen operations between units were similar (PG&E 1988). The densities of impinged skates and rays were greater on the Unit 2 screens than at Unit 1 (PG&E 1988). Impingement rates for both units were similar for rockfishes and total bony fishes (PG&E 1988).

The CWP did not operate continually during the impingement sampling (**Figure 5.1-2**). Equipment repairs on Unit 1 resulted in periods when pumps or traveling screens were not in full operation. Unit 2 was in the final stages of construction and testing during the DCPD Section 316(b) impingement study, which also limited the number of days when the pumps were operational and traveling screens were sampled. Although impingement sampling was scheduled to occur on the same day each week, it was adjusted several times due to operations at the intake. A total of 51 d was sampled for Unit 1, and 24 d were sampled for Unit 2. Unit 2 began operating on a more regular basis by October 1985. There were eight days of sampling when both Units 1 and 2 were fully operational for 24 hr (**Figure 5.1-2**).

Many fishes live within the intake forebays without becoming impinged. Diver observations and underwater video of the DCPD traveling screens during pre-operation (Behrens and Larsson 1979) and operation (PG&E 1988) have recorded both large and small fishes freely swimming throughout the forebays in front of the traveling screens. During the impingement study, divers in the Intake Cove on August 21, 1985, observed over 100 juvenile yellowtail/olive rockfishes in front of the Unit 1 bar racks (PG&E 1988), yet only one rockfish was collected during the two August impingement surveys.

The number of fishes, their combined weight, and the amount of debris collected during each of the 24-hour surveys were compared for samples collected at Units 1 and 2 (**Figure 5.1-3**). There does not appear to be a relationship between the number or weight of fishes and the amount of debris collected by Unit 1. The largest number of fishes was collected from Unit 1 during late June 1985 when the amount of debris collected was low. The total weight of fishes was low because most of the individuals were young-of-the-year rockfishes ca. 60–80 mm in length. At Unit 2, the greatest number and weight of fishes impinged did not consistently occur when the amount of debris was heaviest. The largest amount of debris was collected during late December 1985. During that period, the weight of the fishes in the collection was high, but the number of individuals was low.

A total of 1,314 *Cancer antennarius* was collected in impingement samples from February 1985 through March 1986. Ninety-seven percent of the crabs were juveniles, having an average weight of about 3 g. **Table 5.1-2** presents the standardized biomass (g/million m³ of water entrained) of *Cancer* crab species impinged at DCP. Among the various species of *Cancer* crabs, *C. antennarius* were impinged at the highest rate. The overall impingement rate of *Cancer* crabs was similar for both power plant units.

A report reviewing the 1985–86 DCP impingement study was prepared and submitted to the ETWG (Tenera 1988). The ETWG determined that additional impingement studies were not required at DCP based on this report that showed that the plant had generally low rates of impingement.

Table 5.1-1. Phylogenetic list of fishes collected during the Diablo Canyon Power Plant 316(b) study following primarily the AFS list of Common and Scientific Fish Names (Robins et al. 1991) and secondarily the classification adopted by Moser (1996).

Order	Suborder	Family	Genus & Species	Common Name
Clupeiformes				
		Clupeidae	herrings <i>Etrumeus teres</i> (DeKay 1842)	round herring
			<i>Sardinops sagax</i> (Jenyns 1842)	Pacific sardine
		Engraulididae	anchovies <i>Anchoa compressa</i> (Girard 1858)	deepbody anchovy
			<i>Engraulis mordax</i> Girard 1854	northern anchovy
Salmoniformes				
	Argentinoidei			
		Argentinidae	Argentine <i>Argentina sialis</i> Gilbert 1890	Pacific argentine
		Bathylagidae	blacksmelt and smoothtongues <i>Bathylagus ochotensis</i> Schmidt 1938	popeye blacksmelt
			<i>Bathylagus pacificus</i> Gilbert 1890	Pacific blacksmelt
			<i>Leuroglossus</i> spp.	smooth tongues
			<i>Leuroglossus stilbius</i> Gilbert 1890	California smoothtongue
		Microstomatidae	pencilfishes <i>Microstoma</i> spp.	dusky pencilsmelt
	Salmonoidei			
		Osmeridae	smelts	
Stomiiformes				
		Gonostomatidae	lightfishes <i>Cyclothone</i> spp.	bristlemouths
			<i>Cyclothone signata</i> Garman 1899	showy bristlemouth
		Sternoptychidae	hatchetfishes <i>Sternoptyx</i> spp.	hatchetfish
		Phosichthyidae	highseas lightfishes <i>Vinciguerrria lucetia</i> (Garman 1899)	Pacific lightfish
			<i>Vinciguerrria poweriae</i> (Cocco 1838)	highseas lightfish
		Chauliodontidae	dragonfishes <i>Chauliodus macouni</i> Bean 1890	Pacific viperfish
		Stomiidae	scaly dragonfishes <i>Stomias atriventer</i> Garman 1899	blackbelly dragonfish
Aulopiformes				
	Alepisaurioidei			
		Synodontidae	lizardfishes <i>Synodus lucioceps</i> (Ayres 1855)	California lizardfish
		Paralepididae	barracudinas <i>Lestidiops ringens</i> (Jordan & Gilbert 1880)	slender barracudina

(continued)

Table 5.1-1. (cont'd)

Order	Suborder	Family	Genus & Species	Common Name
Myctophiformes				
		Myctophidae	lanternfishes	
			<i>Ceratoscopelus townsendi</i> (Eigenmann & Eigenmann 1889)	dogtooth lampfish
			<i>Diaphus theta</i> Eigenmann & Eigenmann 1890	California headlight fish
			<i>Diogenichthys atlanticus</i> (Tåning 1928)	longfin lanternfish
			<i>Hygophum atratum</i> (Garman 1899)	thickhead lanternfish
			<i>Nannobranchium regalis</i> (Gilbert 1892)	pinpoint lampfish
			<i>Nannobranchium ritteri</i> (Gilbert 1915)	broadfin lampfish
			<i>Nannobranchium</i> spp.	lanternfishes
			<i>Protomyctophum crockeri</i> (Bolin 1939)	California flashlightfish
			<i>Stenobranchius leucopsarus</i> (Eigenmann & Eigenmann 1890)	northern lampfish
			<i>Symbolophorus californiensis</i> (Eigenmann & Eigenmann 1889)	California lanternfish
			<i>Tarletonbeania crenularis</i> (Jordan & Gilbert 1880)	blue lanternfish
			<i>Triphoturus mexicanus</i> (Gilbert 1890)	Mexican lampfish
Gadiformes				
		Gadidae	cods	
			<i>Microgadus proximus</i> (Girard 1854)	Pacific tomcod
		Merlucciidae	hake	
			<i>Merluccius</i> spp.	hake
			<i>Merluccius productus</i> (Ayres 1855)	Pacific hake
Ophidiiformes				
		Ophidiidae	cusks-eels	
			<i>Chilara taylori</i> (Girard 1858)	spotted cusk-eel
			<i>Ophidion scrippsae</i> (Hubbs 1916)	basketweave cusk-eel
		Bythitidae	brotulas	
			<i>Brosomphycis marginata</i> (Ayres 1854)	red brotula
			<i>Cataetx rubirostris</i> Gilbert 1890	rubynose brotula
Batrachoidiformes				
		Batrachoididae	toadfishes	
			<i>Porichthys notatus</i> Girard 1854	plainfin midshipman
Gobiesociformes				
		Gobiesocidae	clingfishes	
			<i>Gobiesox</i> spp.	clingfish
			<i>Gobiesox maeandricus</i> (Girard 1858)	northern clingfish
			<i>Rimicola</i> spp.	kelp clingfish
Atheriniformes				
		Atherinidae	silversides	
			<i>Atherinops affinis</i> (Ayres 1860)	topsmelt
			<i>Atherinopsis californiensis</i> Girard 1854	jacksmelt
			<i>Leuresthes tenuis</i> (Ayres 1860)	California grunion
		Scomberesocidae	sauries	
			<i>Cololabis saira</i> (Brevoort 1856)	Pacific saury

(continued)

Table 5.1-1. (cont'd)

Order	Suborder	Family	Genus & Species	Common Name
Lampridiformes	Trachipteroidei	Trachipteridae	ribbonfishes <i>Trachipterus altivelis</i> Kner 1858	king-of-the-salmon
Beryciformes	Stephanoberycoidei	Melamphaidae	bigscapes <i>Melamphaes</i> spp. <i>Melamphaes parvus</i> Ebeling 1962 <i>Poromitra crassiceps</i> (Günther 1878)	bigscapes little bigscale crested bigscale
Gasterosteiformes	Gasterosteoidae	Gasterosteidae	sticklebacks <i>Aulorhynchus flavidus</i> Gill 1861	tube-snout
	Syngnathoidae	Syngnathidae	pipefishes <i>Syngnathus</i> spp. <i>Syngnathus californiensis</i> Storer 1845 <i>Syngnathus leptorhynchus</i> Girard 1854	pipefishes kelp pipefish bay pipefish
Scorpaeniformes	Scorpaenoidei	Scorpaenidae	scorpion fishes, rockfishes, and thornyheads <i>Sebastes aurora</i> (Gilbert 1890) <i>Sebastes diploproa</i> (Gilbert 1890) <i>Sebastes jordani</i> (Gilbert 1896) <i>Sebastes levis</i> (Eigenmann & Eigenmann 1889) <i>Sebastes mystinus</i> (Jordan & Gilbert 1881) <i>Sebastes paucispinis</i> Ayres 1854 <i>Sebastes saxicola</i> (Gilbert 1890) <i>Sebastes</i> spp. <i>Sebastes</i> spp. I / V_DeP <i>Sebastes</i> spp. D <i>Sebastes</i> spp. V <i>Sebastes</i> spp. V_ <i>Sebastes</i> spp. V_D <i>Sebastes</i> spp. V_D_ <i>Sebastes</i> spp. V_De <i>Sebastes</i> spp. VD <i>Sebastes</i> spp. VP <i>Sebastes</i> VDP <i>Sebastolobus</i> spp.	aurora rockfish splitnose rockfish shortbelly rockfish cow cod blue rockfish bocaccio stripetail rockfish rockfishes rockfishes rockfishes rockfishes rockfishes rockfishes rockfishes rockfishes rockfishes rockfishes rockfishes rockfishes rockfishes thornyheads

(continued)

Table 5.1-1. (cont'd)

Order	Suborder	Family	Genus & Species	Common Name
Scorpaeniformes (cont'd)				
Hexagrammoidei				
Hexagrammidae				
			greenlings	
			<i>Hexagrammos</i> spp.	greenlings
			<i>Ophiodon elongatus</i> Girard 1854	lingcod
			<i>Oxylebius pictus</i> Gill 1862	painted greenling
			<i>Zaniolepis</i> spp.	combfishes
			<i>Zaniolepis frenata</i>	shortspine combfish
			Eigenmann & Eigenmann 1889	
			<i>Zaniolepis latipinnis</i> Girard 1858	longspine combfish
Cottoidei				
Cottidae				
			sculpins	
			<i>Artedius</i> spp.	sculpin
			<i>Artedius harringtoni</i> (Starks 1896)	scalyhead sculpin
			<i>Artedius lateralis</i> (Girard 1854)	smoothhead sculpin
			<i>Chitonotus / Icelinus</i>	sculpin
			<i>Chitonotus pugetensis</i> (Steindachner 1876)	roughback sculpin
			<i>Clinocottus</i> spp.	sculpins
			<i>Clinocottus analis</i> (Girard 1858)	wooly sculpin
			<i>Clinocottus embryum</i>	calico sculpin
			(Jordan & Starks 1895)	
			<i>Enophrys</i> spp.	sculpin
			<i>Hemilepidotus spinosus</i> (Ayres 1854)	brown Irish lord
			<i>Icelinus</i> spp.	sculpin
			<i>Icelinus quadriseriatus</i> (Lockington 1880)	yellowchin sculpin
			<i>Leptocottus armatus</i> Girard 1854	staghorn sculpin
			<i>Nautichthys oculo-fasciatus</i> (Girard 1858)	sailfin sculpin
			<i>Oligocottus</i> spp.	sculpin
			<i>Oligocottus maculosus</i> Girard 1856	tidepool sculpin
			<i>Oligocottus snyderi</i> Greeley 1898	fluffy sculpin
			<i>Orthonopias triacis</i> Starks & Mann 1911	snubnose sculpin
			<i>Radulinus</i> spp.	sculpin
			<i>Ruscarius creaseri</i> (Hubbs 1926)	roughcheek sculpin
			<i>Ruscarius meanyi</i> Jordan & Starks 1895	Puget Sound sculpin
			<i>Scorpaenichthys marmoratus</i> (Ayres 1854)	cabezon
			<i>Synchirus gilli</i> Bean 1890	manacled sculpin
Agonidae				
			poachers	
			<i>Odontopyxis trispinosa</i> Lockington 1880	pygmy poacher
			<i>Stellerina xyosterna</i>	pricklebreast poacher
			(Jordan & Gilbert 1880)	
Cyclopteridae				
			snailfishes	
			<i>Liparis</i> spp.	snailfishes
Perciformes				
Percoidei				
Serranidae				
			sea basses	
			<i>Paralabrax</i> spp.	sand basses
			<i>Paralabrax clathratus</i> (Girard 1854)	kelp bass

(continued)

Table 5.1-1. (cont'd)

Order	Suborder	Family	Genus & Species	Common Name
Perciformes (cont'd)				
Percoidei				
		Carangidae	jacks <i>Trachurus symmetricus</i> (Ayres 1855)	jack mackerel
		Haemulidae	grunts <i>Xenistius californiensis</i> (Steindachner 1875)	salema
		Sciaenidae	drums <i>Atractoscion nobilis</i> (Ayres 1860) <i>Cheilotrema saturnum</i> (Girard 1858) <i>Genyonemus lineatus</i> (Ayres 1855) <i>Menticirrhus undulatus</i> (Girard 1854) <i>Roncador stearnsi</i> (Steindachner 1875) <i>Seriphus politus</i> Ayres 1860 <i>Umbrina roncadore</i> Jordan & Gilbert 1882	white seabass black croaker white croaker California corbina spotfin croaker queenfish yellowfin croaker
		Kyphosidae	sea chubs <i>Girella nigricans</i> (Ayers 1860)	opaleye
		Pomacentridae	damsel-fishes <i>Chromis punctipinnis</i> (Cooper 1863)	blacksmith
		Sphyraenidae	barracudas <i>Sphyraena argentea</i> Girard 1854	Pacific barracuda
Labroidei				
		Labridae	wrasses <i>Oxyjulis californica</i> (Günther 1861) <i>Semicossyphus pulcher</i> (Ayres 1854)	senorita California sheephead
Zoarcoidei				
		Bathymasteridae	ronquils <i>Rathbunella</i> spp.	ronquils
		Stichaeidae	pricklebacks <i>Cebidichthys violaceus</i> (Girard 1854) <i>Chirolophis nugator</i> (Jordan & Williams 1895) <i>Plectobranchnus evides</i> Gilbert 1890	monkeyface eel mosshead warbonnet bluebarred prickleback
		Pholididae	gunnels	
Blennioidei				
		Clinidae	clinid kelpfishes <i>Gibbonsia</i> spp. <i>Heterostichus rostratus</i> Girard 1854	clinid kelpfishes giant kelpfish
		Chaenopsidae	tube blennies <i>Neoclinus</i> spp.	fringehead
		Blenniidae	combtooth blennies <i>Hypsoblennius</i> spp. <i>Hypsoblennius gilberti</i> (Jordan 1882)	blennies rockpool blenny
Icosteoidi				
		Icosteidae	ragfishes <i>Icosteus aenigmaticus</i> Lockington 1880	ragfish

(continued)

Table 5.1-1. (cont'd)

Order	Suborder	Family	Genus & Species	Common Name
Perciformes (cont'd)				
	Percoidei			
	Trachinoidei			
		Ammodytidae	sand lances <i>Ammodytes hexapterus</i> Pallas 1814	Pacific sand lance
	Gobioidei			
		Gobiidae	gobies <i>Coryphopterus nicholsi</i> (Bean 1882) <i>Eucyclogobius newberryi</i> (Girard 1856) <i>Lepidogobius lepidus</i> (Girard 1858) <i>Lythrypnus</i> spp. <i>Lythrypnus dalli</i> (Gilbert 1890) <i>Lythrypnus zebra</i> (Gilbert 1890) <i>Typhlogobius californiensis</i> Steindachner 1879	blackeye goby tidewater goby bay goby gobies bluebanded goby zebra goby blind goby
	Scombroidei			
		Scombridae	mackerels <i>Scomber japonicus</i> Houttuyn 1782	Pacific mackerel
	Stromateoidei			
		Centrolophidae	medusafishes <i>Icichthys lockingtoni</i> Jordan & Gilbert 1880	medusa fish
		Tetragonuridae	squaretails <i>Tetragonurus cuvieri</i> Risso 1810	smalleye squaretail
		Stromateidae	butterfishes <i>Peprilus simillimus</i> (Ayres 1860)	Pacific butterfish
Pleuronectiformes				
	Pleuronectoidei			
		Paralichthyidae	lefteye flounders <i>Citharichthys</i> spp. <i>Citharichthys sordidus</i> (Girard 1854) <i>Citharichthys stigmaeus</i> Jordan & Gilbert 1882 <i>Hippoglossina stomata</i> Eigenmann & Eigenmann 1890 <i>Paralichthys californicus</i> (Ayres 1859) <i>Xystreurus liolepis</i> Jordan & Gilbert 1880	sanddab Pacific sanddab speckled sanddab bigmouth sole California halibut fantail sole
		Pleuronectidae	righteye flounders <i>Embassichthys bathybius</i> (Gilbert 1890) <i>Eopsetta exilis</i> (Jordan & Gilbert 1880) <i>Errex zachirus</i> (Lockington 1879) <i>Hypsopsetta guttulata</i> (Girard 1856) <i>Lepidopsetta bilineata</i> (Ayres 1855) <i>Microstomus pacificus</i> (Lockington 1879) <i>Parophrys vetulus</i> (Girard 1854) <i>Platichthys stellatus</i> (Pallas 1787)	deepsea sole slender sole rex sole diamond turbot rock sole Dover sole English sole starry flounder

(continued)

Table 5.1-1. (cont'd)

Order	Suborder	Family	Genus & Species	Common Name
Pleuronectiformes				
Pleuronectoidei				
Pleuronectidae				
			righteye flounders	
			<i>Pleuronectes</i> spp.	righteye flounders
			<i>Pleuronectes isolepis</i> (Lockington 1880)	butter sole
			<i>Pleuronichthys</i> spp.	turbots
			<i>Pleuronichthys coenosus</i> Girard 1854	c-o turbot
			<i>Pleuronichthys ritteri</i> Starks & Morris 1907	spotted turbot
			<i>Pleuronichthys verticalis</i> Jordan & Gilbert 1880	hornyhead turbot
			<i>Psettichthys melanostictus</i> Girard 1854	sand sole
Soleioidei				
Cynoglossidae				
			tonguefishes	
			<i>Symphurus atricauda</i> (Jordan & Gilbert 1880)	California tonguefish
Unidentified Larval Fishes:				
			Whole larval fishes	
			Damaged larval fishes	
			Larval fish fragments	

Table 5.1-2. Total abundance, weight (grams), and average biomass (grams/million m³ flow) of impinged fishes at Diablo Canyon Power Plant (DCPP) during 1985–86. Abundance and weight are totals for the sampling periods; biomass is the number of grams per million m³ of water flow during the collection periods.

Taxon	Scientific Name	Common Name	02/05/85 - 03/31/85			Unit 1		Unit 2		04/01/85 - 03/31/86	
			Abun.	Weight	Bio.	Abundance	Weight	Abundance	Weight	Unit 1 Biomass	Unit 2 Biomass
Total All Fishes:			11	1421	6.49	262	140	14441.3	12746.2	65.64	148.21
BONY FISHES (Osteichthyes)											
Engraulidae	<i>Engraulis mordax</i>	northern anchovy					1		24.0		0.28
Batrachoididae	<i>Porichthys notatus</i>	plainfin midshipman				11	8	1056.6	658.2	4.80	7.65
Ophidiidae	<i>Chilara taylora</i>	spotted cusk-eel	1	23.8	0.11						
Gobiesocidae	<i>Gobiesox maeandricus</i>	northern clingfish				2	1	2.6	7.7	0.01	0.09
Atherinidae	<i>Atherinops affinis</i>	topsmelt				1	2	11.0	55.5	0.05	0.65
Gasterosteidae	<i>Aulorhynchus flavidus</i>	tubenout				7	6	14.5	23.2	0.07	0.27
Syngnathidae	<i>Syngnathus californiensis</i>	kelp pipefish	1	4.8	0.02	8	4	143.5	40.2	0.65	0.47
	<i>Syngnathus</i> spp.	unidentified pipefish				2	1	6.9	5.3	0.03	0.06
	<i>Syngnathidae</i> unid.	unidentified pipefish				1		0.7		<0.01	
Scorpaenidae	<i>Sebastes atrovirens</i>	kelp rockfish				6	3	509.2	21.9	2.31	0.25
	<i>Sebastes carnatus</i>	gopher rockfish				2	1	8.4	2.0	0.04	0.02
	<i>Sebastes flavidus</i>	yellowtail rockfish				34	14	207.3	144.5	0.94	1.68
	<i>Sebastes jordani</i>	shortbelly rockfish				1		1.6		0.01	
	<i>Sebastes melanops</i>	black rockfish				1	1	3.9	3.4	0.02	0.04
	<i>Sebastes mystinus</i>	blue rockfish				5	3	326.4	152.1	1.48	1.77
	<i>Sebastes paucispinis</i>	boccacio				2		7.8		0.04	
	<i>Sebastes rastrelliger</i>	grass rockfish	1	70.2	0.32						
	<i>Sebastes serranoides</i>	olive rockfish				19	9	484.7	543.4	2.20	6.32
	<i>Sebastes serranoides/flavidus</i>	olive/yellowtail rockfish				7	3	46.3	16.2	0.21	0.19
	<i>Sebastes</i> spp.	unidentified rockfish				6	2	21.4	6.5	0.10	0.05
Hexagrammidae	<i>Hexagrammos decagrammus</i>	kelp greenling	1	143.1	0.65	1		5.9		0.03	
	<i>Oxylebius pictus</i>	painted greenling				1		29.3		0.13	
	<i>Zaniolepis latipinnis</i>	longspine combfish					1		29.0		0.34
Cottidae	<i>Arctidius creaseri</i>	roughcheek sculpin				1		2.4		0.01	
	<i>Arctidius corallinus</i>	coralline sculpin				8	2	74.4	6.2	0.34	0.07
	<i>Arctidius lateralis</i>	smoothhead sculpin	1	5.8	0.03	7	3	37.7	12.8	0.17	0.15
	<i>Arctidius notosplitonus</i>	bonyhead sculpin				1		2.3		0.01	
	<i>Cottidae</i>	unidentified sculpin				1		3.5		0.02	
	<i>Oligocottus maculosus</i>	tidepool sculpin				1		3.1		0.01	
	<i>Oligocottus rubellio</i>	rosy sculpin				2		9.2		0.04	
	<i>Orthonotus triacis</i>	snubnose sculpin				5	4	29.2	22.7	0.13	0.26
	<i>Scorpaenichthys marmoratus</i>	cabazon				1		4.9		0.02	
Agonidae	<i>Agonopsis stertetus</i>	southern poacher					1		7.8		0.09
Cyclopteridae	<i>Liparis mucosus</i>	slimy snailfish				1		3.0		0.01	
Carangidae	<i>Trachurus symmetricus</i>	jack mackerel	1	273.4	1.24	1	3	329.4	386.8	1.50	4.50
Sciaenidae	<i>Seriphys pollius</i>	queenfish				2	7	8.2	40.5	0.04	0.47
Embiotocidae	<i>Amphistichus argenteus</i>	barred surfperch				2		10.0		0.05	
	<i>Brachyistius frenatus</i>	kelp surfperch				6	3	79.8	29.1	0.36	0.34
	<i>Cymatogaster aggregata</i>	shiner surfperch				17		212.3		0.97	
	<i>Embiotoca jacksoni</i>	black surfperch	1	296.3	1.35	2		517.4		2.35	
	<i>Embiotoca lateralis</i>	striped surfperch			0.03	3		190.7		0.87	
	<i>Embiotocidae</i>	unidentified surfperch	1	6.4	0.03	3		45.3		0.21	
	<i>Hyperprossopon argenteum</i>	walleye surfperch				2	3	23.0	103.8	0.10	1.21
	<i>Micrometrus minimus</i>	dwarf surfperch				1	1	7.7	4.1	0.04	0.05
	<i>Phanerodon furcatus</i>	white surfperch				1		3.6		0.02	
Labridae	<i>Oxyjulis californica</i>	senorita					1		16.0		0.19
Pomacentridae	<i>Chromis punctipinnis</i>	blacksmith				1	2	109.5	66.7	0.50	0.78
Clinidae	<i>Gibbonsia erythra</i>	scarlet kelpfish					2		12.8		0.15
	<i>Gibbonsia metzi</i>	striped kelpfish				8	1	145.0	4.7	0.66	0.05
	<i>Gibbonsia montereyensis</i>	crevice kelpfish				4		16.4		0.07	
	<i>Gibbonsia</i> spp.	unidentified kelpfish					2		55.5		0.65
Stichaeidae	<i>Anoplarchus purpurascens</i>	high cockscomb				2	2	26.5	23.4	0.12	0.27
Pholidae	<i>Ulivicola sanctaerosue</i>	kelp gunnel				1		3.3		0.02	
	<i>Xerepes furcator</i>	rockweed gunnel				1	1	8.5	4.9	0.04	0.06
Scombridae	<i>Scomber japonicus</i>	Pacific mackerel				2	2	801.7	733.4	3.64	8.53
Cynoglossidae	<i>Symphurus atricauda</i>	California tonguefish				2		6.8		0.03	
Paralichthyidae	<i>Citharichthys stigmaeus</i>	speckled sanddab	1	20.7	0.09	4		4.7		0.02	
	<i>Xystreureys liolepis</i>	fantail sole				9		869.2		3.95	
Pleuronectidae	<i>Pleuronectidae</i> unid.	unidentified turbot or sole				1		1.7		0.01	
	<i>Microstomus pacificus</i>	dover sole				1		32.8		0.15	
	<i>Pleuronichthys coenosus</i>	C-O turbot				1		74.8		0.34	
Total Fishes:			9	844.5	3.87	223	100	6586.0	3261.8	29.94	37.93
Sharks and Rays (Chondrichthyes)											
Rajidae	<i>Raja binoculata</i>	big skate				3	2	86.0	73.6	0.39	0.86
Torpedinidae	<i>Torpedo californica</i>	Pacific electric ray	1	374.4	1.70	10	4	1830.2	693.2	8.32	8.06
Platyrrhinidae	<i>Platyrrhinoidis triseriata</i>	thornback ray	1	202.1	0.92	23	32	4687.4	7475.9	21.31	86.93
Dasyatidae	<i>Urolophus halleri</i>	round stingray					1		407.9		4.74
Chimeridae	<i>Hydrolagus collei</i>	spotted ratfish				3	1	1251.7	833.8	5.69	9.70
Total Sharks and Rays:			2	576.5	2.62	39	40	7855.3	9484.4	35.71	110.28

Table 5.1-3. Biomass (grams/million m³ flow) of impinged *Cancer* spp. crabs at DCPD from April 1985 through March 1986.

Species	Unit 1	Unit 2
<i>Cancer antennarius</i>	27.43	21.69
<i>Cancer anthonyi</i>	0.02	0.88
<i>Cancer productus</i>	0.47	1.97
<i>Cancer jordani</i>	0.42	0.27
<i>Cancer magister</i>	0.01	-
<i>Cancer</i> spp.	0.03	0.01
<i>Cancer gracilis</i>	0.29	-
TOTAL	28.67	24.82

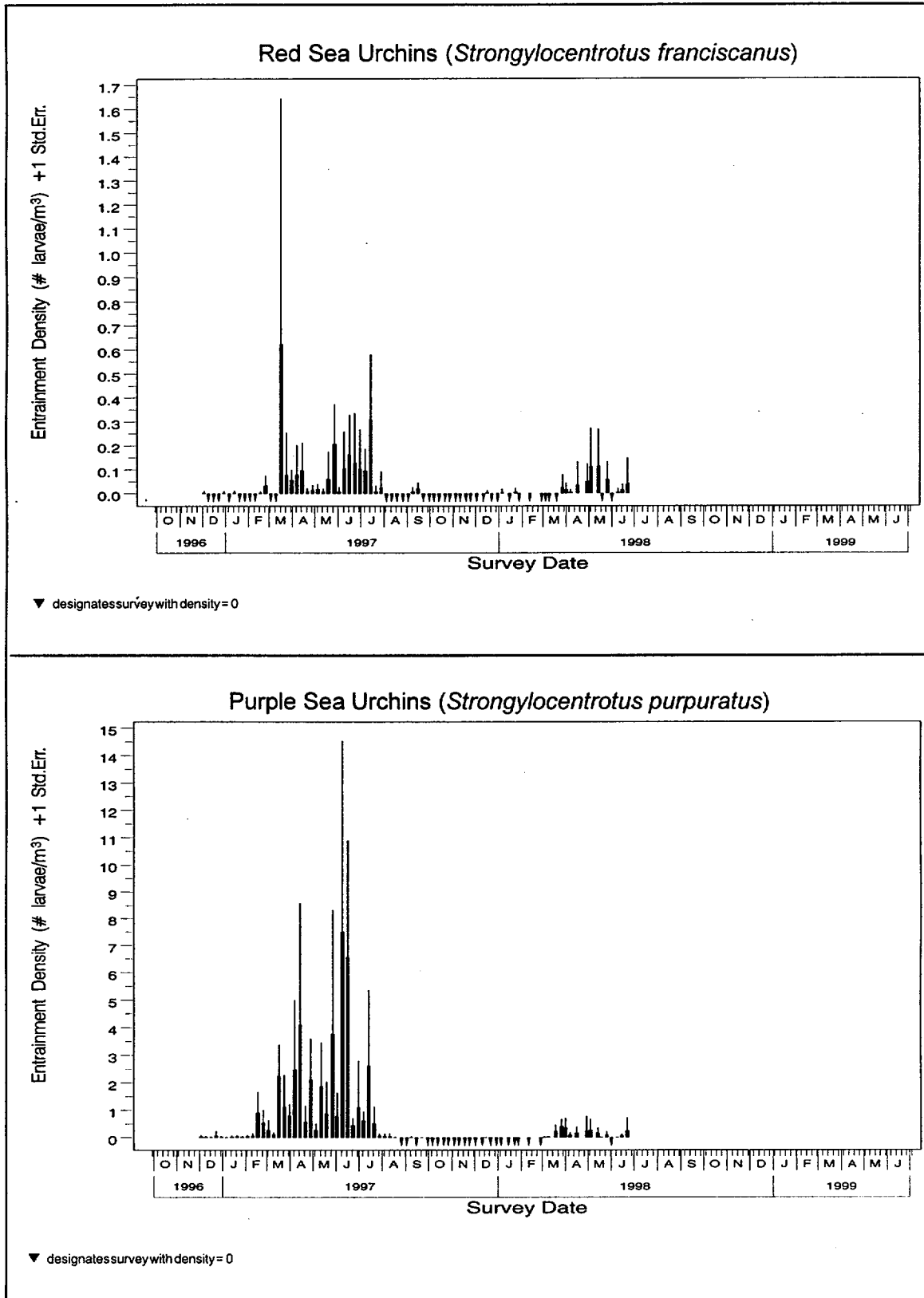
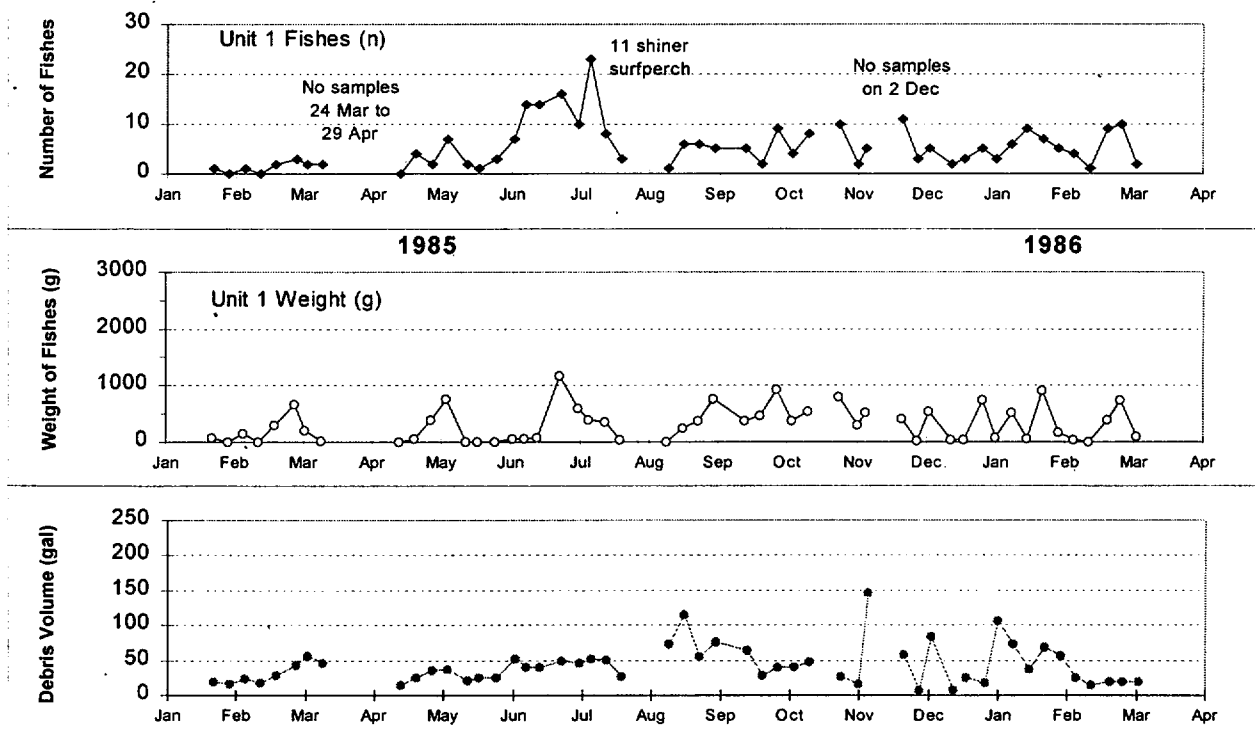


Figure 5.1-1. Weekly mean larval density (#/m³ + 1 S.E.) at the DCP intake. Y-axis scale varies between graphs.

UNIT 1



UNIT 2

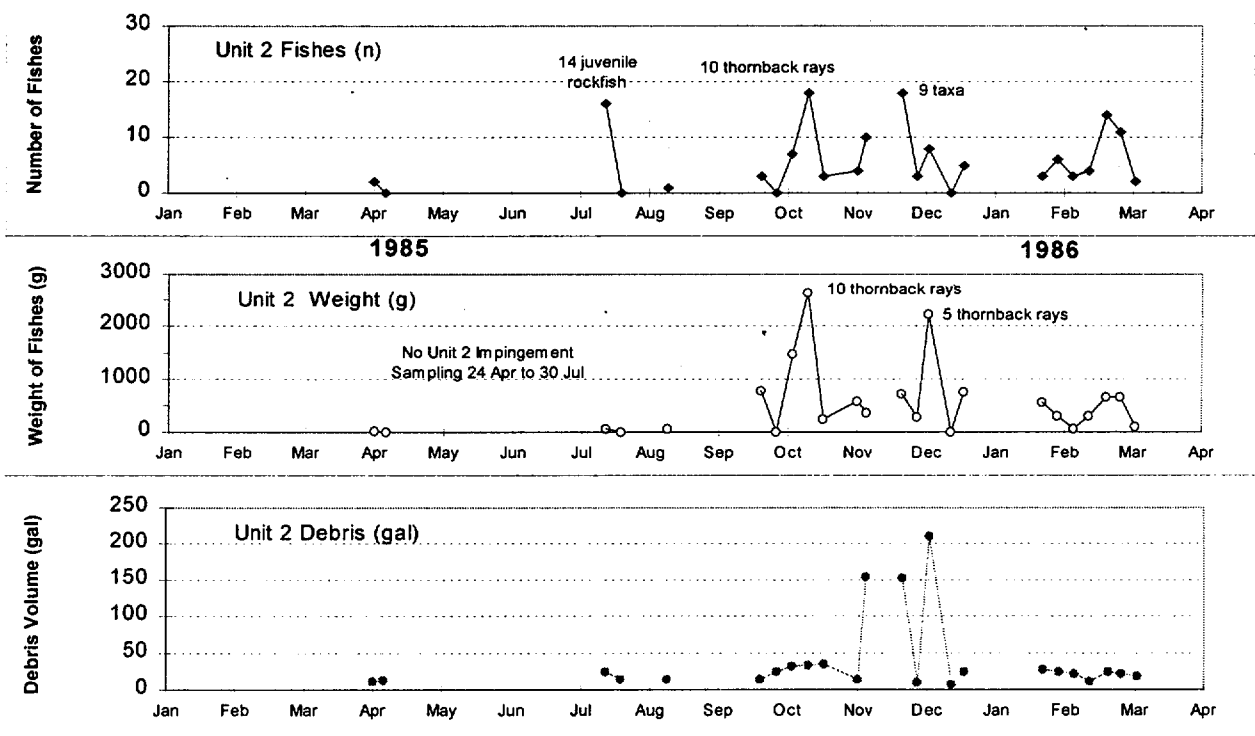


Figure 5.1-3 Comparison of fish abundance (n) and weight (g), and seaweed debris volume (gallons) collected in DCP Unit 1 and 2 impingement samples.

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5.2 Assessment of Effects on Target Taxa

The effects of larval entrainment mortality caused by the DCPD cooling water intake system were assessed for 16 target taxa. In the following sections, life history and distribution information describing the adult and early life stages of these taxa were summarized to give context to the subsequent estimates of entrainment effects. The data generated from the various sampling programs were then used to estimate effects of larval entrainment mortality using demographic data for hindcasting (*FH*) or prediction (*AEL*) of adult losses, or were translated directly into proportional annual losses to the local larval population (P_M).

5.2.1 Assessment of Target Taxa in the Crab Genus *Cancer*

Crabs of the genus *Cancer* are widely distributed in coastal waters of the west coast of North America (Nations 1975). They occur in intertidal and shallow subtidal habitats on both rock and sand substrate. Of the nine species known to occur in the northeast Pacific, four species contribute to economically significant fisheries. Dungeness crab (*Cancer magister*) has the highest economic value among these, and three species of rock crabs (*C. anthonyi*, *C. antennarius*, and *C. productus*) comprise the remainder of the catches. Seven species of *Cancer* larvae have been collected in the DCPD entrainment study and are listed here (in order of relative abundance):

Common name	Scientific Name
Brown rock crab	<i>C. antennarius</i>
Slender crab	<i>C. gracilis</i>
Hairy rock crab	<i>C. jordani</i>
Red rock crab	<i>C. productus</i>
Yellow crab	<i>C. anthonyi</i>
Dungeness crab	<i>C. magister</i>
unknown sp. A	<i>Cancer</i> spp.

The two most abundant species (brown rock crab and slender crab) were selected for a detailed impact assessment in this report. The other five species were not consistently abundant enough in the study to be analyzed.

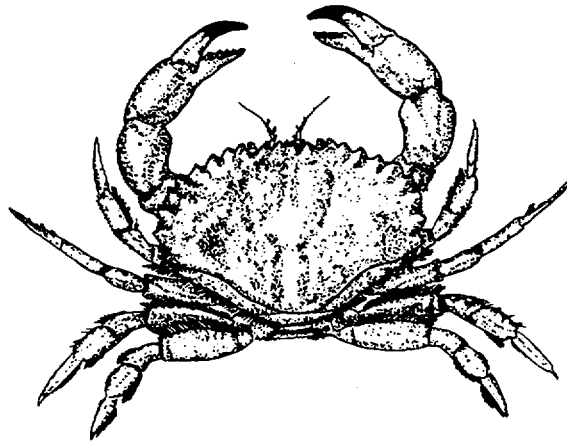
All species of *Cancer* crabs share certain fundamental life history traits. Eggs are extruded from the ovaries through an oviduct and are carried in a sponge-like mass beneath the abdominal flap of the adult female. After a development period of several weeks, the eggs hatch and a pre-zoea larva emerges, 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 1–2 yr. 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 yr, 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 is a relatively large species (carapace width >200 mm) that lives primarily on sand and mud substrates in estuarine and coastal shelf areas. Slender crab is a smaller species (carapace width >130 mm) associated with mixed rock-sand substrates in shallow outer coast habitats. Maximum clutch sizes in *Cancer* crabs can range from as many as 5,000,000 eggs in *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.

Rock crabs are fished along the entire California coast (Leet et al. 1992). Three species are harvested commercially: brown rock crab, red rock crab, 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 takes place. Recreational crabbing is popular in many areas and is often conducted in conjunction with other fishing activities. The commercial harvest has been difficult to assess on a species-by-species basis because the fishery statistics are combined into the general “rock crab” category. Rock crab landings in California in 1990 were 818 MT, including the landings of crab claws only that were converted to whole weight (Leet et al. 1992). Rock crab landings from five ports near the Monterey Bay National Marine Sanctuary averaged 92 MT/yr from 1980–1995 (Starr et al. 1998).

5.2.1.1 Brown rock crab (*Cancer antennarius*)



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

The brown rock crab primarily inhabits rocky shores and rocky subtidal reefs but may bury in coarse to silty sands adjacent to preferred habitat. Ovigerous brown rock crabs have been observed buried in sand at the base of rocks in shallow water and are found more commonly in water less than 18 m (59 ft) deep in southern California. Brown rock crab females can extrude between approximately 156,000 and 5 million eggs per batch (Hines 1991; **Table 5.2.1-1**). Females on average produce a single batch per year; however, due to occasional multiple spawnings, the average number of batches per year may be greater than one (Carroll 1982).

Eggs require a development time of approximately 7–8 wk from extrusion to hatching (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 1 h. Average larval development time (from hatching through completion of the fifth stage) was 36 d at 13.8 °C. Although some crabs molted to the megalops stage, none molted to the first crab instar stage, so the actual duration of the megalops stage is unknown. A reasonable estimate can be derived from studies of slender crab by Ally (1975), who found an average duration of megalops stage of 14.6 d. Therefore, the estimated length of time from hatching to settling for brown rock crab is approximately 50 d.

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 zoea 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; late stage larvae, however, were more abundant near the surface. He suggested that a combination of physical factors (primarily including wind-generated surface currents and tidally forced internal waves) caused megalopae to be transported shoreward. Late stage larvae (megalops) generally begin to recruit to the nearshore habitat in spring (Winn 1985).

There are no published estimates of brown rock crab larval mortality. However, data from the abundance of zoea and megalops in the DCPD entrainment subsamples (**Appendix I**) can be used to estimate mortality between stages. First stage zoea of the taxa *Cancer antennarius*, *C. anthonyi*, and *C. gracilis* (combined because of uncertainties in identification) were substantially

more abundant, on average, than all other stages combined. The proportions of each species of zoea stage 1 were derived by using the proportions of each species in zoea stage 2 that could be identified to species. Larval mortality of brown rock crab was estimated from the entrainment data by comparing adjusted abundances of zoea stage 1 to abundance of megalops. Intermediate stages 2, 3, 4, and 5 were not used in the estimate because they were significantly affected by offshore transport out of the study grid and would, therefore, be under-represented in the subsamples (Paul Reilly, California Department of Fish and Game, pers. comm.). Megalops of all species were more abundant than zoea stage 5 in the entrainment subsamples, indicating that many of the developing megalops were being transported back toward shore.

An instantaneous larval mortality of 0.158/d was estimated by fitting an exponential curve to the estimated numbers of entrained zoea stage 1 (December 1996 through June 1998) and megalops (mid January 1997 through mid August 1998) and using 38 d as the time between stages (i.e., 5 d and 43.3 d, respectively). This procedure is fully described in the following section concerning fecundity hindcasting. Because brown rock crab megalops were more abundant close to shore than slender crab (Graham 1989), the mortality rate developed for brown rock crab is also applied to slender crab larvae (Section 5.2.1.2) that also have a duration of 38 d between zoea and megalops stages.

Estimated weight at age was used in interpreting adult equivalent losses to the population. Brown rock crabs mature at an age of about 18 mo post-settlement with a size of approximately 60 mm carapace width and a weight of 73 g (Carroll 1982). Faster growth rates may occur in highly productive environments such as on the supporting members of offshore oil platforms (Dan Dugan, Tenera Environmental, pers. comm.). A growth curve for brown rock crab was estimated based on asymptotic carapace width and weight (155 mm and 1,050 g for males, 145 mm and 683 g for females), and a growth rate between instars from tag recovery data (ranging from 7–26 % with smaller crabs growing at the highest rate), for a maximum of 12–13 post-larval instars. Brown rock crabs can probably live to a maximum age of about 6 yr. Size at recruitment to the fishery is approximately 125 mm carapace width at age 4 yr for males and 4.5 yr for females.

Summary of Field Collections

Brown rock crab zoeae were removed from subsamples collected at the DCPD intake structure from December 1996 through June 1998 while megalopae were removed for the period October 1996 through June 1999. Zoeae were removed from only some of the subsamples collected during two grid surveys in 1998. Megalopae were removed from subsamples from the study grid from July 1997 until June 1999. Estimated density (numbers per volume of water filtered) of zoeae and megalopae from the processed subsamples are presented in **Appendix H**. The estimated weekly number of zoeae and megalopae entrained (**Appendix I**) was calculated by multiplying the estimated larval density by the volume of water drawn through the CWS. Abundance of both zoea and megalops was greatest in the spring although zoea 1 began to appear in winter months (**Figure 5.2.1-1**).

Larval densities were estimated from bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999; for a daily sampling event there were generally 32 to 64 subsamples processed for estimating megalops densities and 8 subsamples processed for estimating zoea densities. Of a possible 5,524 entrainment subsamples processed for megalopae, 665 (12%) were positive for brown rock crab. Megalops densities in entrainment subsamples were highest during 1997 and lowest in 1999 (**Figure 5.2.1-1**). Of 636 subsamples processed for zoea, the percentages of subsamples by stage were: 83% zoea stage 1, 26% zoea 2, 14% zoea 3, 6% zoea 4 and 2% zoea 5.

Megalops densities in the DCPD study grid were highest in May and June of 1998 and 1999, but much higher in 1998 than in 1999 (**Figure 5.2.1-2**). Of 3,168 bongo net subsamples collected in the grid, 13% contained brown rock crab megalopae.

Estimating Total Annual Entrainment

Estimates of annual entrainment (\widehat{E}_T) of the five zoea and one megalops stages of brown rock crab during the two analysis periods (December 1, 1996–November 30, 1997 and July 1, 1997–June 30, 1998) are presented in **Table 5.2.1-2**. The date of the first analysis period for zoea was adjusted from October 1996 through September 1997 to December 1996 through November 1997

because the entrainment subsamples collected during October and November 1996 were not processed for zoea. Generally there were fewer individuals of each older stage. Although estimates of zoea stages 1–4 abundances were approximately equal between the two analysis periods, the greater abundance of zoea stage 5 during 1998 for Analysis Period 3 ($\widehat{E}_T = 111,000,000$) did not result in an increased megalops abundances for that period. Estimated megalops abundance was actually greater during 1997, Analysis Period 1 ($\widehat{E}_T = 56,500,000$) than during 1998, Analysis Period 3 ($\widehat{E}_T = 24,500,000$). The estimates of annually-entrained brown rock crab were not adjusted to a long-term average because crab larvae were not enumerated in the Intake Cove surface plankton tow samples.

Fecundity Hindcasting (FH)

The *FH* method requires age-specific mortality and fecundity to assess entrainment effects. A single value for instantaneous mortality, Z , was estimated for the two analysis periods by fitting an exponential curve to the zoea 1 and megalops entrainment estimates. The survival rate to 43.3 d post hatching was estimated for all larval stages using an exponential survival model:

$$N_t = N_0 e^{-Z(t-t_0)}$$

where the estimated entrainment of zoea stage 1 (N_0 at time $t_0 = 5$) and megalops (N_t at time $t = 43.3$) stages were used to estimate the rate Z . Zoea 1 abundance was estimated as the fraction of brown rock crab stage 2 larvae times the number of the unidentified zoea 1. The instantaneous mortality rate, Z , can then be solved from the two larval stage abundances (zoea 1, December 1996 through June 1998 and megalops, mid January 1997 through mid August 1998) as

$$Z = \frac{\ln\left(\frac{34,600,000,000}{80,100,000}\right)}{43.3 - 5} = 0.158 \text{ per day .}$$

An estimated survival through larval stages can then be calculated as $\hat{S}_{larvae} = e^{(-0.158)t}$, where t is reported in **Table 5.2.1-3** as mean cumulative duration. Cumulative survival estimates to stage midpoint were

1) zoea 1	0.454
2) zoea 2	0.128
3) zoea 3	0.0497
4) zoea 4	0.0193
5) zoea 5	0.00637
6) megalops	0.00107

The *FH* approach combines larval entrainment losses with survival and adult fecundity to hindcast the numbers of adult females effectively removed from the reproductively active population. An estimate of mean annual fecundity is 1,756,450 eggs. The number of reproductive years was estimated by halving the range between age of maturity of 1.5 yr and longevity of 4 yr. A longevity of 4 yr was chosen because of low abundance of older animals found in a trapping study (Jay Carroll, Tenera, pers. comm.). Coefficients of variation of survival, fecundity, and ages of maturation and longevity are not well known and are therefore reasonably assumed to be 100% with a lognormal error structure.

The number of female brown rock crabs estimated to produce the entrained larvae was calculated for the five zoea and one megalops stage for the two. All larval stages were hindcast and the estimated numbers of females and variances of estimates were added to compute an estimate of total number of brown crab females and the variance of the estimate.

The estimated *FH* values for zoea and megalops stages for the period December 1, 1996 through November 30, 1997 from **Table 5.2.1-2** were

$$\begin{aligned}\widehat{FH}_1 &= 17,500 \text{ females with } \widehat{SE}(\widehat{FH}_1) = 39,000 \\ \widehat{FH}_2 &= 16,300 \text{ females with } \widehat{SE}(\widehat{FH}_2) = 38,100 \\ \widehat{FH}_3 &= 43,300 \text{ females with } \widehat{SE}(\widehat{FH}_3) = 104,000 \\ \widehat{FH}_4 &= 15,700 \text{ females with } \widehat{SE}(\widehat{FH}_4) = 37,400 \\ \widehat{FH}_5 &= 239 \text{ females with } \widehat{SE}(\widehat{FH}_5) = 626 \\ \widehat{FH}_{Mega} &= 24,100 \text{ females with } \widehat{SE}(\widehat{FH}_{Mega}) = 53,400\end{aligned}$$

The total estimated number of breeding females needed to produce the total number of larvae entrained during the period was calculated by summing the \widehat{FH}_i over all stages:

$$\widehat{FH} = 117,000 \text{ females}$$

with $\widehat{SE}(FH) = \sqrt{\sum_{i=1}^6 \widehat{SE}_i(\widehat{FH}_i)^2} = 134,000$. An approximate 90% confidence interval for FH ,

based on a lognormal error structure, is estimated as 17,700 to 773,000 females.

The estimated FH values for zoea and megalops stages for the period July 1, 1997 through June 30, 1998 from **Table 5.2.1-2** were

$$\begin{aligned}\widehat{FH}_1 &= 18,600 \text{ females with } \widehat{SE}(\widehat{FH}_1) = 41,700 \\ \widehat{FH}_2 &= 13,400 \text{ females with } \widehat{SE}(\widehat{FH}_2) = 30,500 \\ \widehat{FH}_3 &= 22,100 \text{ females with } \widehat{SE}(\widehat{FH}_3) = 51,700 \\ \widehat{FH}_4 &= 18,500 \text{ females with } \widehat{SE}(\widehat{FH}_4) = 46,300 \\ \widehat{FH}_5 &= 7,950 \text{ females with } \widehat{SE}(\widehat{FH}_5) = 20,100 \\ \widehat{FH}_{Mega} &= 10,400 \text{ females with } \widehat{SE}(\widehat{FH}_{Mega}) = 23,100\end{aligned}$$

The total estimated number of breeding females needed to produce the total number of larvae entrained during this period was calculated by summing the stage specific estimates as

$$\widehat{FH} = 91,000 \text{ females}$$

with $\widehat{SE}(FH) = \sqrt{\sum_{i=1}^6 \widehat{SE}_i(\widehat{FH}_i)^2} = 91,800$. An approximate 90% confidence interval for FH ,

based on a lognormal error structure, is estimated as 17,300 to 478,000 females.

Sensitivity Analysis

In addition to calculating a confidence interval, a sensitivity analysis (**Table 5.2.1-2**) for all larval stages was performed in which \widehat{FH} was recomputed by varying the input parameter of estimated annual entrainment, \widehat{E}_T , by $\pm 1.645 \widehat{SE}(\widehat{E}_T)$ and survival, \widehat{S} , by using a multiplicative error structure (i.e. $\widehat{S} e^{\pm 1.645 CV(\widehat{S})}$) and using $CV(\widehat{S}) = 1.0$. The range of survival estimates for all stages produced the same relative changes in \widehat{FH} as expected based upon a constant multiplier.

However, \widehat{FH} was less sensitive to entrainment than survival variation. This difference was greatest for the megalops stage and can be explained by the use of sampling variance for

estimating entrainment variability for all stages with *CVs* of close to or less than 100%.

Therefore, improvement in the precision of \widehat{FH} can result from improved estimates of the larval stages' survival.

Females that reach reproductive size are not subject to fishery capture due to their small size.

Therefore, the \widehat{FH} should be extrapolated to fishery size because it will provide more meaningful results for subsequent comparisons. Adult survival can be estimated for brown rock crab as 0.088 yr^{-1} (based on data in Carroll 1982). Hankin et al. (1989) estimated adult survival for dungeness crab exceeding 155 mm as 0.11 yr^{-1} . Therefore, the estimates of FH (117,000 and 90,900 female crabs) can be reasonably extended to full fishery recruitment from the representative female age of 2.3 yr (one third between 1.5 and 4 yr) by applying a survival of 0.1 for an additional year. This would result in a population-wide loss of 11,700 and 9,100 as the two yearly estimates of fishery recruit-size females lost due to entrainment.

Adult Equivalent Loss (AEL)

The *AEL* approach uses estimates of the abundance of entrained organisms to project the loss of equivalent numbers of adults based on mortality schedules and age at recruitment. Survival rates from entrainment of megalopae to recruitment into fishery are not available. However, assuming a 50:50 sex ratio, \widehat{AEL} and \widehat{FH} can be compared as $\widehat{AEL} \equiv 2\widehat{FH} = 234,000$ and 182,000 adults, with an associated standard error of $\widehat{SE}(\widehat{AEL}) = 2\widehat{SE}(\widehat{FH}) = 269,000$ and 184,000.

To reiterate, females that reach reproductive size are not subject to fishery capture due to their small size. Therefore, the \widehat{AEL} also should be extrapolated to fishery size. Adult survival can be estimated for brown rock crab as 0.088 yr^{-1} (Carroll 1982). Hankin et al. (1989) estimated adult survival for dungeness crab exceeding 155 mm as 0.11 yr^{-1} . Therefore, the estimate of *AEL* (234,000 and 182,000 crabs) can be reasonably extended to full fishery recruitment from the representative female age of 2.3 yr (one third between 1.5 and 4 yr) by applying a survival of 0.1 for an additional year. This would result in a population-wide loss of 23,400 and 18,200 as the two yearly estimates of fishery recruits lost due to entrainment.

Empirical Transport Model (ETM)

The *ETM* assessment requires estimates of larval stage duration and larval density in entrainment and grid subsamples. The crab data were collected for only the megalops larval stage in the grid subsamples and will be compared to megalops stage larvae in the entrainment subsamples.

Two entrainment mortality estimates are presented: for July 1, 1997 through June 30, 1998 and for July 1, 1998 through June 30, 1999. Brown rock crab larvae may be susceptible to entrainment by the plant for approximately 43 d, the average age of a megalop. Although the duration is more than one month, each monthly survey period will be assumed to represent discrete groups of larvae, permitting two independent weighted estimates of total entrainment mortality from 24 subsamples. Total annual entrainment mortality (P_M) is estimated from the values of PE_i and f_i for each survey period (**Table 5.2.1-4**), based on larval densities from entrainment (**Figure 5.2.1-1**) and grid surveys (**Figure 5.2.1-2**).

The proportion of the population within the nearshore study grid was based on a linear extrapolation of densities in the grid in the offshore direction and displacement in the alongshore direction. **Table 5.2.1-4** shows monthly estimates of entrainment proportions, of survey period to survey grid abundance (\widehat{PE}_i ; based upon paired surveys) and of survey period to yearly entrainment (\hat{f}_i ; based upon weekly subsamples), for brown rock crab. \widehat{PE}_i from the two years sampled ranged from a minimum of zero to a maximum of 0.0254 ± 0.0219 ($\pm 1 \widehat{SE}(\widehat{PE}_i)$) in October 1997. Because estimated per period survival is weighted to form an annual mortality estimate, the largest values of \hat{f}_i (and of associated \widehat{PE}_i) have the largest effects on the estimate (July and June 1998). No larvae were collected at either the DCPPI intake or the study grid when both \widehat{PE}_i and the annual proportion of larvae hatched (\hat{f}_i) in the i th survey period were equal to zero (September 1998, February 1999, and March 1999). When $\widehat{PE}_i = 0$ and $\hat{f}_i > 0$, larvae were collected at the DCPPI intake during the survey period but not during the entrainment survey paired with the 72-hr study grid survey. Low values of \hat{f}_i indicate periods of the year when brown rock crab megalops are least abundant in weekly entrainment subsamples. While June and July 1998 entrainment fractions were highest overall, May and June 1998 densities were highest in the study grid (**Figure 5.2.1-2**).

Total annual entrainment mortality from the *ETM* is estimated as $\widehat{P}_M = 0.0000186$ for the period July 1, 1997 through June 30, 1998 and $\widehat{P}_M = 0.000146$ for the period July 1, 1998 through June 30, 1999 with associated standard errors of $\widehat{SE}(\widehat{P}_M) = 0.2327$ and 0.0325 , respectively (**Figure 5.2.1-3**). The sensitivity analysis considers the effect of varying values of \widehat{P}_S on the outcome of the *ETM* calculations shown in **Figure 5.2.1-3** for the two periods. The values of \widehat{P}_M resulting from calculations using only the alongshore displacement were higher (0.00563 and 0.00652) than those reported for the offshore extrapolated densities (0.0000186 and 0.000146). Values of \widehat{P}_S ranged from 0.000386 to 0.00239 for \widehat{P}_M extrapolated offshore and ranged from 0.11 to 0.13 for alongshore only.

Interpretation of Assessment Results

The *ETM* estimate of entrainment mortality of megalopae can be assumed to apply to all stages of larval mortality at DCPD and, by extension, can be applied to the adult crab population or to harvest assuming no compensation. Estimates of stock size and density that could be used to convert \widehat{P}_M into an estimate of adult equivalent loss (assuming no compensatory mortality) are not available. Although \widehat{P}_M was estimated using both alongshore current displacement and density extrapolation offshore, the estimate using alongshore currents was used in assessing fishery value because it was more representative of the areas actively fished for rock crab. The rock crab fishery does not extend into the offshore areas included in the extrapolation.

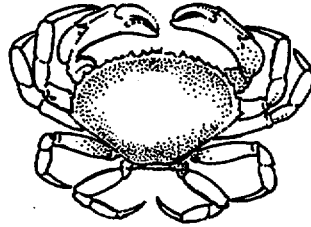
Brown rock crabs have both commercial and recreational fishery value. An area that contains the population at risk, predicted by using the average alongshore displacements of 140 km to 160 km (**Figure 5.2.1-3**), is limited to the region where crabs are landed at the ports of Morro Bay and Avila. From 1975 to 1998 an average of 135,200 kg of rock crabs were landed at Morro Bay and Avila (**Figure 5.2.1-4**). An ex-vessel price of \$2.32 per kg and average weight of 0.34 and 0.45 kg for females and males, respectively, is reported for the Morro Bay area catch (Deborah Johnston, California Department of Fish and Game, pers. comm.). The estimated mortality rates from the *ETM* using alongshore extension ($\widehat{P}_M = 0.00563$ and 0.00652) are applied to the average landings. Assuming that the proportional effect of entrainment mortality on the larval

population also acts on the adult population, then the average yearly historical Morro Bay area catch is affected by the same proportion, which equates to 760 and 880 kg of crabs for the two years, respectively. In terms of monetary value, the yearly valuation would be \$1,760 and \$2,040 for the two years.

The *AEL* model estimates are assigned to population-wide losses but can be compared to the fishery using the ex-vessel price and average weight of 0.4 kg. Crabs that reach reproductive size are not subject to fishery capture due to their small size. Therefore, the number of estimated adults lost to the population is extrapolated to fishery size, and the resulting two yearly estimates of 23,400 and 18,200 crabs lost to the population per yr represent \$21,700 and \$16,900, 7% and 5% of individuals in an average annual catch (based on an average annual catch of 135,200 kg and 0.4 kg per crab). These values overestimate fishery losses since proportional reductions of numbers due to catchability, trapping selectivity, and fishing effort are not considered. In an experimental trapping study by Carroll (1982), tag returns on over 9,000 brown rock crab along the Diablo Canyon coastline averaged 6.3%. Further, fewer than 0.1% of the tagged crabs were recovered in the local commercial fishery over the course of the 5-year study. Although there were no data available on commercial fishing effort during that period, a conservative estimate that 10% of the fishery-sized crabs in the population were actually landed per year would reduce the valuation of the *FH* and *AEL* losses by one order of magnitude.

The *ETM*-based loss assessments of \$1,760 to \$2,040 use a more appropriate valuation method because it considers catch as a proportion of the population and is also conservative because it is calculated using the larger values of \widehat{P}_M (i.e., based on an alongshore-only translation of the survey grid numbers). Because of the low estimated population mortality by power plant entrainment (alongshore and offshore-based $\widehat{P}_M = 0.0000186$ and 0.000146), effects on the brown rock crab population are probably low.

5.2.1.2 Slender crab (*Cancer gracilis*)



Cancer gracilis Dana 1852; slender crab; carapace width to 11.5 cm (4.5 in); Prince William Sound, Alaska to Bahia Playa Maria, Mexico; low intertidal to 143 m (470 ft); carapace purple with white edging; claws with white tips, legs purple (Jensen 1995).

The slender crab is commonly found on mud flats and in beds of eelgrass although it is usually not found intertidally south of central California (Morris et al. 1980). Although seasonally found in bays, the slender crab does not tolerate brackish conditions. Slender crabs can extrude between approximately 143,000 and 1,000,000 eggs per batch (Hines 1991; **Table 5.2.1-5**). Females, on average, produce a single batch per yr. Total lifetime spawning occurs over a maximum of three seasons and more commonly only two (Orensanz and Gallucci 1988). In Elkhorn Slough, mating is common in November, and ovigerous females were noted in July and August (Morris et al. 1980). Farther north, in Puget Sound, animals held in the laboratory bore eggs from December to April, and a few females produced a small second batch. Graham (1989) recorded both spring and fall spawning periods in Monterey Bay.

Larval development in the slender crab was described by Ally (1975). Eggs hatch into pre-zoea larvae, which quickly molt to first stage zoea. Average larval development time (from hatching through completion of the megalops stage) was 48.9 d at 17 °C, with most stages lasting approximately one week (**Table 5.2.1-6**).

During their planktonic existence, crab larvae can become widely distributed in nearshore waters. In a study in Monterey Bay, Graham (1989) found that slender crab stage 1 zoeae were very abundant close to shore (within 6 km) during March and April. During an autumn spawning period in August, he found stage 1 zoeae concentrated approximately 11 km from shore. Later

stage larvae, including megalopae, were found further from shore during all times of the year. This offshore larval distribution, compared to the nearshore distribution of brown rock crab, reflects the fact that adult slender crabs are widely distributed in coastal shelf areas, further offshore than brown rock crabs. The megalops larvae and juvenile crabs are frequently found crawling unharmed on and under the bells, and even in the stomachs, of larger jellyfishes, especially *Pelagia colorata* (Morris et al. 1980).

There are no published estimates of larval mortality in slender crab, except for in laboratory culture (Ally 1975). From December 1996 until July 1997, megalopae of *C. gracilis* were more abundant than all zoea stages 2–5 in the entrainment subsamples, indicating that many of the developing megalopae were being transported back toward shore. However, slender crab megalopae are less abundant close to shore than brown rock crab (Graham 1989). As a result, it is difficult to estimate slender crab larval survival from entrainment sampling. Therefore, data from the abundance of stage 1 zoeae and of megalopae for brown rock crab in the DCPD entrainment were used to estimate the larval mortality of slender crab. An instantaneous larval mortality of 0.158/d, estimated for another species, the brown rock crab, and described in **Section 5.2.1.1**, was applied for estimating the number of females that produced the entrained slender crab.

Based on field growth studies, it was estimated that slender crabs matured at an age of about 10 months post-settlement to a size of approximately 60 mm carapace width (Orensanz and Gallucci 1988). Growth occurs through 11–12 instars, with crabs attaining an estimated maximum age of 4 yr post-settlement.

Summary of Field Collections

Cancer gracilis zoea were removed from subsamples collected at the DCPD intake structure from December 1996 through June 1998, while megalops were removed for the period October 1996 through June 1999. Zoea were removed only from some of the subsamples collected during two grid surveys in 1998. Megalops were removed from subsamples from the study grid from July 1997 until June 1999. Estimated density (numbers per volume of water filtered) of zoea and megalops from the processed subsamples are presented in **Appendix H**. The estimated weekly

number of zoea and megalops entrained (**Appendix I**) was calculated by multiplying the estimated larval density by the volume of water drawn through the CWS. Zoea abundance was greatest in the spring although zoea 1 began to appear in the entrainment subsamples during the winter months (**Figure 5.2.1-5**). Megalops were found throughout the entire year, with peak abundances in winter 1996–97, fall 1998, and spring 1999.

Larval densities were estimated from bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999. For a daily sampling event there generally were 32 to 64 subsamples processed for estimating megalops densities and eight subsamples processed for counting zoea. Of a possible 5,524 subsamples processed for megalopae, slender crab were found in 590 (11%). Megalops densities appear relatively constant with peaks in late fall and winter (**Figure 5.2.1-5**). Of 636 subsamples processed for zoea, the frequencies of subsamples by stage were 83% zoea 1, 6% zoea 2, 3% zoea 3, 1% zoea 4, and no zoea 5.

Megalops densities in the DCPD offshore study grid were highest in May and June 1998 and frequently encountered at all other times, especially July 1997, April 1998, August 1998, September 1998, March 1999, and May 1999 (**Figure 5.2.1-6**). There were 3,168 bongo net subsamples processed for megalops, of which 15% contained slender crab megalops.

Estimating Total Annual Entrainment

As previously mentioned, estimates of entrainment of zoea 1 of the taxa brown rock crab, yellow crab, and slender crab were combined because of uncertainties in identification. The proportions of slender crab zoea stage 1 were derived by using the proportions of slender crab in zoea stage 2 that could be identified to species.

Estimates of annual entrainment (\widehat{E}_T) of the five zoea and one megalops stages of brown rock crab during the two analysis periods (December 1, 1996–November 30, 1997 and July 1, 1997–June 30, 1998) are presented in **Table 5.2.1-7**. The date of the first analysis period for zoea was adjusted from October 1996 through September 1997 to December 1996 through November 1997 because the entrainment subsamples collected during October and November 1996 were not

processed for zoea. Generally there were fewer individuals of each older zoea stage, although no zoea stage 4 were collected during 1997 in Analysis Period 1, and no zoea stage 5 were collected in either period. Although zoea abundance overall was estimated to be less in 1997 during Analysis Period 1, the estimate of megalops abundance ($\widehat{E}_T = 20,300,000$) was greater than 1998 during Analysis Period 3 ($\widehat{E}_T = 4,870,000$). The estimates of annually-entrained slender rock crab were not adjusted to a long-term average because crab larvae were not enumerated in the Intake Cove surface plankton tow samples.

Fecundity Hindcasting (FH)

An instantaneous daily mortality rate, -0.158, calculated for brown rock crab is used for slender crab. Estimated survival through larval stages can then be calculated as $\hat{S}_{larvae} = e^{(-0.158)t}$, where t is reported in **Table 5.2.1-6** as mean cumulative duration. Survival estimates to stage midpoint were

1) zoea 1	0.584
2) zoea 2	0.375
3) zoea 3	0.063
4) zoea 4	0.0222
5) zoea 5	0.0077
6) megalops	0.0014

The *FH* approach combines larval entrainment losses with survival and adult fecundity to hindcast the numbers of adult females effectively removed from the reproductively active population. Mean annual fecundity, using data through age three (**Table 5.2.1-5**), was estimated as 555,583 eggs. The number of reproductive years was estimated by halving the range between age of maturity of 1 yr and assumed effective longevity of 3 yr (supported by linear survivorship model for adults). Coefficients of variation of survival, fecundity, and ages of maturation and longevity are not well known and are, therefore, reasonably assumed to be 100% with a lognormal error structure.

The number of female slender crabs estimated to produce the entrained larvae was calculated for the five zoea and one megalops stage for the two periods. All larval stages were hindcast, and the estimated numbers of females and variances of estimates were added to compute an estimate of total number of slender crab females and the variance of the estimate. The estimated FH for zoea and megalops stages for the period December 1, 1996 through November 30, 1997 from **Table 5.2.1-7** were

$$\begin{aligned}\widehat{FH}_1 &= 538 \text{ females with } \widehat{SE}(\widehat{FH}_1) = 1,150 \\ \widehat{FH}_2 &= 220 \text{ females with } \widehat{SE}(\widehat{FH}_2) = 563 \\ \widehat{FH}_3 &= 221 \text{ females with } \widehat{SE}(\widehat{FH}_3) = 528 \\ \widehat{FH}_4 &= 143 \text{ females with } \widehat{SE}(\widehat{FH}_4) = 392 \\ \widehat{FH}_{Mega} &= 26,200 \text{ females with } \widehat{SE}(\widehat{FH}_{Mega}) = 55,500\end{aligned}$$

No slender crab zoea stage 5 were collected during this period. The total estimated number of breeding females needed to produce the total number of larvae entrained was calculated by summing the \widehat{FH} over all stages:

$$\widehat{FH} = 27,300 \text{ females,}$$

with $\widehat{SE}(\widehat{FH}) = \sqrt{\sum_{i=1}^5 \widehat{SE}_i(\widehat{FH}_i)^2} = 55,500$. An approximate 90% confidence interval for FH ,

based on a lognormal error structure, is estimated as 959 to 776,000 females.

The estimated FH for slender crab zoea and megalops stages for the period July 1, 1997 through June 30, 1998 from **Table 5.2.1-7** were

$$\begin{aligned}\widehat{FH}_1 &= 1,480 \text{ females with } \widehat{SE}(\widehat{FH}_1) = 3,180 \\ \widehat{FH}_2 &= 469 \text{ females with } \widehat{SE}(\widehat{FH}_2) = 1,050 \\ \widehat{FH}_3 &= 729 \text{ females with } \widehat{SE}(\widehat{FH}_3) = 1,670 \\ \widehat{FH}_{Mega} &= 6,270 \text{ females with } \widehat{SE}(\widehat{FH}_{Mega}) = 13,300\end{aligned}$$

No slender crab zoea stage 4 or 5 were collected during this period. The total estimated number of breeding females needed to produce the total number of larvae entrained during this period was calculated by summing the stage specific estimates as

$$\widehat{FH} = 8,950 \text{ females}$$

with $\widehat{SE}(\widehat{FH}) = \sqrt{\sum_{i=1}^5 \widehat{SE}_i(\widehat{FH}_i)^2} = 13,800$. An approximate 90% confidence interval for FH ,

based on a lognormal error structure, is estimated as 703 to 114,000 females.

Sensitivity Analysis

In addition to calculating a confidence interval, a sensitivity analysis (Table 5.2.1-7) for all larval stages was performed, in which \widehat{FH} was recomputed by varying the input parameter of estimated annual entrainment, \widehat{E}_T , by $\pm 1.645 \widehat{SE}(\widehat{E}_T)$ and survival, \widehat{S} , by using a multiplicative error structure (i.e. $\widehat{S} e^{\pm 1.645 CV(\widehat{S})}$) and using $CV(\widehat{S}) = 1.0$. The range of survival estimates for all stages produced the same relative changes in \widehat{FH} , as expected based upon a constant multiplier. However, \widehat{FH} was less sensitive to entrainment than survival variation. This difference was especially pronounced for the zoea 1 and megalops stages and can be explained by the use of sampling variance for estimating entrainment variability, with CV s of less than 100%. Therefore, improvement in the precision of \widehat{FH} can result from improved estimates of the larval stages' survival.

Adult Equivalent Loss (AEL)

The *AEL* approach uses estimates of the abundance of entrained organisms to project the loss of equivalent numbers of adults based on mortality schedules and age at recruitment. Survival rates from entrainment of megalopae to recruitment into fishery are not available. However, assuming a 50:50 sex ratio, \widehat{AEL} and \widehat{FH} can be compared as $\widehat{AEL} \cong 2\widehat{FH} = 54,600$ and 17,900 adults, with an associated standard error of $\widehat{SE}(\widehat{AEL}) = 2\widehat{SE}(\widehat{FH}) = 111,000$ and 27,700.

5.2.1.2e Empirical Transport Model (ETM)

The *ETM* assessment requires estimates of larval stage duration and larval density in entrainment and grid subsamples. The crab data were collected for only the megalops larval stage in the grid subsamples and will be compared to megalops stage larvae in the entrainment subsamples.

Two entrainment mortality estimates are presented: for July 1, 1997 through June 30, 1998 and for July 1, 1998 through June 30, 1999. Slender crab megalops larvae may be susceptible to entrainment by the power plant for approximately 42 d, based on the average estimated larval duration (Ally 1975). Although the duration is more than one month, each monthly survey period will be assumed to represent discrete groups of larvae, permitting two independent weighted estimates of total entrainment mortality from 24 subsamples. Total annual entrainment mortality (P_M) is estimated from the values of PE_i and f_i for each survey period (Table 5.2.1-8), based on larval densities from entrainment (Figure 5.2.1-5) and grid surveys (Figure 5.2.1-6).

The proportion of the population within the nearshore study grid was based on a linear extrapolation of densities in the grid in the offshore direction and displacement in the alongshore direction. Monthly estimates of proportional entrainment (\widehat{PE}_i) for slender crab in each i th survey from the two years sampled ranged from a minimum of zero to a maximum of 0.859 ± 0.911 ($\pm 1 \widehat{SE}(\widehat{PE}_i)$) in August 1997 (Table 5.2.1-8). Periods when both \widehat{PE}_i and the annual proportion of larvae hatched in the i th survey period (\widehat{f}_i) were equal to zero (December 1997 and January 1998) indicate that no larvae were collected at either the DCP intake or the study grid. When $\widehat{PE}_i = 0$ and $\widehat{f}_i > 0$, larvae were collected at the DCP intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. Low values of \widehat{f}_i indicate periods of the year when slender crab megalops are least abundant in weekly entrainment subsamples. June 1998 and October 1998 were highest for the two annual periods. May and June 1998 densities were highest in the study grid during the first period, and August and September 1998 were highest in the second period (Figure 5.2.1-6).

Total annual entrainment mortality from the *ETM* is estimated as $\widehat{P}_M = 0.0107$ for the period July 1, 1997 through June 30, 1998 and $\widehat{P}_M = 0.000784$ for the period July 1, 1998 through June 30, 1999 with associated standard errors of $\widehat{SE}(\widehat{P}_M)$ 0.0515 and 0.0373, respectively (Figure 5.2.1-7). The sensitivity analysis, which considers the effect of varying values of \widehat{P}_S on the outcome of the *ETM* calculations, is shown in Figure 5.2.1-7. The values of \widehat{P}_M resulting from calculations using only the alongshore displacement were higher (both years $\widehat{P}_M = 0.09$) than those reported

for the offshore extrapolated densities (0.0107 and 0.000784). Values of \widehat{P}_S ranged from 0.00422 to 0.00875 for \widehat{P}_M extrapolated offshore and 0.125 for both years using alongshore only.

Interpretation of Assessment Results

Interpretation of assessment results for slender crabs is limited by the absence of any information on population size. The *ETM* estimates of 1.07% and 0.0784% probably represent low population impacts. Values of \widehat{P}_S that were calculated based on extrapolation offshore were also larger than for brown crabs. As a result (comparing $1/\widehat{P}_S$), the population of slender crab at risk proportional to the study grid was estimated to be approximately 5–10 times smaller than the population of brown rock crabs relative to the study grid. However, values of $1/\widehat{P}_S$ are nearly the same for both slender and brown rock crabs, from the calculation using alongshore currents only. There is no fishery value for the estimates of slender crab adult equivalent loss (54,600 and 17,900 crabs).

Table 5.2.1-1. Schedule of estimated fecundity by age for brown rock crab (*Cancer antennarius*; from Carroll 1982 and Hines 1991).

Age (yr post-settlement)	Estimated carapace width (mm)	Estimated no. eggs per batch	Number of Batches
1.5	62	156,400	1.0
2	83	513,100	1.5
3	105	1,401,800	1.5
4	123	2,664,700	1.5
5	135	3,994,600	1.5
6	143	5,004,000	1.5

Table 5.2.1-2. Brown rock crab (*Cancer antennarius*): Annual estimated number of zoeae and megalopae entrained, estimated FH , and sensitivity of zoea- and megalops-based FH estimates for two analysis periods. Sensitivity estimates recalculated for model parameters (θ) of entrainment ($\hat{\theta} \pm 1.645 \cdot \widehat{SE}(\hat{\theta})$), and survival ($\hat{\theta} e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\hat{\theta}) = 1.0$). \widehat{E}_T = estimated annual # crab larvae entrained (by stage), FH = number of adult female crabs, and S = finite survivorship.

a) Analysis Period 1 (date adjusted): December 1, 1996–November 30, 1997

Larval Stage	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Sensitivity Analysis Parameters of Recalculated \widehat{FH}			
					\widehat{E}_T $+1.645\widehat{SE}(\hat{\theta})$	\widehat{E}_T $-1.645\widehat{SE}(\hat{\theta})$	\hat{S} $\times e^{+1.645 CV(\hat{\theta})}$	\hat{S} $\times e^{-1.645 CV(\hat{\theta})}$
Zoea 1	17,400,000,000	3,940,000,000	17,500	39,000	24,000	11,000	3,370	90,600
Zoea 2	4,580,000,000	3,410,000,000	16,300	38,100	36,200	0	3,140	84,400
Zoea 3	4,720,000,000	4,370,000,000	43,300	104,000	109,000	0	8,350	224,000
Zoea 4	665,000,000	572,000,000	15,700	37,400	38,000	0	3,040	81,500
Zoea 5	3,480,000	4,140,000	249	626	735	0	48	1,290
Megalops	56,500,000	4,480,000	24,100	53,400	27,200	20,900	4,650	125,000
TOTAL			117,000					

b) Analysis Period 3: July 1, 1997–June 30, 1998

Larval Stage	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Sensitivity Analysis Parameters of Recalculated \widehat{FH}			
					\widehat{E}_T $+1.645\widehat{SE}(\hat{\theta})$	\widehat{E}_T $-1.645\widehat{SE}(\hat{\theta})$	\hat{S} $\times e^{+1.645 CV(\hat{\theta})}$	\hat{S} $\times e^{-1.645 CV(\hat{\theta})}$
Zoea 1	18,500,000,000	6,260,000,000	18,600	41,700	28,900	8,270	3,590	96,400
Zoea 2	3,770,000,000	1,900,000,000	13,400	30,500	24,500	2,310	2,590	69,400
Zoea 3	2,420,000,000	1,760,000,000	22,100	51,700	48,700	0	4,280	115,000
Zoea 4	781,000,000	910,000,000	18,500	46,300	53,900	0	3,570	95,700
Zoea 5	111,000,000	135,000,000	7,950	20,100	23,800	0	1,530	41,200
Megalops	24,500,000	2,200,000	10,400	23,100	12,000	8,880	2,010	54,000
TOTAL			91,000					

Table 5.2.1-3. Duration of laboratory-reared zoea stages (@ 13.8°C) of brown rock crab (*Cancer antennarius*; Roesijadi 1976) and megalops stage duration from Ally (1975). Mean cumulative duration is cumulative duration minus half of the stage duration.

Larval Stage	Stage Duration (d)	Cumulative duration	Mean Cumulative duration
Zoea 1	10	10	5
Zoea 2	6	16	13
Zoea 3	6	22	19
Zoea 4	6	28	25
Zoea 5	8	36	32
Megalops	14.6	50.6	43.3
Total	50.6		

Table 5.2.1-4. Brown rock crab (*Cancer antennarius*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (\widehat{SE}) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0	0	0.00600	0.00134
Aug 25, 1997	0	0	0.00586	0.00167
Sep 29, 1997	0	0	0.00169	0.000640
Oct 20, 1997	0.0254	0.0219	0.0127	0.00206
Nov 17, 1997	0.0224	0.0313	0.00163	0.000620
Dec 10, 1997	0	0	0.00106	0.000470
Jan 22, 1998	0	0	0.00370	0.00103
Feb 26, 1998	0	0	0.00201	0.000660
Mar 18, 1998	0	0	0.00251	0.000830
Apr 15, 1998	0.00248	0.00146	0.0528	0.00504
May 18, 1998	0.000260	0.0000700	0.289	0.0157
Jun 8, 1998	0.000890	0.000390	0.621	0.0162

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.00114	0.00117	0.650	0.0232
Aug 26, 1998	0	0	0.0132	0.00384
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0.00807	0.00903	0.0302	0.00637
Nov 11, 1998	0.00644	0.00723	0.0156	0.00435
Dec 9, 1998	0.0108	0.00917	0.0274	0.00582
Jan 12, 1999	0	0	0.0179	0.00483
Feb 3, 1999	0	0	0	0
Mar 17, 1999	0	0	0	0
Apr 14, 1999	0	0	0.0212	0.00535
May 24, 1999	0	0	0.171	0.0164
Jun 23, 1999	0.000820	0.000520	0.0532	0.00963

Table 5.2.1-5. Schedule of estimated fecundity by age for slender crab (*Cancer gracilis*) (from Orensanz and Gallucci 1988; Hines 1991).

Age (yr post-settlement)	Estimated carapace width (mm)	Estimated no. eggs per batch	Number of Batches
1.5	47	143,800	1.0
2	62	342,400	1.5
3	77	672,900	1.5
4	86	953,400	1.0

Table 5.2.1-6. Duration of planktonic zoea and megalops stages of slender crab (*Cancer gracilis*) reared in the laboratory (Ally 1975).

Larval Stage	Mean duration (d)	Lower limit (d)	Upper limit (d)	Cumulative duration	Mean Cumulative duration
Zoea 1	6.8	5	11	6.8	3.4
Zoea 2	7.2	5	12	14.0	6.2
Zoea 3	7.0	5	10	21.0	17.5
Zoea 4	6.2	5	8	27.2	24.1
Zoea 5	7.1	6	8	43.3	30.8
Megalops	14.6	12	17	48.9	41.6
Total	48.9	38	66		

Table 5.2.1-7. Slender crab (*Cancer gracilis*): Annual estimated number of zoeae and megalopae entrained, estimated FH , and sensitivity of zoea- and megalops-based FH estimates for two analysis periods. Sensitivity estimates recalculated for model parameters (θ) of entrainment ($\hat{\theta} \pm 1.645 \cdot \widehat{SE}(\hat{\theta})$), and survival ($\hat{\theta} e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\hat{\theta}) = 1.0$). \widehat{E}_T = estimated # crab larvae entrained (by stage), FH = number of adult female crabs, and S = finite survivorship.

a) Analysis Period 1 (date adjusted): December 1, 1996–November 30, 1997

Larval Stage	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Sensitivity Analysis Parameters of Recalculated \widehat{FH}			
					\widehat{E}_T $+1.645\widehat{SE}(\hat{\theta})$	\widehat{E}_T $-1.645\widehat{SE}(\hat{\theta})$	\widehat{S} $\times e^{+1.645 CV(\hat{\theta})}$	\widehat{S} $\times e^{-1.645 CV(\hat{\theta})}$
Zoea 1	175,000,000	39,600,000	538	1,150	739	338	104	2,790
Zoea 2	46,000,000	65,600,000	220	563	737	0	43	1,140
Zoea 3	7,740,000	8,510,000	221	528	621	0	43	1,150
Zoea 4	1,770,000	3,040,000	143	392	549	0	28	742
Zoea 5	0	0	0	.	0	0	0	0
Megalops	20,300,000	1,140,000	26,200	55,500	28,600	23,700	5,050	136,000
TOTAL			27,300					

b) Analysis Period 3: July 1, 1997–June 30, 1998

Larval Stage	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Sensitivity Analysis Parameters of Recalculated \widehat{FH}			
					\widehat{E}_T $+1.645\widehat{SE}(\hat{\theta})$	\widehat{E}_T $-1.645\widehat{SE}(\hat{\theta})$	\widehat{S} $\times e^{+1.645 CV(\hat{\theta})}$	\widehat{S} $\times e^{-1.645 CV(\hat{\theta})}$
Zoea 1	480,000,000	162,000,000	1,480	3,180	2,300	658	286	7,670
Zoea 2	97,700,000	67,200,000	469	1,050	999	0	90	2,430
Zoea 3	25,500,000	21,800,000	729	1,670	1,760	0	141	3,780
Zoea 4	0	0	0	.	0	1	0	0
Zoea 5	0	0	0	.	0	2	0	0
Megalops	4,870,000	633,000	6,270	13,300	7,610	4,930	1,210	32,500
TOTAL			8,950					

Table 5.2.1-8. Slender crab (*Cancer gracilis*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (\widehat{SE}) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0	0	0.0602	0.00969
Aug 25, 1997	0.859	0.911	0.0726	0.0131
Sep 29, 1997	0	0	0.0754	0.0158
Oct 20, 1997	0.0230	0.0137	0.0961	0.0114
Nov 17, 1997	0.00102	0.00105	0.0644	0.00974
Dec 10, 1997	0	0	0	0
Jan 22, 1998	0	0	0	0
Feb 26, 1998	0	0	0.000680	0.000680
Mar 18, 1998	0	0	0.00422	0.00173
Apr 15, 1998	0.000860	0.000890	0.144	0.0152
May 18, 1998	0.000350	0.000130	0.151	0.0160
Jun 8, 1998	0.000190	0.000140	0.332	0.0259

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0	0	0.0442	0.00675
Aug 26, 1998	0.000310	0.000310	0.0508	0.00591
Sep 16, 1998	0.000910	0.000670	0.0267	0.00471
Oct 6, 1998	0.00439	0.00288	0.302	0.0231
Nov 11, 1998	0.000900	0.000910	0.242	0.0193
Dec 9, 1998	0.00432	0.00334	0.0535	0.00609
Jan 12, 1999	0.00490	0.00557	0.0226	0.00433
Feb 3, 1999	0	0	0.00923	0.00261
Mar 17, 1999	0.000670	0.000490	0.0434	0.00567
Apr 14, 1999	0	0	0.0869	0.0141
May 24, 1999	0.00106	0.000770	0.0859	0.0083
Jun 23, 1999	0.00278	0.00153	0.0325	0.00488

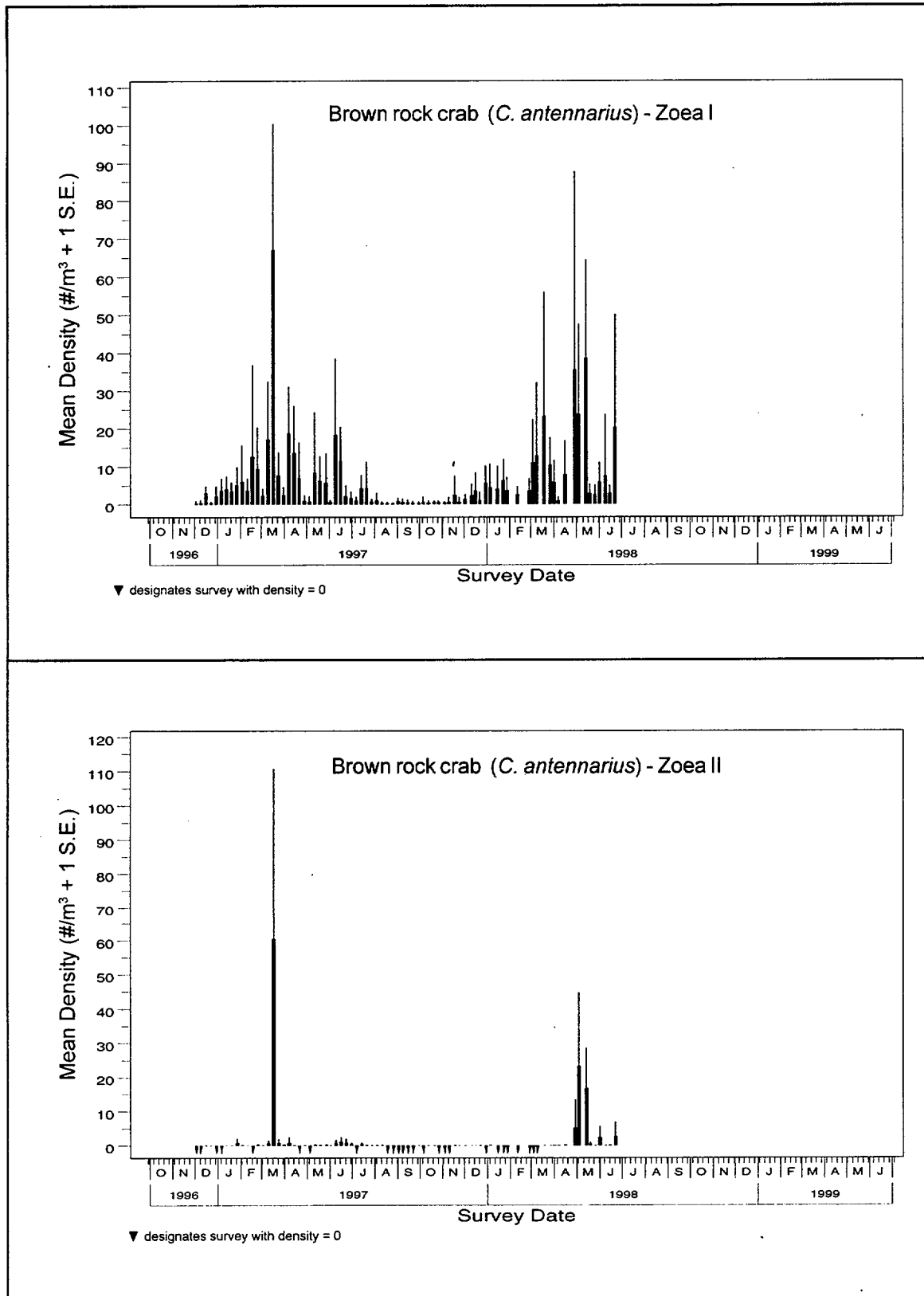


Figure 5.2.1-1. Weekly mean zoeae and megalops larval density ($\#/m^3 + 1 \text{ S.E.}$) at the DCPP intake. Y-axis scale varies between graphs. Zoea not sorted from July 1998 through June 1999 samples.

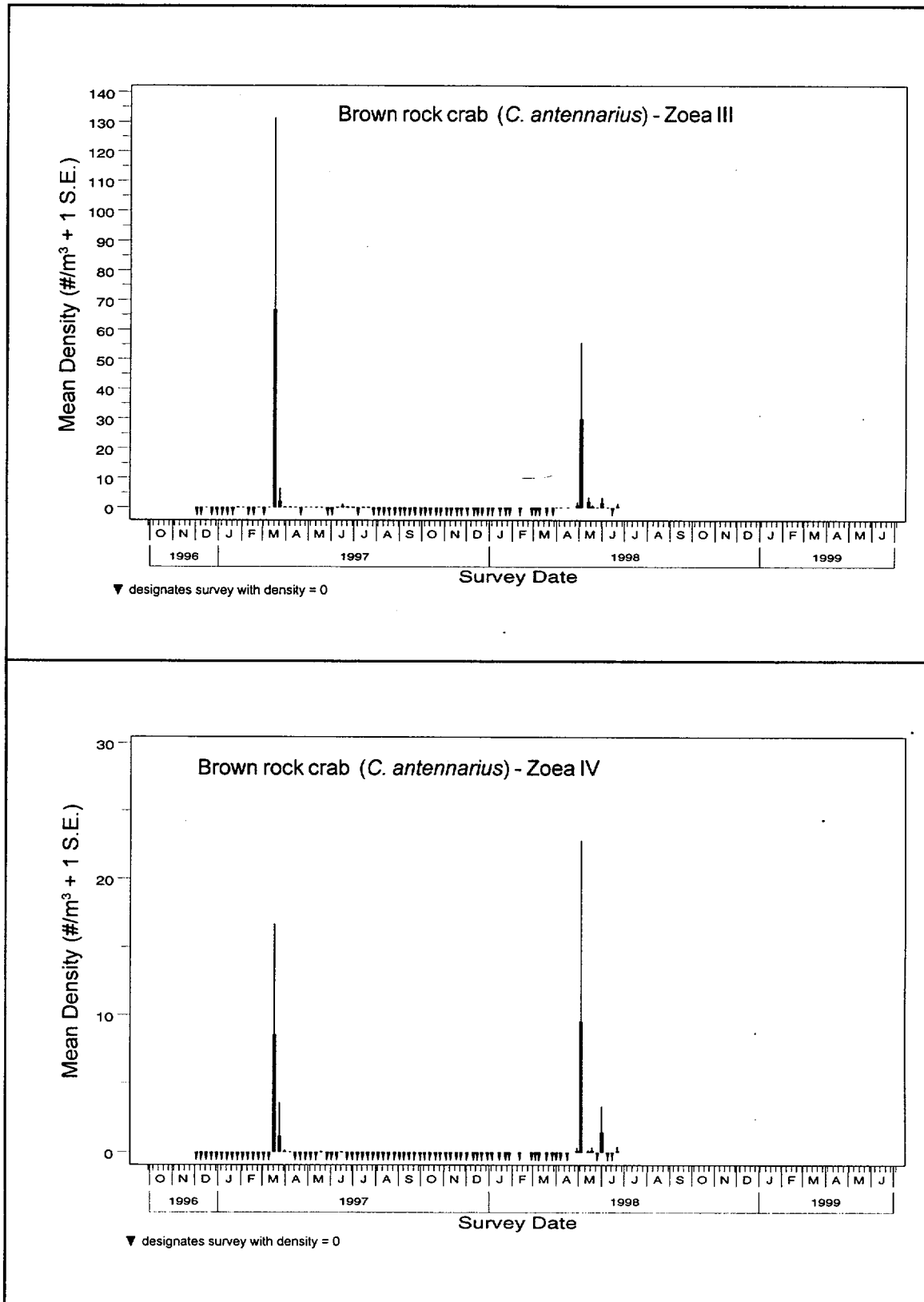


Figure 5.2.1-1 (continued). Weekly mean zoeae and megalops larval density (#/m³ + 1 S.E.) at the DCP intake. Y-axis scale varies between graphs. Zoea not sorted from July 1998 through June 1999 samples.

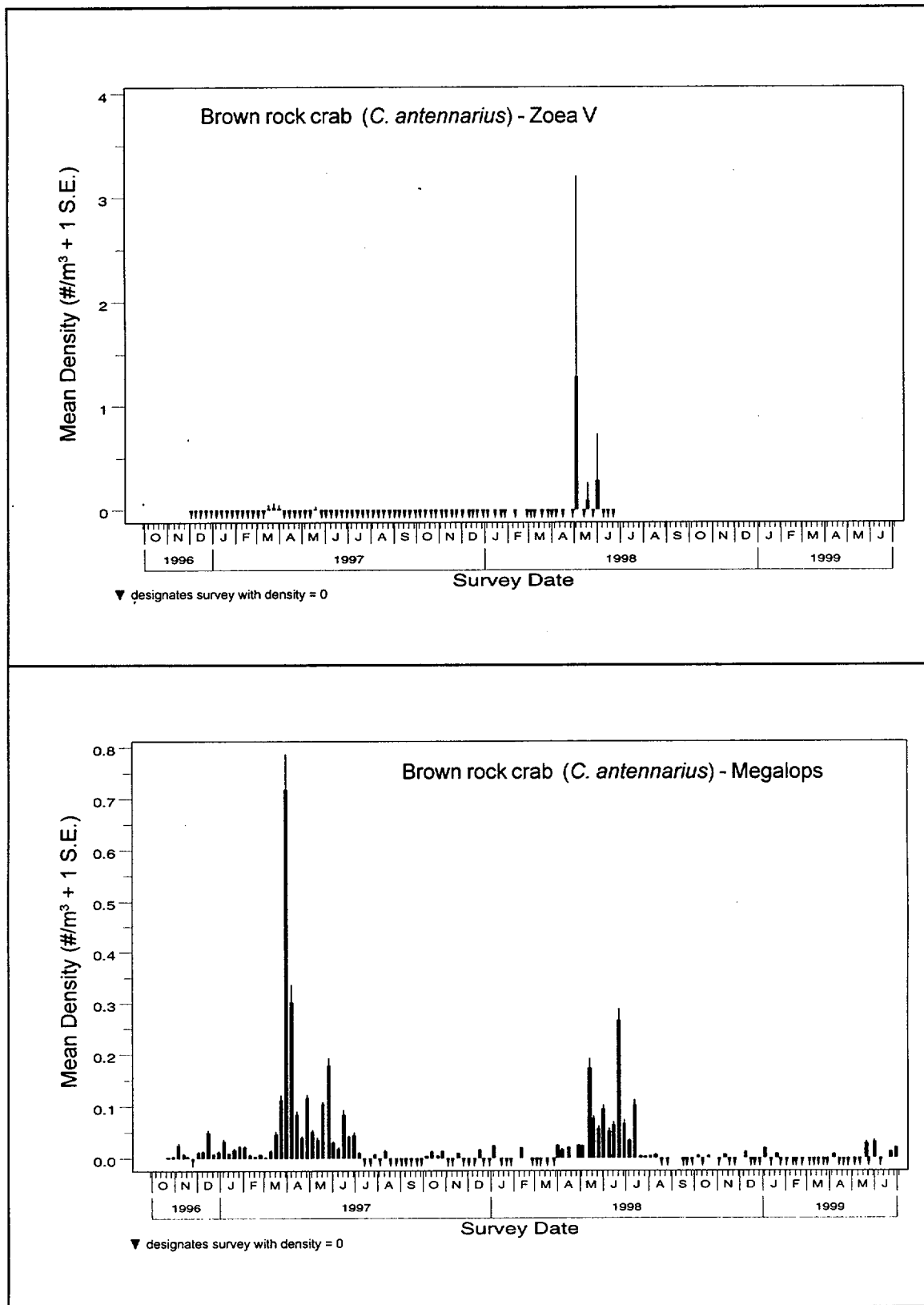


Figure 5.2.1-1 (continued). Weekly mean zoeae and megalops larval density (#/m³ + 1 S.E.) at the DCP intake. Y-axis scale varies between graphs. Zoea not sorted from July 1998 through June 1999 samples.

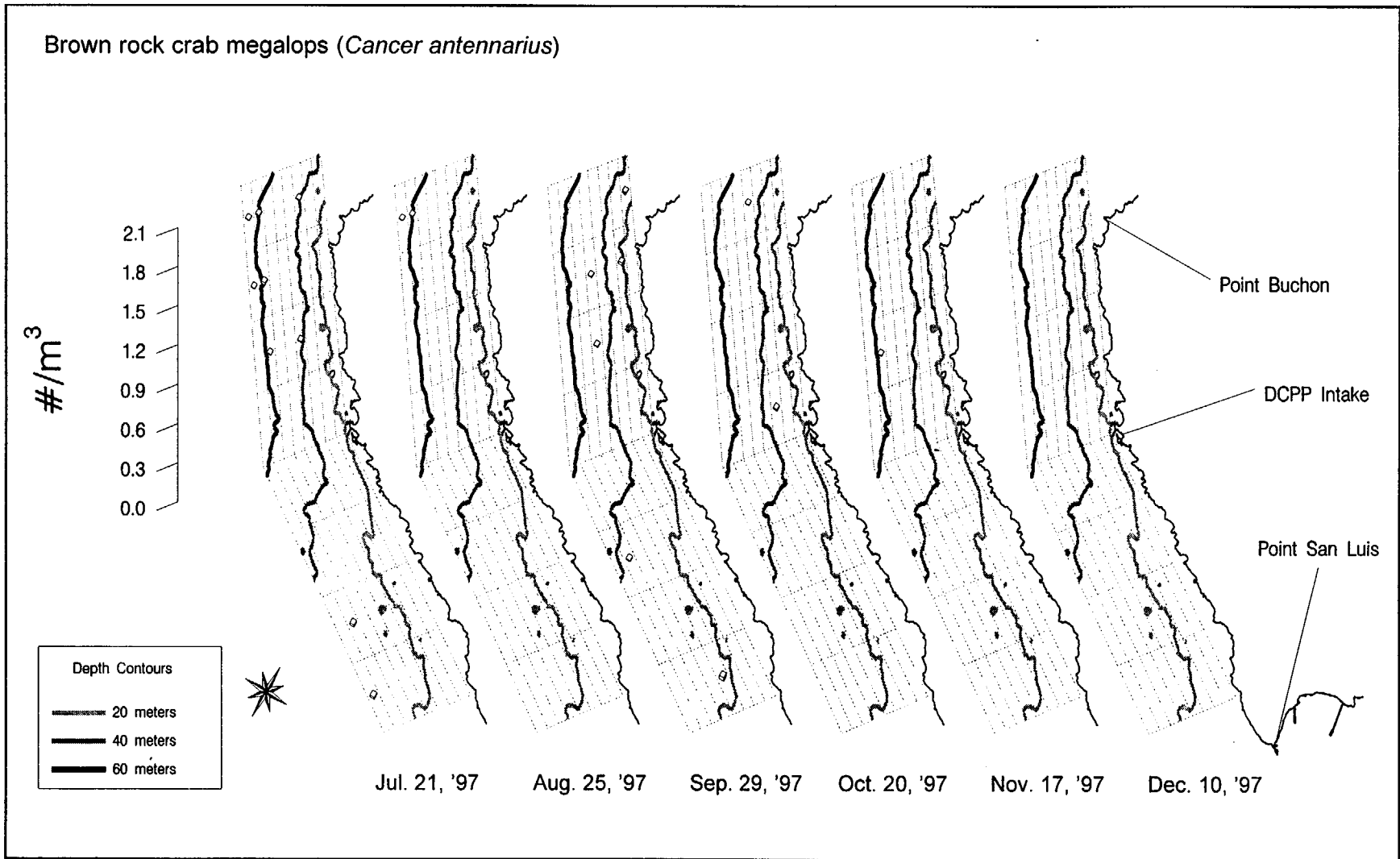


Figure 5.2.1-2a . Mean larval density ($\#/m^3$) collected in the DCPP study grid cells and at the entrainment sampling location.

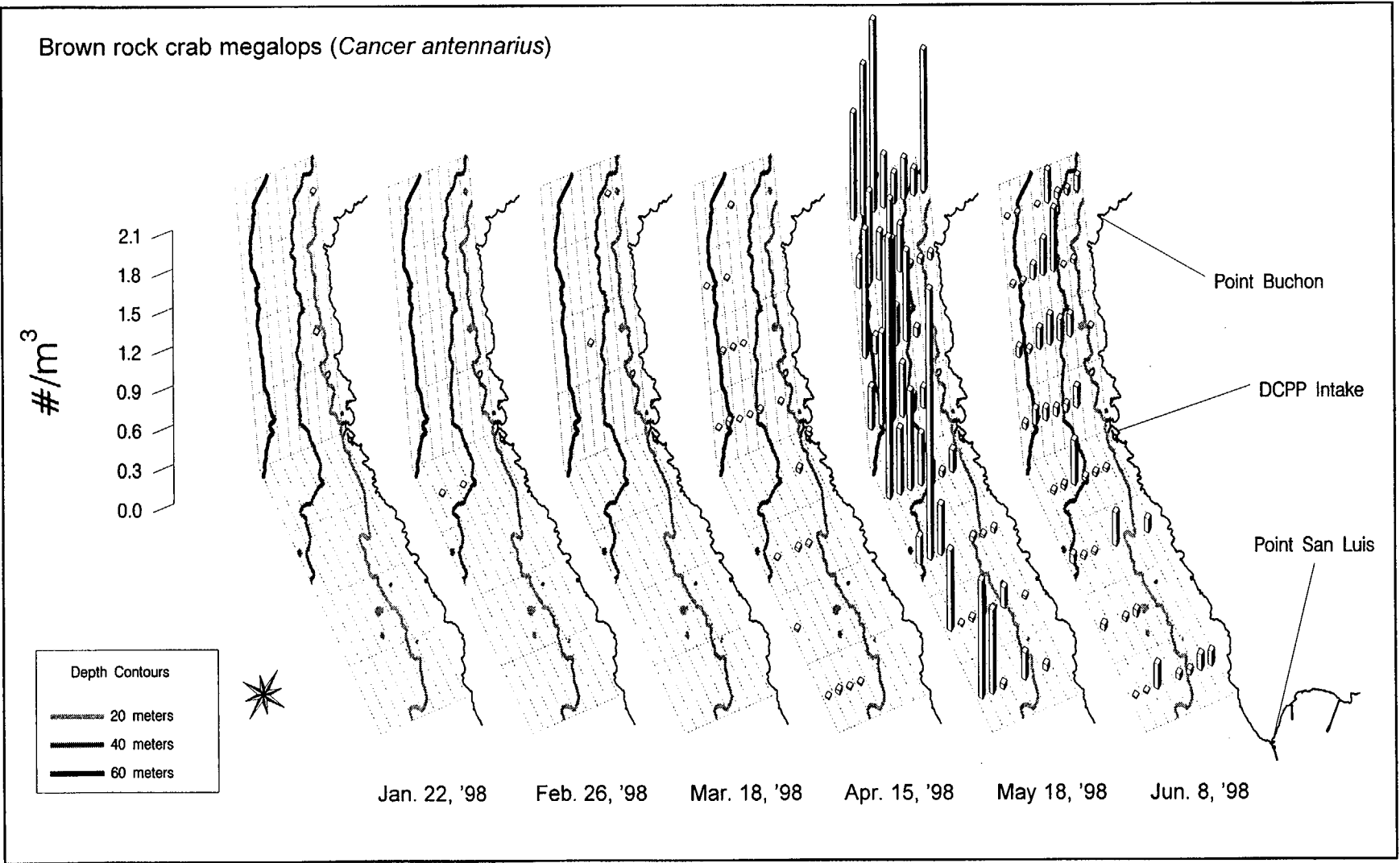


Figure 5.2.1-2b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

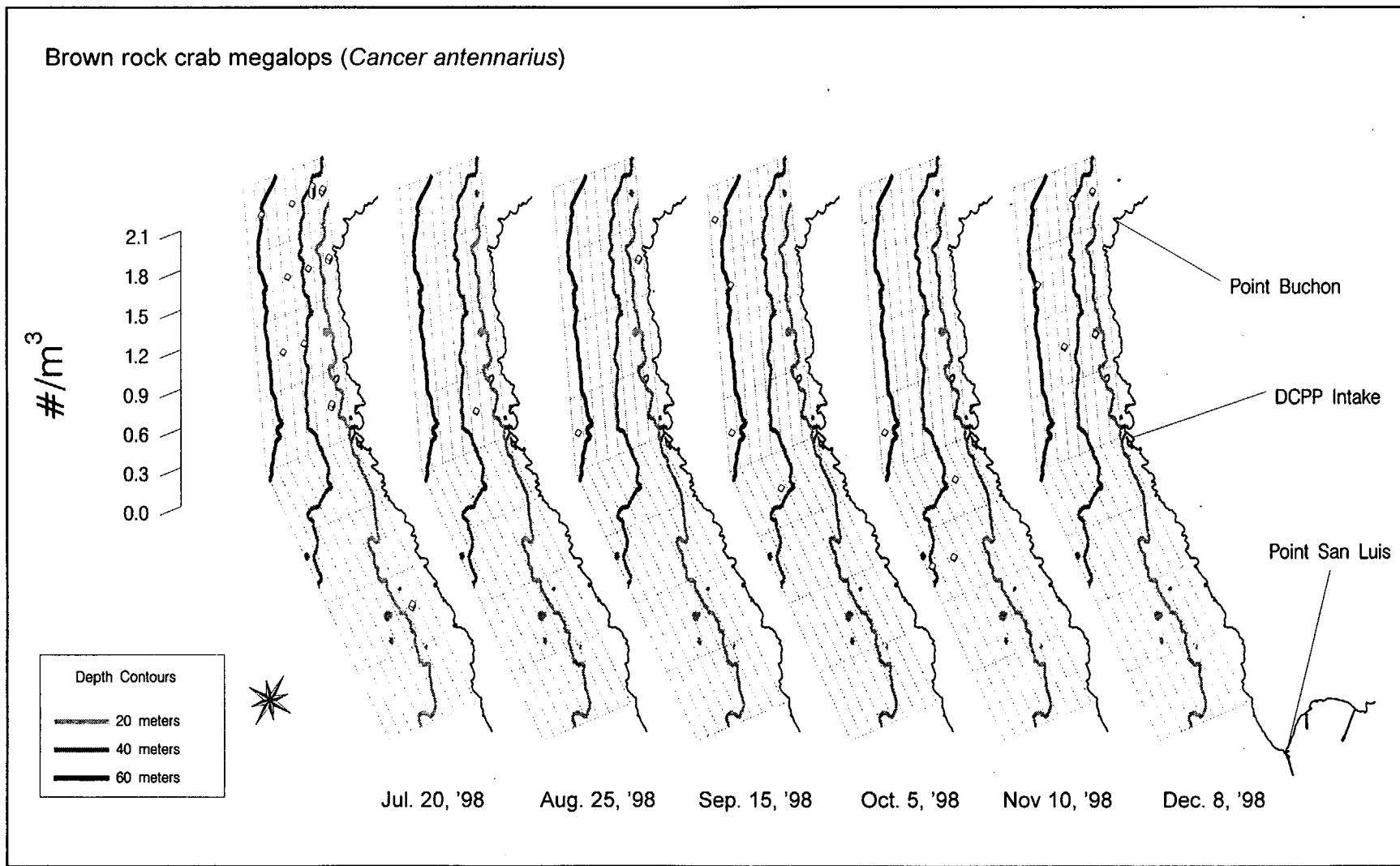


Figure 5.2.1-2c (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

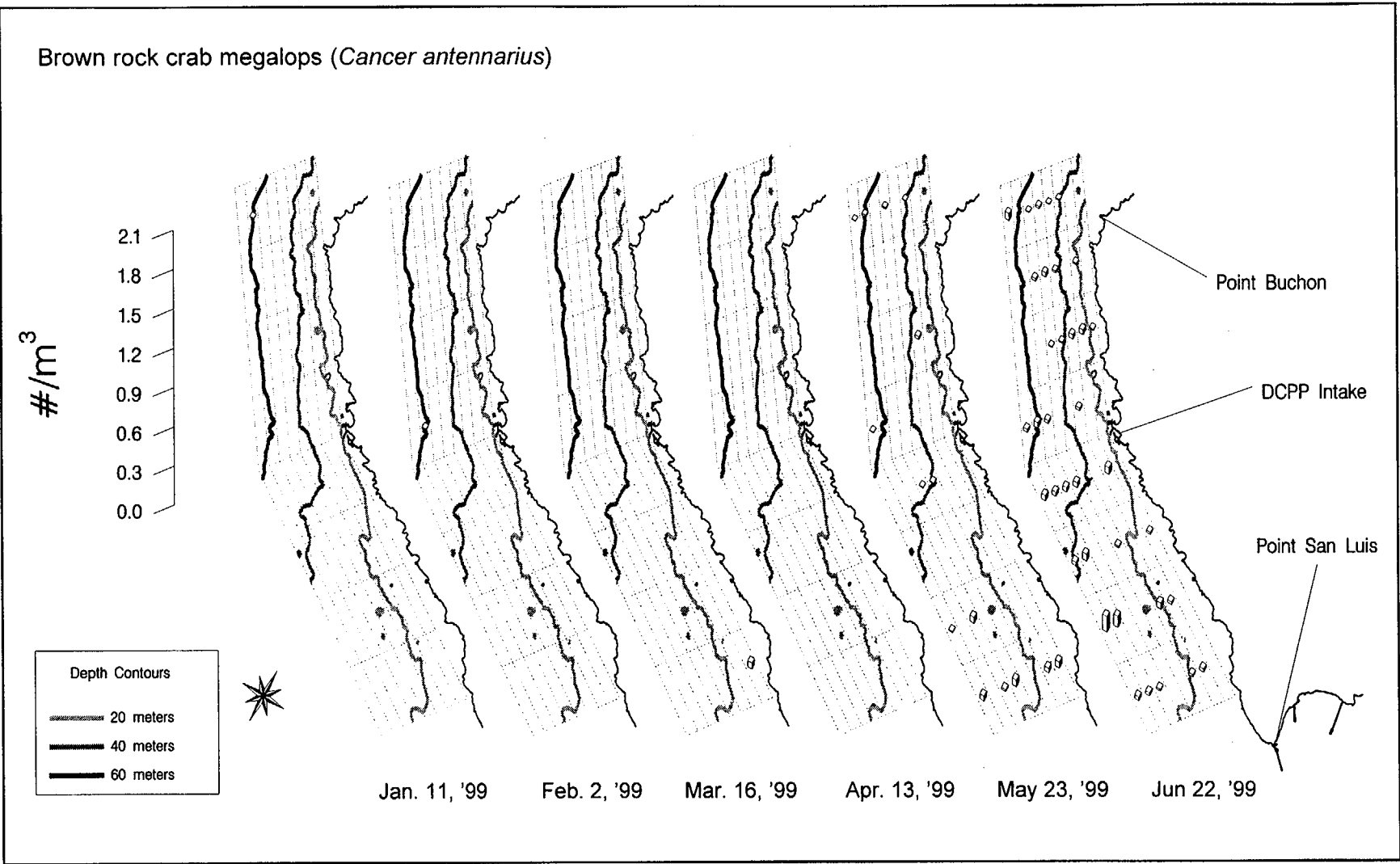


Figure 5.2.1-2d (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

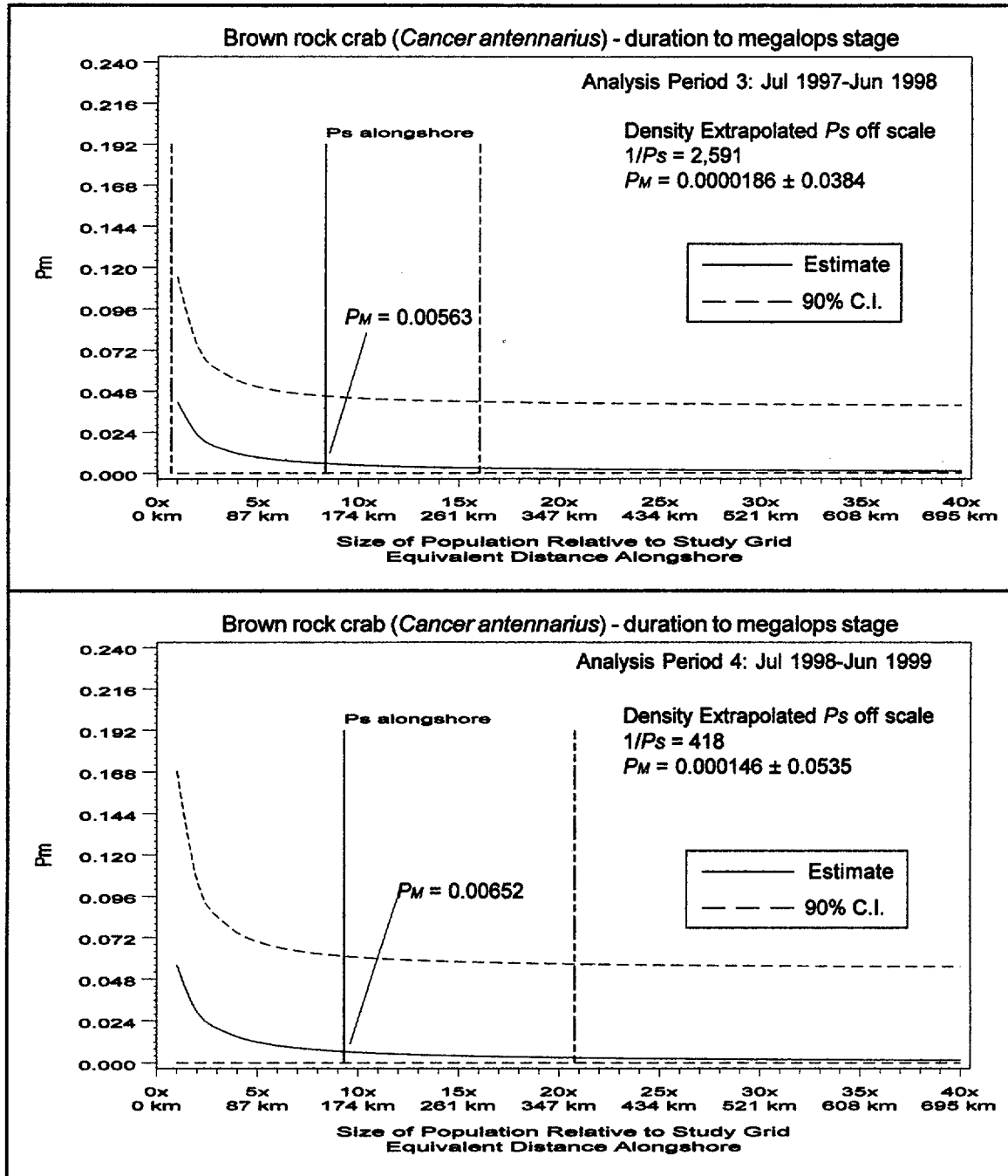


Figure 5.2.1-3. Total annual entrainment mortality (P_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (P_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

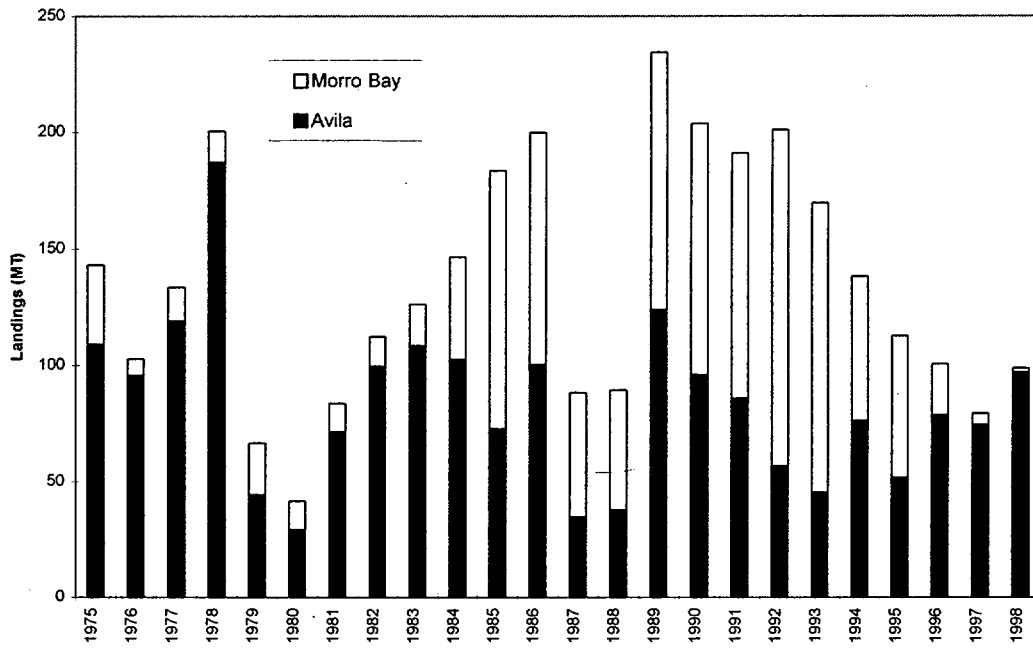


Figure 5.2.1-4. Rock crab (*Cancer* spp.) landings (MT) at Morro Bay and Port San Luis between the years 1975–1998 (source: CDF&G database).

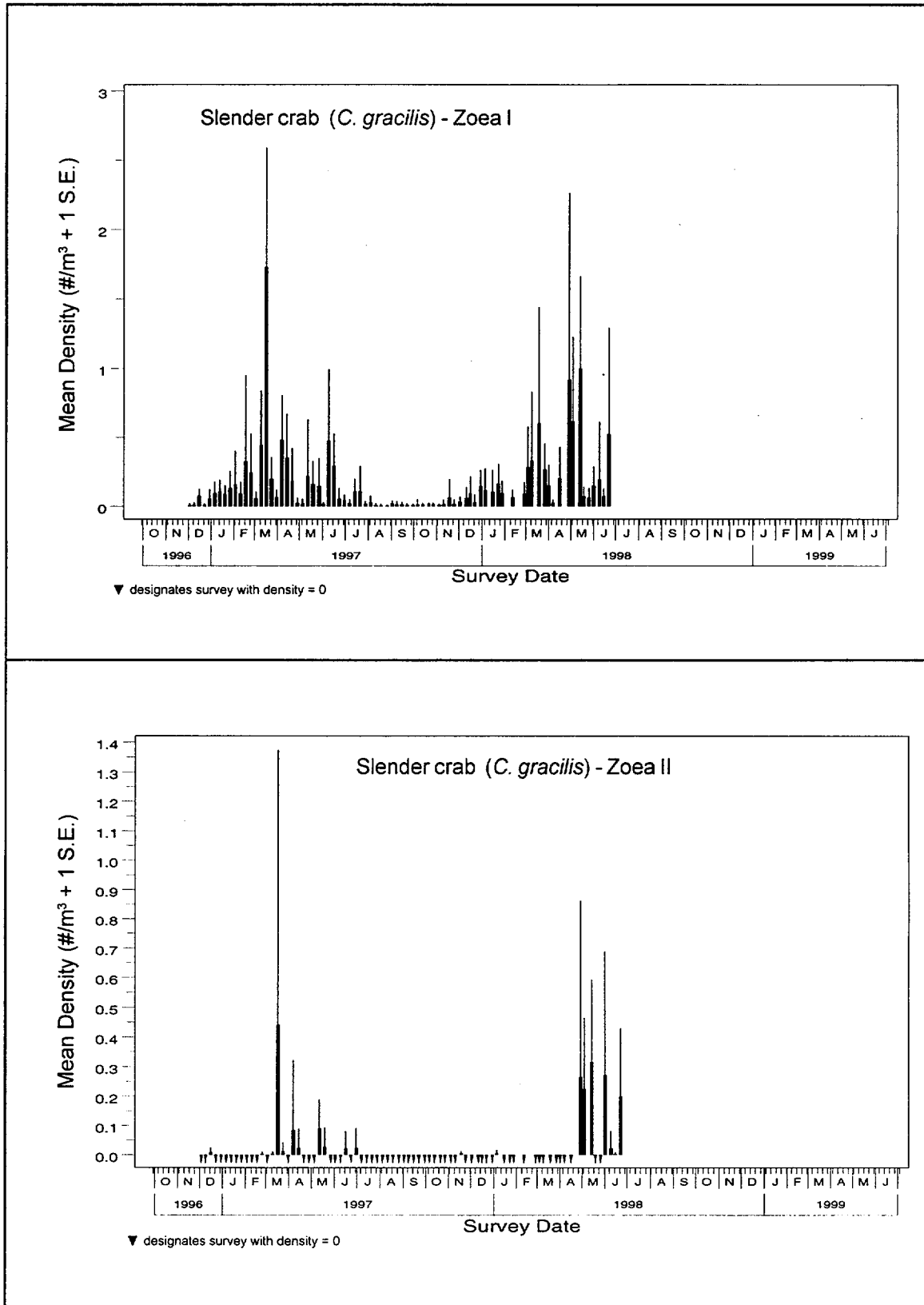


Figure 5.2.1-5. Weekly mean zoeae and megalops larval density (#/m³ + 1 S.E.) at the DCP intake. Y-axis scale varies between graphs. Zoea not sorted from July 1998 through June 1999 samples.

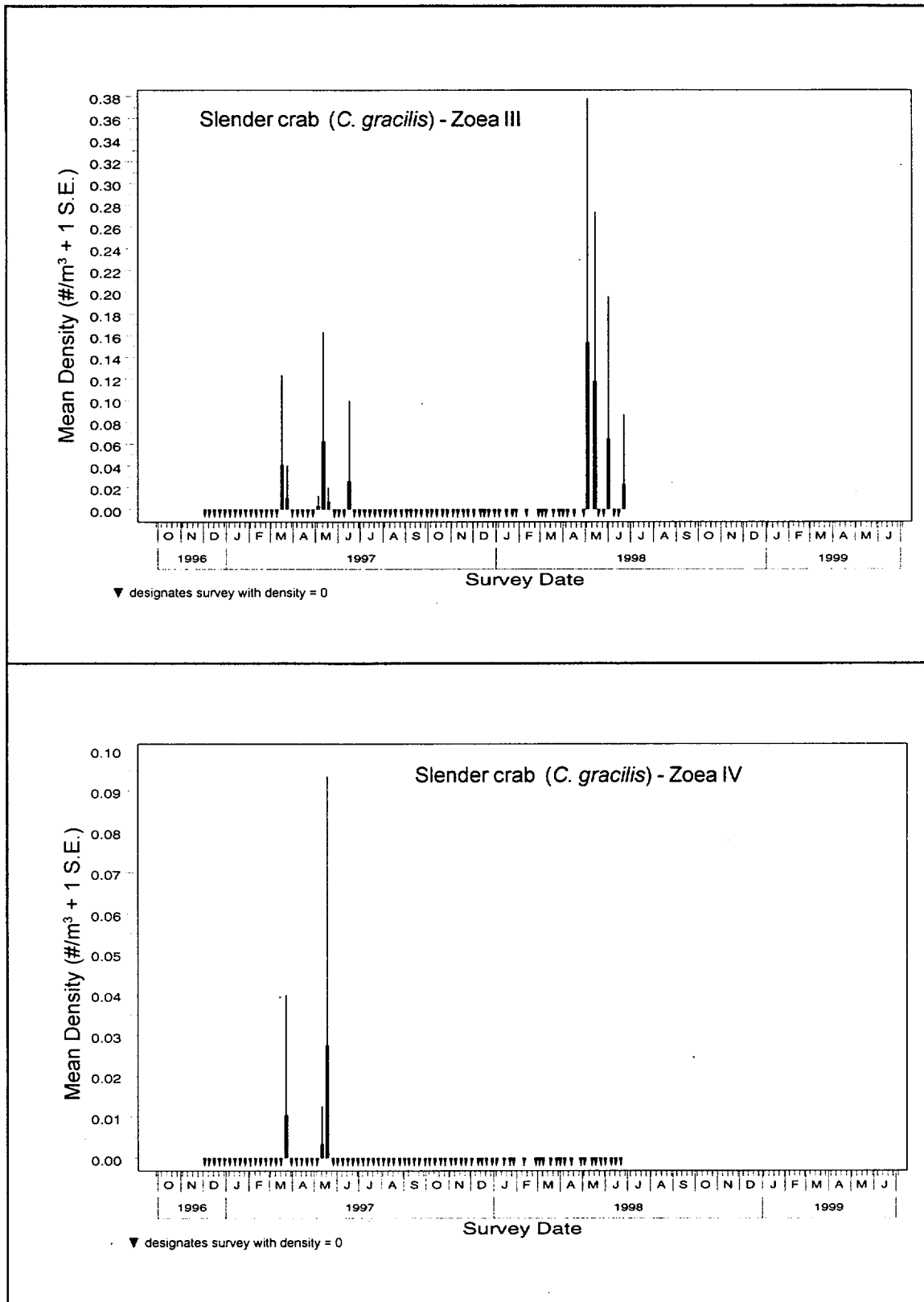


Figure 5.2.1-5 (continued). Weekly mean zoeae and megalops larval density ($\#/m^3 + 1 \text{ S.E.}$) at the DCP intake. Y-axis scale varies between graphs. Zoea not sorted from July 1998 through June 1999 samples.

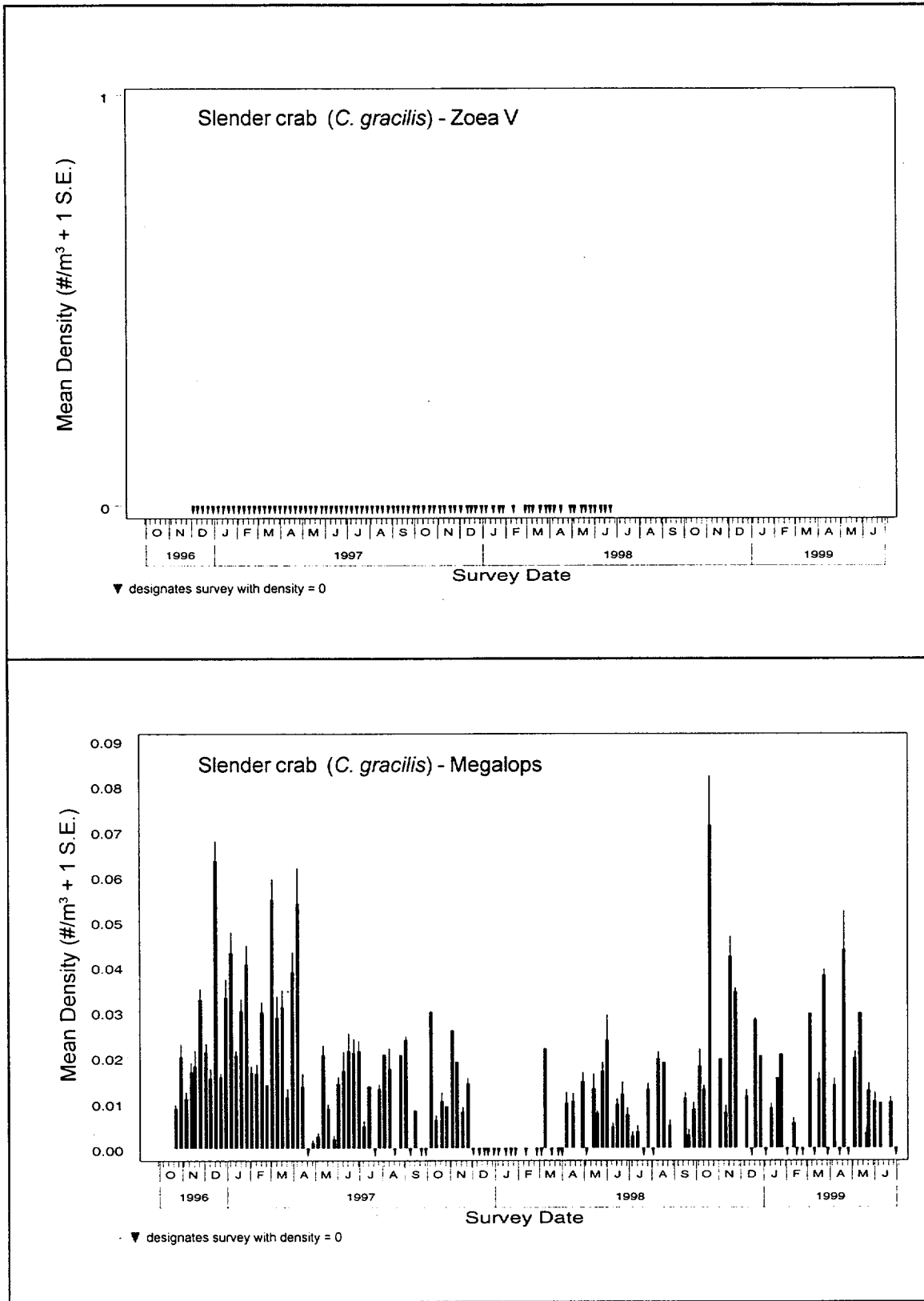


Figure 5.2.1-5 (continued). Weekly mean zoeae and megalops larval density (#/m³ + 1 S.E.) at the DCP intake. Y-axis scale varies between graphs. Zoea not sorted from July 1998 through June 1999 samples.

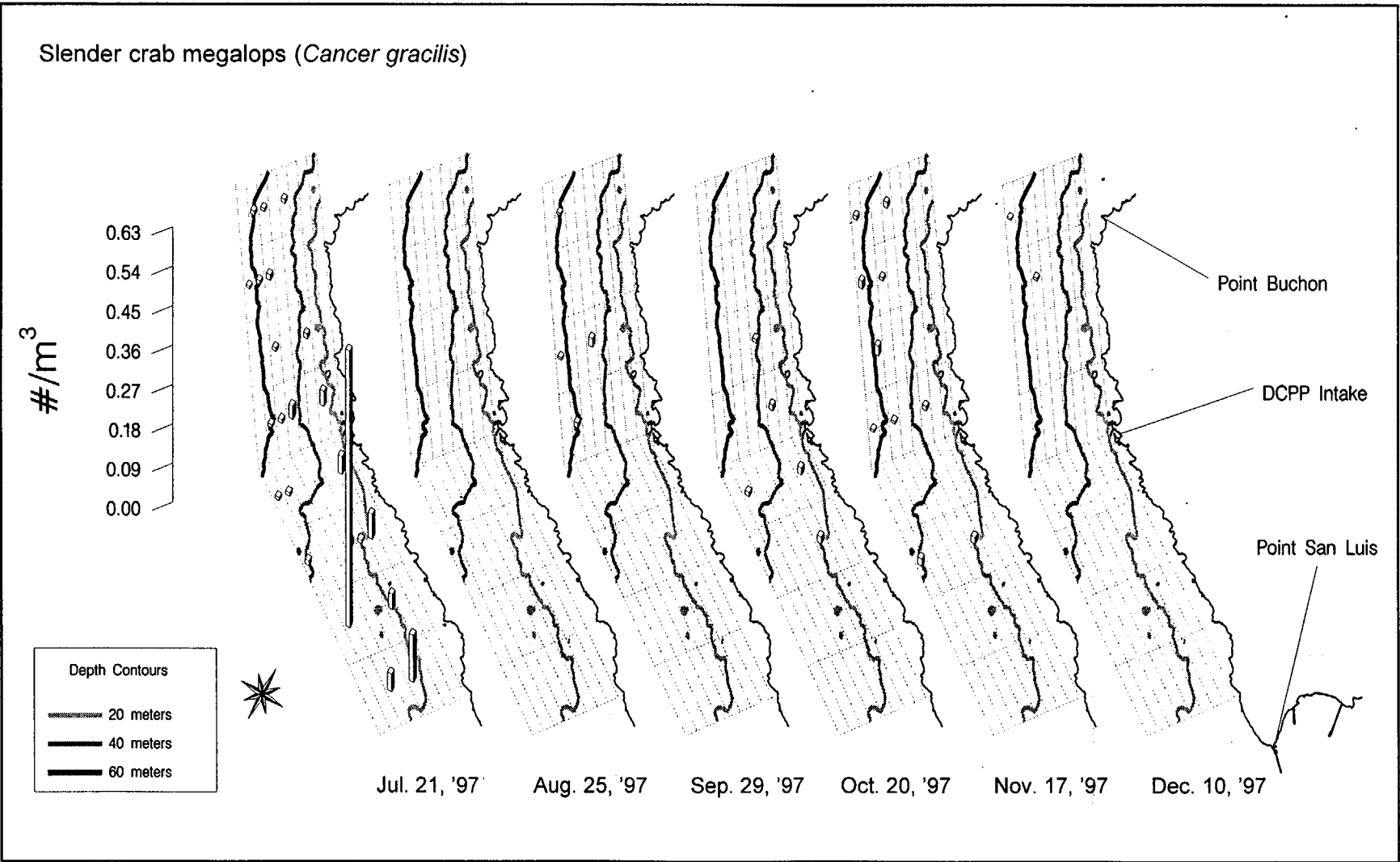


Figure 5.2.1-6a . Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

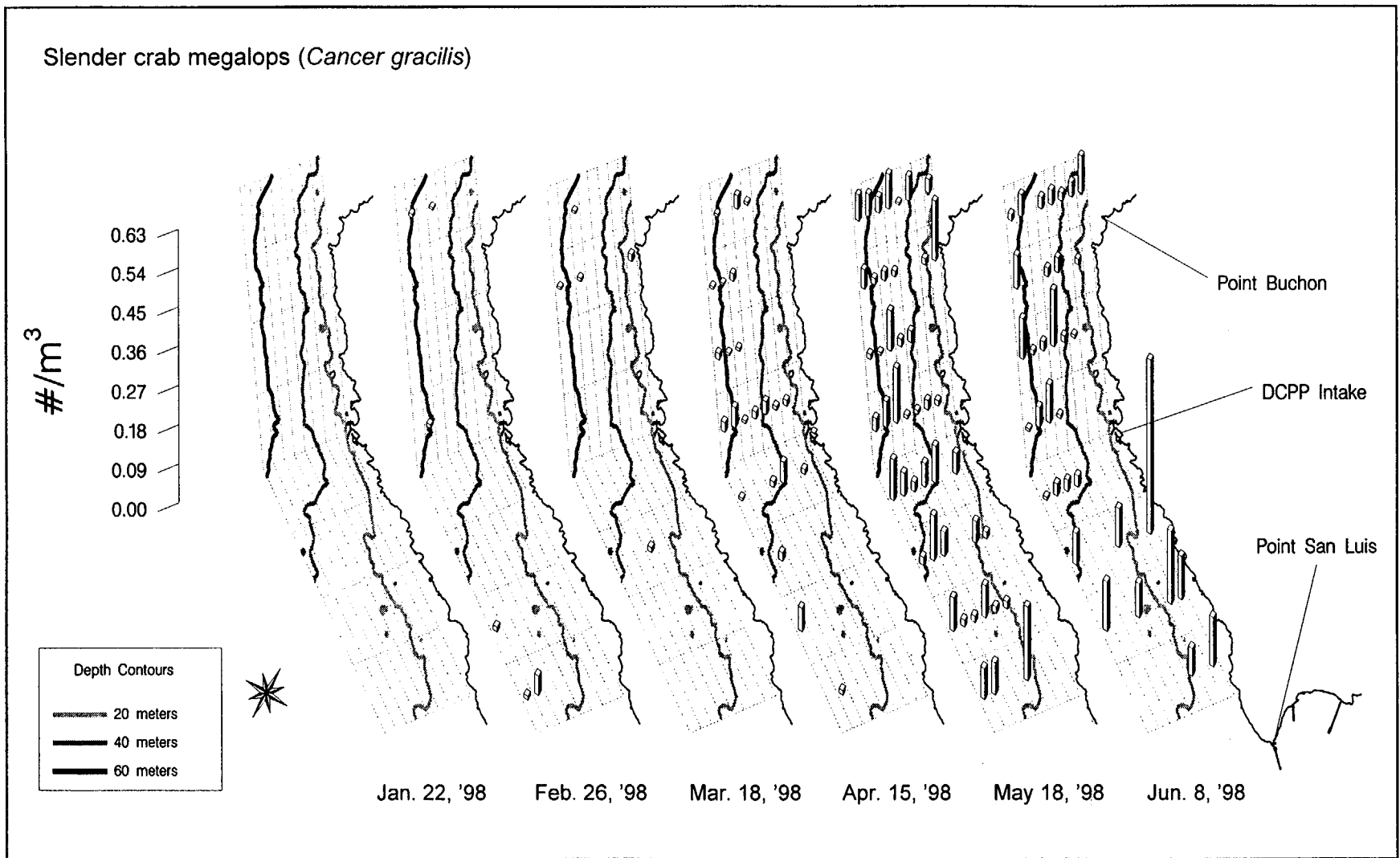


Figure 5.2.1-6b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

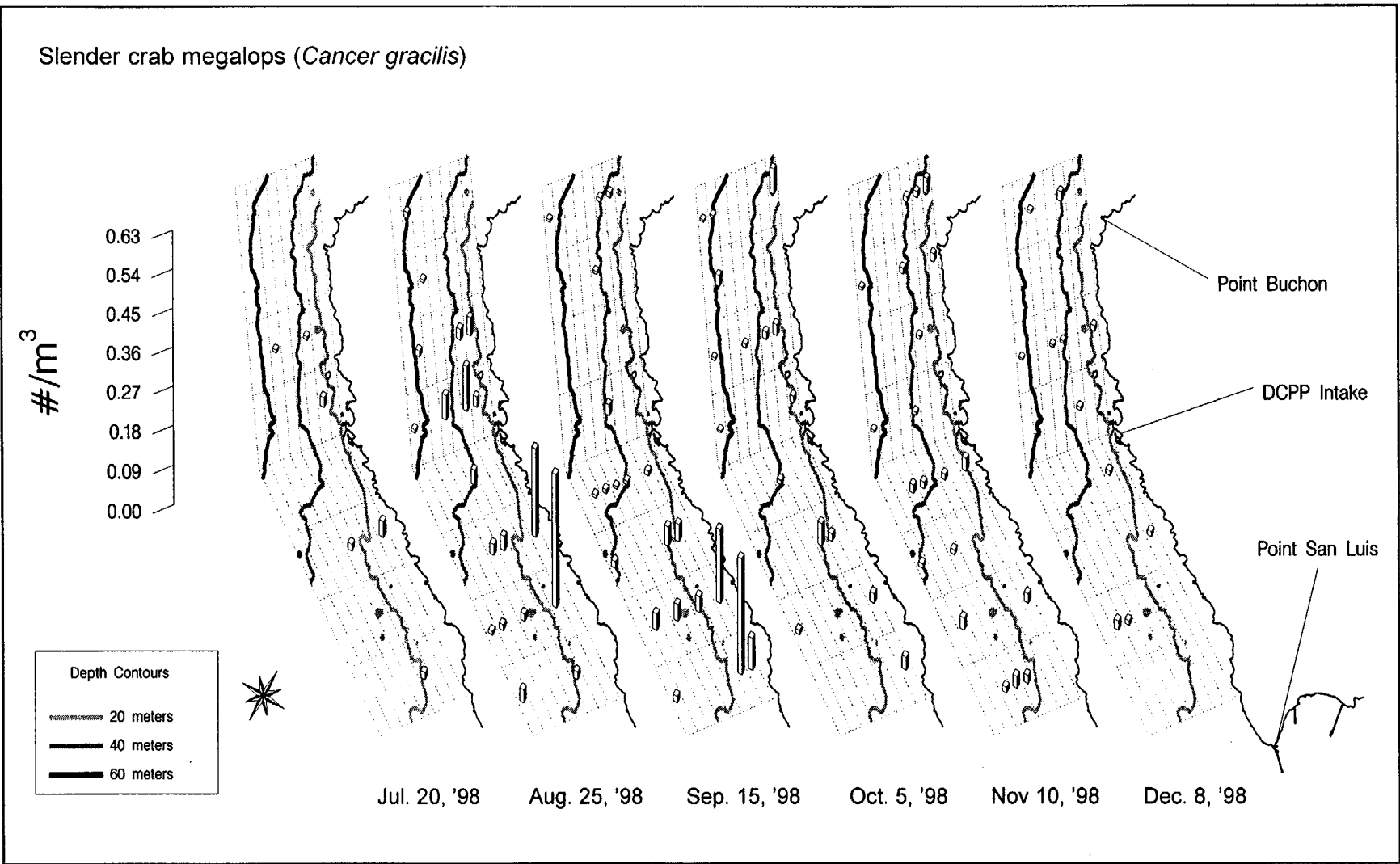


Figure 5.2.1-6c (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

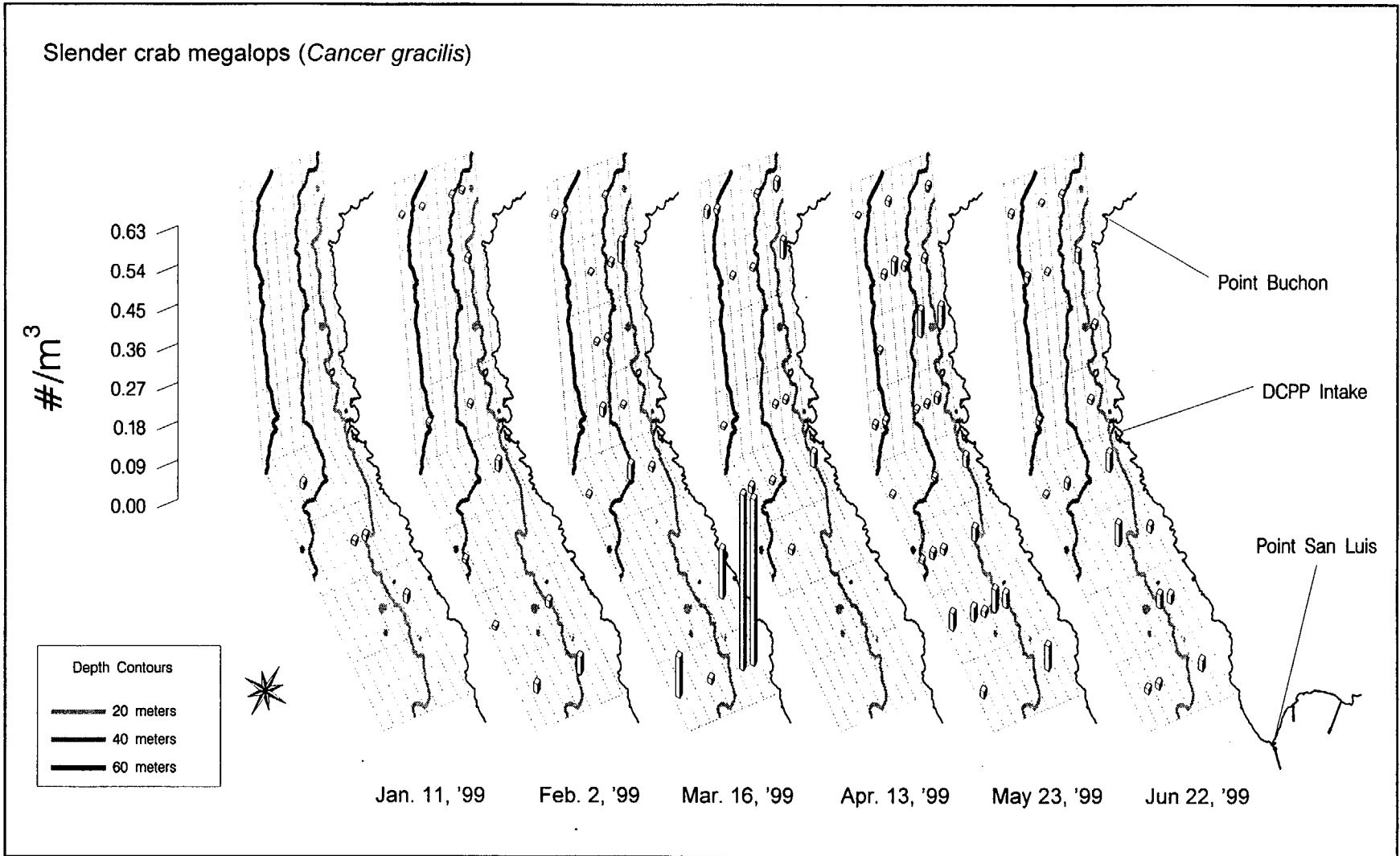


Figure 5.2.1-6d (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

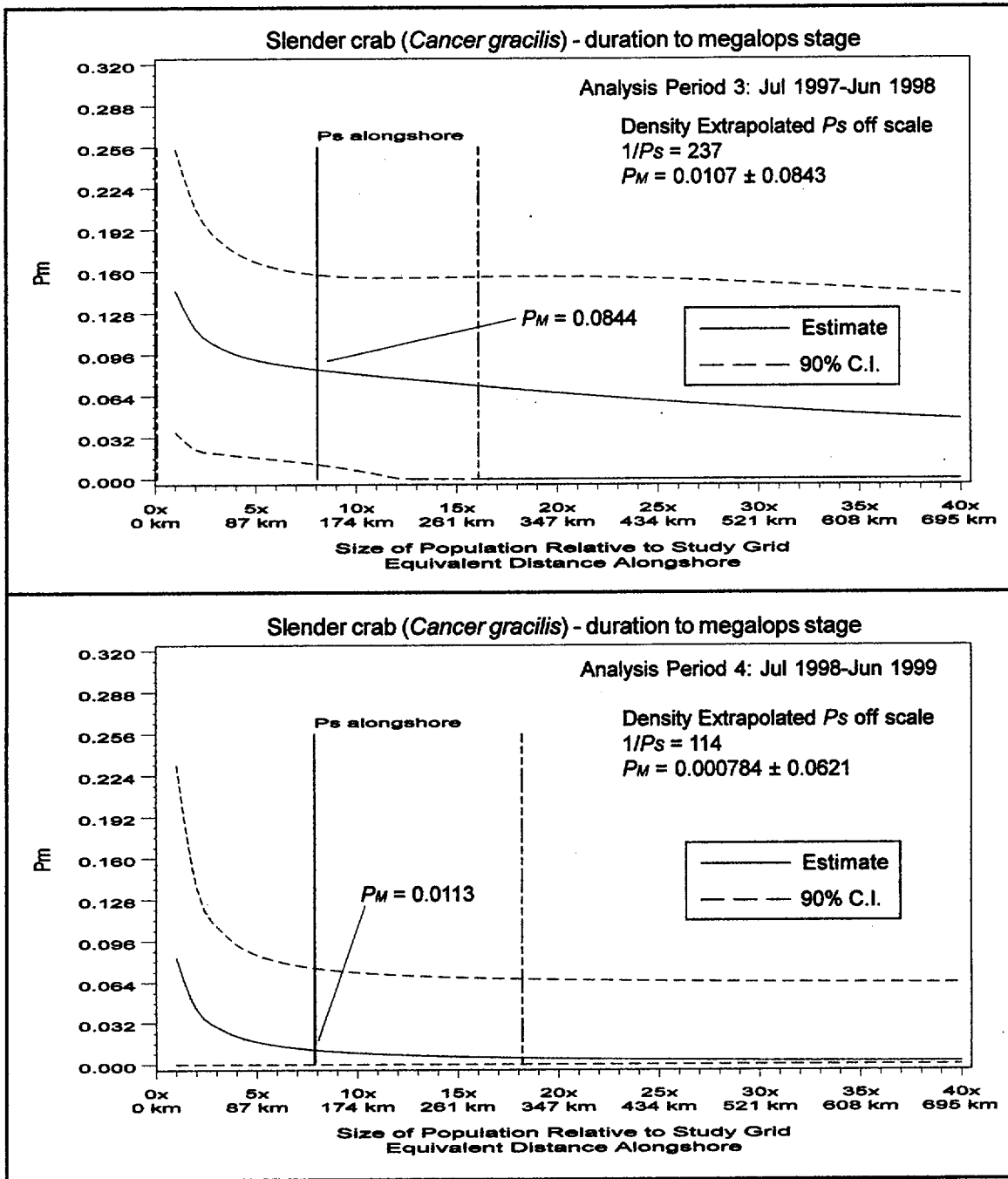
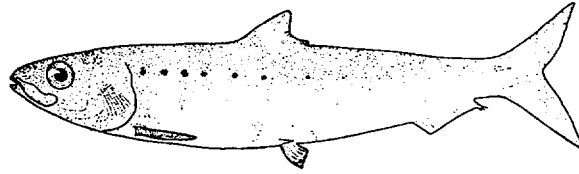


Figure 5.2.1-7. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_s) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

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5.2.2 Assessment of Pacific Sardine (*Sardinops sagax*)



Sardinops sagax (Jenyns 1842); Pacific sardine; length to 41 cm but usually less than 30 cm; Kamchatka, Russia to southeast Alaska and Guaymas, Mexico to Peru and Chile; schools over continental shelf, often near shore (Eschmeyer et al. 1983). Blue-green above, white below, series of black spots on back (Miller and Lea 1972).

Pacific sardine is a member of the family Clupeidae (herrings), which is also represented in the waters around Diablo Canyon by American shad (*Alosa sapidissima*), Pacific herring (*Clupea pallasii*), threadfin shad (*Dorosoma petenense*), and round herring (*Etrumeus teres*). The sharp decline of the Pacific sardine population in the mid-1940's led to the demise of the world's largest commercial fishery and to the establishment of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program (originally named the Cooperative Sardine Research Program) in 1947 (Moser 1996). Recently, the California Department of Fish and Game (CDF&G) issued a press release (January 15, 1999) indicating that the Pacific sardine resource has now fully recovered. Their most recent stock assessment indicated the catch quota be increased from the 1998 quota of 43,574 metric tons (MT) to a 1999 harvest of 120,556 MT (Hill et al. in press). Pacific sardine larvae were not among the ten most abundant larval fish taxa collected in the DCP study, but are a species of interest because of their recovery status, their recent inclusion in the Fishery Management Plan for Coastal Pelagic Species (PFMC 1998), and their potentially growing fishery.

Pacific sardine spawn pelagic eggs and larvae year round with a fall/winter minimum and a spring/summer maximum (Moser 1996) primarily south of Point Conception to the south of San Diego (Hart 1973). Reproduction is temperature dependent, and the spawning biomass may move north during El Niño years. Age at maturity also may be temperature dependent, with 50% of females maturing at about 16 cm standard length (SL) in southern California (Macewicz et al.

1996) and 50% of the females maturing at about 13 cm off Ensenada, Baja California Norte, Mexico in 1958 during an El Niño year (Ahlstrom 1960). Relatively large proportions of fish at age class 0-yr have reached maturity in both the Southern California Bight and Monterey Bay (Table 5.2.2-1; Deriso et al. 1996).

Estimates from previous studies of sardine fecundity range widely. Hart (1973) estimated 30,000–65,000 eggs/batch with large individuals producing 200,000 eggs/yr. Fitch and Lavenberg (1971) reported an estimate of sardine fecundity of 90,000–200,000 eggs/yr. Lo et al. (1996) estimated an average batch fecundity of 24,282 (CV=11%). The highest estimates of annual fecundity from Butler et al. (1993) indicate that Pacific sardine fecundity ranged from 146,754 eggs/two-yr-old female to as many as 2,156,600 eggs for ten-yr and older females (Table 5.2.2-2). Fitch and Lavenberg (1971) indicated that Pacific sardine can live to 25 yr, but longevity is more likely about 13 yr according to Butler et al. (1993); however, Leet et al. (1992) indicated that Pacific sardine older than five years were seldom encountered in the fishery; this was supported by data on catch-at-age presented in Hill et al. (in press).

Each year sardines migrate northward early in summer and return south in fall, migrating farther with each year of life. The timing and extent of these migrations are complex and may be affected by oceanographic conditions. Age stratification of the adult population does appear to occur over a latitudinal gradient, with the larger, older fish occurring farther north (Hart 1973). The adult population off the central coast of California generally consists of young adults (2–4 yr) that have migrated from the primary spawning grounds in southern California to feeding grounds in the waters near Diablo Canyon (PFMC 1998).

Age and growth characteristics of Pacific sardine at all life stages have been well described. Larval growth estimated from otoliths has been measured in several temperature regimes (Miller 1952), from which we are able to derive an approximate growth rate for larvae collected in the DCP study. Growth of the adults has been described with a von Bertalanffy growth function (VBGF: $L_{\infty}=205.4 \text{ mm} \pm 1.6 \text{ mm SE}$, $k=1.19 \pm 0.04 \text{ SE}$, $t_0 = 0$) by Butler et al. (1996).

Pacific sardine are among the few fishes with age- and stage-specific mortality estimates from the egg stage through later life stages reported in the scientific literature. Instantaneous egg mortality has been estimated as 0.13/d off of Oregon with a CV=243% (Barnes et al. 1992). Lo et al. (1996) produced a similar estimate of embryonic (yolk-sac) mortality of 0.12/d, but with a CV=97%. Butler et al. (1993) modeled the demography of Pacific sardine from the egg stage through the late adult stages with estimates of instantaneous daily natural mortality, the estimated duration of each stage, and daily fecundity. Deriso et al. (1996) modeled the annual fishing mortality of Pacific sardine for the years 1983–1995 (Table 5.2.2-3). The natural adult mortality rate in fished populations has been assumed to be 0.4/yr (Murphy 1966; MacCall 1979).

A recent stock assessment of Pacific sardine incorporated fishery harvest statistics collected through 1998 (Hill et al. in press). They indicate that in 1998 the ex-vessel revenue of the commercial sardine fishery (i.e., wetfish) in the state of California totaled \$3.5 million, which is down from the \$4.1 million generated in 1997. Directed fishery harvests in southern and central California are mostly canned for human consumption and sold overseas, with a small proportion sold fresh for human consumption or animal food (PFMC 1998). The ex-vessel price for sardines in the wetfish fishery ranged from \$55–91 per MT, averaging \$73.70/MT for January through September of 1998. In addition to the wetfish fishery, a small live bait fishery exists that usually takes <4,540 MT/yr. The overall revenue generated by the live bait fishery exceeds that of the directed fishery because of the higher dollar value for live bait, averaging \$817/MT in 1998.

5.2.2.1 Summary of Field Collections

Pacific sardine larvae were present intermittently in the entrainment subsamples during the years 1997–1999 (Appendix H), with their greatest abundance occurring during March–May, 1998 (Figure 5.2.2-1). There was a total of 2,191 larval Pacific sardines in 230 bongo net subsamples collected at the DCP intake structure between October 1996 and June 1999, representing 5% of the subsamples collected and processed from the sampling locations in front of the DCP intake structure. An El Niño event began during the spring of 1997, influencing oceanographic conditions along the California coast in the fall/winter season of 1997–98 (Lynn et al. 1998;

NOAA 1999), and corresponds with the observed peak in larval Pacific sardine abundance in DCPD subsamples collected in 1998. The spread of warm water during the El Niño may have shifted the sardine spawning biomass north of their primary spawning grounds from south of Point Conception in the Southern California Bight (Hart 1973; Hill et al. in press) to the vicinity of Diablo Canyon.

Larval Pacific sardine occurred in the DCPD study grid during February–July 1998, in December 1998, and again during April–June 1999 (**Appendix H**), with the highest abundance occurring in March and April of 1998 (**Figure 5.2.2-2**). The patterns observed in the study grid further support the supposition that the 1997–98 El Niño may have displaced the Pacific sardine spawning biomass center further north than its distribution in a cooler water year. There was 5,122 larval Pacific sardines identified from 368 bongo net subsamples, representing 12% of the study grid subsamples collected and processed from July 1997–June 1999.

Standard lengths of all Pacific sardine larvae collected at the DCPD intake structure between October 1996 and June 1999 ranged from a minimum of 1.5 mm to a maximum of 25 mm, with corresponding age estimates ranging from 0–94 d (**Figure 5.2.2-3**). The growth rate of larval Pacific sardine (0.24 mm/d; Miller 1952) was used to estimate ages of entrained larvae. The central 98% of this length-frequency distribution resulted in minimum and maximum lengths used for the analyses of 2.4 mm and 19.1 mm, respectively. We assumed that larvae shorter than the minimum length of the central 98% of the distribution were just hatched and, therefore, age 0 d, and we calculated estimated ages from this point. However, reported hatching size for this species ranges from 3.5–3.8 mm (Moser 1996), indicating that the smallest larvae observed represent either natural variation in hatch lengths within the population or the phenomenon of shrinkage following preservation (Theilacker 1980). The possibility remains that all larvae from the observed minimum length of 1.5 mm to the greatest reported hatching length of 3.8 mm (Moser 1996) could have just hatched, leading to gross overestimation of ages for all larvae <3.8 mm. The mean larval length in this distribution was 5.5 mm and approximately 13 d of age based on a minimum length of 2.4 mm.

Mean lengths of Pacific sardine larvae sampled at the DCP intake structure and from the study grid (**Figure 5.2.2-4**) were not different (t -test: $p=0.185$), but the Kolmogorov-Smirnov goodness of fit test detected a significant difference between the distributions of the two collections ($p=0.003$). Since mean lengths were not significantly different between the two locations, it was determined that the estimated mean ages were not significantly different either (about 14 d). The length-frequency distributions of Pacific sardine larvae were based on 155 larvae from the intake and 2,882 larvae from the study grid mirroring their adult distribution. It was concluded from these data that the Pacific sardine larvae entrained came from the same population available in the study grid, but that there was a greater proportion of small individuals present in the study grid subsamples as compared with the entrainment subsamples.

5.2.2.2 Estimating Total Annual Entrainment

Annual estimated numbers of Pacific sardine larvae entrained at DCP increased by greater than three orders of magnitude between Analysis Period 1 (October 1996–September 1997; $\widehat{E}_T = 368,000$) and Analysis Period 2 (October 1997–September 1998; $\widehat{E}_T = 104,000,000$; **Table 5.2.2-4**). Estimates for Analysis Periods 2 and 3 (July 1997–June 1998) were the same because they included the same period of 1998 when peak abundance of Pacific sardine larvae occurred. Most of the spawning biomass of Pacific sardine is located south of Point Conception in the Southern California Bight (Hill et al. in press) during non-El Niño years. However, during El Niño events (e.g., fall and winter of 1997–98), warm water moves up the California coast from the south (NOAA 1999), probably carrying southern California spawning stocks north with it. This appeared to be indicated in the waters near Diablo Canyon by the increase in larval Pacific sardine abundance in 1997 and 1998 during Analysis Period 2.

The estimates of annually entrained Pacific sardine larvae were adjusted (**Table 5.2.2-5**) to the long-term average Intake Cove surface plankton tow index (\bar{I}/I_i) calculated as the ratio between the 9 yr average (\bar{I}) of Intake Cove sampling (**Figure 5.2.2-5**) and the average annual index estimated from these same tows during the year being adjusted (I_i). The average indices for Analysis Period 1 and Analysis Periods 2 and 3 were <0.001 and 0.070 larvae/ m^3 , respectively,

and the long-term average index for 1990–98 was 0.0152 larvae/m³. Thus, the ratios used to adjust the Analysis Period 1 and Analysis Period 2 estimates of larvae entrained were 23.0 and 0.217, respectively. The same trends in overall abundance as noted for unadjusted entrainment values are apparent in the adjusted values: larval Pacific sardine were less abundant in Analysis Period 1 ($\hat{E}_{Adj-T} = 8,470,000$) than in Analysis Periods 2 and 3 ($\hat{E}_{Adj-T} = 22,600,000$). However, the adjustment to the long-term average had the effect of reducing the difference in abundance between years from three orders of magnitude to less than one. The adjusted CV ranged from 28% in Analysis Period 1, reflecting the low and patchy abundance during the period, to 7% in Analysis Periods 2 and 3 when the larvae were found in greater abundance and were more evenly distributed.

5.2.2.3 Fecundity Hindcasting (*FH*)

Fecundity hindcasting requires age-specific fecundity (M_x) and mortality (L_x) to assess entrainment effects. Butler et al. (1993) modeled egg and larval survivorship of Pacific sardine for several life stages (Table 5.2.2-2). Their ‘best’ estimate is derived by fitting the range of field-estimated mortalities to the assumption of a stable and stationary population. Instantaneous mortality rates from Butler et al. (1993) were used to describe survivorship of egg (0.720), yolk-sac (0.670), and early larval stages (0.242) of Pacific sardine. Applying these rates over their respective average stage durations (Butler et al. 1993), they can then be used to estimate finite survivorship for each developmental stage: 0.165 (egg), 0.125 (yolk-sac), and 0.077 (early larvae). The survival rate from egg stage to entrainment (0.002) was then calculated from an average age at entrainment of 16 d, estimated using a growth rate of 0.24 mm/d (Miller 1952), and an average and smallest size at entrainment of 5.5 mm and 1.5 mm, respectively.

The *FH* approach combines larval entrainment losses and adult fecundity to hindcast the numbers of adult females effectively removed from the reproductively active population. For Pacific sardine, there is substantial regional variation in size-at-age, and ages generally increase from north to south (Phillips 1948). Size and age at maturity may decline with a decrease in biomass, but latitude and temperature are also important (Butler 1987). At low biomass levels, MacCall

(1979) reports that all 1 yr old sardines appear to be reproductively mature, whereas at high biomass levels some 2 yr old fish have yet to reach maturity. Butler et al. (1993) also developed models using age at first maturity as 2 yr. Geographic distribution, however, influenced maturity as Deriso et al. (1996) estimated that 58% of age 0 sardines (<1 yr) were mature in Monterey Bay and 65% mature in the Southern California Bight in 1995 (Table 5.2.2-1). In subsequent calculations, we will assume that age at first maturity is 2 yr as modeled in Butler et al. (1993).

Pacific sardines may live as long as 13 yr (Butler et al. 1993; Love 1996), but Deriso et al. (1996) and Hill et al. (in press) report that the oldest fish in their samples from off the California coast were aged 9 yr. Leet et al. (1992) reports that fish older than 5 yr are seldom caught in the fishery, and this is supported by the catch-at-age data reported in Hill et al. (in press) that extends through June 1998.

Since both longevity and age at maturation are biomass dependent (Hart 1973) and likely changing in this recovering population (Hill et al. in press), we will use what appears to be the fishery longevity (i.e., 5 yr; Leet et al. 1992; Hill et al. in press) to calculate total lifetime fecundity (TLF). If 5 yr is an underestimate of the actual reproductive life span of this fish, then it represents an assumption that reduces the total lifetime fecundity and thus may overestimate the impact of entrainment losses on adult females. The average fecundity from age-2 to age-5 modeled by Butler et al. (1993) is 496,018 eggs per female per year. This fecundity is multiplied by one half the difference between the fishery-modified longevity and age at maturation yielding

$$\widehat{TLF} = 496,018 \cdot \left(\frac{5-2}{2} \right) = 744,027 .$$

The adjusted total larval entrainment for Pacific sardine (\hat{E}_{Adj-T}) was used to estimate the number of breeding females needed to produce the number of larvae entrained (Table 5.2.2-5). The estimated number of breeding females (\widehat{FH}) whose fecundity equals the estimated total loss of entrained larvae is calculated assuming age of maturation is 2 yr and longevity in the fishery is 5 yr (Table 5.2.2-6). The number of adult females hindcast from the larvae entrained at DCPD during Analysis Period 1 ($\widehat{FH} = 3,170$) was less than one-half of the adult females hindcast during Analysis Periods 2 and 3 ($\widehat{FH} = 8,460$).

Sensitivity Analysis

Two parameters, survivorship and fecundity, had the greatest leverage on recalculated values of \widehat{FH} (Table 5.2.2-7). Varying either of these two parameters in the model resulted in an \widehat{FH} range of 613–43,800 adult females for Analysis Period 1 and Analysis Periods 2 and 3, compared to the original estimate of 3,170–8,460 adult females. Maturation and longevity had the next greatest amount of leverage on recalculated \widehat{FH} .

5.2.2.5 Adult Equivalent Loss (AEL)

Similar to the \widehat{FH} results, estimates of adult equivalents lost (AEL) due to larval entrainment were smaller during Analysis Period 1 (2,630) than during Analysis Periods 2 and 3 (7,000) (Table 5.2.2-8). The \widehat{AEL} of 2,630 adults predicted from \hat{E}_{Adj-T} at DCPD during Analysis Period 1 reflects the low abundance of Pacific sardine larvae during this period. As indicated from the long term Intake Cove surface tows, these low abundance estimates represent a more typical year relative to the following years that appeared to be influenced by El Niño conditions. \widehat{AEL} values were almost three times higher during Analysis Periods 2 and 3 (i.e., 7,000 adult equivalents) when spawning stocks generally found south of Point Conception were likely displaced northward as warm El Niño waters spread up the California coast.

Sensitivity Analysis

Late larval survivorship had the greatest leverage on recalculated values of \widehat{AEL} (Table 5.2.2-9). Varying this parameter in the model resulted in an \widehat{AEL} ranges of 507–36,300 adult equivalents for Analysis Period 1 and Analysis Periods 2 and 3, compared to the original estimate of 2,630–7,000 adult equivalents. Early juvenile survivorship had the next greatest leverage on \widehat{AEL} , while varying the estimate of entrainment did not substantially change the original estimate of \widehat{AEL} .

5.2.2.6 Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) in each i th survey from the two years sampled ranged from a minimum of zero to a maximum of 0.859 ± 0.911 ($\pm 1SE(\widehat{PE}_i)$) in January 1999 (Table 5.2.2-10). When both \widehat{PE}_i and the annual proportion of larvae hatched in the i th

survey period (\hat{f}_i) were equal to zero, no larvae were collected at either the DCPD intake nor from the study grid. When $\widehat{PE}_i = 0$ and $\hat{f}_i > 0$, larvae were collected at the DCPD intake during the survey period but not during the entrainment survey paired with the 72-hr study grid survey. For Pacific sardine, the relatively large \widehat{PE}_i for January 1999 was accompanied by an $f_i = 1$ since this was the only month in which Pacific sardine were collected during Analysis Period 4. In addition, there were no Pacific sardine larvae collected in the study grid during the paired 72-hour sampling period. A PE was calculated for the survey period because the larval density from the weekly entrainment sample (**Appendix H**) was used to estimate the densities in the unsampled volume inshore of the two cells nearest the intake (D1 and E1). As a result no estimates of larval mortality due to entrainment (P_M) were calculated for Analysis Period 4.

By varying the estimated proportion of the sardine population in the study grid (P_S) over the mean and maximum larval durations, estimates of \widehat{P}_M ranged over nearly an order of magnitude during Analysis Period 3 (**Figure 5.2.2-6**). The differences in \widehat{P}_M resulted from longer larval duration and consequently greater alongshore and onshore transport during the period which decreased P_S , although it increased time the larvae were susceptible to entrainment. The \widehat{P}_M values calculated from offshore extrapolated abundance extended alongshore were small regardless of the larval duration used (i.e., 0.0000669 and 0.000284 for the maximum and mean durations, respectively). The extrapolations developed in this analysis indicated that sardine larvae were at risk over an area ranging from 938 km² to 14,800 km² (based on 1997–1998 data of current velocities, gradients in larval distribution, and durations at risk for mean and maximum larval sizes entrained, respectively). These areas represent 0.6–9.1%, respectively, of the total area of the 1998 spawning population of Pacific sardine extending from San Francisco Bay to Ensenada, Mexico (based on values reported by Hill et al. [in press] and the PSMFC database; **Figure 5.2.2-7**).

5.2.2.7 Interpretation of Assessment Results

Estimates of entrainment losses using AEL estimates can be used to estimate effects on local harvest of Pacific sardine. An estimated annual average equivalent loss of approximately 5,000 adult sardines (AEL) at DCPD translates into 0.625 MT/yr using an average weight of 125 g for

two year old sardines (Hill et al. in press). Assuming, conservatively, that all of these sardines were vulnerable to the fishery, approximately 10% of this biomass would be directed to the live bait fishery (average value of \$817/MT) and the remainder would be directed to the wetfish fishery (average value of \$74/MT). These amounts translate into \$51/yr from the live bait fishery and \$42/yr from the wetfish fishery.

Alternatively, the estimates of annual entrainment mortality probability (\widehat{P}_M ranges from 0.0000669–0.000284) can be applied to the proportion of the recent stock size estimates at risk to entrainment assuming no compensation. Hill et al. (in press) report that approximately 337,596 MT of Pacific sardine were present in the area from Monterey Bay to San Diego. The proportion of this amount to which \widehat{P}_M would be applied would be 16,900 MT, which is approximately 5% (the average area of the spawning population potentially affected by entrainment, based on the two estimates using maximum and mean larval durations) of the total biomass within the area from San Diego to Monterey. Using the larger more conservative P_M estimate yields a potential loss of 4.8 MT of Pacific sardine as a result of entrainment. By apportioning the valuation of catches as in the *AEL* loss estimates, 4.8 MT represents direct annual dollar value losses of \$390 to the live bait fishery and \$320 to the wetfish fishery.

These estimates indicate that DCPD entrainment effects represent minimal risk to local or regional populations of Pacific sardine. During the period of power plant operations that began in 1985, adult stocks of Pacific sardine have fully recovered (Hill et al. in press) from their population crash in the late 1940's and early 1950's (PFMC 1998), and commercial catches have steadily increased (Starr et al. 1998). Pacific sardine larvae occurred episodically in plankton samples collected at DCPD during the present study and in data sets spanning a larger time frame. There is little possibility that any additional larval mortality due to entrainment of this species at DCPD is affecting the adult stocks when one considers the uncommon occurrence of Pacific sardine larvae in plankton tows near DCPD combined with the trends of increasing abundance and catch.

Table 5.2.2-1. Percent maturity of female Pacific sardines (*Sardinops sagax*) in the Southern California Bight and in Monterey Bay (Deriso et al. 1996).

Age (yr)	% Mature (Southern California Bight)	% Mature (Monterey, California)
0	65	58
1	87	79
2	96	91
3	99	97
4	100	99
5+	100	100

Table 5.2.2-2. Life table for Pacific sardine (*Sardinops sagax*): a) Age-specific fecundity schedule (M_x =natality rate; L_x =survivorship) and b) stage-specific survivorship schedule (Z =instantaneous daily mortality; S =finite survival rate) modified from Butler et al. (1993).

a) Age-specific fecundity

Age (yr)	M_x	L_x	$M_x L_x$
1	0	1,000	0
2	146,754	670	98,325,180
3	388,188	449	174,296,412
4	599,640	301	180,491,640
5	849,490	202	171,596,980
6	1,167,457	135	157,606,695
7	1,487,528	91	135,365,048
8	1,617,450	61	98,664,450
9	1,887,025	41	77,368,025
10	2,156,600	27	58,228,200
11	2,156,600	18	38,818,800
12	2,156,600	12	25,879,200
13	2,156,600	8	17,252,800

(continued)

Table 5.2.2-2. (continued)

b) Stage-specific survivorship										
Stage	Z_{\min}	Z_{best}	Z_{\max}	Duration		S_{\max}	S_{best}	S_{\min}	CV_{best}	
				(d)	Cumulative (d)					
Egg	0.3100	0.7200	2.1200	3		3	0.4607	0.1653	0.0050	0.4595
Yolk-sac larva	0.3940	0.6698	0.9710	3	6	3	0.2948	0.1254	0.0493	0.3264
Early larva	0.1423	0.2417	0.3502	11	17	7.26	0.356	0.173	0.0788	0.267
Survivorship from egg to entrainment:								0.0036		
Early larva	0.1423	0.2417	0.3502	11	17	3.74	0.587	0.4047	0.270	0.131
Late larva	0.0570	0.0964	0.1390	35	52	35	0.1360	0.0343	0.0077	0.6243
Early juvenile	0.0290	0.0560	0.0810	25	77	25	0.4843	0.2466	0.1320	0.2381
Juvenile I	0.0116	0.0197	0.0285	50	127	50	0.5599	0.3734	0.2405	0.1425
Juvenile II	0.0023	0.0040	0.0058	110	237	110	0.7765	0.6440	0.5283	0.0642
Juvenile III	0.0016	0.0028	0.0040	146	383	146	0.7917	0.6644	0.5577	0.0587
Juvenile IV	0.0012	0.0022	0.0032	170	553	170	0.8155	0.6880	0.5804	0.0569
Pre-recruit	0.0006	0.0011	0.0015	175	728	175	0.9003	0.8249	0.7691	0.0265
Survivorship from entrainment to recruitment:								0.0003		

Table 5.2.2-3. Estimated fishing mortality rates (F) on Pacific sardine (*Sardinops sagax*) from 1983–1995. Data from Deriso et al. (1996).

Age (yr)	Estimated F Range
0	0.00–0.04
1	0.01–0.30
2	0.04–0.71
3	0.04–1.08
4	0.03–1.05
5	0.03–0.96

Table 5.2.2-4. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for Pacific sardine (*Sardinops sagax*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	368,000	103,000
2) Oct 1, 1997–Sep 30, 1998	104,000,000	7,430,000
3) Jul 1, 1997–Jun 30, 1998	104,000,000	7,430,000

Table 5.2.2-5. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for Pacific sardine (*Sardinops sagax*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	8,470,000	2,360,000
2) Oct 1, 1997–Sep 30, 1998	22,600,000	1,610,000
3) Jul 1, 1997–Jun 30, 1998	22,600,000	1,610,000

Table 5.2.2-6. Estimated number of Pacific sardine (*Sardinops sagax*) adult females (\widehat{FH}) whose reproductive output was equivalent to the adjusted number of larvae entrained per year (\hat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{FH})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Upper	Lower
			90% C.L.	90% C.L.
1) Oct 23, 1996–Sep 30, 1997	3,170	12,100	1,690,000	6
2) Oct 1, 1997–Sep 30, 1998	8,460	32,300	4,490,000	16
3) Jul 1, 1997–Jun 30, 1998	8,460	32,300	4,490,000	16

Table 5.2.2-7. Pacific sardine (*Sardinops sagax*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 3,170$				
\hat{E}_{Adj-T}	8,470,000	1,720	4,630	2,910
\hat{S}_{egg}	0.165	613	16,400	15,800
$\hat{S}_{yolk-sac}$	0.125	613	16,400	15,800
\hat{S}_{larvae}	0.173	613	16,400	15,800
# Eggs/yr	496,000	613	16,400	15,800
Longevity	5	1,190	6,350	5,160
Maturation	2	2,380	9,520	7,140

Table 5.2.2-7 (continued). Pacific sardine (*Sardinops sagax*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 8,460$				
\hat{E}_{Adj-T}	22,600,000	7,460	9,450	1,990
\hat{S}_{egg}	0.165	1,630	43,800	42,200
$\hat{S}_{yolk-sac}$	0.125	1,630	43,800	42,200
\hat{S}_{larvae}	0.173	1,630	43,800	42,200
# Eggs/yr	496,000	1,630	43,800	42,200
Longevity	5	3,170	16,900	13,700
Maturation	2	6,340	25,400	19,000

c) Analysis Period 3: July, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 8,460$				
\hat{E}_{Adj-T}	22,600,000	7,470	9,450	1,990
\hat{S}_{egg}	0.165	1,630	43,800	42,200
$\hat{S}_{yolk-sac}$	0.125	1,630	43,800	42,200
\hat{S}_{larvae}	0.173	1,630	43,800	42,200
# Eggs/yr	496,000	1,630	43,800	42,200
Longevity	5	3,170	16,900	13,700
Maturation	2	6,350	25,400	19,000

Table 5.2.2-8. Estimated number of equivalent Pacific sardine (*Sardinops sagax*) adults (\widehat{AEL}) equal to the adjusted number of larvae entrained per year (\hat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{AEL})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{AEL}	$\widehat{SE}(\widehat{AEL})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	2,630	10,300	1,650,000	4
2) Oct 1, 1997–Sep 30, 1998	7,000	27,400	4,390,000	11
3) Jul 1, 1997–Jun 30, 1998	7,000	27,400	4,390,000	11

Table 5.2.2-9. Pacific sardine (*Sardinops sagax*): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 2,630$				
\hat{E}_{Adj-T}	8,470,000	1,420	3,830	2,410
$\hat{S}_{early\ larvae}$	0.405	507	6,490	5,980
$\hat{S}_{late\ larvae}$	0.0343	507	13,600	13,100
$\hat{S}_{early\ juvenile}$	0.247	507	10,700	10,100
$\hat{S}_{juv. I}$	0.373	507	7,030	6,530
$\hat{S}_{juv. II}$	0.644	507	4,080	3,570
$\hat{S}_{juv. III}$	0.664	507	3,950	3,450
$\hat{S}_{juv. IV}$	0.688	507	3,820	3,310
$\hat{S}_{pre-recruit}$	0.825	507	3,180	2,680

Table 5.2.2-9 (continued). Pacific sardine (*Sardinops sagax*): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 7,000$				
\hat{E}_{Adj-T}	22,600,000	6,180	7,820	1,650
$\hat{S}_{early\ larvae}$	0.405	1,350	17,300	15,900
$\hat{S}_{late\ larvae}$	0.0343	1,350	36,300	34,900
$\hat{S}_{early\ juvenile}$	0.247	1,350	28,400	27,000
$\hat{S}_{juv. I}$	0.373	1,350	18,700	17,400
$\hat{S}_{juv. II}$	0.644	1,350	10,900	9,520
$\hat{S}_{juv. III}$	0.664	1,350	10,500	9,180
$\hat{S}_{juv. IV}$	0.688	1,350	10,200	8,820
$\hat{S}_{pre-recruit}$	0.825	1,350	8,490	7,130

Table 5.2.2-9 (continued). Pacific sardine (*Sardinops sagax*): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 7,000$				
\hat{E}_{Adj-T}	22,600,000	6,180	7,830	1,650
$\hat{S}_{early\ larvae}$	0.405	1,350	17,300	16,000
$\hat{S}_{late\ larvae}$	0.0343	1,350	36,300	34,900
$\hat{S}_{early\ juvenile}$	0.247	1,350	28,400	27,000
$\hat{S}_{juv. I}$	0.373	1,350	18,800	17,400
$\hat{S}_{juv. II}$	0.644	1,350	10,900	9,520
$\hat{S}_{juv. III}$	0.664	1,350	10,500	9,190
$\hat{S}_{juv. IV}$	0.688	1,350	10,200	8,830
$\hat{S}_{pre-recruit}$	0.825	1,350	8,490	7,140

Table 5.2.2-10. Pacific sardine (*Sardinops sagax*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) within an analysis period (e.g., July 1, 1997–June 30, 1998) with associated standard errors (SE) used in estimating entrainment mortality for two years of paired entrainment and study grid surveys.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0	0	0	0
Aug 25, 1997	0	0	0	0
Sep 29, 1997	0	0	0.00091	0.00024
Oct 20, 1997	0	0	0	0
Nov 17, 1997	0	0	0	0
Dec 10, 1997	0	0	0	0
Jan 22, 1998	0	0	0.00043	0.00015
Feb 26, 1998	0	0	0	0
Mar 18, 1998	0.00092	0.00011	0.066	0.00254
Apr 15, 1998	0.00084	0.00021	0.123	0.00538
May 18, 1998	0.00096	0.00032	0.802	0.00676
Jun 8, 1998	0.00199	0.0007	0.00784	0.00107

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0	0	0	0
Aug 26, 1998	0	0	0	0
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0	0	0	0
Jan 12, 1999	0.859	0.911	1	–
Feb 3, 1999	0	0	0	0
Mar 17, 1999	0	0	0	0
Apr 14, 1999	0	0	0	0
May 24, 1999	0	0	0	0
Jun 23, 1999	0	0	0	0

“–” = no estimate of standard error because only one fish was collected during this survey period

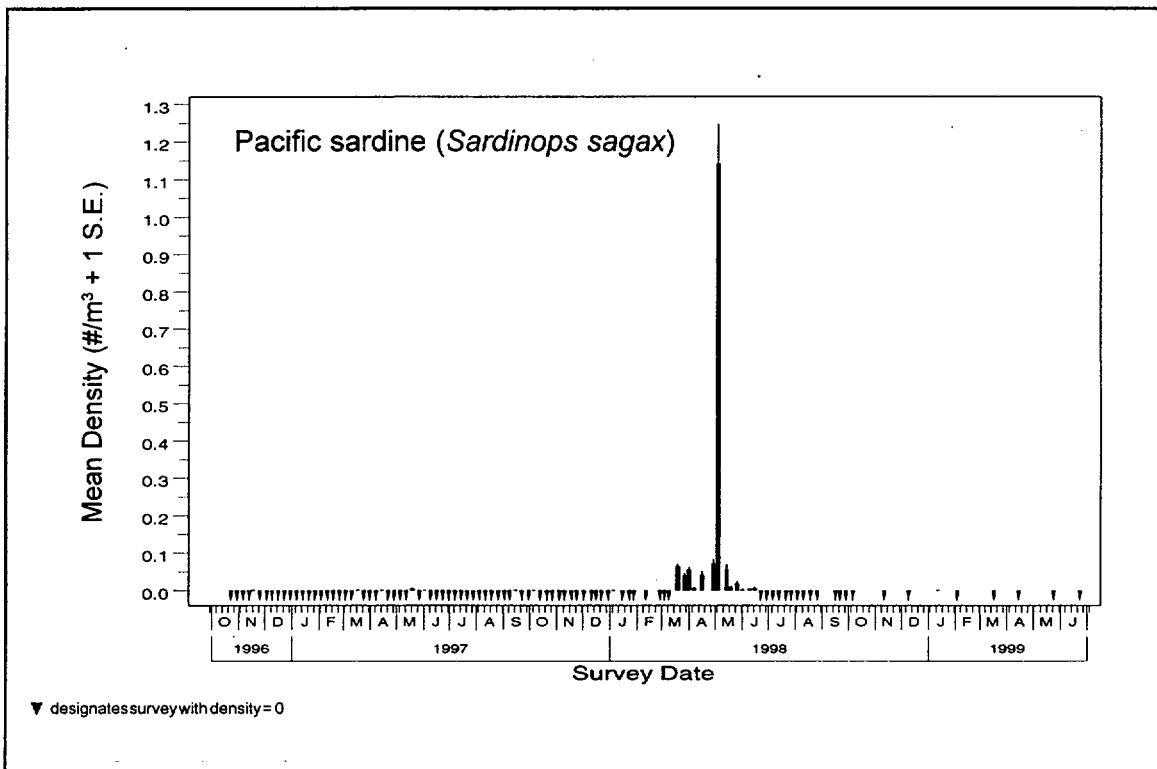


Figure 5.2.2-1. Weekly mean larval density (#/m³ + 1 S.E.) at the DCP intake.

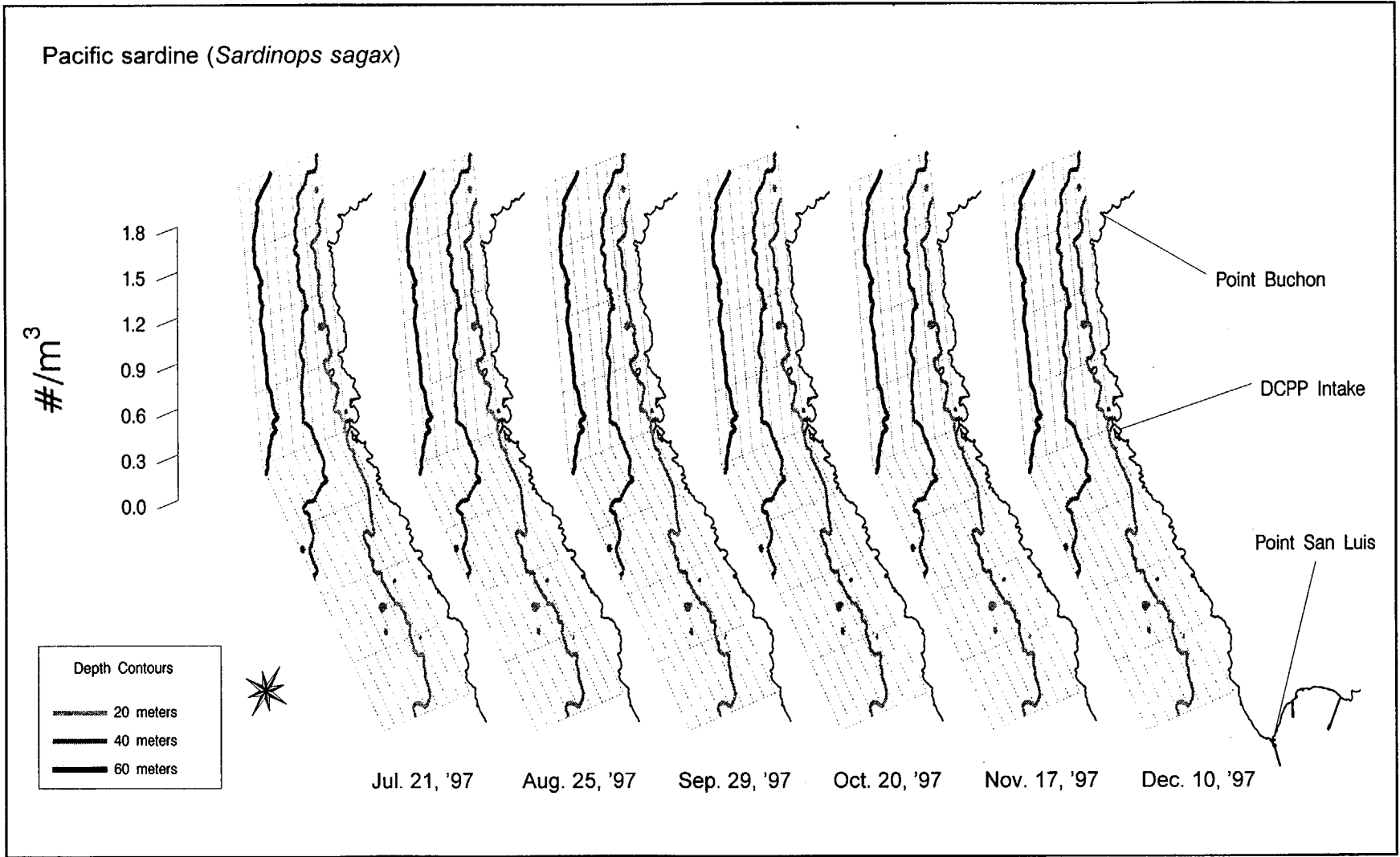


Figure 5.2.2-2a. Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

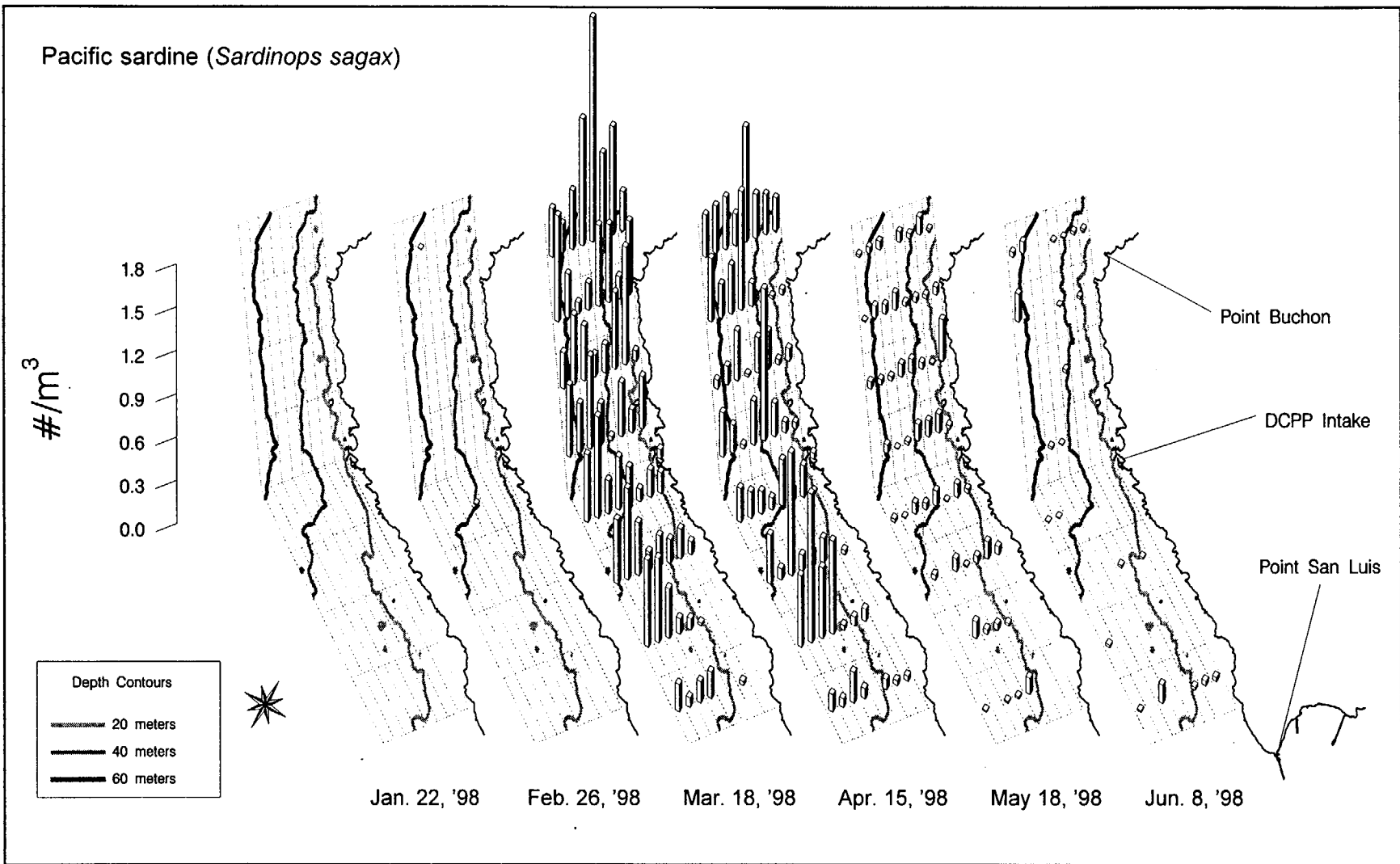


Figure 5.2.2-2b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

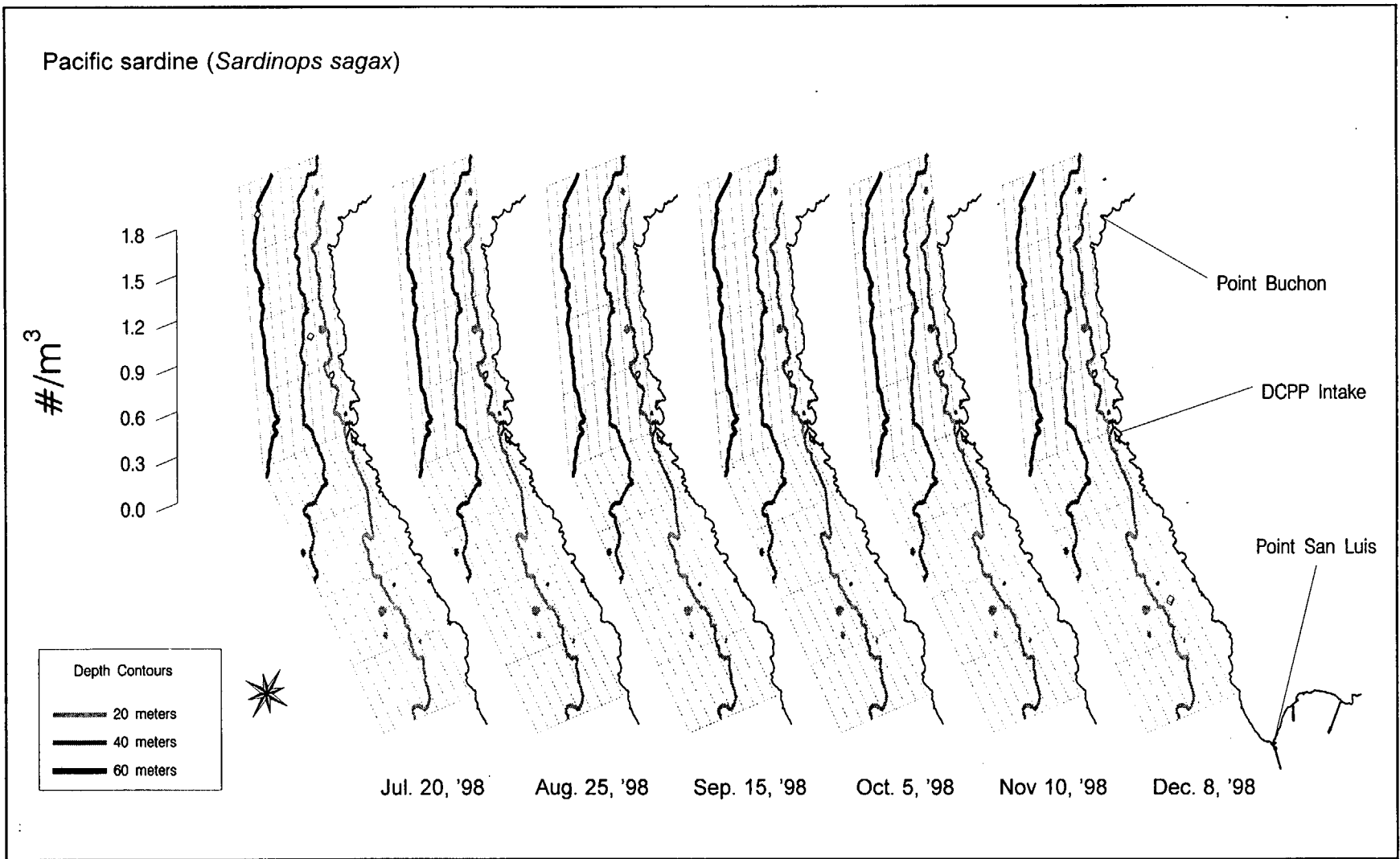


Figure 5.2.2-2c (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

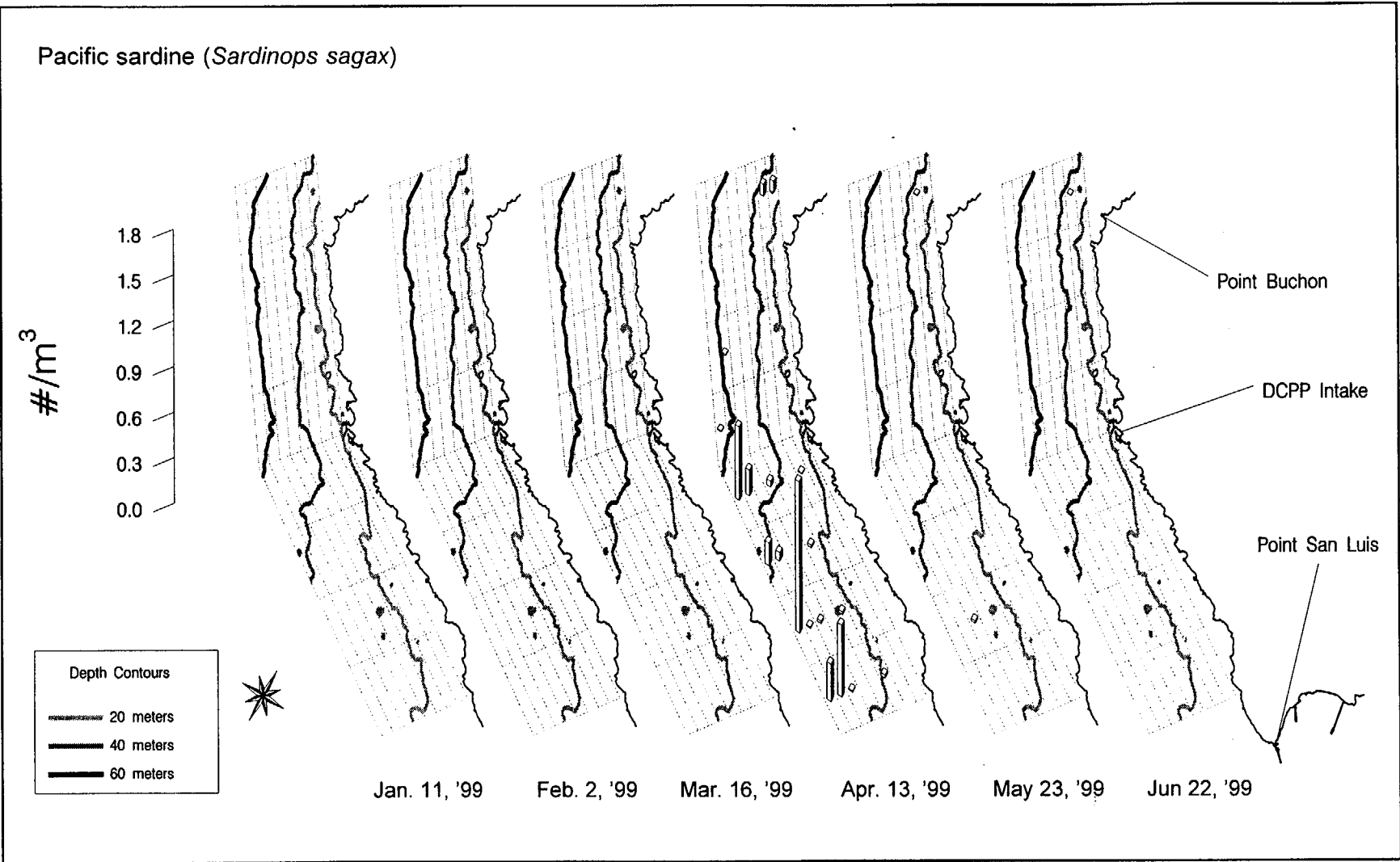


Figure 5.2.2-2d (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

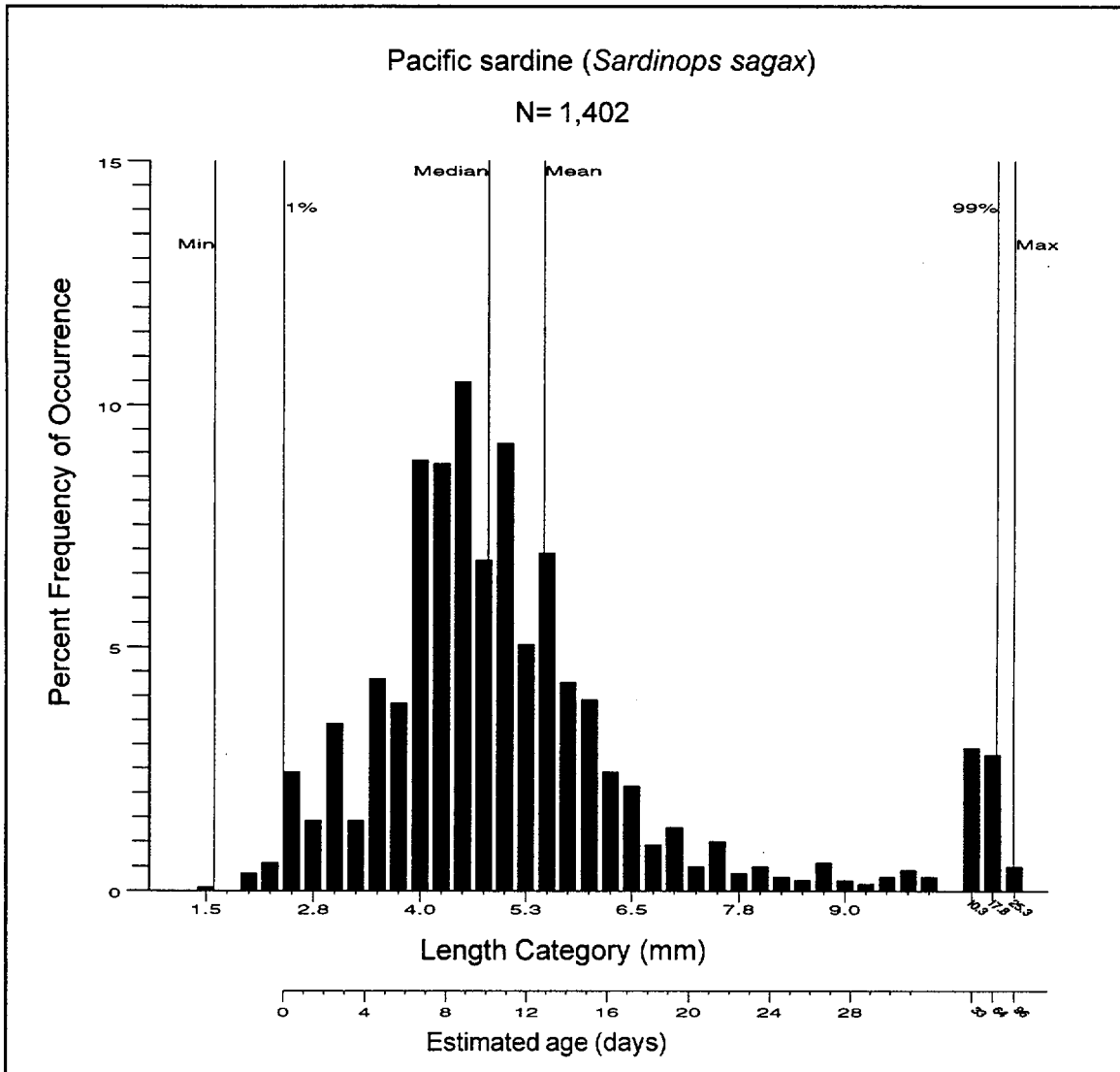


Figure 5.2.2-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

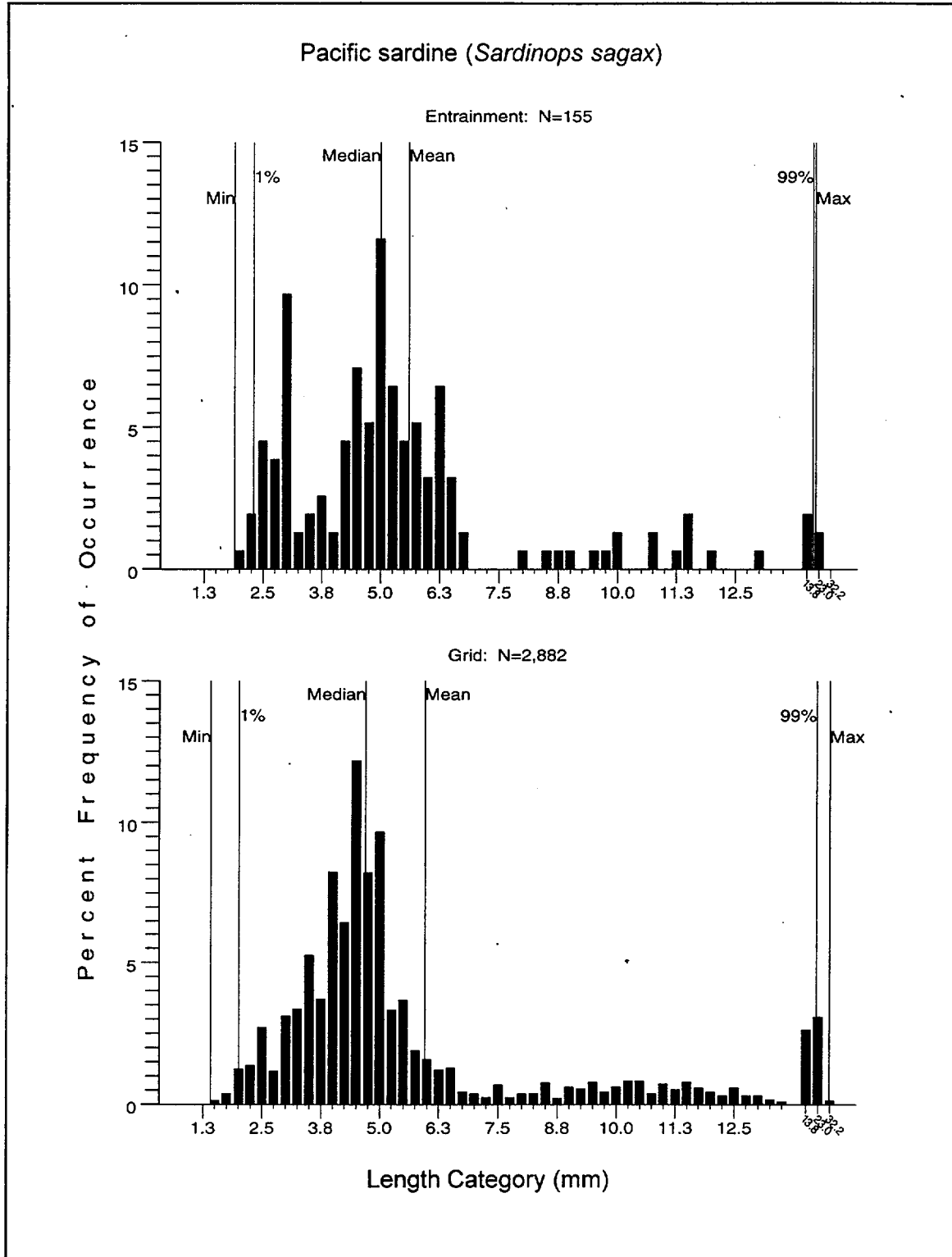


Figure 5.2.2-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

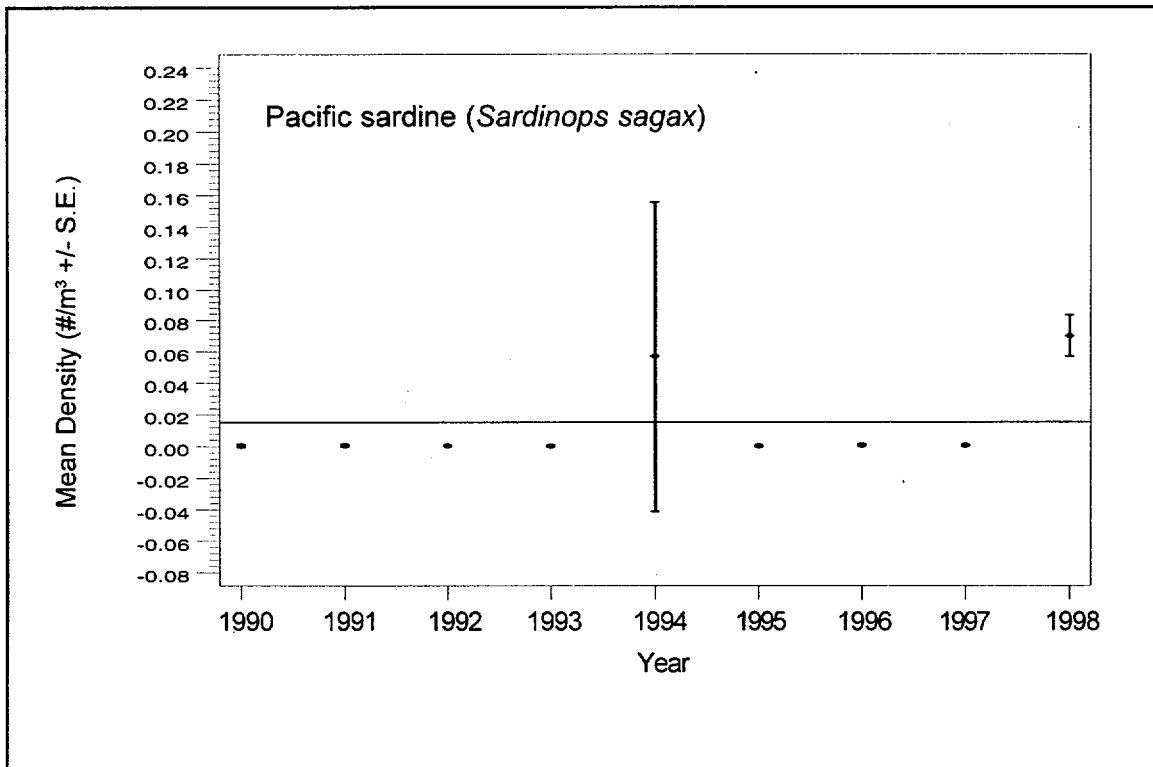


Figure 5.2.2-5. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

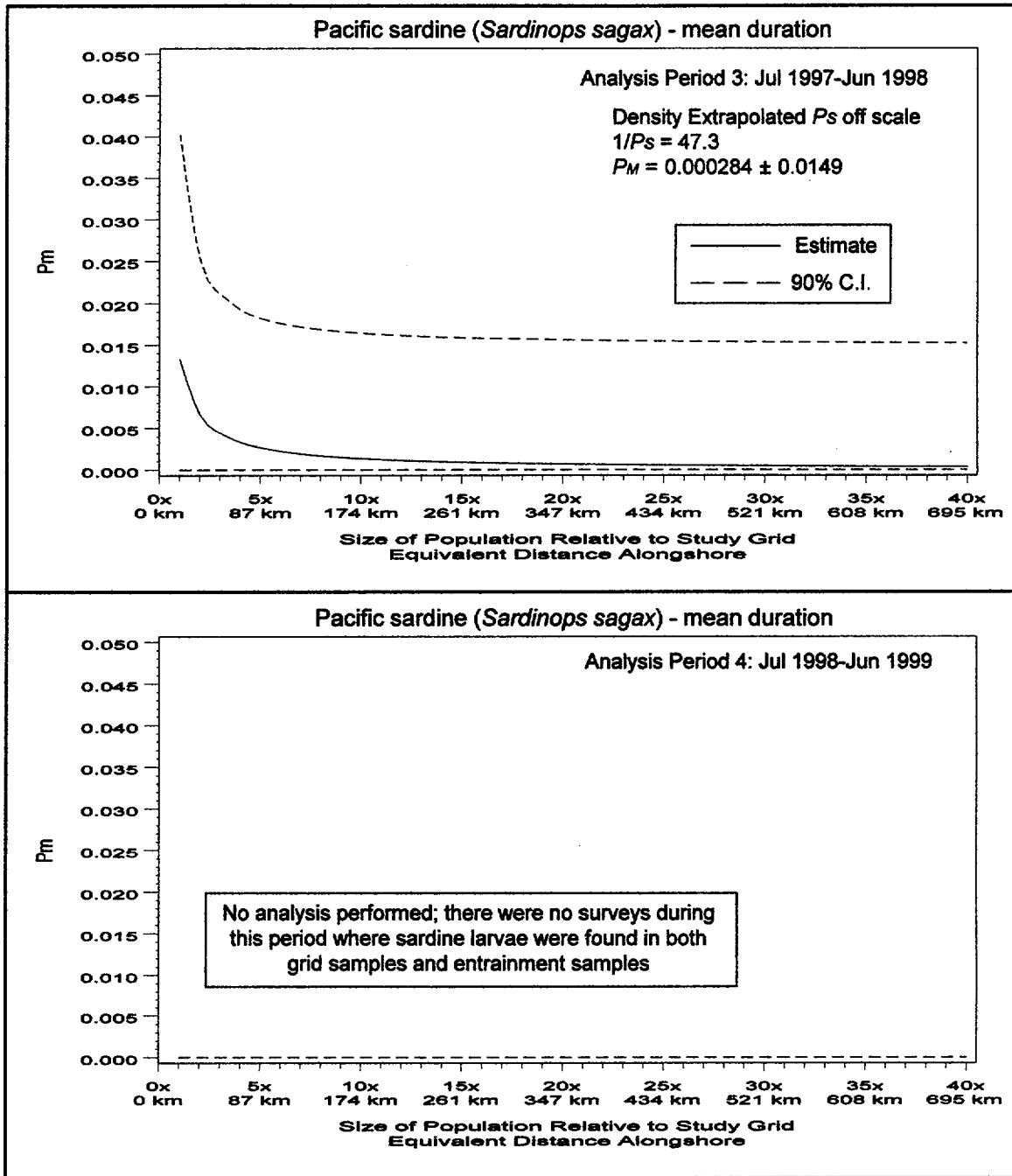


Figure 5.2.2-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_s) used to approximate the extent of the study grid population based on offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with the 90% C.I. indicated.

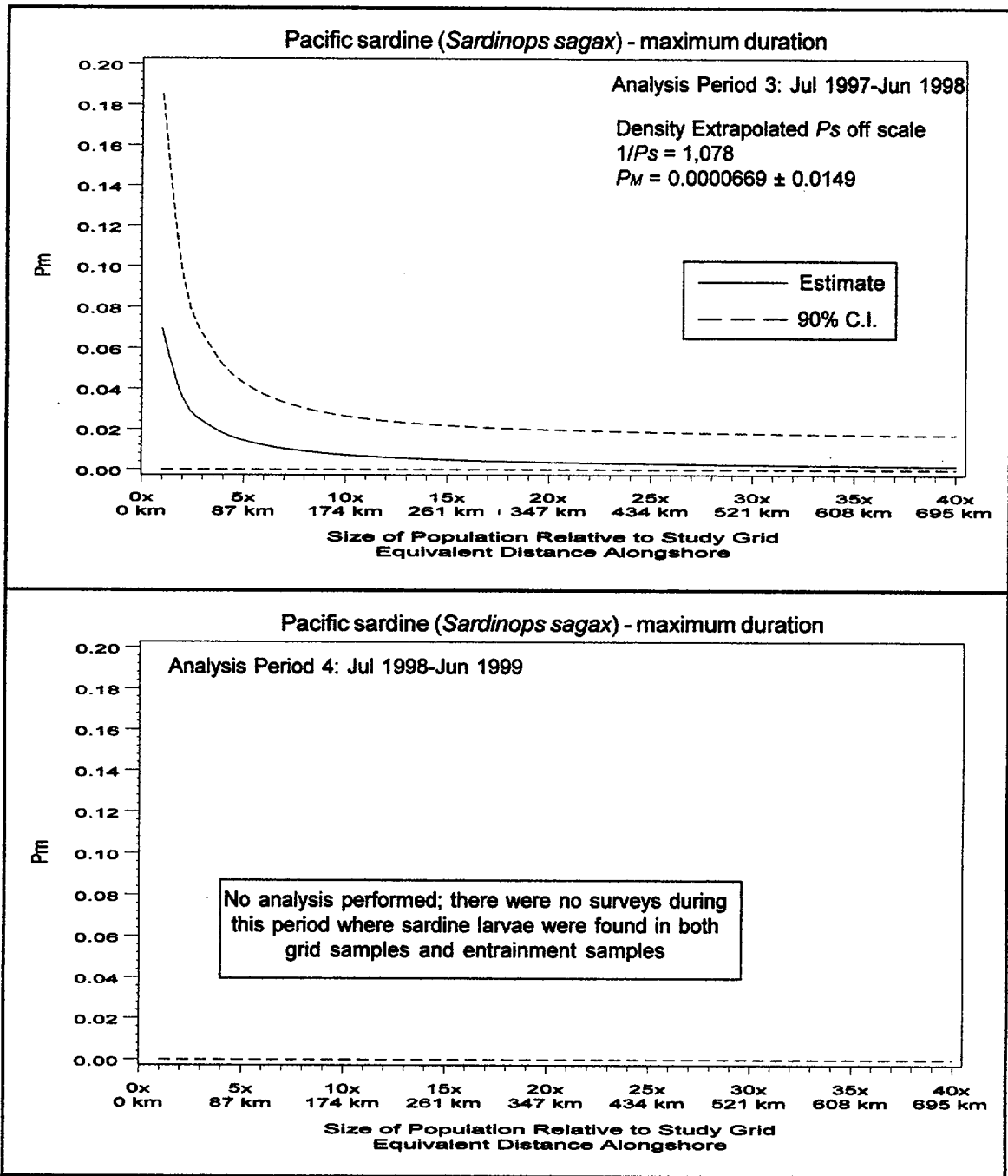


Figure 5.2.2-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the extent of the study grid population based on offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with the 90% C.I. indicated.

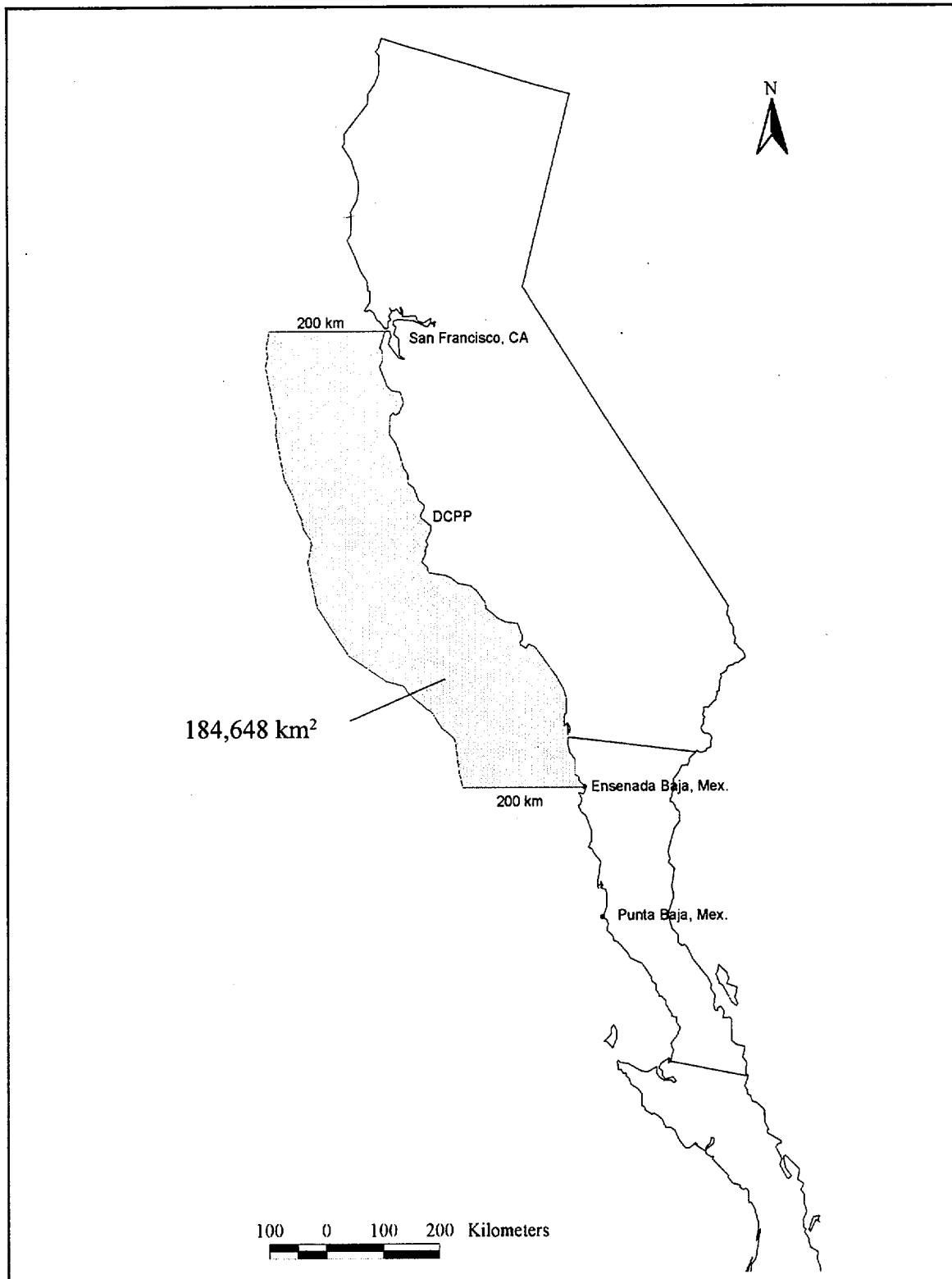


Figure 5.2.2-7. PFMC management area containing the spawning population of the Pacific sardine (Hill et al. in press).

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5.2.3 Assessment of Northern Anchovy (*Engraulis mordax*)



Engraulis mordax (Girard 1854); northern anchovy; length to 23 cm; Queen Charlotte Island in British Columbia to Cabo San Lucas, Baja California Sur and lower Gulf of California; surface and inshore to 310 m; blue to greenish on back, silvery below; adults with faint silvery side stripe (Miller and Lea 1972; Eschmeyer et al. 1983).

The northern anchovy is one of four species in the family Engraulididae (the anchovies) reported from California coastal waters (Miller and Lea 1972). Other representatives of this family are the deepbody anchovy (*Anchoa compressa*), slough anchovy (*Anchoa delicatissima*), and the anchoveta (*Centengraulis mysticetus*; Eschmeyer et al. 1983; Love et al. 1996). Potentially three distinct sub-populations of northern anchovy live along the Pacific coast of the United States (Lo 1985; PFMC 1990; Love 1996). One group is found from British Columbia to north of San Francisco, another is found from San Francisco to northern Baja California, and the last is found along the southern coast of Baja. This grouping of adult sub-populations has been accepted as part of the Fishery Management Plan (FMP) for Coastal Pelagic Species (CPS) by the Pacific Fishery Management Council (PFMC 1998).

Northern anchovy in the central subpopulation are harvested commercially in Mexico and California for human consumption, live bait, dead bait, and other commercial uses (PFMC 1998). Landings of northern anchovy in California between 1916 and 1997 varied from a low of 72 metric tons (MT) in 1926 to a high of 143,799 MT in 1975 (PFMC 1998). Although northern anchovy are fished throughout the state, commercial landings are usually made in San Francisco, Monterey, and Los Angeles; therefore, landing records for local ports are limited. The most recent annual (1997) local landings data for northern anchovy reported by CDF&G are from Port San Luis (22.6 MT), but the average annual landing from Avila during the period 1990–1998 is

2.7 MT, and the most recent northern anchovy landing at the port of Morro Bay occurred in 1981 (Figure 5.2.3-1).

Reproduction of northern anchovy varies with time and location. Northern anchovy off southern and central California can reach sexual maturity by the end of their first year, with all individuals maturing by 4 yr of age; off Oregon and Washington they do not mature until their third year (Love 1996). An early estimate of northern anchovy fecundity (Baxter 1967) indicates an annual range of 20,000–30,000 eggs per female. More recent data from Love (1996) indicates that females can release from 2,700–16,000 eggs per batch, with annual fecundity as high as 130,000 eggs in southern California and around 35,000 eggs per year in northern populations. Parrish et al. (1986) indicate that total annual fecundity from the first to the fourth-plus spawning seasons ranges from 32,514 to 322,957 eggs per female, respectively.

In southern California, anchovy spawn year-round with peaks during late winter to spring (Love 1996; Moser 1996). In Oregon and Washington, spawning can occur from mid-June to mid-August (Love 1996). During the peak of the spawning season, females can spawn every 6–8 d (Love 1996; Schlotterbeck and Connally 1982). Spawning normally occurs at night in the upper layers of the water column (Hart 1973). The most recent stock assessment for northern anchovy estimated spawning biomass at 388,000 MT (CV 38%) during the middle of February 1995 (Jacobson et al. 1995). Although no more recent stock assessments have been made, a qualitative analysis of the available data indicates that this remains the best estimate of current spawning biomass (Jacobson et al. 1997).

Females are oviparous, producing planktonic eggs and larvae (Moser 1996). Eggs occur from the surface to 75 m depth but usually are found in the upper 50 m (Emmett et al. 1991). The eggs hatch in 2–4 d, depending on the water temperature, and release 2.5–3.0 mm long relatively undeveloped larvae (Moser 1996). The larvae remain largely inactive, floating over 90% of the time, with intense swimming events taking place about once per minute and lasting from one to two seconds (Hunter 1976). Larvae begin schooling at 11–12 mm and transform into juveniles at 35–40 mm in approximately 70 d (Hart 1973).

5.2.3.1 Summary of Field Collections

Northern anchovy larvae were collected intermittently at the DCPD intake structure during the years 1996–1999 (**Appendix H**), with their greatest abundance tending to occur between December and May and their highest abundance in January 1998 (**Figure 5.2.3-2**). These larval density estimates represented a total of 3,443 larval northern anchovies in 879 bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999, representing 19% of the subsamples collected and processed from that location during that period. An El Niño event began during the spring of 1997 (NOAA 1999) and was detected along the California coast in fall/winter of 1997–98 (Lynn et al. 1998). This climatological and oceanographic event may account for the observed peak in larval northern anchovy abundance during 1997–98. The primary spawning grounds of northern anchovy are south of Point Conception (Hart 1973; PFMC 1998), but the warm water that moved up the coast as a result of this El Niño could have carried the anchovy spawning biomass to the north of their normal southerly distribution.

Larval northern anchovy occurred in the DCPD study grid during all but one month (October 1998) of the sampling period (**Appendix H**), with their highest abundance during March–May 1998 (**Figure 5.2.3-3**). The patterns observed in the study grid further support the supposition that the 1997–98 El Niño may have displaced their spawning biomass center further north than its expected distribution in a cooler water year. The density estimates from the study grid represented 8,464 larval northern anchovies identified from 1,134 bongo net subsamples, representing 37% of the study grid subsamples processed from July 1997–June 1999.

Standard lengths of all northern anchovy larvae collected at the DCPD intake structure between October 1996 and June 1999 ranged from a minimum of 1.6 mm to a maximum of 37.1 mm (**Figure 5.2.3-4**). The central 98% of this length-frequency distribution resulted in a minimum length of 2.1 mm and a maximum length of 25 mm. Reported hatching size for this species ranges from 2.5–3.0 mm (Moser 1996). The fact that we observed some larvae smaller than the reported hatching lengths can be explained partly by natural variation of hatch lengths within the population and partly by the phenomenon of shrinkage following preservation (Theilacker 1980).

The mean larval length in this distribution was 6.1 mm. The growth rate of larval northern anchovy (0.45 mm/d) reported by Methot and Kramer (1979) was used to estimate ages of entrained larvae. Assuming that larvae less than the minimum 1% length (2.1 mm) were immediately post-hatch and aged zero days, then the estimated age of larvae entrained could range from zero days up to 51 d post-hatching for the longest larva measured (25 mm). On average, the estimated age of northern anchovy larvae entrained at DCPD was ca. 9 d post-hatching.

No significant differences were detected between the bi-modal distributions of larval northern anchovy lengths at the DCPD intake and from the study grid (**Figure 5.2.3-5**) using a Kolmogorov-Smirnov test ($p \geq 0.299$; **Appendix J**). Additionally, no significant difference between mean lengths at the DCPD intake (8.8 mm) and study grid (9.2 mm) was detected by a t-test ($p \geq 0.358$). These results, combined with the similarity of the length-frequency distributions, indicate that the subsamples in the two locations came from the same population.

5.2.3.2 Estimating Total Annual Entrainment

The annual estimated mean entrainment and associated standard error for northern anchovy larvae are presented in **Table 5.2.3-1**. Estimates of total annual entrainment (\widehat{E}_T) were nearly four times higher in 1997–98 Analysis Period 2 ($\widehat{E}_T = 104,000,000$) than in 1996–97 Analysis Period 1 ($\widehat{E}_T = 26,600,000$). A value of $2 \cdot \widehat{SE}(\widehat{E}_T)$ can be used to approximate a 95% confidence interval around the point estimates for each analysis period. The confidence intervals for Analysis Periods 1 and 2 do not overlap, indicating that there were probably statistically significant differences between the estimates from the two years (although not all variance terms are considered). The larger estimate for 1997–98 may have been due to the El Niño event that occurred during this time period. The warm water transported northward likely brought more northern anchovy into the waters around Diablo Canyon from the center of their spawning distribution that typically occurs south of Point Conception.

Estimates of annual northern anchovy entrainment for all three analysis periods were adjusted (**Table 5.2.3-2**) to the long-term average larval fish abundance index from the Intake Cove

plankton tows (Figure 5.2.3-6). The average index (I_i) was 0.015 larvae/m³ in 1997 and 0.021 larvae/m³ in 1998. The long-term average index (\bar{I}) was 0.077 larvae/m³ for the years 1990–1998. The ratio used to adjust total annual entrainment to the long-term average (\bar{I}/I_i) was calculated as 5.11 for 1997 and 3.62 for 1998, indicating that larval abundance during those years was lower than the long-term average. Although the correction resulted in larger estimates for both periods, the difference between \hat{E}_{Adj-T} for 1996–97 ($\hat{E}_{Adj-T} = 136,000,000$) and 1997–98 ($\hat{E}_{Adj-T} = 376,000,000$) was reduced from a factor of 4 for \hat{E}_T to less than a factor of 3. The adjusted entrainment estimates for analysis periods 2 and 3 were very close in value because both periods overlap for much of the period of peak larval abundance for northern anchovy.

5.2.3.4 Fecundity Hindcasting (FH)

Fecundity hindcasting requires age-specific fecundity (M_x) and mortality (L_x) to assess entrainment effects. Butler et al. (1993) modeled egg and larval survivorship of northern anchovy (Table 5.2.3-3). Their ‘best’ estimate is derived by fitting the range of mortality estimates from field collections to the assumption of a stable and stationary population. Instantaneous daily mortality estimates were used from Butler et al. (1993) for egg (0.231), yolk-sac (0.366), and early larval stages (0.286). These rates can be converted, over their average stage durations, to finite survivorship rates for each developmental stage: egg (0.512), yolk-sac (0.268), and early larval stages (0.414). Survival rates for eggs and larvae were then calculated for an estimated average age at entrainment of ca 9 d, using a growth rate of 0.45 mm/d (Methot and Kramer 1979) and an average (6.1 mm) and 1% smallest (2.1 mm) size at entrainment. Survival to entrainment for average-aged larvae was thus estimated as

$$S_{Egg-8.99days} = 0.0660 .$$

The FH approach combines larval entrainment losses, adult fecundity, age at maturity, and longevity to hindcast the numbers of adult females effectively removed from the reproductively active population. Clark and Phillips (1952) report age at sexual maturity as 1–2 yr. In subsequent calculations, we will assume the mid-value of 1.5 yr and assume the reported range

corresponds to 99% of a normal distribution. For longevity, Hart (1973) reports a value of 7 yr, but Leet et al. (1992) states that northern anchovy in the fished population rarely exceed 4 yr of age. We will use the value of 4 yr to represent the most likely reproductive life span. Parrish et al. (1986) estimates an annual fecundity in the second spawning season of 102,174 eggs per female.

The adjusted estimate of annually entrained northern anchovy larvae (\hat{E}_{Adj-T}) was used to estimate the number of breeding females needed to produce those larvae in analysis periods 1, 2, and 3 (Table 5.2.3-4). Estimates of FH for the 1996–97 analysis period ($\widehat{FH} = 16,100$) were less than half of those estimated for the 1997–98 Analysis Period 2 ($\widehat{FH} = 44,600$). Similar to the results seen with entrainment, these differences are a result of the entrainment estimates for those periods postulated to be due to the El Niño event that occurred during the second sampling year.

Sensitivity Analysis

Fecundity had the greatest leverage on recalculated values of \widehat{FH} (Table 5.2.3-5). Varying this parameter in the model resulted in an \widehat{FH} range of 3,110–232,000 adult females among the three analysis periods, compared to the original estimate of 16,100–44,700 adult females. Survivorship (specifically, yolk-sac survivorship) had the next greatest amount of leverage on recalculated \widehat{FH} .

5.2.3.5 Adult Equivalent Loss (AEL)

The *AEL* approach used estimates of the abundance of entrained organisms to project the loss of equivalent numbers of adults based on mortality schedules and age at recruitment into the fishery. The instantaneous survival rate from the entrained larval stage to recruitment into the northern anchovy fishery (through juvenile and early adult stages to 2 yr of age) is 0.000318 estimated from the life table produced by Butler et al. (1993; Table 5.2.3-4). Average age at entrainment for northern anchovy larvae (9 d) was calculated by dividing the average larval length at entrainment (minus length at hatching) by a literature-based growth rate of 0.45 mm per day (Methot and Kramer 1979). Butler et al. (1993) apportioned survivorship to recruitment into

several developmental stages, and AEL was calculated using the entrainment of a single age class having the average age at recruitment of 2 yr.

The numbers of equivalent adult northern anchovies predicted from adjusted total annual entrainment ranged from 43,200 2 yr-old recruits in 1996–97 to 120,000 in 1997–98 (Table 5.2.3-6). The estimates nearly tripled between years, possibly due to El Niño-induced increases in larval abundance during the second year. However, the 90% confidence intervals overlap, which may indicate that these estimates are not significantly different between sampling periods.

Sensitivity Analysis

Early and late larval survivorship had the greatest leverage on recalculated values of \widehat{AEL} (Table 5.2.3-7). Varying either of these two parameters in the model resulted in an \widehat{AEL} range of 8,330–621,000 adult equivalents among the three analysis periods, compared to the original estimate of 43,200–120,000 adult equivalents. Pre-recruit and early juvenile survivorship had the next greatest leverage on estimates of \widehat{AEL} .

5.2.3.6 Empirical Transport Model (ETM)

There was large variation in the estimates of proportional entrainment (\widehat{PE}) for each i th survey during the two analysis periods (July 1997–June 1998 and July 1997–June 1998; Table 5.2.3-8). Estimates of proportional entrainment ranged from zero to as high as 0.0102. Maximum values of \widehat{PE}_i in the two periods occurred during January 1998 (0.00186) and February 1999 (0.0102). During Analysis Period 3, the largest proportion of larvae were collected during January 1998 ($\hat{f}_i = 0.468$), the same monthly survey period as the maximum \widehat{PE}_i . In the second period, the largest proportion of larvae were collected during August 1998 ($\hat{f}_i = 0.431$). The February 1999 \hat{f}_i was 0.055, indicating that the maximum \widehat{PE}_i was weighted less than others during the study period in calculating the larval mortality estimate \widehat{P}_M .

When both \widehat{PE}_i and \hat{f}_i were equal to zero, no larvae were collected at either the DCP intake or from the study grid. When $\widehat{PE}_i = 0$ and $\hat{f}_i > 0$, larvae were collected at the DCP intake during the

survey period but not during the entrainment survey paired with the 72-hour study grid survey. This occurred in February and again in September of 1998 and, as expected, were accompanied by low \hat{f}_i values.

Larval entrainment mortality (\widehat{P}_M) was estimated for the two, year-long periods, using two estimates of the duration of time that northern anchovy larvae may be susceptible to entrainment. These durations were estimated as 9 d and 51.2 d using the mean and maximum lengths, respectively, of entrained larvae. Northern anchovy larvae were dispersed throughout the study grid (Figure 5.2.3-3), but they are typically found in their greatest density offshore (Moser et al. 1993). Therefore, \widehat{P}_S was calculated by extrapolating study grid abundance patterns offshore and then extending them alongshore. Estimates of total entrainment mortality (\widehat{P}_M) were 0.000575 for the 1997–1998 analysis period and 0.00187 for the 1998–1999 analysis period, using the mean larval duration. Smaller values of \widehat{P}_M were estimated using the maximum larval duration: 0.0000786 in the 1997–1998 period and 0.000184 in the 1998–1999 period. Standard errors of \widehat{P}_M were large relative to the estimates: 0.0168 in the first period and 0.0385 in the second period.

\widehat{P}_S was calculated as a proportion of larval numbers in the study grid to an extrapolated number using the grid density and a larger area defined by alongshore and offshore current measurements. These areas were a function of the estimated duration of larval susceptibility to entrainment, and for the periods 1997–1998 and 1998–1999, averaged 639 and 370 km² for the mean larval duration, and 6,670 and 6,140 km² for the maximum larval duration, respectively.

For the plots showing the sensitivity analysis for each analysis period, \widehat{P}_M declined rapidly with increasing $1/\widehat{P}_S$, using either average or maximum length to calculate larval duration (Figure 5.2.3-7). As duration increased within an analysis period, \widehat{P}_M decreased and $1/\widehat{P}_S$ increased. There were large differences between analysis periods in the point estimates of \widehat{P}_M for both larval durations. The large error associated with calculating \widehat{P}_M may account for some of the differences and contributes to the level of uncertainty associated with these estimates.

5.2.3.7 Interpretation of Assessment Results

Population-level losses, using the estimated larval mortality \widehat{P}_M due to entrainment at DCP, can be compared, as a small fraction, to recent spawning stock estimates of 388,000 MT of northern anchovy in the region from San Francisco to Punta Baja, Mexico (Jacobson et al. 1997). The estimated losses by weight are calculated, using the average areas to determine \widehat{P}_M (Section 5.2.3.6), as a proportion of the larger stock assessment area of 231,192 km² (Figure 5.2.3-8). The spawning stock biomass is multiplied by the product of this proportion and \widehat{P}_M . For the 1997–1998 and 1998–1999 analysis periods, these losses are conservatively estimated, assuming no compensation, as 0.61 MT and 1.16 MT (based on mean larval duration) and 0.88 MT and 1.90 MT (based on maximum larval duration), respectively.

By comparison, approximately 1,185 MT of northern anchovy were landed in the Monterey Bay National Marine Sanctuary-wetfish (whole fish) fishery in 1995 (Starr et al. 1998). During 1980 to 1988, the price paid for anchovy landed by the U.S. non-reduction wetfish (other than live bait) fishery averaged \$288/MT (Leet et al. 1992). In 1988, the price for anchovy sold in the reduction wetfish (processed for meal) fishery was \$32/MT (Leet et al. 1992).

Estimates of *AEL* can be converted to direct reductions of the standing stock by converting them to units of biomass (e.g., kilograms of northern anchovy). Estimating that the average weight of a northern anchovy from the live bait and wetfish fisheries is 19 g (estimated from Clark and Phillips 1952) and assuming that this represents an average weight of an adult in the population at large, *AEL* estimates (43,200 in 1996–97 and 120,000 in 1997–98) translate to a maximum estimated weight of 1.92 MT. These can be further translated into an annualized reduction of the estimated standing stock (388,000 MT; Jacobson et al. 1995, 1997) of <0.001%. These adult equivalents are assigned the average age of a recruit (2 yr), so this annualized reduction necessarily assumes that all of the standing stock was 2 yr of age. Since it is likely that the average age in the standing stock is somewhat greater than the youngest recruits, this percent reduction is likely an underestimate of the loss to the 2 yr old cohort present in the standing stock.

It is noteworthy that not only are *AEL* estimated losses similar to \widehat{P}_M -based losses in northern anchovy biomass, but also, when estimates are aligned to age 2 (Section 4.4.3.1), \widehat{FH} gives similar results. Assuming a linear population decline, an estimated average age of female anchovies (\widehat{FH}) is one third of the age from maturity to longevity, 2.33 yr. Using a natural mortality estimate of $Z = 0.0031 \text{ d}^{-1}$, the numbers ($AEL = 2\widehat{FH} = 89,400$) and biomass lost is estimated as 130,000 fish and 2.08 MT.

One method of interpreting population lost to entrainment converts their estimated weight into dollars using the fishery value of \$288/MT reported in Leet et al. (1992). The predicted equivalent adult losses using 2 MT would then be valued at \$576 annually. Another approach would be to compare the weight of equivalent adults (approximately 2 MT) with that of the most recent catch landed in the Morro Bay area, which was approximately 23 MT in 1997 (Figure 5.2.3-1). [CDF&G records included no northern anchovy catch at either Morro Bay area port for either 1995–96 or 1998 although northern anchovy were caught and sold as live bait during these years]. A fractional comparison of annual *AEL* with the 1997 catch statistics indicates that potential losses as a result of DCP, conservatively assuming 100% catchability of the equivalent adults, equaled approximately 10% of the 1997 Morro Bay area catch. Although \widehat{P}_M -based results produce a similar proportion of Morro Bay area catch, when applied to the population from San Francisco to Punta Baja, Mexico, the loss is insignificant, less than 0.001%. In addition, harvesting parameters such as selectivity, catchability, and fishing effort indicate that this estimate is likely conservative further reducing the impact to the fishery.

Table 5.2.3-1. Estimated total annual entrainment (\widehat{E}_T) of northern anchovy larvae at the DCPD intake structure for the three analysis periods with their standard errors ($\widehat{SE}(\widehat{E}_T)$).

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	26,600,000	1,510,000
2) Oct 1, 1997–Sep 30, 1998	104,000,000	7,320,000
3) Jul 1, 1997–Jun 30, 1998	104,000,000	7,320,000

Table 5.2.3-2. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) of northern anchovy larvae at the DCPD intake structure for the three analysis periods with their standard errors ($\widehat{SE}(\widehat{E}_{Adj-T})$).

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	136,000,000	7,690,000
2) Oct 1, 1997–Sep 30, 1998	376,000,000	26,500,000
3) Jul 1, 1997–Jun 30, 1998	377,000,000	26,500,000

Table 5.2.3-3. Survivorship of northern anchovy (*Engraulis mordax*): a) Age-specific fecundity schedule (M_x = natality rate; L_x = survivorship) and b) stage-specific life-history parameters (Z =instantaneous daily mortality; S =finite survival rate) modified from Butler et al. (1993).

a)

Age (yr)	M_x	L_x	$M_x L_x$
1	22,500	1,000	22,500,000
2	93,500	468	43,800,000
3	195,000	216	42,000,000
4	280,000	102	28,600,000
5	328,000	48	15,700,000
6	328,000	22	7,210,000
7	328,000	10	3,280,000

b)

Stage	Z_{best}	Stage duration (d)	Age (d)	Duration modified by DCP data	S_{best}	CV_{best}
Egg	0.231	2.9		2.9	0.512	0.142
Yolk-sac larva	0.366	3.6	6.5	3.6	0.268	0.240
Early larva	0.286	12	18.5	2.56	0.481	0.071
Survivorship from egg to entrainment:					0.0660	
Early larva	0.286	12	18.5	9.44	0.0671	0.329
Late larva	0.0719	45	63.5	45	0.0393	0.427
Early juvenile	0.0141	62	125.5	62	0.417	0.239
Late Juvenile	0.00440	80	205.5	80	0.703	0.0328
Pre-recruit	0.00310	287	492.5	287	0.411	0.0882
Survivorship from entrainment to recruitment:					0.000318	

Table 5.2.3-4. Estimated number of northern anchovy adult females (\widehat{FH}) whose reproductive output was equivalent to the adjusted number of larvae entrained per year (\hat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{FH})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	16,100	57,300	5,630,000	46
2) Oct 1, 1997–Sep 30, 1998	44,700	159,000	15,600,000	128
3) Jul 1, 1997–Jun 30, 1998	44,700	159,000	15,600,000	128

Table 5.2.3-5. Northern anchovy (*Engraulis mordax*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 16,100$				
\hat{E}_{Adj-T}	136,000,000	14,600	17,600	3,000
\hat{S}_{egg}	0.512	8,240	83,400	75,200
$\hat{S}_{yolk-sac}$	0.268	4,310	83,400	79,100
\hat{S}_{larvae}	0.481	7,750	83,400	75,700
# Eggs/yr	102,000	3,110	83,400	80,300
Longevity	4	6,190	32,200	26,000
Maturation	1.5	12,400	40,300	27,900

Table 5.2.3-5 (continued). Northern anchovy (*Engraulis mordax*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 44,600$				
\hat{E}_{Adj-T}	376,000,000	39,500	49,800	10,300
\hat{S}_{egg}	0.512	22,800	231,000	208,000
$\hat{S}_{yolk-sac}$	0.268	12,000	231,000	219,000
\hat{S}_{larvae}	0.481	21,500	231,000	210,000
# Eggs/yr	102,000	8,620	231,000	223,000
Longevity	4	17,200	89,300	72,100
Maturation	1.5	34,300	112,000	77,300

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 44,700$				
\hat{E}_{Adj-T}	377,000,000	39,500	49,900	10,300
\hat{S}_{egg}	0.512	22,900	232,000	209,000
$\hat{S}_{yolk-sac}$	0.268	12,000	232,000	220,000
\hat{S}_{larvae}	0.481	21,500	232,000	210,000
# Eggs/yr	102,000	8,620	232,000	223,000
Longevity	4	17,200	89,400	72,200
Maturation	1.5	34,400	112,000	77,300

Table 5.2.3-6. Estimated number of equivalent northern anchovy adults (\widehat{AEL}) equal to the adjusted number of larvae entrained per year (\hat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{AEL})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{AEL}	$\widehat{SE}(\widehat{AEL})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	43,200	160,000	19,300,000	97
2) Oct 1, 1997–Sep 30, 1998	120,000	444,000	53,400,000	268
3) Jul 1, 1997–Jun 30, 1998	120,000	444,000	53,500,000	268

Table 5.2.3-7. Northern anchovy (*Engraulis mordax*): Sensitivity analysis of \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 43,200$				
\hat{E}_{Adj-T}	136,000,000	39,100	47,200	8,050
$\hat{S}_{early\ larvae}$	0.0671	8,330	224,000	215,000
$\hat{S}_{late\ larvae}$	0.0393	8,330	224,000	215,000
$\hat{S}_{early\ juvenile}$	0.417	8,330	103,000	95,100
$\hat{S}_{juv. I}$	0.703	8,330	61,400	53,000
$\hat{S}_{pre-recruit}$	0.411	8,330	105,000	96,800

Table 5.2.3-7 (continued). Northern anchovy (*Engraulis mordax*): Sensitivity analysis of \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 120,000$				
\hat{E}_{Adj-T}	376,000,000	106,000	134,000	27,700
$\hat{S}_{early\ larvae}$	0.0671	23,100	620,000	597,000
$\hat{S}_{late\ larvae}$	0.0393	23,100	620,000	597,000
$\hat{S}_{early\ juvenile}$	0.417	23,100	287,000	264,000
$\hat{S}_{juv. I}$	0.703	23,100	170,000	147,000
$\hat{S}_{pre-recruit}$	0.411	23,100	291,000	268,000

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 120,000$				
\hat{E}_{Adj-T}	377,000,000	106,000	134,000	27,700
$\hat{S}_{early\ larvae}$	0.0671	23,100	621,000	598,000
$\hat{S}_{late\ larvae}$	0.0393	23,100	621,000	598,000
$\hat{S}_{early\ juvenile}$	0.417	23,100	287,000	264,000
$\hat{S}_{juv. I}$	0.703	23,100	170,000	147,000
$\hat{S}_{pre-recruit}$	0.411	23,100	292,000	269,000

Table 5.2.3-8. Northern anchovy (*Engraulis mordax*): Monthly estimates of proportional entrainment (\widehat{PE}_i), the annual proportion of larvae hatched in the i th survey period (\hat{f}_i), and their associated standard errors (SE).

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.000310	0.000320	0.00474	0.000730
Aug 25, 1997	0.000310	0.000310	0.0102	0.000790
Sep 29, 1997	0.000730	0.000330	0.00822	0.000870
Oct 20, 1997	0.000840	0.000320	0.00768	0.00150
Nov 17, 1997	0.000270	0.000190	0.00574	0.00169
Dec 10, 1997	0.000620	0.000260	0.0238	0.00155
Jan 22, 1998	0.00186	0.000970	0.468	0.0131
Feb 26, 1998	0	0	0.00219	0.000310
Mar 18, 1998	0.000080	0.0000400	0.155	0.00584
Apr 15, 1998	0.000380	0.000140	0.103	0.00412
May 18, 1998	0.000390	0.0000800	0.198	0.00697
Jun 8, 1998	0.00148	0.000390	0.0131	0.00101

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.000400	0.000210	0.170	0.0176
Aug 26, 1998	0.0010	0.000220	0.431	0.0204
Sep 16, 1998	0	0	0.00863	0.00353
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0.000580	0.000590	0.0582	0.0103
Jan 12, 1999	0.00200	0.00153	0.137	0.0175
Feb 3, 1999	0.0102	0.0117	0.0547	0.00987
Mar 17, 1999	0	0	0	0
Apr 14, 1999	0	0	0	0
May 24, 1999	0.00208	0.00156	0.140	0.0154
Jun 23, 1999	0	0	0	0

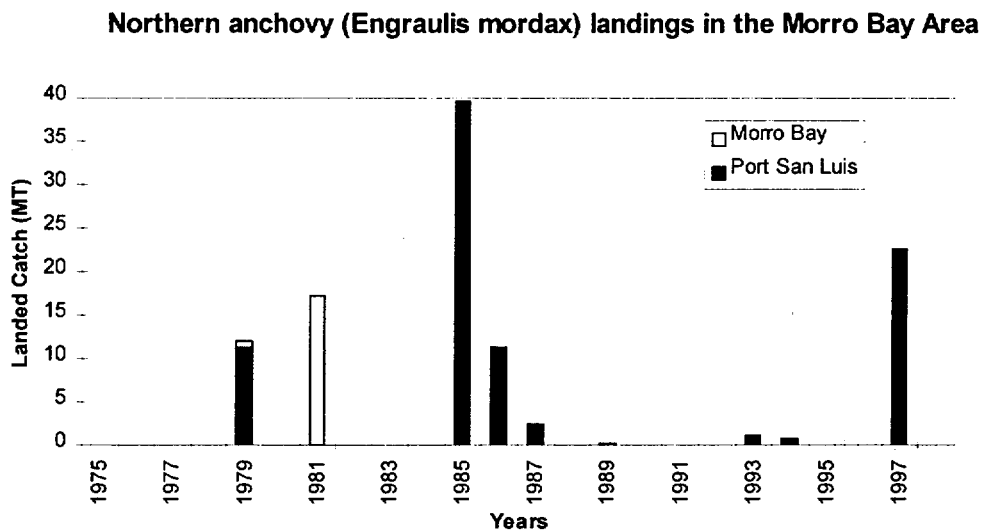


Figure 5.2.3-1. Commercial landings of northern anchovy (*Engraulis mordax*) at the ports in the Morro Bay Area between 1975 and 1997 (source: CDF&G Database).

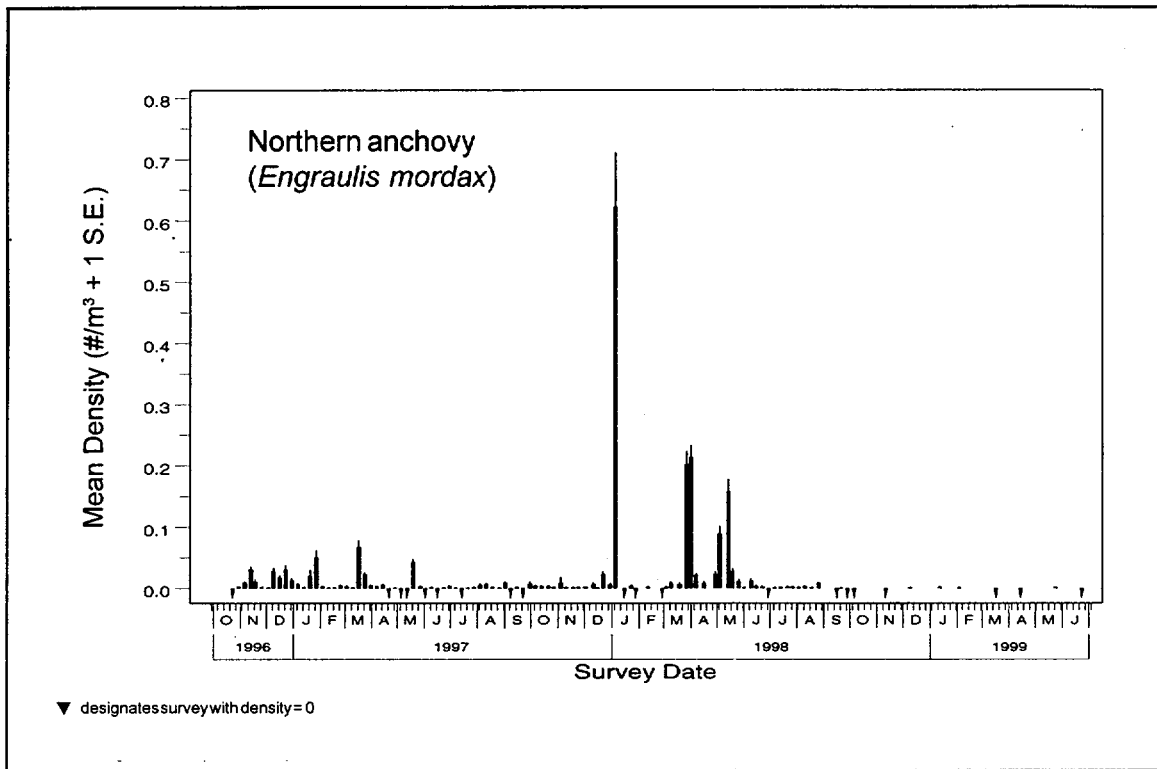


Figure 5.2.3-2. Weekly mean larval density (#/m³ + 1 S.E.) at the DCP intake.

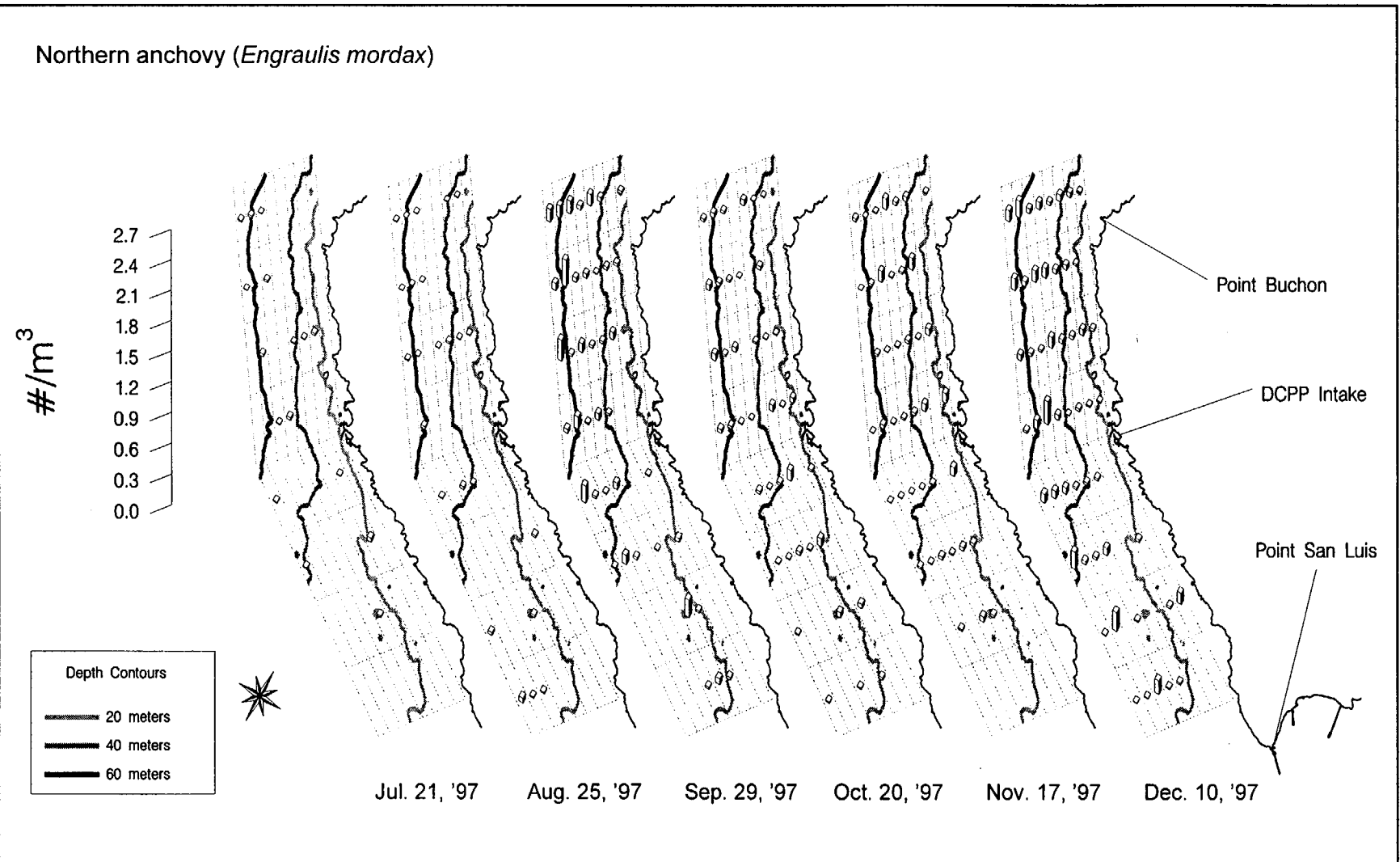


Figure 5.2.3-3a. Mean larval density ($\#/m^3$) collected in the DCPP study grid cells and at the entrainment sampling location.

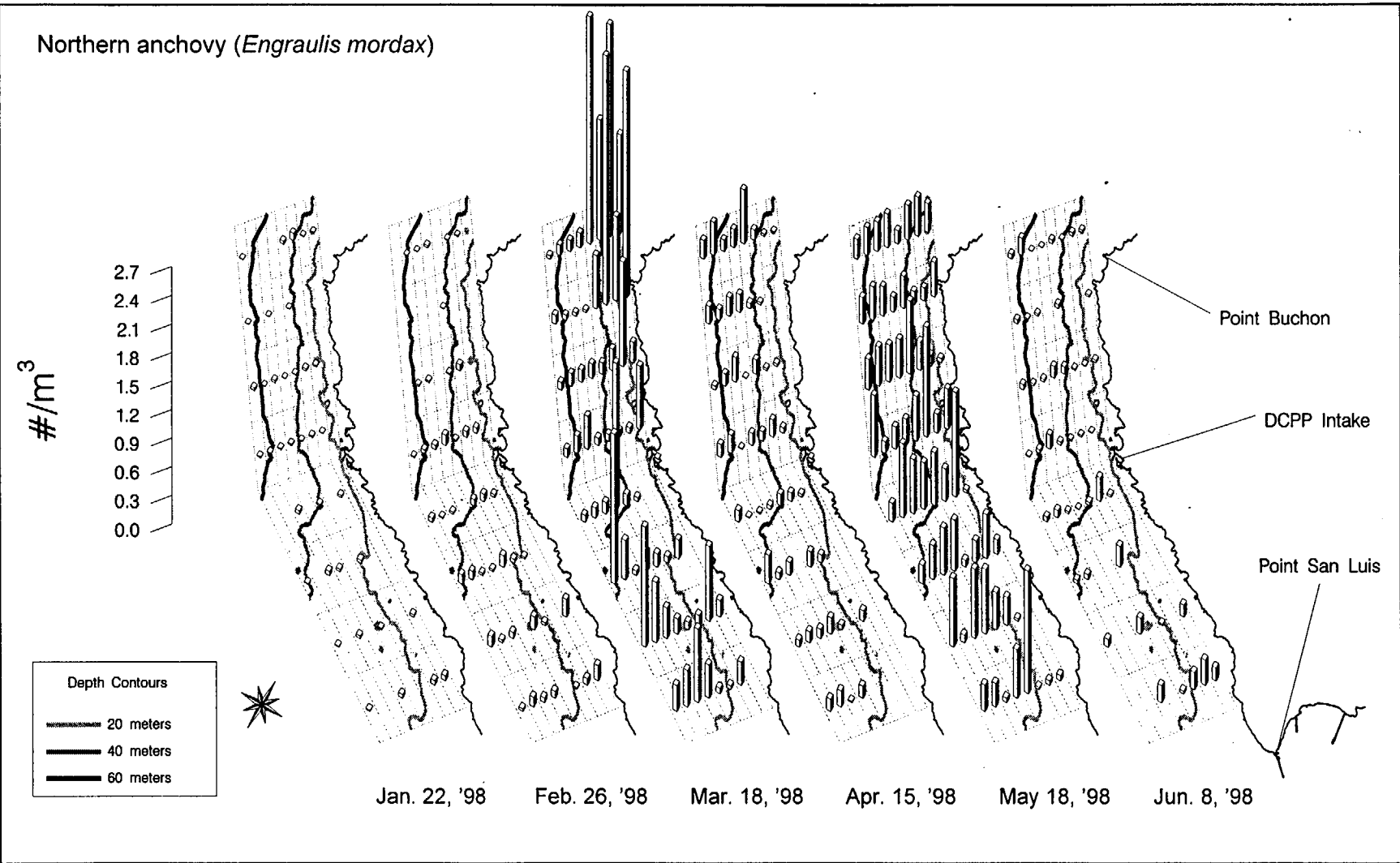


Figure 5.2.3-3b (continued). Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

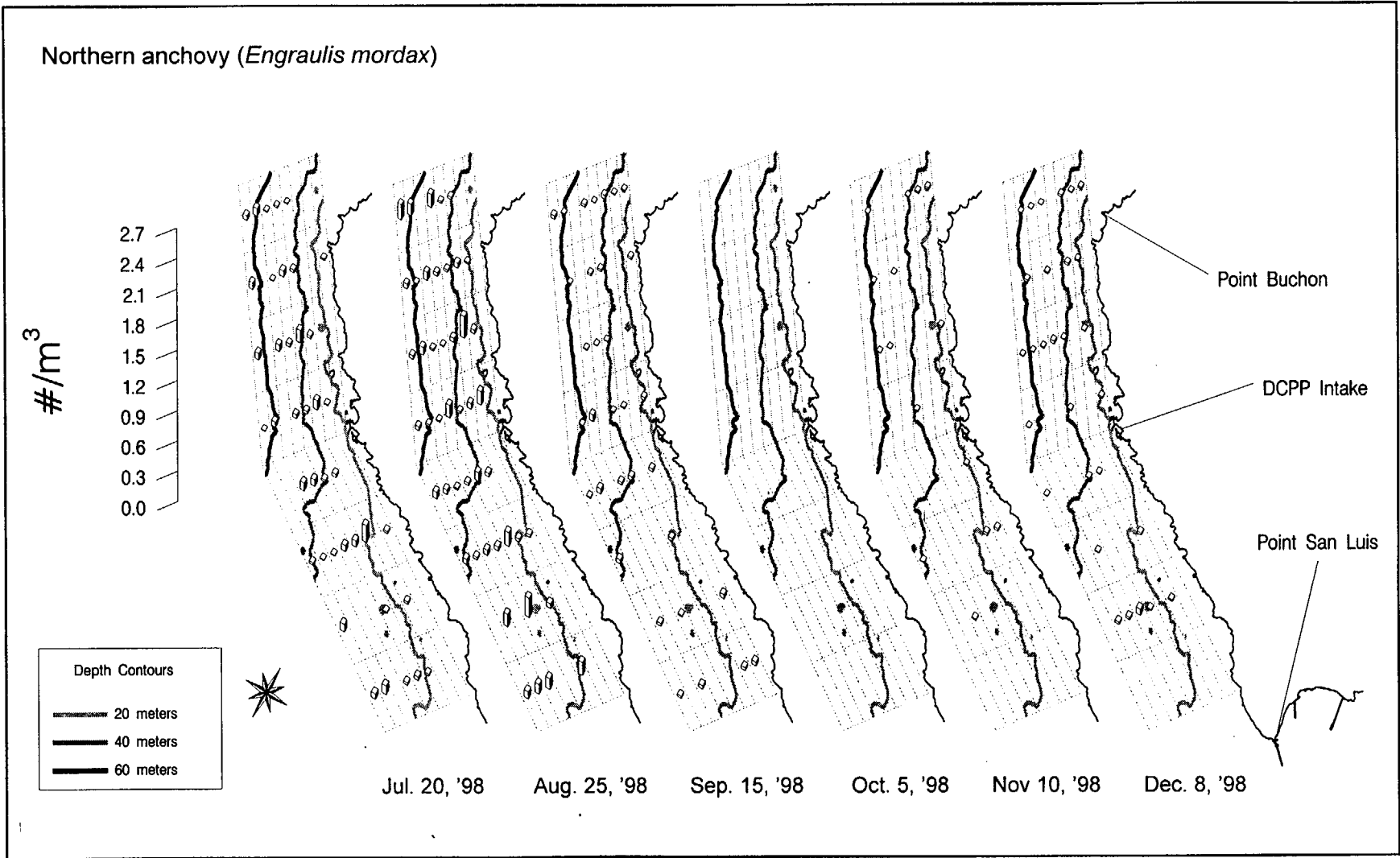


Figure 5.2.3-3c (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

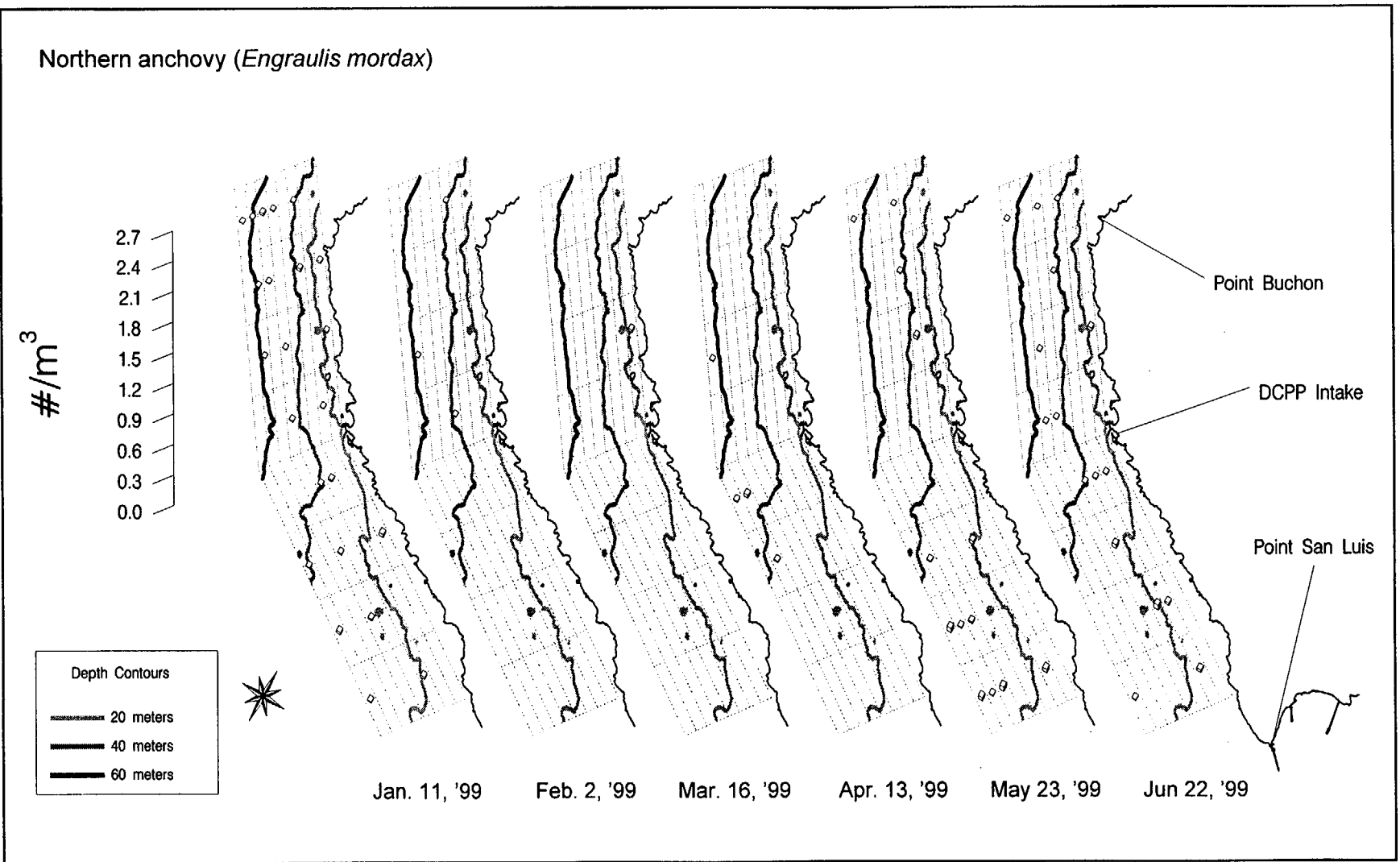


Figure 5.2.3-3d (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

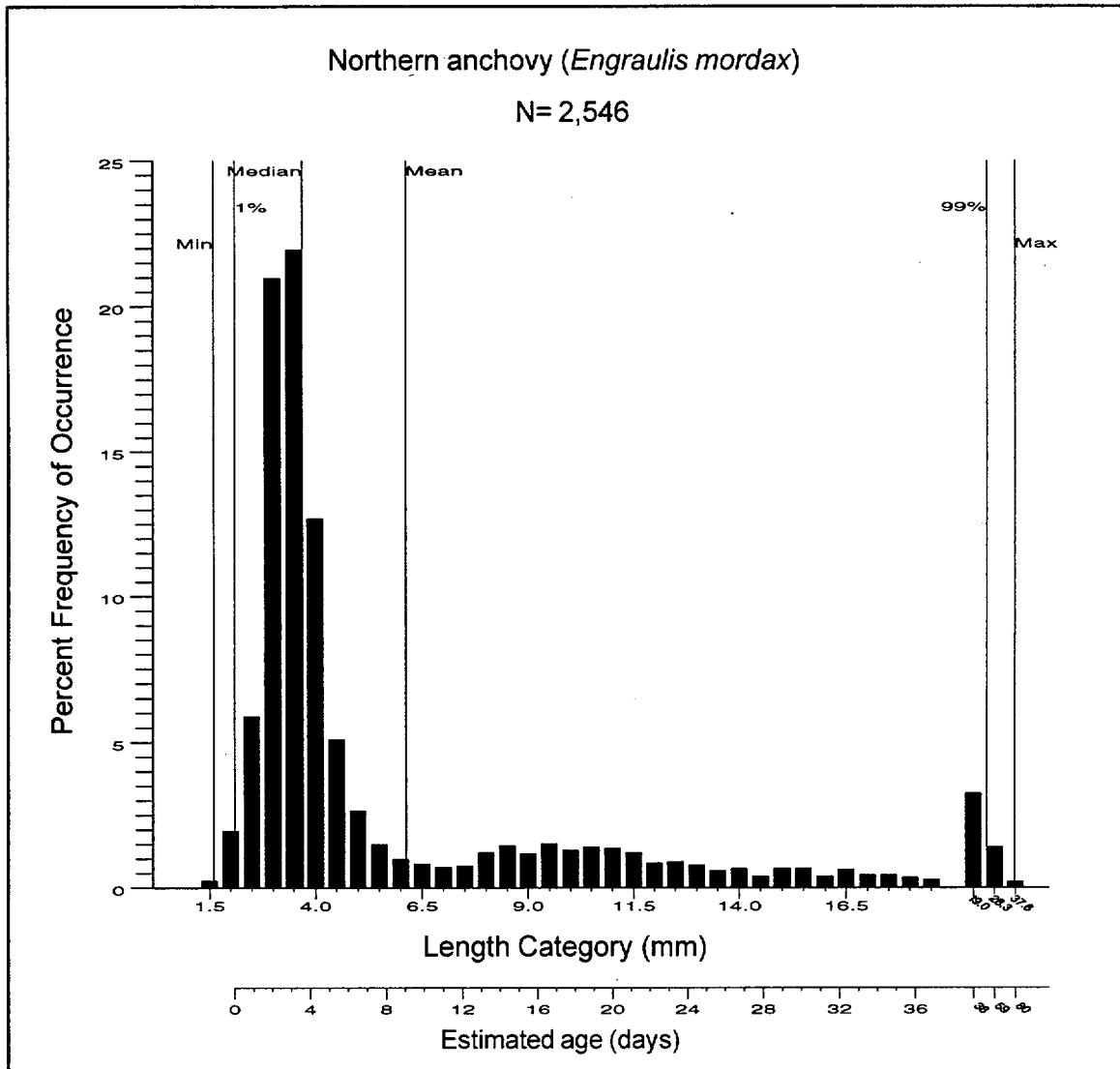


Figure 5.2.3-4. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

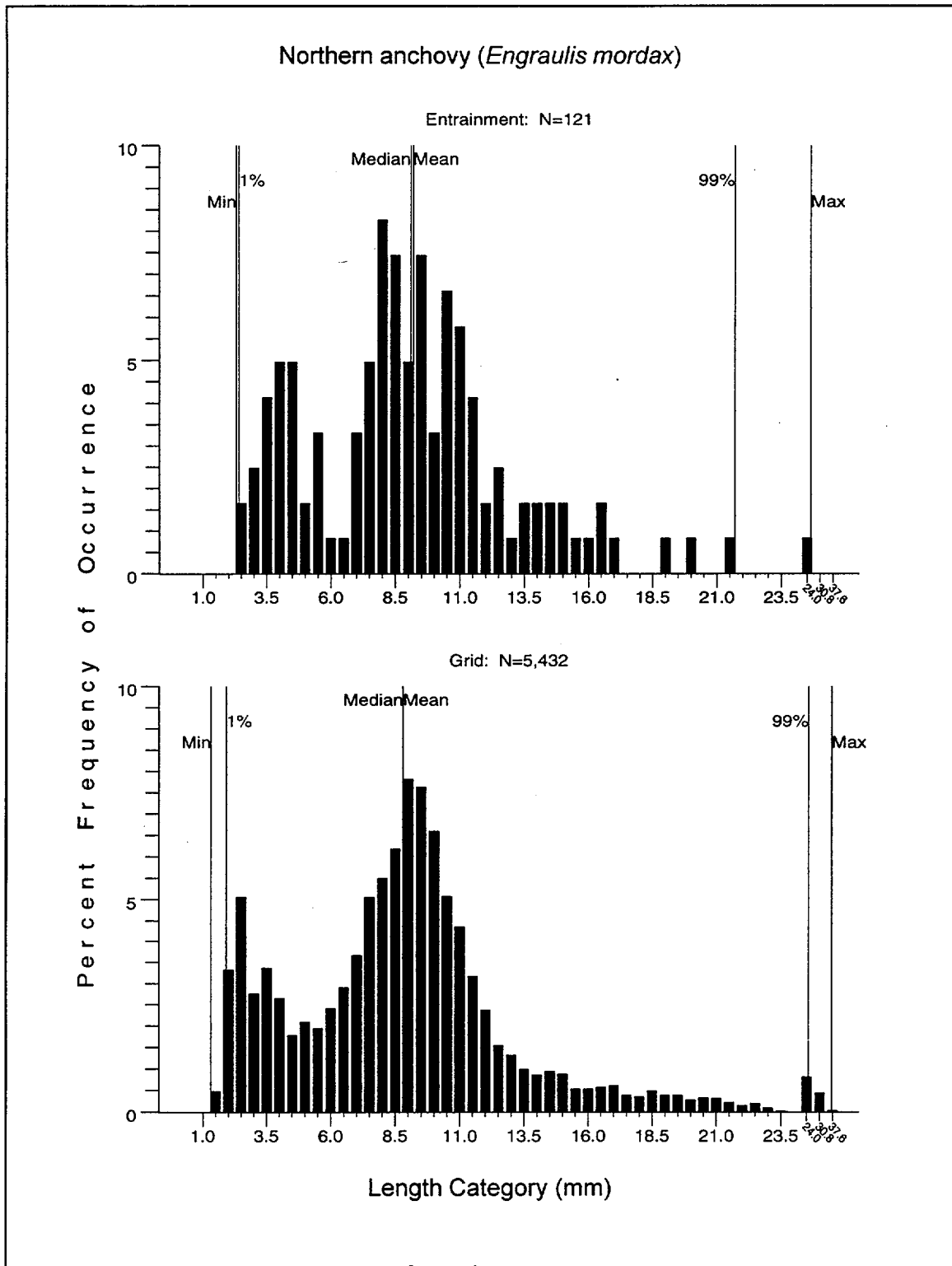


Figure 5.2.3-5. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

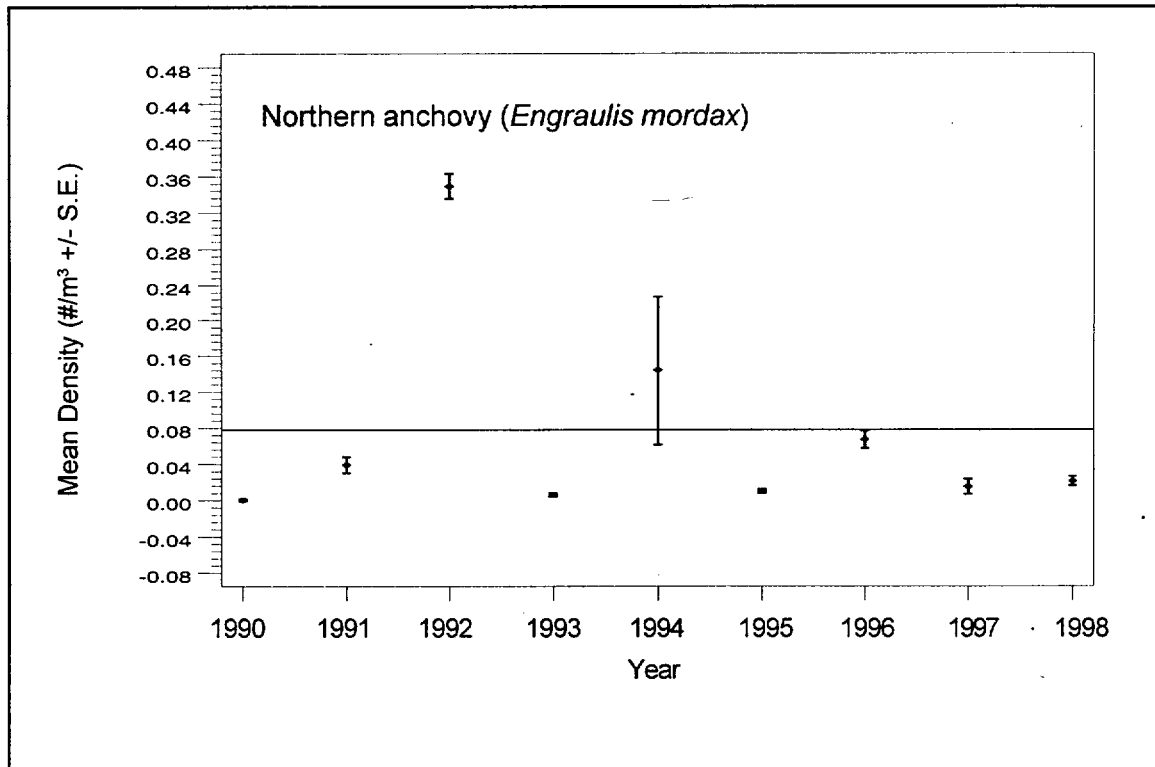


Figure 5.2.3-6. Annual mean density +/- 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

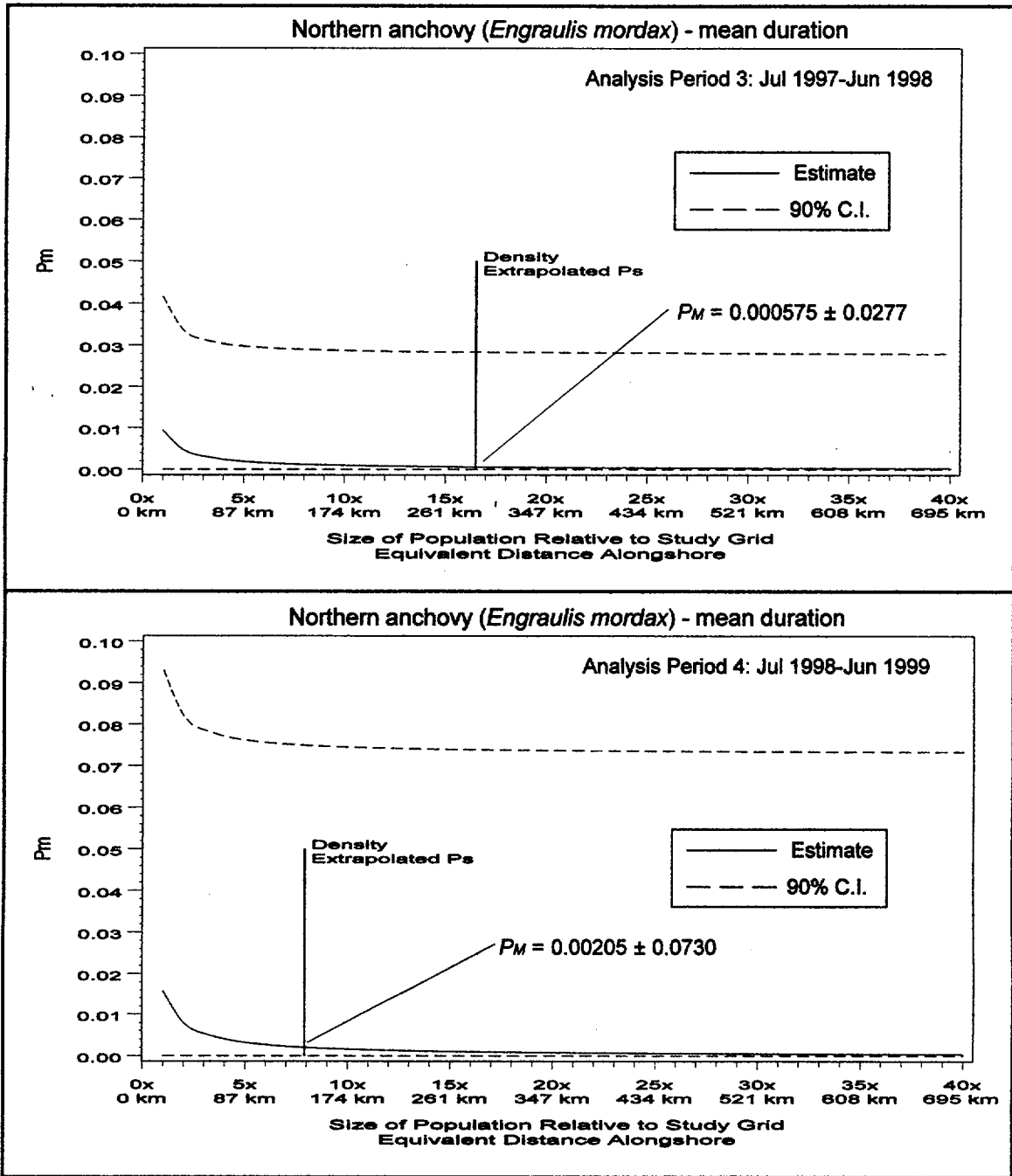


Figure 5.2.3-7a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the extent of the study grid population based on offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with the 90% C.I. indicated.

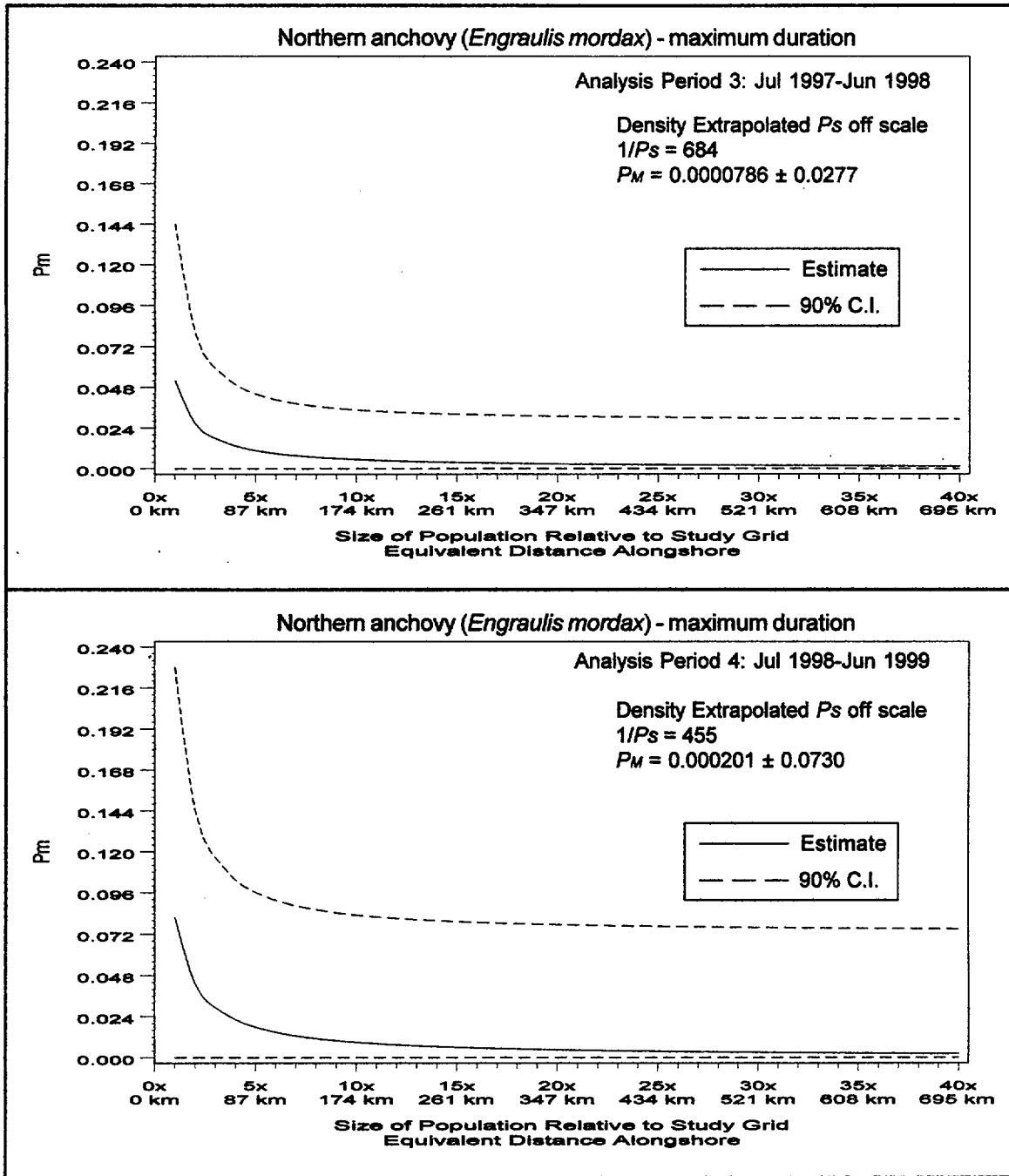


Figure 5.2.3-7b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the extent of the study grid population based on offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with the 90% C.I. indicated.

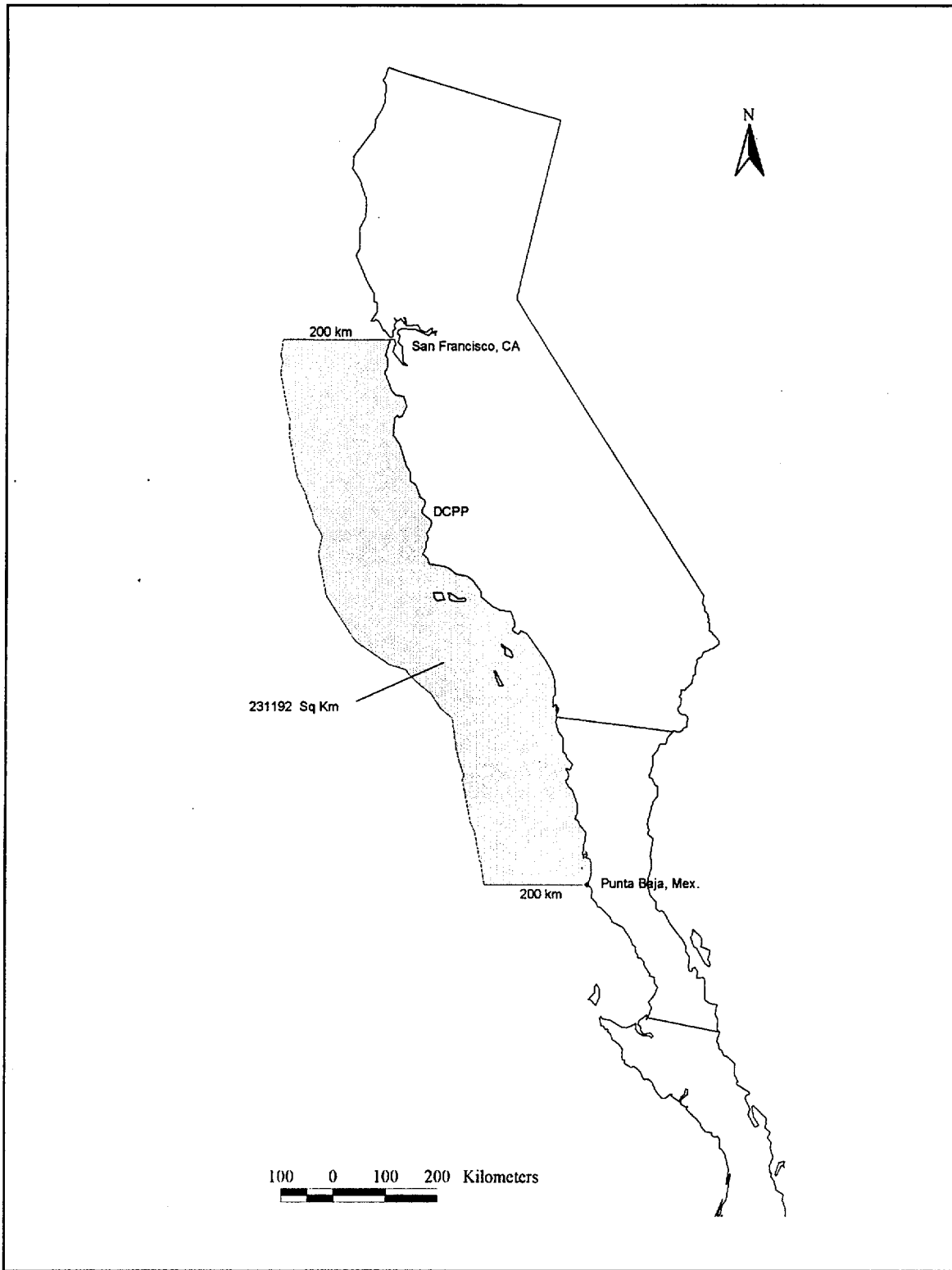


Figure 5.2.3-8. PFMC management area containing the spawning biomass of the central subpopulation of the northern anchovy .

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5.2.4 Assessment of Target Taxa in the Family Scorpaenidae

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. Adult California scorpionfish (*Scorpaena guttata*) are reported as far north as Santa Cruz, California, but adults are most common in waters south of Point Conception where they are an important component of the sport and commercial catch between Santa Monica Bay and San Diego, California (Leet et al. 1992; Love 1996). No California scorpionfish larvae were entrained at DCPD during the study. Commercial landings of rockfishes (*Sebastes* spp.) have historically included fishes in the genus *Sebastolobus* (thornyheads) represented by two species: the shortspine thornyhead (*Sebastolobus alascamus*) and the longspine thornyhead (*S. altivelis*). Until recently (mid-1980's), most rockfishes and thornyheads were landed together in a single market category, but they now are reported separately (Starr et al. 1998). Few thornyheads were entrained during the study at DCPD (**Appendix H**). The rockfishes (*Sebastes* spp.) are the most diverse genus in the Scorpaenidae with some 62 species reported from California coastal waters (Starr et al. 1998), approximately 85% of which are harvested in California commercial or sport fisheries.

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 1 mo to approximately 1 yr 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

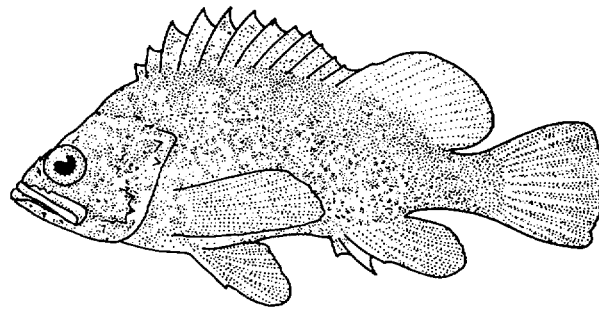
population abundance of many rockfish species since their vulnerable life stages are exposed to potentially adverse conditions for greater periods of time. Once on the bottom, individuals of many species migrate to deeper water as they mature.

Many rockfish species are closely related, and the larvae share many morphological and meristic characteristics, making it difficult to visually identify the individual larvae to species (Moser et al. 1977; Moser and Ahlstrom 1978; Baruskov 1981; Kendall and Lenarz 1987; Moreno 1993; Nishimoto in prep.). To standardize the identification of *Sebastes* spp. larvae, we collaborated with Mary Nishimoto at the University of California at Santa Barbara in developing a system of grouping rockfish larvae by pigment characters (Table 5.2.4-1; Nishimoto in prep.).

Using this system the two most abundant pigment groupings entrained at DCP (*Sebastes* spp. V_De and *Sebastes* spp. V) were genetically identified to determine the species composition of each proposed pigment grouping (Vetter and Stannard 1999; Appendix J). Results from these analyses indicated that the species contained in the *Sebastes* spp. V_De grouping (brown, gopher, copper, calico, and grass rockfishes) were genetically indistinguishable from the species contained in the *Sebastes* spp. V_D_ grouping (kelp, black-and-yellow, quillback, China, and halfbanded). Therefore, these two groups were combined into a single complex called the *Sebastes* spp. KGB Complex. This complex has historically been used to describe indistinguishable young-of-the-year (YOY) kelp forest rockfishes thought to be either kelp (K), gopher (G), or black-and-yellow (B) rockfishes in subtidal surveys (David VenTresca, CDF&G, Monterey, CA, pers. comm.). Results of the genetic analyses on the *Sebastes* spp. V grouping indicated that more than half of the larvae selected for analysis were blue rockfish (*Sebastes mystinus*) leading to the promotion of blue rockfish from their original pigment grouping of *Sebastes* spp. Vdp to the *Sebastes* spp. V group and to the subsequent designation of a second complex, the Blue Rockfish Complex, used in this report to describe the *Sebastes* spp. V / *S. mystinus* pigment grouping.

5.2.4.1 KGB Complex (*Sebastes* spp. V_De & V_D_)

The larval rockfishes that comprise the KGB complex share pigment characteristics that make individual larvae difficult to identify to species (e.g., V_De and V_D_; **Table 5.2.4-1**). The primary pigment characters distinguishing this grouping from other rockfish larvae are a long ventral series (V_), either a long or developing dorsal series (D_ or De, respectively), and lack of pectoral pigmentation. Fishes that are classified into these pigment groupings also appear to be genetically similar (Vetter and Stannard 1999; **Appendix J**). Since most of the species in this complex have similar life histories and share the same adult habitats, the KGB complex can be considered a guild of nearshore, benthic, or epi-benthic rockfishes sharing similar ecological roles that form a basis for their combination into this complex above and beyond the morphometric and meristic similarities of their larval forms.



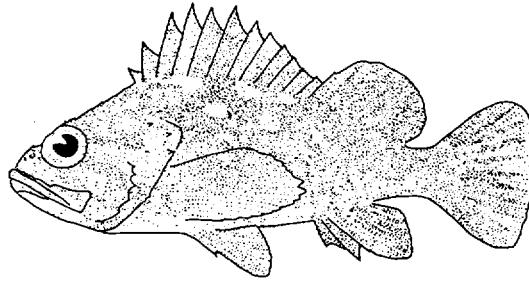
Sebastes atrovirens (Jordan and Gilbert 1880); kelp rockfish; length to 42 cm; Timber Cove, northern California to Punta San Pablo, central Baja California; inshore to 46 m; olive-brown to gray brown, with darker brown mottling, sometimes pinkish below (Miller and Lea 1972; Eschmeyer et al. 1983).

The kelp rockfish is typically found near the bottom in kelp beds or among the canopy blades living in rocky areas of nearshore waters (common at 10 m; Moser 1996). While they may occasionally move into deeper water during storms (Love 1996), they generally demonstrate high site fidelity throughout adult life (Miller and Geibel 1973; Lea et al. 1999). Principal food items are crustaceans and juvenile fishes, with some of those being other rockfish juveniles (Lea et al. 1999).

Kelp rockfish are important in both recreational and commercial fisheries. Recreational fishermen regularly take kelp rockfish on hook-and-line in and around kelp beds, and sport divers can easily spear them because of their docile nature (Love 1996; Lea et al. 1999). Commercially, this species is harvested on hook-and-line, in traps, and in gill nets (Love 1996). Many of them are sold as whole fish, sometimes live, in fish markets (Leet et al. 1992; Starr et al. 1998; Bloeser 1999). For the ports in the Monterey Bay National Marine Sanctuary (MBNMS) and San Francisco, kelp rockfish landings have increased markedly in the last ten years, with landings exceeding 14,500 MT in 1995. This equals an estimated average number of fish taken per year for the period 1980–1995 of 24,270 (Starr et al. 1998).

Kelp rockfish fecundity ranges from 344 to 403 eggs/g (female body weight), and spawning occurs once during late winter to spring (MacGregor 1970; Love et al. 1990; Moser 1996). The reproductive period lasts about 7 mo (Lea et al. 1999) and parturition occurs in April and May (Moreno 1993). Larval kelp rockfish are extruded at around 4.0 mm (Moser 1996). Young-of-the-year (YOY) first appear under nearshore kelp canopies from July through August and then as schooling fish in the water column from August through October. Lengths of YOY range from 20 to 40 mm total length (TL; Lea et al. 1999).

Longevity for the kelp rockfish is estimated at 15–20 yr (Burge and Schultz 1973; Lea et al. 1999; Ralph Larson, CSU San Francisco, pers. comm.). These ages are validated for fish up to about 5 yr and assumed to be accurate for older fish (Lea et al. 1999). The smallest sexually mature male was 246 mm TL at 4 yr, and the largest immature male was 338 mm TL (not aged; Lea et al. 1999). The smallest sexually mature female was 218 mm TL at 5 yr, and the largest immature female was 320 mm TL at 7 yr (Lea et al. 1999). Females attain 50% maturity at 4–5 yr and 100% maturity at 6–7 yr (Bloeser 1999).



Sebastes carnatus (Jordan and Gilbert 1880); gopher rockfish; length to 30 cm; Eureka, northern California to San Roque, central Baja California; inshore to 55 m; brownish to olive, mottled with pale areas, flesh-colored to slightly whitish areas on back (Miller and Lea 1972; Eschmeyer et al. 1983).

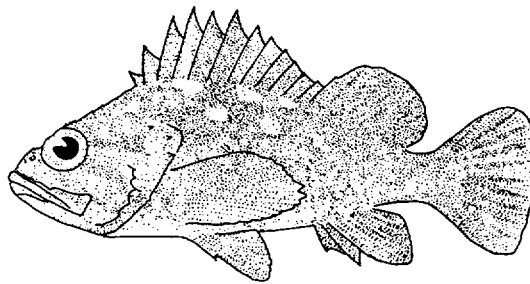
Gopher rockfish are benthic as adults, often found in crevices down to 55 m depth (Moser 1996). They appear to be very residential (Lea et al. 1999), but other evidence shows that they occasionally move over short distances to inhabit artificial reefs (Matthews 1986). Small fish eat zooplankton and larger fish eat benthic items like crustaceans, fishes (up to 80% YOY rockfishes), and octopi (Love 1996; Lea et al. 1999).

Gopher rockfish have both recreational and commercial fishery value. Recreational and commercial fishermen typically take gopher rockfish on hook-and-line while fishing for other species (Love 1996). Many of them are sold whole, sometimes live, in fish markets (Leet et al. 1992; Starr et al. 1998; Bloeser 1999). For the MBNMS ports and San Francisco, the gopher rockfish has shown variable landings over the past two decades. Landings exceeded 100,000 MT from 1980–81, declined to almost negligible landings by 1991, and then rapidly increased to greater than 118,200 MT in 1992. By 1995, landings exceeded 136,400 MT (Starr et al. 1998) possibly reflecting the increased effort in the live-fish fishery (Bloeser 1999). An estimated average number of gopher rockfish taken in recreational fisheries per year for the period 1980–1995 was 95,200 (Starr et al. 1998).

Gopher rockfish fecundity ranges from 176–307 eggs/g female weight, and spawning occurs once per season in spring (MacGregor 1970; Wyllie Echeverria 1987; Moser 1996). The reproductive period lasts 10 mo (Lea et al. 1999), and parturition occurs in March–May (Moreno 1993). Planktonic duration is approximately 2–3 mo (Larson 1980). Metamorphosing juveniles

first appear in nearshore habitats in mid- to late-June (Larson 1980). YOY first appear associated with nearshore reefs in July and August at 20 to 40 mm TL (Lea et al. 1999).

Longevity for the gopher rockfish was estimated at 24 yr (Lea et al. 1999). Age estimates were validated for fish up to about 5 yr and assumed to be accurate for older fish (Lea et al. 1999). The 24 yr old (316 mm TL) tagged fish reported by Lea et al. (1999) grew only 4 mm in nearly 11 years between capture dates. A 15 yr old tagged fish (282 mm TL) grew 10 mm TL in 6.7 yr between capture dates (Lea et al. 1999). The smallest sexually mature male in their study was 237 mm TL at 10 yr, and the largest immature male was 237 mm TL at 10 yr (Lea et al. 1999). The smallest sexually mature female was 207 mm TL (not aged), and the largest immature female was 306 mm TL at 9 yr (Lea et al. 1999). Females are estimated to attain 50% maturity at 4 yr (Wyllie Echeverria 1987; Bloeser 1999).



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

Black-and-yellow rockfish typically inhabit holes and crevices in rocky areas and can be found up into the intertidal zone (Eschmeyer et al. 1983). They appear to be very residential (Lea et al. 1999), and short-range homing has been demonstrated (Hallacher 1984). Benthic organisms comprise a majority of the diet with crustaceans making up the largest proportion (89%; Lea et al. 1999). Of the rockfishes studied by Lea et al. (1999), black-and-yellow rockfish exhibited the greatest diversity of prey items.

Black-and-yellow rockfish are important to both recreational and commercial fisheries. Recreational and commercial fishermen typically take black-and-yellow rockfish on hook-and-line while fishing for other species (Love 1996). Many of them are sold whole, sometimes live, in fish markets (Leet et al. 1992; Starr et al. 1998; Bloeser 1999). For the MBNMS ports and San Francisco, the commercial landings for black-and-yellow rockfish increased from no landings between 1980 and 1991 (except 1987 where 30.8 MT were landed) to greater than 24.5 MT by 1995 (Starr et al. 1998). This increase may reflect the increasing effort directed at the live-fish fishery along the California coast (Bloeser 1999). The estimated average number of black-and-yellow rockfish taken annually in the northern California sport fishery during the period 1980–1995 was 24,860 (Starr et al. 1998).

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

Longevity for the black-and-yellow rockfish was estimated at 21 yr (Lea et al. 1999). Age estimates were validated for fish up to about 5 yr and assumed to be accurate for older fish (Lea et al. 1999). Highest assigned age was 15 yr at 252 mm TL by Burge and Schultz (1973). The smallest sexually mature male was 239mm TL at 4 yr, while the largest immature male was 301 mm TL at 9 yr (Lea et al. 1999). The smallest sexually mature female was 243 mm TL at 6 yr and the largest immature female was 270 mm TL at 7 yr (Lea et al. 1999). Females are estimated to attain 50% maturity at 3 yr and 100% maturity at 4 yr (Wyllie Echeverria 1987; Bloeser 1999).

Other members of the KGB 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 depth (Love 1996). The notable exception to this distribution is the halfbanded rockfish (*Sebastes semicinctus*), which is commonly observed on hard and soft, flat bottom habitat in waters up to 402 m 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 the greatest total lengths and ages for the complex. Brown, copper, quillback, and grass rockfishes can attain maximum lengths of >50 cm (Miller and Lea 1972; Eschmeyer et al. 1983). This is also true for estimated longevity. Copper and quillback rockfishes may reach 41 yr and 76 yr, respectively, in the Canadian fishery (Yamanaka and Kronlund 1997). The smallest and shortest living rockfish of this group is the calico rockfish that attains a total length of 25 cm and has an estimated longevity of about 12 yr (Chen 1971; Miller and Lea 1972; Eschmeyer et al. 1983). The calico rockfish also has the lowest fecundity recorded in the KGB complex at about 2,000 eggs per female at 50% maturity but ranging to as high as 113,000 eggs per female (Haldorson and Love 1991). The most fecund rockfish from this group is the grass rockfish with about 760,000 eggs for a 26 cm female (Love and Johnson 1999). The highest age range at 50% maturity is 6–11 yr for quillback rockfish (Wyllie Echeverria 1987; Yamanaka and Kronlund 1997).

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 3 mo, 1–2 mo, and 2–3 mo, respectively (Larson 1980; Moser and Butler 1981; Matarese et al. 1989; D. Woodbury, NOAA, Tiburon Laboratories, pers. comm.). There are no published estimates of egg or larval survivorship for the species in the KGB complex.

The KGB complex formed a large part of the rockfish numbers in both the larval entrainment surveys (**Appendix H**) and subtidal fish surveys (Tenera 1997c) along the Diablo Canyon coastline. However, compared to the overall rockfish catch in California, which is comprised of both nearshore and offshore species, the KGB complex is a relatively minor, but increasing,

component (Leet et al. 1992; Starr et al. 1998; Bloeser 1999). Nearly all members of the KGB complex, except for halfbanded rockfish, are components of the live-fish fishery that targets nearshore habitats (Leet et al. 1992; Starr et al. 1998; Bloeser 1999). Brown rockfish landings averaged ca. 134 MT from 1979 to 1986, or 2–4% of the total recreational rockfish catch in California (Leet et al. 1992; Starr et al. 1998). The copper rockfish has followed a similar trend at about 2–3% of the recreational rockfish landings (Leet et al. 1992; Starr et al. 1998). The average number of brown and copper rockfishes landed per year at MBNMS ports and San Francisco over the period 1980–1995 was 160,670 and 106,390, respectively (Starr et al. 1998). The only KGB complex species listed by Bloeser (1999) within the top ten rockfishes landed on trolling gear in 1997 was the China rockfish, which ranked ninth. Similarly, the only KGB complex species listed within the top ten rockfishes landed in 1997 using hook-and-line gear was the gopher rockfish, which also ranked ninth. However, in this latter gear category, unspecified rockfishes ranked highest. In contrast, no KGB complex members were listed in the top ten trawl-caught rockfish landings that made up 88% of the west coast landings in 1997. In 1997, the average price for rockfish from commercial landings was varied by gear type with the lowest value (\$0.93/kg) attributed to trawl gear and the highest (\$3.15/kg) from pots and traps (Bloeser 1999). The KGB rockfishes that ranked in the top ten landings at Morro Bay, California in 1997 were grass (2), gopher (6), and black-and-yellow (8) rockfishes (ranks given in parentheses; Bloeser 1999). The average price in 1999 for all KGB complex rockfishes landed in the Morro Bay area (black-and-yellow, brown, China, copper, gopher, grass, and kelp) was \$7.65/kg (Source: PSMFC Database).

Summary of Field Collections

Larval rockfishes in the KGB complex showed distinct seasonal peaks of abundance at the DCP intake structure during the years 1996–1999 (**Appendix H**), with their greatest abundance tending to occur between March and July (**Figure 5.2.4-1**). There were 17,863 larval KGB rockfishes identified from 774 bongo net subsamples collected at the DCP intake structure between October 1996 and June 1999 representing 20% of the entrainment subsamples collected and processed during that period. An El Niño began developing during the spring of 1997

(NOAA 1999) and was detected along the coast of California in fall of that year (Lynn et al. 1998). This may have affected density in 1997 compared with the previous year. This warm water event may also have delayed spawning slightly during the 1997–98 spawning season (Woodbury and Ralston 1991).

Larval KGB rockfishes generally occurred in the DCPD study grid with similar seasonality to that observed at the DCPD intake structure (**Appendix H**) with peak abundance occurring in May of both 1998 and 1999 (**Figure 5.2.4-2**). There were 5,377 KGB rockfish larvae identified from 701 bongo net subsamples representing 23% of the study grid subsamples collected and processed from July 1997–June 1999. Mean density in May of each sampling year was very similar (May 1998: $0.29/\text{m}^3$; May 1999: $0.28/\text{m}^3$), indicating little change in abundance between the El Niño and subsequent La Niña season.

Standard lengths of all measured KGB rockfish larvae collected at the DCPD intake structure between October 1996 and June 1999 (9,926 larvae) ranged from a minimum of 2.4 mm to a maximum of 8.0 mm (**Figure 5.2.4-3**). The central 98% of this length-frequency distribution resulted in minimum and maximum lengths for the analyses of 3.3 mm and 5.6 mm, respectively. The mean larval length in this distribution was 4.2 mm. The growth rate applied to the KGB complex (0.14 mm/d) derived from Yoklavich et al. (1996) was used to estimate ages of entrained larvae. Assuming that the shortest larvae of the central 98% of the length-frequency distribution was immediately post-extrusion and aged zero days, then the estimated ages of larvae entrained could range from zero up to ca. 34 d post-extrusion for the largest larva measured. The average estimated age of KGB larvae entrained at DCPD was estimated as 6 d post-extrusion.

There were significant differences between mean lengths (t -test: $p \leq 0.004$) and between length-frequency distributions (Kolmogorov-Smirnov test: $p < 0.001$) of larval KGB rockfishes from the DCPD intake structure and study grid despite the appearance of similarity between the two unimodal distributions (**Figure 5.2.4-4**). The large sample size (1,282 larvae from the intake structure and 2,850 larvae from the study grid) could cause the t -test to be highly sensitive to small differences between the means (Zar 1984). The mean standard lengths from the intake

structure and study grid were 4.2 mm and 4.1 mm, respectively. The maximum difference between the length-frequency distributions detected by the Kolmogorov-Smirnov goodness of fit test occurred at 4.1 mm, further indicating that a greater number of small individuals were collected from the study grid. While these differences were statistically detectable and significant, we believe that the biological significance of these differences is low.

Reported extrusion size for species in this complex ranges from 4.0–5.5 mm (Moser 1996). The fact that we observed many larvae smaller than the reported extrusion lengths can be explained partly by natural variation of extrusion lengths within the population and partly by the phenomenon of shrinkage following preservation (Theilacker 1980). If larvae less than 5.5 mm were zero days old, then the presently assumed aged-0 d length of 2.4 mm would lead to an overestimate of larval ages for those individuals with a consequent overestimation of entrainment mortality probability.

Estimating Total Annual Entrainment

Annual estimated numbers of KGB rockfish larvae entrained at DCPD varied relatively little between 1996–97 Analysis Period 1 ($\widehat{E}_T = 268,000,000$) and 1997–98 Analysis Period 2 ($\widehat{E}_T = 199,000,000$) (Table 5.2.4-2). The results for analysis periods 2 and 3 are the same because the overlap between the periods occurred during the peak larval abundances of KGB rockfish larvae. Values of $2 \cdot \widehat{SE}(\widehat{E}_T)$ can be used to approximate 95% confidence intervals around the point estimates. The confidence intervals overlap for the estimates indicating that the differences between them were probably not statistically significant and that entrainment of these rockfish larvae was relatively constant between years. Therefore, reproductive output in the KGB rockfish complex did not appear to be substantially affected by the 1997–98 El Niño event (Figure 5.2.4-1).

The estimates of annually entrained KGB rockfish larvae above were adjusted (Table 5.2.4-3) to the long-term average Intake Cove surface plankton tow index (\bar{I} / I_i), calculated as the ratio between the 9 yr average (\bar{I}) of Intake Cove sampling (Figure 5.2.4-5) and the average annual

index estimated from these same tows during the year being adjusted (I_i). The average indices for the years 1997 and 1998 were 0.0703 and 0.0647 larvae/m³, respectively, and the long-term average index for 1990–98 was 0.0722 larvae/m³. Thus, the ratios used to adjust the 1997 and 1998 estimates of larvae entrained were 1.027 and 1.13, respectively, indicating that larval density was slightly lower than the long-term average during those years. The adjustments resulted in an estimate of 275,000,000 for 1996–97 Analysis Period 1 and 222,000,000 for 1997–98 Analysis Period 2. The same trends in overall abundance as noted for unadjusted entrainment values are apparent in the adjusted values: namely, larval KGB rockfish abundance changed little between analysis periods. Annual estimates of abundance during the study period were low relative to the long-term average index of larval abundance from the Intake Cove plankton tows as indicated by the index ratios greater than one.

Fecundity Hindcasting (FH)

The parameters required for the formulation of *FH* estimates for the KGB rockfish complex were compiled from references on different species within the group. Rockfish within the KGB complex spawn once per year. From multiple references on fecundity for various species within the KGB complex an average annual fecundity estimate of 213,158 eggs per female was used to calculate *FH* (DeLacy 1964: 52,000–339,000; MacGregor 1970: 44,118–104,101 and 143,156–182,890; Love and Johnson 1999: 80,000–760,000), with a CV of 100%. From the various sources of information on KGB complex rockfishes (**Table 5.2.4-4**), longevity of 15 yr and age at maturation of 5 yr were used to calculate *FH*.

Survival of larvae from the time of release to entrainment was estimated using an instantaneous mortality rate of 0.14/d from blue rockfish (Mary Yoklavich, NOAA/NMFS/PFEG, Pacific Grove, CA, pers. comm.) over 6.21 d since no independent estimates of larval KGB rockfish mortality were available. This was calculated from a mean length at entrainment (4.17 mm) minus the minimum length of the central 98% of the length frequency distribution (3.3 mm) and divided by a larval growth rate for brown rockfish of 0.14 mm/d (Love and Johnson 1999; Yoklavich et al. 1996), as

$$\hat{S}_{larvae} = e^{(-0.14)(6.21)} = 0.419.$$

The estimated number of adult KGB rockfish females (\widehat{FH}) whose reproductive output was equivalent to the adjusted number of larvae entrained per year at DCPD ranged from 617 in 1996–97 to 497 in 1997–98 (Table 5.2.4-5). Hindcast adult estimates differed minimally among the analysis periods. These fairly low values also reflected the relatively high fecundity of the adults and the young average entrainment age for the larvae in this complex.

Sensitivity Analysis

Fecundity had the greatest leverage on recalculated values of \widehat{FH} (Table 5.2.4-6). Varying this parameter in the model resulted in an \widehat{FH} range of 96–3,200 adult females among the three analysis periods, compared to the original estimate of 497–617 adult females. Larval survivorship had the next greatest amount of leverage on recalculated \widehat{FH} .

Adult Equivalent Loss (AEL)

Larval blue rockfish survival estimates were used in *AEL* estimates for the KGB complex because of the absence of data on later-stage survival rates in KGB rockfishes (Table 5.2.4-7). The survival rate of the KGB larvae from size at entrainment to size at recruitment into the fishery was partitioned into six stages from parturition to recruitment. Survivorship, to an assumed recruitment age of 3 yr, was apportioned into these life stages, and *AEL* was calculated assuming the entrainment of a single age class having the average age of recruitment.

Similar to the results seen with \widehat{FH} , estimates of adult equivalents lost (*AEL*) due to larval entrainment were fairly similar among survey periods (Table 5.2.4-8). The \widehat{AEL} of 1,120 adults predicted from \hat{E}_{Adj-T} at DCPD during 1996–97 reflects the slightly higher abundance of KGB rockfish larvae present during this year when compared to 1997–98 Analysis Period 2 ($\widehat{AEL} = 905$). The relatively constant larval abundance and subsequent estimates of effects varied little among survey periods, indicating that recruitment for the species in this complex remained relatively constant.

Sensitivity Analysis

Larval and juvenile survivorship had the greatest leverage on recalculated values of \widehat{AEL} (Table 5.2.4-9). Varying these parameters in the model resulted in an \widehat{AEL} range of 175–5,820 adult equivalents for the 1996–97 and 1997–98 analysis periods, compared to the original estimate of 905–1,120 adult equivalents. Pre-recruit survivorship had the next greatest leverage on estimates of \widehat{AEL} . Varying the estimate of entrainment did not substantially change the original value of calculated \widehat{AEL} .

Empirical Transport Model (ETM)

The lengths of entrained KGB larvae, excluding the largest 1% and smallest 1% of all measurements, ranged from 3.3 to 5.6 mm. Thus, KGB larvae may have been susceptible to entrainment for approximately 16.4 d based on a growth rate from larval brown rockfish of 0.14 mm/d (Love and Johnson 1999; Yoklavich et al. 1996). On average, however, entrained KGB rockfish larvae were estimated to be ca. 6.2 d old.

Monthly estimates of proportional entrainment (PE_i) in each i th survey ranged from a minimum of zero to a maximum of 0.587 ± 0.297 ($\pm 1 SE(\widehat{PE}_i)$) in March 1998 (Table 5.2.4-10). When both \widehat{PE}_i and the annual proportion of larvae extruded in the i th survey period (\hat{f}_i) were equal to zero, no larvae were collected at either the DCP intake or from the study grid. Highest \widehat{PE}_i values occurred in March during the peak parturition of many species in the KGB complex (Moser 1996). However, the highest \hat{f}_i values typically occurred a couple of months later in May. The greatest \widehat{PE}_i occurred during the 1997–98 El Niño event when onshore water movement was also greatest.

Due to the broad dispersion of KGB rockfish larvae across the study grid (Figure 5.2.4-2), P_s for this complex was calculated using both alongshore and onshore current movements. Current speed and direction, measured at the single current meter near DCP, were used to extend the estimates of P_s beyond the bounds of the study grid (see Figure 4-3). Density of KGB larvae within the study grid was extended alongshore on the basis of current speed and direction

constrained by average and maximum estimates of larval duration and the width of the study grid perpendicular to the shore. The pattern of larval KGB density within the study grid was extrapolated offshore using onshore current movement inferred from the current meter and then extended alongshore. The offshore extrapolation of abundance was also modeled on the basis of average and maximum estimated larval durations, yielding a range of possible entrainment probability values.

Total entrainment mortality probability (\widehat{P}_M) was calculated for estimated average and maximum larval duration in days based on current speed and direction measured at the single DCPD current meter (Figure 5.2.4-6). Both larval duration and currents were used to determine the magnitude of \widehat{P}_S . Alongshore extended estimates of P_M ranged from 0.04–0.05 over both mean and maximum larval duration and between years indicating that \widehat{P}_M represented a nearly constant probability of larval entrainment alongshore. Offshore extrapolation of the study grid abundance of KGB rockfish larvae resulted in larger $1/\widehat{P}_S$ values with longer larval durations and consequently lower \widehat{P}_M values. Estimates of P_M using offshore extrapolated abundance extended alongshore and based on the two larval durations ranged from approximately 0.02 in both years using mean duration to 0.01 in Analysis Period 3 (July 1997–June 1998) and 0.005 in Analysis Period 4 (July 1998–June 1999) using maximum larval duration. The differences between the offshore density extrapolated estimates of P_M showed that while onshore transport did not play a significant role in the variation of $1/\widehat{P}_S$ over short larval durations, its combination with different annual values of PE and alongshore flow did result in larger differences over longer durations. The average areas over which larval densities were extrapolated were more similar between 1997–98 and 1998–99 based on mean duration (5 and 4 times the grid study area, respectively) than on maximum duration (23 and 30 times the grid study area, respectively).

Interpretation of Assessment Results

Abundance of larval, juvenile, and adult KGB rockfishes varies between years, but there are no apparent decreasing trends in abundance over time. Subtidal fish abundance estimates collected at the DCPD South Control station from 1978 to 1998 (Tenera 1997c) varied seasonally between

years with occasional peaks (Figure 5.2.4-7). The relatively stable adult and YOY abundance noted in the DCPD subtidal fish observation dataset is also reflected by fairly stable larval abundance in Intake Cove plankton tows (Figure 5.2.4-5). Thus, local abundance of all life stages of KGB rockfishes is not declining, indicating that larval losses due to entrainment are not adversely impacting the local population.

Rockfishes in the KGB complex have both commercial and recreational fishery value (Starr et al. 1998; Bloeser 1999; Lea et al. 1999). Commercial groundfish landings from all gear types reported by Pacific States Marine Fishery Council (PSMFC) in their PacFIN database for the years 1993–1999 show landings of black-and-yellow, gopher, and grass rockfishes in the Morro Bay area increasing from 1993–1996 but then decreasing and remaining relatively stable through 1999 (Figure 5.2.4-7). These three species are the members of the KGB complex that ranked in the top ten landings at Morro Bay, California in 1997 (Bloeser 1999). The majority of the peak landings in 1996 were accounted for by a single species; the gopher rockfish (*Sebastes carnatus*), but this relationship has alternated between gopher and grass rockfishes (*S. rastrelliger*) over recent years. Bloeser (1999) indicates that catches of KGB rockfishes in California have risen over the last 10–15 yr. Starr et al. (1998) note that while catches were stable or increasing between 1980–1995, abundance of many species was much higher before 1980.

The PSMFC database provides ex-vessel prices of rockfishes landed at the ports in the Morro Bay area during 1999. The members of the KGB complex that were landed at these ports in 1999 were the black-and-yellow rockfish (\$7.05/kg), brown rockfish (\$7.38/kg), gopher rockfish (\$6.84/kg), grass rockfish (\$11.22/kg), kelp rockfish (\$6.53/kg), China rockfish (\$11.36/kg), and copper rockfish (\$3.15/kg). Thus, the average price-per-kilogram for KGB complex rockfishes landed at Morro Bay area ports in 1999 was \$7.65. In 1999, 64 MT (ex-vessel revenue \cong \$500,000) of these rockfishes were landed in the Morro Bay area (PSMFC PacFIN database). Grass, gopher, black-and-yellow, and copper rockfishes represented 93% of the catch by weight and, consequently, produced the most revenue within this group of landings. Copper, grass, calico, and kelp rockfish accounted for 85% of the southern California recreational catch by number.

Estimates of *AEL* were compared to harvest data assuming 100% catchability of the adult equivalents and assuming no compensatory mortality. These assumptions will cause an overestimate when directly converting *AEL* into fishery values (e.g., price-per-kilogram). Given these conditions, an estimated economic loss to the local fishery could be based on an average weight of 1.0 kg for a 3-yr old KGB rockfish recruiting to the live-fish fishery. The annual *AEL* estimate of 977 rockfishes translates to a potential direct economic loss of \$7,474 based on the average price of \$7.65/kg. This value represents approximately 2% of the ex-vessel revenue attributed to KGB complex rockfishes landed at ports in the Morro Bay area in 1999 (PSMFC PacFin Database).

Alternatively, estimates of proportional entrainment mortality could be translated into losses to local fisheries. The probable effect of entrainment losses at DCP on fisheries is likely localized to the ports within the Morro Bay area since most fishes in this complex demonstrate high site fidelity (Heilprin 1992; Lea et al. 1999). In addition, extension of effects based on alongshore currents and larval duration indicate that the area potentially affected is three to seven times the size of the study grid, which is likely within the range of fishers from either Port San Luis or Morro Bay. The estimate of entrainment mortality (\widehat{P}_M) is between 4–5% for this area. Applying this range of proportional reduction to the local catch from the Morro Bay area in 1999 yields estimated dollar losses to the Morro Bay area fishery of approximately \$20,000.

5.2.4.2 Blue Rockfish (*Sebastes* spp. *VIS. mystinus*) Complex

The species that comprise the blue rockfish complex are those rockfish larvae that have a short ventral pigment series and no dorsal series or pectoral pigmentation. This group currently consists of 16 rockfish species (Table 5.2.4-1). The blue rockfish (*S. mystinus*) is being placed in this group despite its designation as a member of the Vdp group. The pigment characteristics of young blue rockfish place them in this complex because they cannot be distinguished from other species in the group until they develop pectoral and dorsal pigmentation.

Vetter and Stannard (1999; **Appendix J**) genetically identified larvae from the *Sebastes* spp. V pigment group. Their conclusions indicated that more than half of the larvae in this pigment group were actually blue rockfish larvae. Additional evidence supporting the fact that many of the individuals in this complex would be blue rockfish is that they have the earliest parturition that occurs in January (Wyllie Echeverria 1987; Love 1996) and corresponds to the larval abundance data collected at DCPD in the present study (**Appendix H**). These data, combined with the fact that young blue rockfish larvae are indistinguishable from other rockfish larvae in this pigment group, led to the designation given of Blue Rockfish Complex.

Sebastes spp. V

Three species from the blue rockfish complex that commonly occur off central California are used here to represent the demography of other species from the complex: splitnose rockfish (*S. diploproa*), greenstriped rockfish (*S. elongatus*), and vermilion rockfish (*S. miniatus*). As a late addition to this grouping, the blue rockfish is treated separately as a representative of this complex as well. In the earliest larval stages, blue rockfish resemble the other larvae in this pigment grouping.

The splitnose rockfish is demersal and usually seen on soft substrata, often singly in small depressions or in near bottom aggregations, with a peak population density between depths of 92 and 460 m (Love 1996; Moser 1996). Pelagic juveniles congregate around drifting kelp and settle in shallow water (Love 1996). Greenstriped rockfish are demersal and semi-pelagic and found at depths of 25–500 m, but are most common between 46–245 m (Matarese et al. 1989; Love 1996). They are typically solitary on mud or cobble (Love 1996), and juveniles recruit in depths of 30–89 m depths (Love et al. 1990).

Vermilion rockfish are demersal and semi-pelagic and aggregate near or slightly above the bottom, often over high relief rocky substrata. They are most abundant in depths of 60 to at least 239 m within the Southern California Bight (Love et al. 1990). Adults have been found in depths as shallow as 7 m near Diablo Canyon (Burge and Schultz 1973), and they appear to have a high

degree of site fidelity (Lea et al. 1999). Juveniles settle in water depths of 5–30 m and peak abundance of juveniles and small adults occurs in 90–149 m depths (Love et al. 1990).

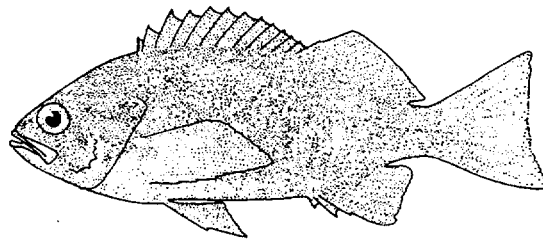
Splitnose rockfish ranging in size from 195–365 mm produce 14,400–303,700 eggs/female (Phillips 1964). Their spawning period is from January through September (Phillips 1964; Wyllie Echeverria 1987; Moser 1996) with possibly two broods per year (Westrheim 1975). Growth for wild caught larvae was 0.21–0.96 mm/d (Boehlert 1981). Pre-juvenile splitnose remain pelagic for about 1 yr and reach sizes of 55 mm prior to settling to benthic habitat (Boehlert 1977). A planktonic duration of ca. 2.5 mo was estimated from growth rates and from extrusion and transformation lengths (Boehlert 1981; Moser 1996). Estimates of age at 50% maturity of splitnose rockfish vary from 4–7 yr (Phillips 1964; Chen 1971; Wyllie Echeverria 1987) with 100% maturity estimated to occur at 10 yr (Bloeser 1999). Greenstriped fecundity ranges from 26,000 at 50% maturity to 344,000 at ca. 100% maturity (Haldorson and Love 1991). Spawning occurs two or more times per year (Love et al. 1990) from January through June or July (Hart 1973; Wyllie Echeverria 1987). Female greenstriped rockfish reach 50% maturity at 7 yr (Wyllie Echeverria 1987) and their estimated longevity is 28 yr for females and 37 yr for males in the Southern California Bight (Love et al. 1990). The fecundity of vermilion rockfish ranging in length from 315 to 550 mm SL ranged from 3,300–1,625,600 eggs (Phillips 1964). Vermilions ranging in length from 460 to 680 mm SL produced 158,915–2,683,768 eggs per individual in the Southern California Bight (Love et al. 1990). At 50% maturity they are estimated to produce 151,000 eggs with a maximum possible production of 5,602,000 (Haldorson and Love 1991). Vermilion rockfish spawn once per year from September through March (Phillips 1964; Wyllie Echeverria 1987; Love et al. 1990). Age at 50% maturity for vermilion rockfish is estimated to be 3–5 yr for females (Chen 1971; Wyllie Echeverria 1987) and 8 yr at 100% maturity (Bloeser 1999). Young-of-the-year are common over sandy pockets in and near kelp beds (Lea et al. 1999).

Rockfishes in this species complex exhibit a wide range of estimates of longevity. Longevity of splitnose rockfish was estimated at 18 yr in early studies (Phillips 1964; Chen 1971). Radiometric age validation, however, indicates a longevity exceeding 80 yr (Bennett et al. 1982). Subsequent

studies utilizing otolith sections support these findings with estimates of 81–84 yr (Wilson and Boehlert 1990). No estimates of longevity exist for greenstriped rockfish. In an early study, the longevity of vermilion rockfish was estimated to be 22 yr (Chen 1971). More recently they have been aged as high as 43 yr (Paul Reilly, CDF&G, Monterey, CA, pers. comm.). The oldest fish reported in a study of whole vermilion rockfish otoliths was 29 yr for a 597 mm TL individual (Lea et al. 1999).

Each of these three species has varying levels of commercial and recreational fishery importance. Splitnose rockfish are primarily a commercially harvested fish with the major fishery occurring from central California northward to at least Washington; it was ranked 9th in the trawled rockfishes off the U.S. west coast in 1997 (Love 1996; Bloeser 1999). Splitnose rockfish ranked 4th in Monterey Bay, California landings, but did not place in the top ten in Morro Bay landings (Bloeser 1999). For the five major ports of the MBNMS and San Francisco, the splitnose rockfish has shown average landings of about 235.5 MT/yr, with catches declining since 1983 (Starr et al. 1998). Greenstriped rockfish are typically taken in the deep-water recreational fishery but are incidentally caught in commercial fisheries (Love 1996). This species is noted as exhibiting reductions in mean length over the period of 1950 to 1994 (Starr et al. 1998). For the five major ports of the MBNMS and San Francisco, the average number of greenstriped rockfish taken per year was 23,070 (Starr et al. 1998). Annual landings for the U.S. west coast, however, do not rank in the top ten for any fishing gear types used to harvest rockfishes (Bloeser 1999).

Vermilion rockfish are an important component of both recreational and commercial fisheries and a majority of the catch occurs south of Monterey Bay (Love 1996). These fish make up 2–4% of the total marine recreational fishery catch in areas where they are abundant (Love 1996). Landings of vermilion rockfish in the MBNMS have varied widely over the period 1980–1995 but have averaged about 67.7 MT/yr (Starr et al. 1998). For the five major ports of the MBNMS and San Francisco, the average number of vermilion rockfish taken per year was 59,490 (Starr et al. 1998).



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

The typical habitat for blue rockfish is schooling in midwater or near kelp forests, at the surface near shallow to deep reefs, where adults can range to depths of 500 m (Moser 1996). Blue rockfish appear to have a high degree of site fidelity (Lea et al. 1999), and homing ability has been demonstrated (Heilprin 1992). Primary food items are midwater organisms (Gotshall et al. 1965 from Lea et al. 1999).

Blue rockfish are viviparous with planktonic larvae and juveniles (Moser 1996). Miller and Geibel (1973) estimated that their fecundity ranges from 50,000–300,000 eggs per female per year. However, a female that measured 405 mm TL had 524,000 young (Wales 1952). Spawning (extrusion of larvae) occurs November through March with a peak in January through February (Miller and Geibel 1973; Wyllie Echeverria 1987; Moser 1996), making this one of the earliest species of rockfish larvae to be released seasonally. Larvae are released once annually (Lea et al. 1999). However, Moreno (1993) found that this species may produce multiple spawns. Larvae are about 3.5 mm at parturition (Miller and Geibel 1973), with an average planktonic duration of 129 d, as calculated from observations of nine larvae (Dave Woodbury, NOAA/NMFS, Tiburon Laboratories, CA, pers. comm.). A period of 3–5 mo was observed for pelagic juveniles to settle to the nearshore benthos (Adams and Howard 1996). Young-of-the-year (YOY) were first observed in nearshore kelp beds in May and June at 40–60 mm TL (Lea et al. 1999). In April, juveniles of about 45–50 mm TL concentrate in shallow rocky areas and in kelp canopies. By October these fish range from 65–90 mm TL (Miller and Geibel 1973). Estimated instantaneous

mortality for juveniles in their first year of life ranged from 0.001 to 0.008 (Adams and Howard 1996).

Longevity for the blue rockfish was estimated at 17 yr for males and 24 yr for females. Scales were used to estimate age, however, and no validation was performed (Miller and Geibel 1973). Growth of 0.23 to 0.35 mm/d was observed for 85 mm individuals (Miller and Geibel 1973), and mean monthly growth from tag returns on adults was 2.46 mm (Wales 1952). The smallest sexually mature male Lea et al. (1999) collected was 219 mm TL, and the largest immature male was 332 mm TL. The smallest sexually mature female was 196 mm TL, and the largest immature female was 293 mm TL. Females were estimated to attain first maturity at 4–5 yr, 50% maturity at 6 yr, and 100% maturity at 11 yr (Wales 1952; Wyllie Echeverria 1987; Bloeser 1999).

Blue rockfish are one of the most important rockfish in recreational sport fishery along the California coast. In some years, at some locations, up to 31% of all fishes taken in the marine recreational fishery were blue rockfish (Love 1996). Blue rockfish are taken on hook-and-line or while diving (Love 1996). The commercial fishery is typically small with a few exceptions (Starr et al. 1998). For the five major ports of the MBNMS and San Francisco, the blue rockfish has had variable but high landings from 1980 to 1995 (Starr et al. 1998). The calculated average number of fish taken per year was the second highest of all rockfishes at 752,000 (Starr et al. 1998). In 1996, the average price for rockfish from commercial hook-and-line landings was approximately \$0.43/kg (Bloeser 1999).

Other members of the V-group complex

All but four of the rockfishes in this group have their centers of distribution in the northern Pacific Ocean. The northernmost range of the rosy rockfish is Puget Sound, Washington, while the treefish, honeycomb, and Mexican rockfishes' northernmost range is off central California. The Mexican rockfish extends all the way into the Gulf of California. The rougheye and yelloweye rockfishes are the largest and longest living rockfishes in this group. The rougheye can attain a length of 96 cm TL and an age of 95 yr (Miller and Lea 1972; Nelson and Quinn II

1986). The yelloweye rockfish can attain a similar length of 91 cm TL and a longevity of 118 yr, one of the highest ever recorded in fishes (Kris Munk, Alaska Department of Fish and Game, Sitka, AK, pers. comm.). The rosy and honeycomb rockfishes appear to be the shortest lived (18 and 17 yr, respectively; Chen 1971) and are among the smallest (36 cm and 27 cm TL, respectively; Chen 1971) in this group. Age and longevity information is not available for the Mexican, darkblotched, pygmy, and treefish rockfishes. The most fecund species for which information was available is the yelloweye rockfish that can produce up to 2.7 million eggs (Clemens and Wilby 1961). However, there is a paucity of information for many of the remaining species regarding fecundity. The latest ages at 50% maturity belongs to the rougheyeye rockfish at 20 yr (Gunderson 1997) and the yelloweye rockfish at 18 yr (Yamanaka and Kronlund 1997). While these figures may represent the highest ages at maturity for the group, given that these two species reach the greatest length and age, there is a lack of information in this regard for several of the other long-lived group members, namely, silvergrey and darkblotched rockfishes.

Summary of Field Collections

Larvae in the blue rockfish complex showed distinct seasonal peaks in abundance at the DCP intake structure during the years 1996–1999 (**Appendix H**), with their greatest abundance tending to occur between January and March (**Figure 5.2.4-8**). Larvae in this complex appeared in the water column sooner than did those in the KGB complex. There were 2,731 larvae identified from 537 bongo net subsamples collected at the DCP intake structure between October 1996 and June 1999 representing 11% of the subsamples collected and processed from that location during that period. An El Niño that began during the spring of 1997, was detected along the coast of California in the fall of 1997 (Lynn et al. 1998; NOAA 1999), and may account for lowered density in 1998 compared with the previous season. The warm water El Niño event may also have delayed spawning slightly in 1997–98 (Woodbury and Ralston 1991). Additionally, VenTresca et al. (1995) demonstrated that blue rockfish in post- El Niño years do not have sufficient reserves to produce large amounts of young, so these years typically have low larval abundance.

Blue rockfish complex larvae generally occurred in the DCPD study grid and at the DCPD intake structure with similar seasonality (**Appendix H**), and their peak abundance occurred in January and February (**Figure 5.2.4-9**). As with the entrainment data, density appears to be depressed during the 1997–98 El Niño relative to density estimates from 1999. There were 2,965 larvae identified from 792 bongo net subsamples representing 26% of the study grid subsamples collected and processed from July 1997–June 1999. Mean density in the peak season of blue rockfish complex larval abundance appears to be greater during the Winter/Spring of 1996–97 than that measured during 1997–98 (the El Niño year).

Standard lengths of all blue rockfish complex larvae collected from the DCPD intake structure between October 1996 and June 1999 and measured (2,407 larvae) ranged from a minimum of 1.7 mm to a maximum of 8.9 mm (**Figure 5.2.4-10**). The central 98% of this length-frequency distribution yielded a truncated distribution with minimum and maximum lengths for the analyses of 2.7 mm and 4.5 mm, respectively. The mean larval length in this distribution was 3.6 mm. The growth rate applied to the blue rockfish complex (0.14 mm/d) derived for brown rockfish from Yoklavich et al. (1996) and reported in Love and Johnson (1999) was used to estimate ages of entrained larvae. Assuming that the shortest larva of the central 98% of the length-frequency distribution were immediately post-extrusion and aged zero days, the estimated ages of larvae entrained could range from zero days up to 44 d post-extrusion for the largest larva measured. The average estimated age of blue rockfish larvae entrained at DCPD was 6 d post-extrusion.

Significant differences were detected when comparing mean larval lengths (t -test: $p < 0.001$) and length-frequency distributions (Kolmogorov-Smirnov test: $p < 0.001$) of blue rockfish complex larvae from the DCPD intake structure and study grid despite the apparent similarity of the distributions in the two locations (**Figure 5.2.4-11**). It is likely that the large number of individuals measured and tested with the t -test led to the ability of the statistical test to detect a difference between the two means of 3.6 mm at the intake structure and 3.5 mm from the study grid. The maximum difference between the two distributions measured by the Kolmogorov-Smirnov test occurred at 3.9 mm and indicated that more smaller individuals were found in the grid than at the intake structure, confirming the result of the t -test. While slight differences were

detected as statistically significant, it appears that the larvae found in these two locations were from very similarly structured populations.

Reported extrusion size for species in this complex ranges from 3.8–5.2 mm (Moser 1996). The fact that we observed some larvae smaller than the reported extrusion lengths can be explained partly by natural variation of extrusion lengths within the population and partly by the phenomenon of shrinkage following preservation (Theilacker 1980). If all larvae less than 5.2 mm were assumed to be aged-0 d, then the present \widehat{P}_M will be an underestimate of the probability of entrainment since larval duration could have been overestimated by approximately 17 d.

Estimating Total Annual Entrainment

Annual estimates at DCPD of the number of entrained larvae from the blue rockfish complex were greatest during 1996–97 Analysis Period 1 ($\widehat{E}_T = 49,700,000$) when compared to 1997–98 Analysis Period 2 ($\widehat{E}_T = 5,410,000$) (Table 5.2.4-11). In contrast to the relative similarity among annual estimates of entrained KGB rockfish larvae, there was a large difference between the sampling years for larvae of fishes in the blue rockfish complex. Non-overlapping 95% confidence intervals approximated by $2 \cdot \widehat{SE}(\widehat{E}_T)$ indicated that these differences were probably statistically significant. The second year of sampling, when entrained numbers of larvae from the blue rockfish complex were lower, was during the El Niño event. This climatological and oceanographic event could have had an effect on the reproductive output of rockfishes in this complex.

Annual estimates of the number of blue rockfish complex larvae entrained were adjusted (Table 5.2.4-12) to a long-term mean based on annual indices using weekly Intake Cove surface plankton tows (Figure 5.2.4-12). The average indices for the years 1997 and 1998 (I_i) were 0.0181 and 0.0049 larvae/m³, respectively, while the long-term average index (\bar{I}) was 0.0307 larvae/m³ for the years 1990–1998. The ratio combining these values (\bar{I}/I_i) yielded the correction factor used to adjust the annual entrainment estimates to the long-term average. These

factors were 1.69 for 1997 and 6.26 for 1998. Numbers of entrained larvae for each of the analysis periods were increased by these corrections, indicating that larval abundance of the blue rockfish complex was below the long-term average during both sampling years. Non-overlapping 95% confidence intervals approximated by $2 \cdot \widehat{SE}(\hat{E}_{Adj-T})$ indicated that the differences between the point estimates for 1996–97 Analysis Period 1 ($\hat{E}_{Adj-T} = 84,000,000$) and 1997–98 Analysis Period 2 ($\hat{E}_{Adj-T} = 33,800,000$) were statistically significant even after the adjustment.

Fecundity Hindcasting (FH)

The parameters required for the formulation of *FH* estimates for the blue rockfish complex were compiled from references on different species within the group. Rockfishes within this group spawn once or twice per year. From multiple references on fecundity for various species within the complex, an annual fecundity estimate of 508,607 eggs per female, with assumed CV=100%, was used to calculate *FH* (Wales 1952: 524,000; Phillips 1964: 14,400–303,700 and 3,300–1,625,600; Miller and Geibel 1973: 50,000–300,000, and 524,000; MacGregor 1970: 69,599; Love et al. 1990: 158,915–2,683,768; Haldorsen and Love 1991: 26,000–344,000). For blue rockfish complex fishes, longevity estimates of 24.7 yr and age at maturation of 6 yr were used in *FH* calculations (longevity- Chen 1971: 22 yr; Miller and Geibel 1973: 24 yr; Love et al. 1990: 28 yr; Age at 50% maturity - Wyllie Echeverria 1987: 6 yr; Bloeser 1999: 6 yr; Lea et al. 1999: 6 yr). Larval survivorship was estimated from extrusion to entrainment using an instantaneous blue rockfish larval mortality of 0.14/d (Mary Yoklavich, NOAA/NMFS/PFEG, Pacific Grove, CA, pers. comm.), over 6.43 d based upon the minimum 1% larval length and mean larval length of 2.7 to 3.6 mm and a larval brown rockfish growth rate of 0.14 mm/d (Yoklavich et al. 1996; Love and Johnson 1999):

$$\hat{S}_{larvae} = e^{(-0.14)(6.43)} = 0.407 .$$

The estimated number of adult blue rockfish complex females (\widehat{FH}) whose reproductive output was equivalent to the adjusted number of larvae entrained per year at DCPD ranged from 43 in 1996–97 to ca. 20 in 1997–98 (Table 5.2.4-13). The reduction in the number of adult females

estimated from the second sampling season reflects the lowered larval abundance during this time period. These fairly low values also reflected the relatively high fecundity of the adults and the young average entrainment age for the larvae from this complex.

Sensitivity Analysis

Fecundity and larval survival had the greatest leverage on recalculated values of \widehat{FH} (Table 5.2.4-14). Varying fecundity or larval survival in the model resulted in an \widehat{FH} range of ca. 3–225 adult females, compared to the original estimate of 18–43 adult females. Longevity had the next greatest amount of leverage on recalculated \widehat{FH} , while varying either entrainment or maturation had no effect on \widehat{FH} .

Adult Equivalent Loss (AEL)

The parameters used to formulate *AEL* estimates for the blue rockfish complex were survival estimates for the blue rockfish (Table 5.2.4-15). Early mortality was provided by Mary Yoklavich (NOAA/NMFS/PFEG, Pacific Grove, CA, pers. comm.) for 6.43 to 20 d ($Z=0.14/d$), 20 to 60 d ($Z=0.8/d$), 60 to 80 d ($Z=0.04/d$), 180 to 365 d ($Z=0.0112/d$). The survival rate from entrainment of the larval stage to recruitment into the fishery also included a fifth stage prior to recruitment into the fishery ($Z=0.000548/d$). Survivorship, to an assumed age at recruitment into the fishery of three years, was apportioned into these stages, and *AEL* was calculated assuming the entrainment of a single age class having the average age of recruitment.

Estimated numbers of equivalent adults of the blue rockfish complex decreased by more than half between the 1996–97 analysis period (353 adults) and the 1997–98 analysis period (164 adults: Table 5.2.4-16). These values directly reflect the changing abundance of larvae during this time. Despite the large differences in the estimates of larvae for the blue rockfish complex between these two periods (Table 5.2.4-11), the relatively small difference in estimated adults may indicate that year-to-year recruitment may be less variable.

Sensitivity Analysis

Larval and juvenile survivorship had the greatest leverage on recalculated values of \widehat{AEL} (Table 5.2.4-17). Varying these parameters in the model resulted in an \widehat{AEL} range of 27–1,830 adult equivalents, compared to the original estimate of 142–353 adult equivalents. Pre-recruit survivorship had the next greatest leverage on estimates of \widehat{AEL} . Varying the estimate of entrainment did not substantially change the original value of calculated \widehat{AEL} .

Empirical Transport Model (ETM)

The lengths of entrained blue rockfish complex larvae, excluding the largest 1% and smallest 1% of all measurements, ranged from 2.7 to 4.5 mm. Thus, larvae from the central 98% of the length-frequency distribution may have been susceptible to entrainment for approximately 12.8 d based on a growth rate for brown rockfish of 0.14 mm/d (Love and Johnson 1999; Yoklavich et al. 1996). On average, entrained blue rockfish complex larvae were ca. 6.4 d old.

Monthly estimates of proportional entrainment (PE_i) in each i th survey ranged from a minimum of zero to a maximum of 0.037 ± 0.022 ($\pm 1 SE(\widehat{PE}_i)$) in April 1999 (Table 5.2.4-18). When both \widehat{PE}_i and the annual proportion of larvae extruded in the i th survey period (\hat{f}_i) were equal to zero, no larvae were collected at either the DCP intake structure or from the study grid. When $\widehat{PE}_i = 0$ but $\hat{f}_i > 0$, larvae were collected at the DCP intake structure during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. The highest \widehat{PE}_i values occurred in April of both years which typically had the higher associated \hat{f}_i values. The next highest \widehat{PE}_i 's occurred in January or February. This latter time frame corresponds to the expected parturition for blue rockfish (Wyllie Echeverria 1987; Moser 1996), but a peak later in the year also contained blue rockfish larvae (Appendix J).

Due to the broad dispersion of blue rockfish complex larvae across the study grid (Figure 5.2.4-9), P_s for this complex was calculated using both alongshore and onshore current movement. Current speed and direction measured at the single current meter near DCP were used to extend the estimates of P_s beyond the bounds of the study grid. Abundance of blue rockfish complex larvae within the study grid was extended alongshore on the basis of current

speed and direction constrained by average and maximum estimates of larval duration and the width of the study grid perpendicular to the shore. The pattern of larval blue rockfish complex abundance within the study grid was extrapolated offshore using onshore current movement inferred from the current meter. The offshore extrapolation of abundance was also modeled on the basis of mean and maximum estimated larval durations to yield a range of possible entrainment probability values.

Total entrainment mortality probability (\widehat{P}_M) was calculated for estimated average and maximum larval duration based on current speed and direction measured at the single current meter (**Figure 5.2.4-13**). There were large differences for \widehat{P}_M between the two analysis periods, but little change in \widehat{P}_M when varying larval duration within an analysis period. Estimates of \widehat{P}_M using alongshore current movement only varied from ~0.004 (both mean and maximum durations) in the 1997–1998 analysis period to ~0.05 during 1998–1999. When both alongshore and onshore currents were considered, \widehat{P}_M ranged from ~0.001 in the 1997–1998 analysis period regardless of duration to 0.02 for mean duration and 0.004 for maximum duration in the 1998–1999 analysis period. Blue rockfish complex larvae were in much greater abundance in both entrainment and study grid subsamples during 1998–1999 when compared to 1997–1998. El Niño conditions may have contributed to the reduced numbers of larvae during 1997–1998.

Interpretation of Assessment Results

Fishes in the blue rockfish complex have both commercial and recreational fishery value and can be relatively abundant in both larval and YOY surveys near DCP (Figure 5.2.4-14). These data can be compared with local fishery catch trends from the Morro Bay area to determine if there are any concurrent trends in these two indices of rockfish abundance (Figure 5.2.4-14). The probable effect on fisheries is likely localized to the ports within the Morro Bay area since most fishes in this complex demonstrate high site fidelity (Heilprin 1992), and, in general, most local catches are landed locally. Long-term subtidal fish observations at Diablo Canyon's South Control site (Tenera 1997c) show *Sebastes* spp. V group abundance characterized by periods of stability (e.g., 1980–1990) punctuated by rapid changes (e.g., 1991–1993) again followed by a period of stability (1993–1998). The overall trend from 1978–1998 appears to be one of declining abundance. Similar trends were also observed in the Intake Cove plankton tow data (Figure 5.2.4-12). Local catch records from Morro Bay area ports also show a generally decreasing trend in landings since 1993. While there is a possibility that larval entrainment losses at DCP play a part in these declines, it seems more likely, based on the estimates of equivalent adult losses and annual entrainment probabilities for this complex, that general declines in northerly distributed species (e.g., blue rockfish) are attributed to a climate regime shift that began in the late 1970's as noted by Holbrook et. al. (1997).

In 1999, 14.6 MT of blue rockfish (*Sebastes mystinus*), greenstriped rockfish (*S. elongatus*), treefish (*S. serripes*), vermilion rockfish (*S. miniatus*), and yelloweye rockfish (*S. ruberimus*) represented an ex-vessel revenue of \$61,500 landed in the Morro Bay area. Blue and vermilion rockfish represented the majority of the catch by weight and also produced most of the revenue. Vermilion and blue rockfish accounted for 70% of the individuals captured in the southern California recreational fishery in 1998 (PSMFC PacFin Database).

The estimates of *AEL* (142–353 fish) represent the estimated loss of 3 yr old fish to the population. Converting these adult equivalents to direct losses from a fishery requires assumptions of 100% catchability of the individuals and no compensatory mortality. Both of

these assumptions will lead to an overestimate of the loss to the fishery. Using an estimate of the weight per adult blue rockfish in the fishery of 0.5 kg, we can estimate that 343 adults represent 172 kg of 3 yr old recruits that represent ca. 1% of the catch landed in the Morro Bay area in 1999. This 172 kg of biomass potentially lost to the fishery could have been worth approximately \$740 in 1999 based on the average ex-vessel price paid in Morro Bay for blue, greenstriped, vermilion, and yelloweye rockfishes, as well as treefish.

Fecundity hindcast estimates can also be aligned to the age at recruitment used in *AEL* calculations. This is accomplished by hindcasting the number of females aged 12.2 yr (i.e., one third of the duration between maturity and longevity) to the age of *AEL* recruits (3 yr). The estimates of *FH* from the three analysis periods ranged from 18–43 adult females aged 12.2 yr. Using an instantaneous natural mortality rate ($Z=0.000548/d$), the relationship $2FH \equiv AEL$ yields 114–273 three year-old recruits. This aligned estimate, when compared with the *AEL* estimate above (142–353), is similar and confirms the validity of the parameter estimates used in both *FH* and *AEL* estimates.

Alternately, estimates of proportional larval entrainment mortality to the local area can be converted to proportionate losses to local fisheries assuming no compensatory mortality. Entrainment effects (\widehat{P}_M) ranged over extrapolated areas from 4–6 times and 17–21 times the study grid area, using mean and maximum larval durations, respectively, as the time over which current flows were measured. These extrapolations resulted in \widehat{P}_M estimates that ranged from around 0.001 to 0.02. This range of proportional loss, applied to the 1999 ex-vessel revenue from Morro Bay area ports (\$61,500) could represent between \$62–1,230 during that year.

Table 5.2.4-1. Pigment groups, parturition peak periods (PPM), and seasonality of preflexion *Sebastes* spp. larvae from Nishimoto (in prep.).

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	SUBGENUS	'77-'84 PPM	Parturition period N and C CA (Wyllie Echeverria 1987)
V_P	Long ventral series, no dorsal, pectoral pigment				
	<i>S. chlorostictus</i>	greenspotted	Sebastes	?	Apr-Sep
	<i>S. ensifer</i>	swordspine	Sebastes	?	Uncommon in central CA (Miller and Lea 1972)
V_D	Long ventral series, short dorsal series, no pectoral pigment				
	<i>S. saxicola</i>	stripetail	Allosebastes	Jan	Jan-Mar (Nov-Mar, Phillips 1964)
V_D_	Long ventral series, short dorsal series, no pectoral pigment				
	<i>S. atrovirens</i>	kelp	Mebarus	ND	ND
	<i>S. chrysomelas</i>	black and yellow	Pteropodus	Feb	Feb-Mar (Jan-May (Larson 1980))
	<i>S. maliger</i>	quillback	Pteropodus	Apr	Apr-July
	<i>S. nebulosus</i>	China	Pteropodus	?	?
	<i>S. semicinctus</i>	halfbanded	Allosebastes	ND	Jan-Apr for southern CA (Love et al. 1990)
V_De	Long ventral series, elongating dorsal series, pectoral pigment				
or	<i>S. auriculatus</i>	brown	Auctospina	June	Dec-Jan, principally May-July (May, Larson 1980)
V_DeP	<i>S. carnatus</i>	gopher	Pteropodus	Mar	Mar-May (May, Larson 1980)
or	<i>S. caurinus</i>	copper	Pteropodus	Feb	Feb
V_dep	<i>S. dalli</i>	calico	Allosebastes	?	Uncommon in central CA (Miller and Lea 1972)
	<i>S. rastrelliger</i>	grass	Pteropodus	ND	ND

Table 5.2.4-1. (continued). Pigment groups, parturition peak periods (PPM), and seasonality of preflexion *Sebastes* spp. larvae from Nishimoto (in prep.).

LETTER CODE	SPECIES	COMMON NAME	SUBGENUS	'77-'84 PPM	Parturition period N and C CA (Wyllie Echeverria 1987)
V	Short ventral series, no dorsal series, no pectoral				
	<i>S. aleutianus</i>	roughey	Zalopyr	ND	
	<i>S. alutus</i>	POP	Acutomentum	Mar	Jan-Mar (?)
	<i>S. brevispinis</i>	silvergry	Acutomentum	ND	
	<i>S. crameri</i>	darkblotched	Eosebastes	Jan	Nov-Mar (Nov-Mar, Larson 1980)
	<i>S. diploproa</i>	splitnose	Allosebastes	July	Jan-Sep (Feb-July, Phillips 1964)
	<i>S. elongatus</i>	greenstriped	Hispaniscus	May	May-July
	<i>S. macdonaldi</i>	Mexican	Acutomentum	ND	
	<i>S. miniatus</i>	vermilion	Rosicola	Sep	Sep (Nov, Moser 196; Nov-Mar, Phillips 1964)
	<i>S. nigrocinctus</i>	tiger	Sebastichtys	ND	
	<i>S. proriger</i>	redstripe	Allosebastes	?	July-Aug
	<i>S. rosaceus</i>	rosy	Sebastomus	June	Apr-July
	<i>S. ruberrimus</i>	yelloweye	Sebastopyr	June	Apr-July (?)
	<i>S. serriceps</i>	treefish	Sebastocarus	ND	
	<i>S. umbrosus</i>	honeycomb	Sebastomus	ND	ND
	<i>S. wilsoni</i>	pygmy	Acutomentum	ND	
	<i>S. zacentrus</i>	sharpchin	Allosebastes	?	May-June
VP	Short ventral series, no dorsal series, various patterns of pectoral pigmentation				
	(At smaller size might fit into group V above)				
	<i>S. constellatus</i>	starry	Sebastodes	Apr	Apr-May
	<i>S. eos</i>	pink	Sebastomus	ND	ND
	<i>S. goodei</i>	chilipepper	Sebastodes	Jan	Nov-June (Nov-Mar, Phillips 1964)
	<i>S. helvomaculatus</i>	rosethorn	Sebastomus	?	May-June
	<i>S. levis</i>	cowcod	Hispaniscus	Dec	Dec-Feb
	<i>S. melanostomus</i>	blackgill	Eosebastes	Feb	Feb-Apr
	<i>S. paucispinis</i>	bocaccio	Sebastodes	Feb	Jan-May (Nov-Mar, Moser 1967)
	<i>S. rosenblatti</i>	greenblotched	Sebastomus	ND	ND
	<i>S. rubrivinctus</i>	flag	Hispaniscus	?	July
Vdp	Short ventral series, develops dorsal series, develops various patterns of pectoral pigmentation				
	(At stage 1-2 can confuse with VP above due to lack of dorsal pigmentation.)				
	<i>S. entomelas</i>	widow	Acutomentum	Feb	Dec-Apr (Nov-Mar, Phillips 1964)
	<i>S. flavidus</i>	yellowtail	Sebastosomus	Feb	Jan-July (Nov-Mar, Phillips 1964)
	<i>S. melanops</i>	black	Sebastosomus	Feb	Jan-May
	<i>S. mystinus</i>	blue	Sebastosomus	Jan	Nov-Jan (Nov-Jan, Wales 1952)
	<i>S. rufus</i>	bank	Acutomentum	Feb	Dec-May
	<i>S. serranoides</i>	olive	Sebastosomus	Feb	Jan-Mar
VD	Short ventral series, short dorsal series				
	<i>S. aurora</i>	aurora	Eosebastes	Apr	Mar-May
	<i>S. babcocki</i>	redbanded	Rosicola	May	May
	<i>S. gilli</i>	bronzespotted	Sebastosomus	?	Uncommon in central CA (Miller and Lea 1972)
	<i>S. hopkinsi</i>	squarespot	Acutomentum	Mar	Feb-Mar
	<i>S. jordani</i>	shortbelly	Sebastodes	Feb	Feb-Apr (Nov-Apr, Phillips 1964)
	<i>S. ovalis</i>	speckled	Acutomentum	May	May
	<i>S. pinniger</i>	canary	Rosicola	Dec	Dec-Mar (Nov-Mar, Moser 1967)
Species without descriptions or illustrations					
	<i>S. phillipsi</i>	chameleon	?	?	Uncommon in central CA (Miller and Lea 1972)

Table 5.2.4-2. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for KGB rockfish larvae (*Sebastes* spp. V_De/V_D_) from three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	268,000,000	24,000,000
2) Oct 1, 1997–Sep 30, 1998	199,000,000	25,900,000
3) July 1, 1997–June 30, 1998	199,000,000	25,900,000

Table 5.2.4-3. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for KGB rockfish larvae (*Sebastes* spp. V_De/V_D_) from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	275,000,000	24,700,000
2) Oct 1, 1997–Sep 30, 1998	222,000,000	28,900,000
3) July 1, 1997–June 30, 1998	222,000,000	28,900,000

Table 5.2.4-4. Age at sexual maturation and longevity (years) for three rockfish species within the KGB complex.

Rockfish species	Maturation age	Longevity
kelp	5 yr ⁴	15 yr ^{1,4,5}
	4-5 yr ³	
black and yellow	3-4 yr ²	15 yr ¹
	6 yr ⁴	
gopher	4 yr ²	
	9 yr ⁴	

¹Burge and Schultz 1973

²Wyllie Echeverria 1987

³Bloeser 1999

⁴Lea et al. 1999

⁵Ralph Larson, CSU San Francisco, personal communication

Table 5.2.4-5. Estimated number of adult KGB rockfish (*Sebastes* spp. V_De/V_D_) females (\widehat{FH}) whose reproductive output was equivalent to the adjusted number of larvae entrained per year (\widehat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{FH})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	617	1,470	31,500	12
2) Oct 1, 1997–Sep 30, 1998	497	1,190	25,400	10
3) Jul 1, 1997–Jun 30, 1998	497	1,190	25,400	10

Table 5.2.4-6. KGB rockfishes (*Sebastes* spp. V_De/V_D_): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 617$				
\hat{E}_{Adj-T}	275,000,000	526	708	182
\hat{S}_{larvae}	0.419	258	3,200	2,940
# Eggs/yr	213,000	119	3,200	3,080
Longevity	15	247	1,230	987
Maturation	5	493	1,230	740

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 497$				
\hat{E}_{Adj-T}	222,000,000	391	603	213
\hat{S}_{larvae}	0.419	208	2,570	2,370
# Eggs/yr	213,000	95.9	2,570	2,480
Longevity	15	199	994	795
Maturation	5	398	994	596

Table 5.2.4-6 (continued). KGB rockfishes (*Sebastes* spp. V_De/V_D_): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 497$				
\hat{E}_{Adj-T}	222,000,000	391	604	213
\hat{S} larvae	0.419	208	2,580	2,370
# Eggs/yr	213,000	96	2,580	2,480
Longevity	15	199	995	796
Maturation	5	398	995	597

Table 5.2.4-7. Three-year survival for the KGB rockfish complex larvae (*Sebastes* spp. $V_De/V_D_$), based on blue rockfish data. Survival was estimated from release as $\hat{S} = e^{(-Z)(Day(end)-Day(start))}$. Daily instantaneous mortality rates (Z) up to 1 yr of blue rockfish, *Sebastes mystinus*, larvae that were used to calculate KGB larval survivorship were provided by Mary Yoklavich (NOAA/NMFS/PFEG, Pacific Grove, CA, personal communication). Annual instantaneous mortality was assumed as 0.2/yr after 1 yr. Average age of entrainment was estimated as 6.21 d based on average size at entrainment and a growth rate of 0.14 mm/d (Yoklavich et al. 1996).

Day (start)	Day (end)	Instantaneous Natural Mortality (Z)	Survival (\hat{S})
0	6.21	0.14	0.419
6.21	20	0.14	0.145
20	60	0.08	0.041
60	180	0.04	0.008
180	365	0.0112	0.126
365	1,095	0.0006	0.670

Table 5.2.4-8. Estimated number of equivalent KGB rockfish (*Sebastes* spp. $V_De/V_D_$) adults (\widehat{AEL}) equal to the adjusted number of larvae entrained per year (\hat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{AEL})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{AEL}	$\widehat{SE}(\widehat{AEL})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	1,120	3,410	166,000	8
2) Oct 1, 1997–Sep 30, 1998	905	2,750	134,000	6
3) Jul 1, 1997–Jun 30, 1998	906	2,750	134,000	6

Table 5.2.4-9. KGB rockfishes (*Sebastes* spp. V_De/V_D_): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 1,120$				
\hat{E}_{Adj-T}	275,000,000	958	1,290	331
$\hat{S}_{early\ larvae}$	0.145	217	5,820	5,600
$\hat{S}_{late\ larvae}$	0.0408	217	5,820	5,600
$\hat{S}_{early\ juvenile}$	0.00823	217	5,820	5,600
$\hat{S}_{juv. I}$	0.125	217	5,820	5,600
$\hat{S}_{pre-recruit}$	0.670	217	1,680	1,460

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 905$				
\hat{E}_{Adj-T}	222,000,000	712	1,100	387
$\hat{S}_{early\ larvae}$	0.145	175	4,690	4,520
$\hat{S}_{late\ larvae}$	0.0408	175	4,690	4,520
$\hat{S}_{early\ juvenile}$	0.00823	175	4,690	4,520
$\hat{S}_{juv. I}$	0.125	175	4,690	4,520
$\hat{S}_{pre-recruit}$	0.670	175	1,350	1,180

Table 5.2.4-9 (continued). KGB rockfishes (*Sebastes* spp. V_De/V_D_): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ):

$\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 906$				
\hat{E}_{Adj-T}	222,000,000	712	1,100	387
$\hat{S}_{early\ larvae}$	0.145	175	4,700	4,520
$\hat{S}_{late\ larvae}$	0.0408	175	4,700	4,520
$\hat{S}_{early\ juvenile}$	0.00823	175	4,700	4,520
$\hat{S}_{juv. I}$	0.125	175	4,700	4,520
$\hat{S}_{pre-recruit}$	0.670	175	1,350	1,180

Table 5.2.4-10. KGB rockfishes (*Sebastes* spp. V_De/V_D_): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae extruded in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997 - June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.0107	0.0151	0.00257	0.000560
Aug 25, 1997	0	0	0	0
Sept 29, 1997	0	0	0	0
Oct 20, 1997	0	0	0	0
Nov 17, 1997	0	0	0	0
Dec 10, 1997	0	0	0	0
Jan 22, 1998	0.000810	0.000880	0.00122	0.000190
Feb 26, 1998	0.00207	0.00127	0.00403	0.000370
Mar 18, 1998	0.0587	0.0297	0.0816	0.00961
Apr 15, 1998	0.00762	0.00348	0.130	0.0102
May 18, 1998	0.00337	0.000760	0.487	0.0249
Jun 8, 1998	0.0353	0.00842	0.293	0.0166

b) Analysis Period 4: July 1, 1998 - June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.00330	0.00345	0.000780	0.000130
Aug 26, 1998	0	0	0	0
Sept 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0	0	0	0
Jan 12, 1999	0	0	0	0
Feb 3, 1999	0.000460	0.000460	0.000630	0.000120
Mar 17, 1999	0.0327	0.0198	0.175	0.0156
Apr 14, 1999	0.0137	0.00752	0.204	0.0154
May 24, 1999	0.0115	0.00262	0.545	0.0166
Jun 23, 1999	0.0170	0.0125	0.0754	0.00533

Table 5.2.4-11. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for larvae of the blue rockfish complex (*Sebastes* spp.V/S. *mystinus*) from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	49,700,000	7,940,000
2) Oct 1, 1997–Sep 30, 1998	5,410,000	855,000
3) Jul 1, 1997–Jun 30, 1998	6,220,000	868,000

Table 5.2.4-12. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) of blue rockfish complex larvae (*Sebastes* spp.V/S. *mystinus*) and their standard errors ($\widehat{SE}(\widehat{E}_{Adj-T})$) from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	84,040,000	13,400,000
2) Oct 1, 1997–Sep 30, 1998	33,800,000	5,350,000
3) Jul 1, 1997–Jun 30, 1998	38,900,000	5,430,000

Table 5.2.4-13. Estimated number of adult blue rockfish complex (*Sebastes* spp.V/S. *mystinus*) females (\widehat{FH}) whose reproductive output was equivalent to the adjusted number of larvae entrained per year (\widehat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{FH})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	43	97	1,700	1
2) Oct 1, 1997–Sep 30, 1998	18	39	684	0
3) Jul 1, 1997–Jun 30, 1998	20	45	787	1

Table 5.2.4-14. Blue rockfish complex (*Sebastes* spp./*S. mystinus*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 43$				
\hat{E}_{Adj-T}	84,000,000	54.9	32.0	23
\hat{S} larvae	0.407	17.7	225	208
# Eggs/yr	509,000	8.39	225	217
Longevity	24.7	18.7	86.9	68.2
Maturation	6	64.0	37.5	26.5

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 18$				
\hat{E}_{Adj-T}	33,800,000	22.1	13.0	9.10
\hat{S} larvae	0.407	7.12	90.7	83.6
# Eggs/yr	509,000	3.38	90.7	87.3
Longevity	24.7	7.54	35.0	27.5
Maturation	6	25.8	15.1	10.7

Table 5.2.4-14 (continued). Blue rockfish complex (*Sebastes* spp./*S. mystinus*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 20$				
\hat{E}_{Adj-T}	38,900,000	24.7	15.5	9.23
\hat{S} larvae	0.407	8.18	104	96.1
# Eggs/yr	509,000	3.88	104	100
Longevity	24.7	8.67	40.3	31.6
Maturation	6	29.6	17.3	12.3

Table 5.2.4-15. Three year survival for the blue rockfish complex (*Sebastes* spp. V/*S. mystinus*) larvae. Survival was estimated from release as $\hat{S} = e^{(-Z)(Day(end)-Day(start))}$. Daily instantaneous mortality rates (Z) up to 1 yr of blue rockfish, *Sebastes mystinus*, larvae that were used to calculate larval survivorship were provided by Mary Yoklavich (NOAA/NMFS/PFEG, Pacific Grove, CA, personal communication). Annual instantaneous mortality was assumed as 0.2/yr after 1 yr. Average age of entrainment was estimated as 6.43 d, based on average size at entrainment and a growth rate of 0.14 mm/d.

Day (start)	Day (end)	Instantaneous Natural Mortality (Z)	Survival (\hat{S})
0	6.43	0.14	0.4066
6.43	20	0.14	0.150
20	60	0.08	0.041
60	180	0.04	0.008
180	365	0.011	0.126
365	1,095	0.0006	0.6703

Table 5.2.4-16. Estimated number of equivalent blue rockfish complex (*Sebastes* spp. V/S. *mystinus*) adults (\widehat{AEL}) equal to the adjusted number of larvae entrained per year (\hat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{AEL})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{AEL}	$\widehat{SE}(\widehat{AEL})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	353	1,100	51,000	2
2) Oct 1, 1997–Sep 30, 1998	164	494	23,500	1
3) Jul 1, 1997–Jun 30, 1998	142	430	20,000	1

Table 5.2.4-17. Blue rockfish complex (*Sebastes* spp. V/S. *mystinus*): Sensitivity analysis of \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \cdot SE(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 353$				
\hat{E}_{Adj-T}	84,000,000	260	446	186
\hat{S} early larvae	0.150	68	1,830	1,760
\hat{S} late larvae	0.0408	68	1,830	1,760
\hat{S} early juvenile	0.00823	68	1,830	1,760
\hat{S} juv. I	0.125	68	1,830	1,760
\hat{S} pre-recruit	0.670	68	527	459

Table 5.2.4-17 (continued). Blue rockfish complex (*Sebastes* spp. V/S. *mystinus*): Sensitivity analysis of \widehat{AEL} for the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \cdot SE(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 \cdot CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

c) Analysis Period 3: July 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 164$				
\hat{E}_{Adj-T}	38,900,000	126	201	75
$\hat{S}_{early\ larvae}$	0.150	32	848	816
$\hat{S}_{late\ larvae}$	0.0408	32	848	816
$\hat{S}_{early\ juvenile}$	0.00823	32	848	816
$\hat{S}_{juv. I}$	0.125	32	848	816
$\hat{S}_{pre-recruit}$	0.670	32	244	213

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 142$				
\hat{E}_{Adj-T}	33,800,000	105	179	74
$\hat{S}_{early\ larvae}$	0.150	27	737	710
$\hat{S}_{late\ larvae}$	0.0408	27	737	710
$\hat{S}_{early\ juvenile}$	0.00823	27	737	710
$\hat{S}_{juv. I}$	0.125	27	737	710
$\hat{S}_{pre-recruit}$	0.670	27	212	185

Table 5.2.4-18. Blue rockfish complex (*Sebastes* spp./*S. mystinus*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae extruded in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997 - June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.00105	0.000510	0.127	0.0113
Aug 25, 1997	0.00125	0.000800	0.0439	0.00606
Sep 29, 1997	0	0	0	0
Oct 20, 1997	0	0	0.0129	0.00347
Nov 17, 1997	0	0	0	0
Dec 10, 1997	0	0	0	0
Jan 22, 1998	0.000770	0.000300	0.161	0.0133
Feb 26, 1998	0	0	0.151	0.0130
Mar 18, 1998	0.000900	0.000920	0.0546	0.00892
Apr 15, 1998	0.00416	0.00294	0.238	0.0281
May 18, 1998	0.000400	0.000210	0.129	0.0141
Jun 8, 1998	0.000810	0.000590	0.0826	0.0150

a) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.000420	0.000430	0.00389	0.000550
Aug 26, 1998	0	0	0	0
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0	0	0	0
Jan 12, 1999	0.00521	0.00291	0.181	0.0169
Feb 3, 1999	0.00822	0.00213	0.495	0.0209
Mar 17, 1999	0	0	0	0
Apr 14, 1999	0.0370	0.0218	0.308	0.0225
May 24, 1999	0.000590	0.000310	0.00791	0.000760
Jun 23, 1999	0.000250	0.000250	0.00352	0.000750

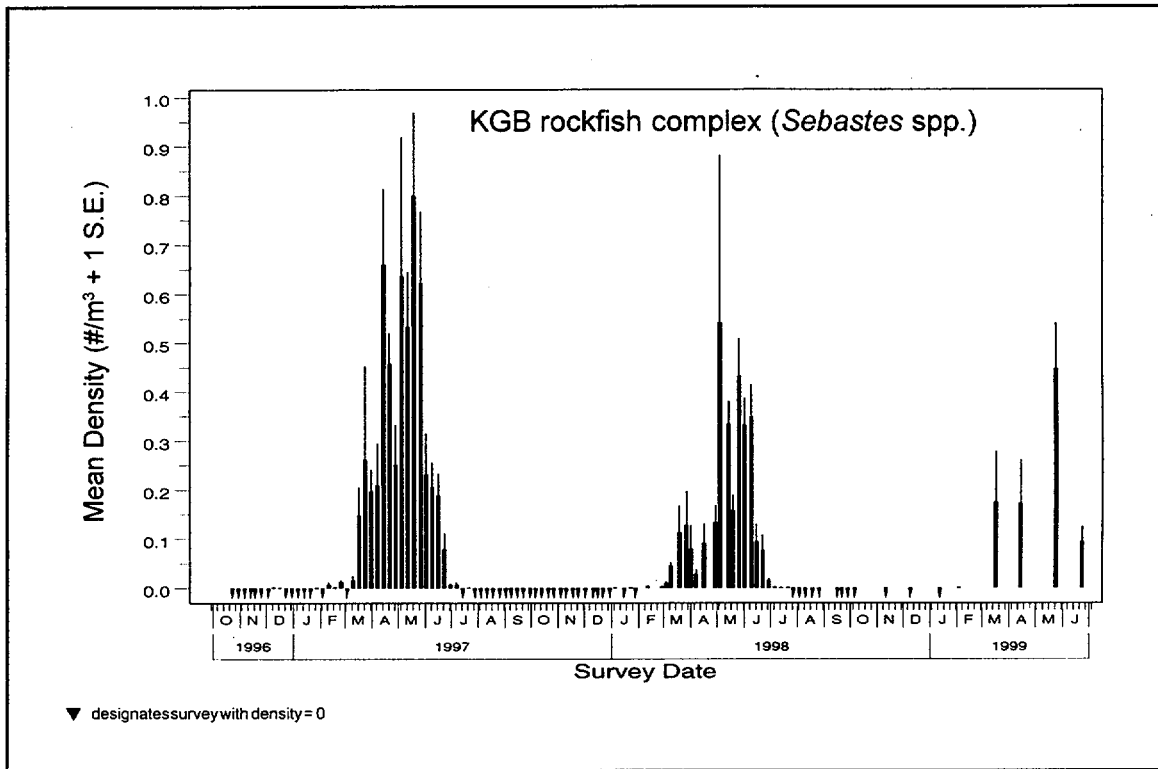


Figure 5.2.4-1. Weekly mean larval density (#/m³ + 1 S.E.) at the DCP intake.

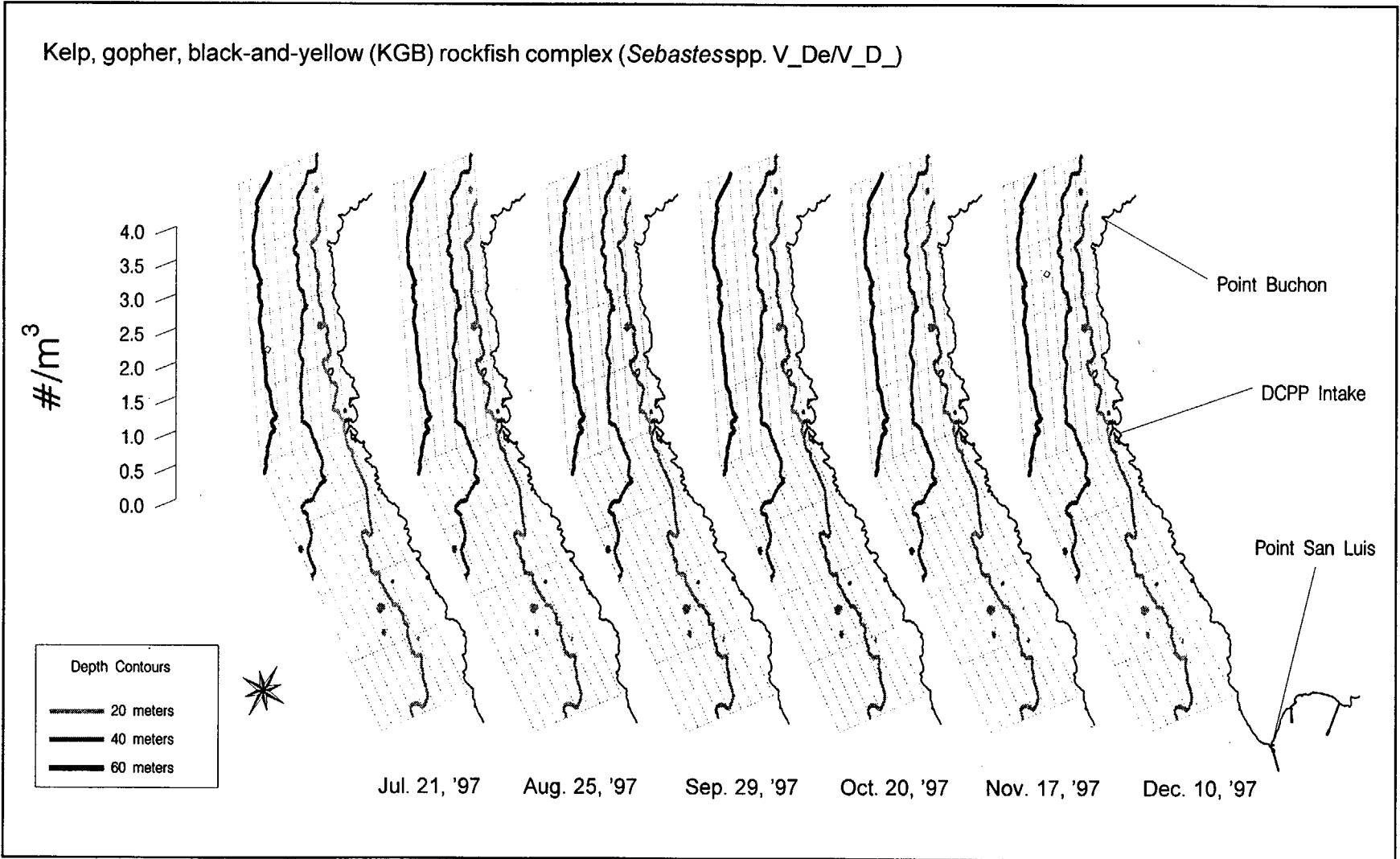


Figure 5.2.4-2a. Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

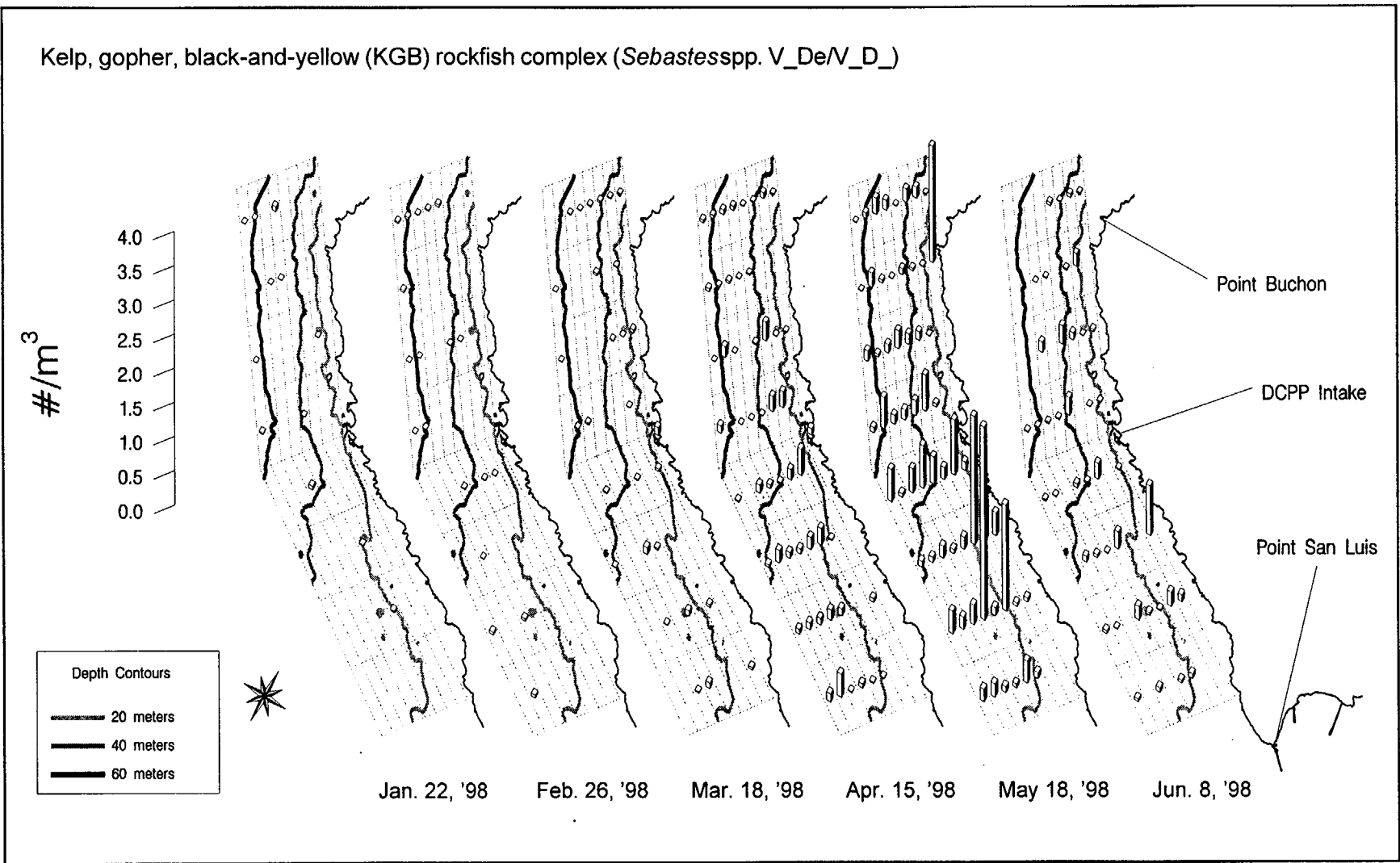


Figure 5.2.4-2b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

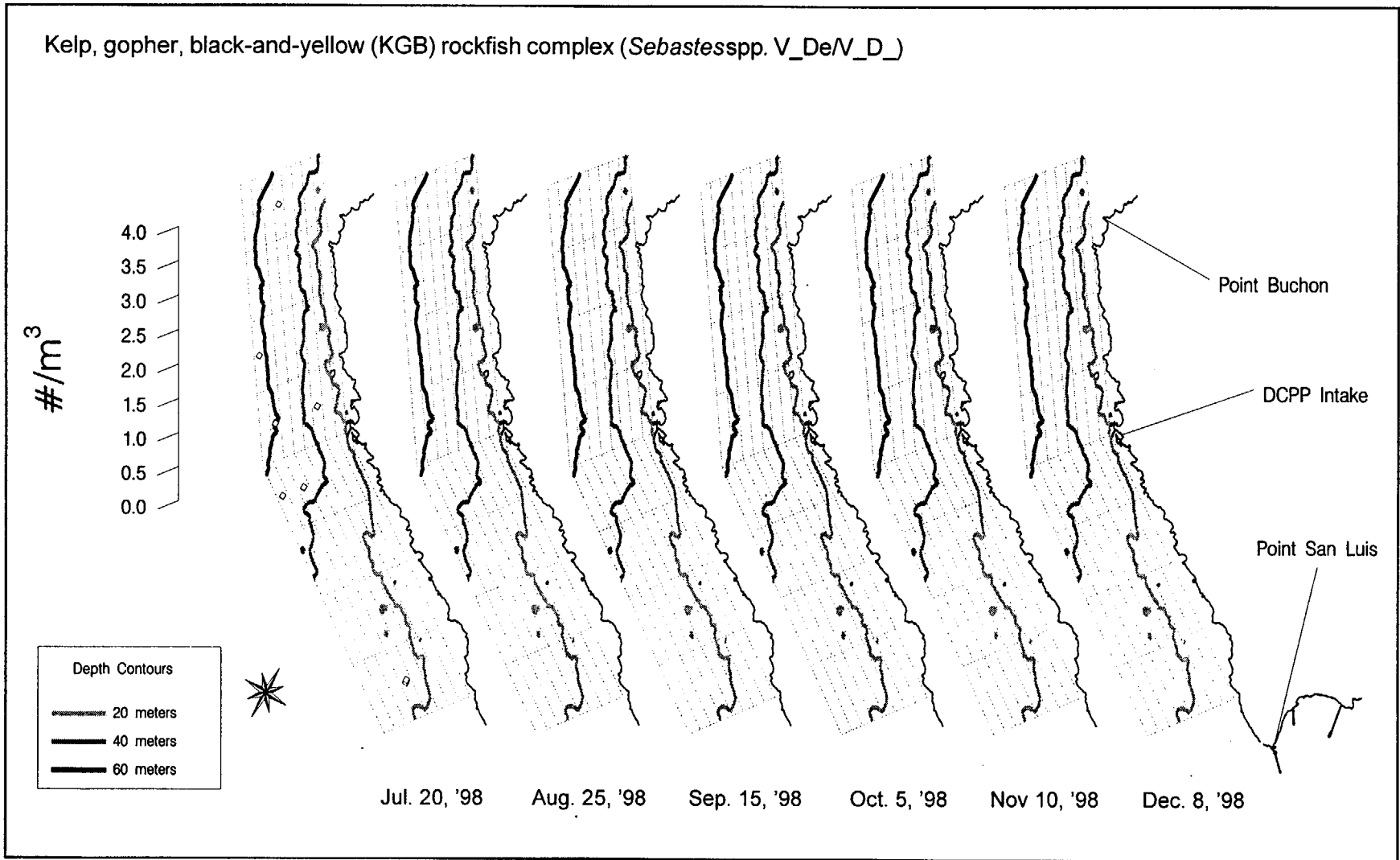


Figure 5.2.4-2c (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

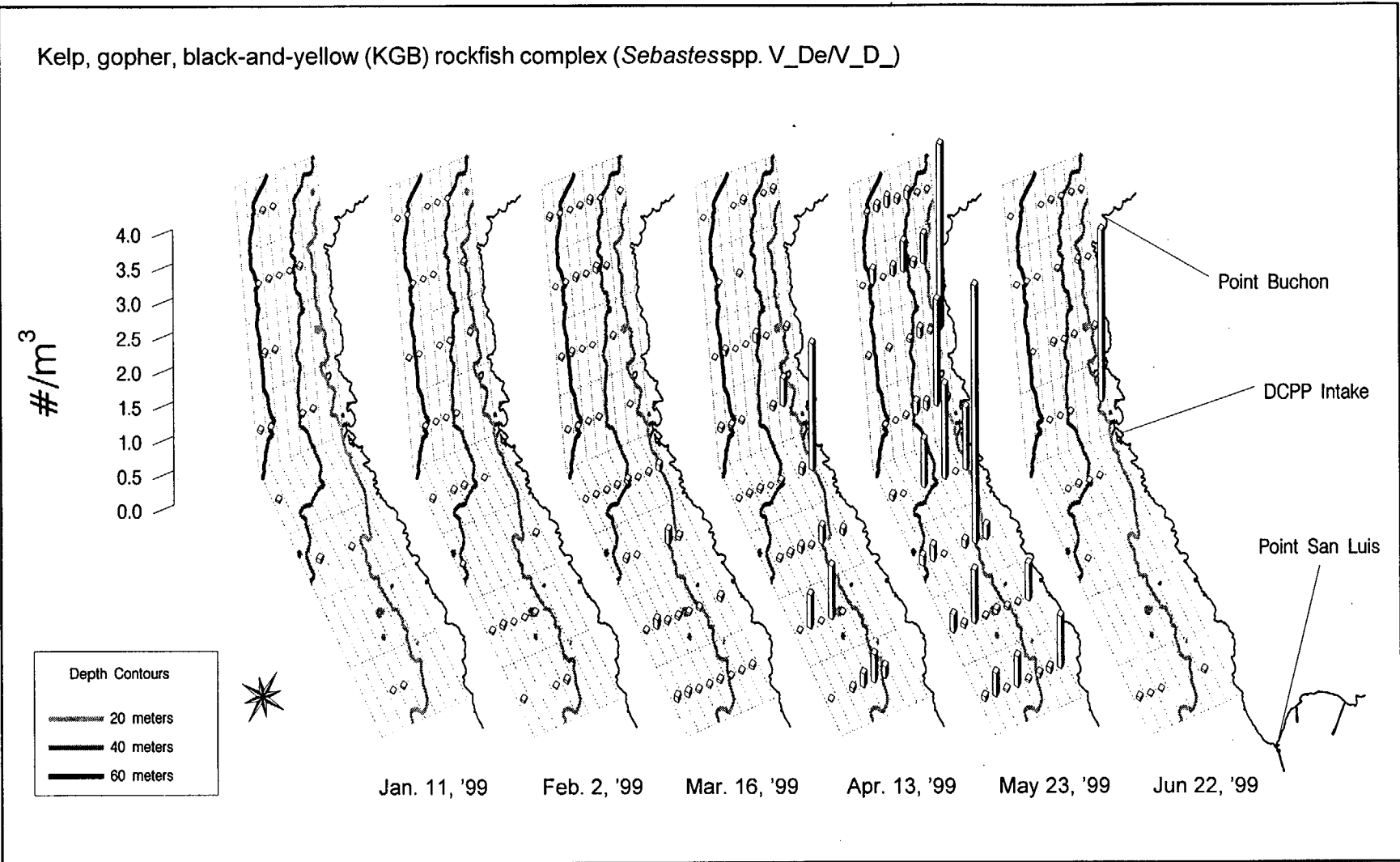


Figure 5.2.4-2d (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

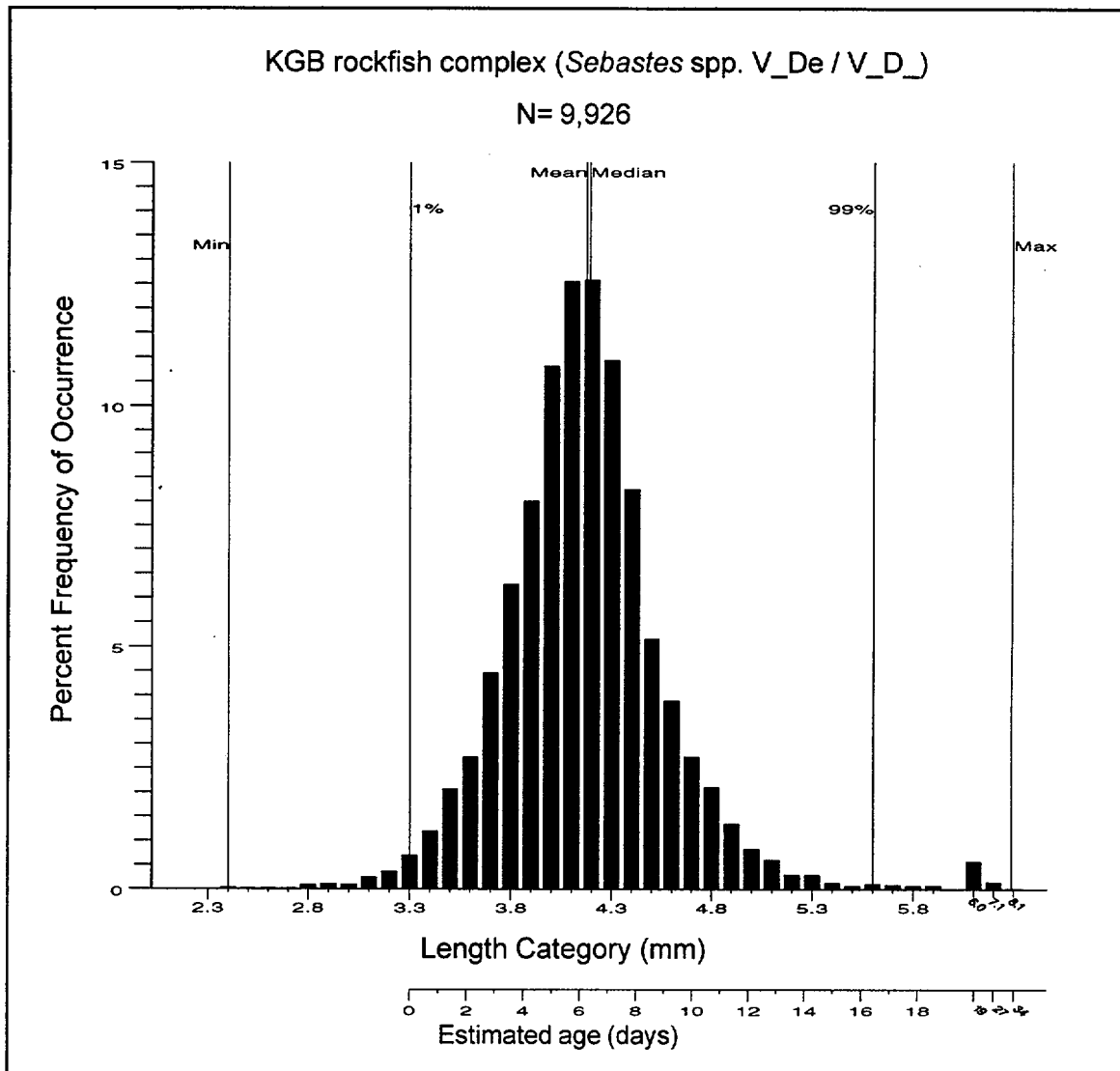


Figure 5.2.4-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

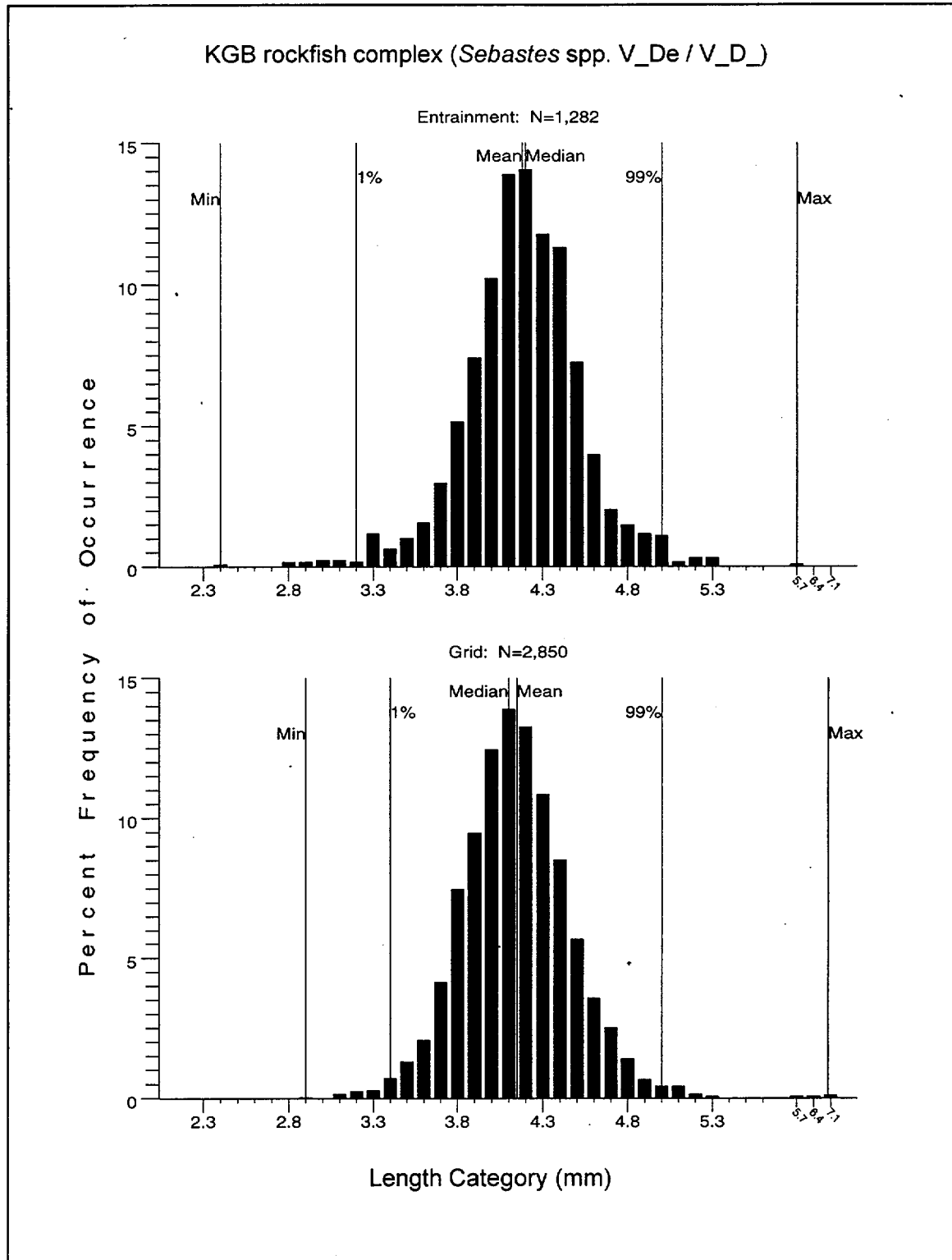


Figure 5.2.4-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

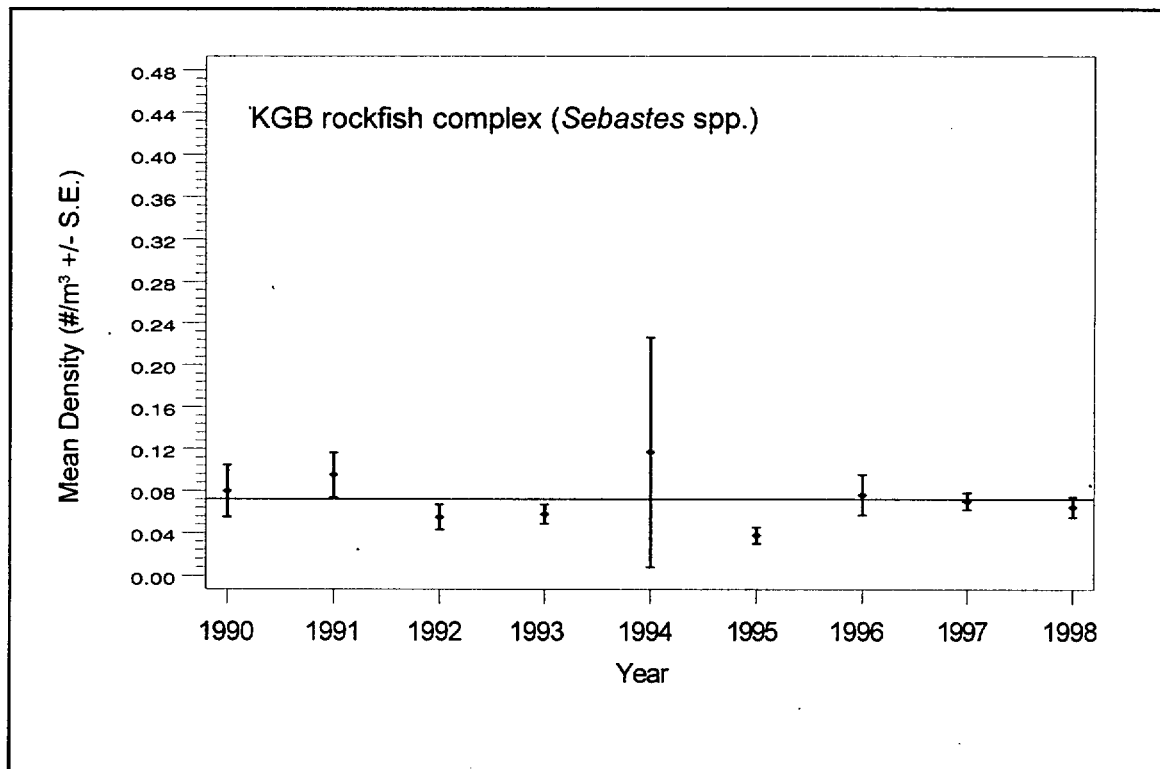


Figure 5.2.4-5. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

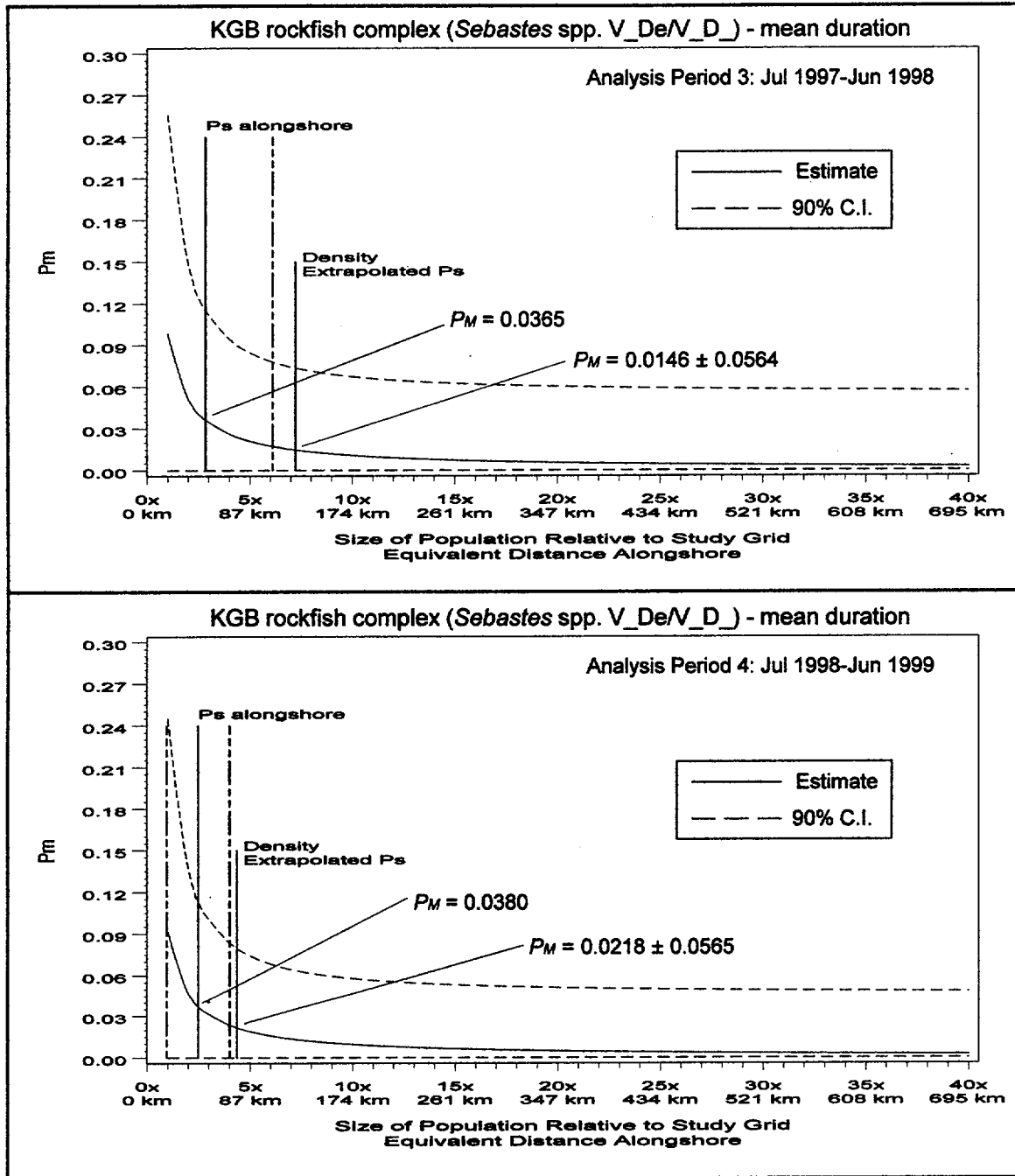


Figure 5.2.4-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

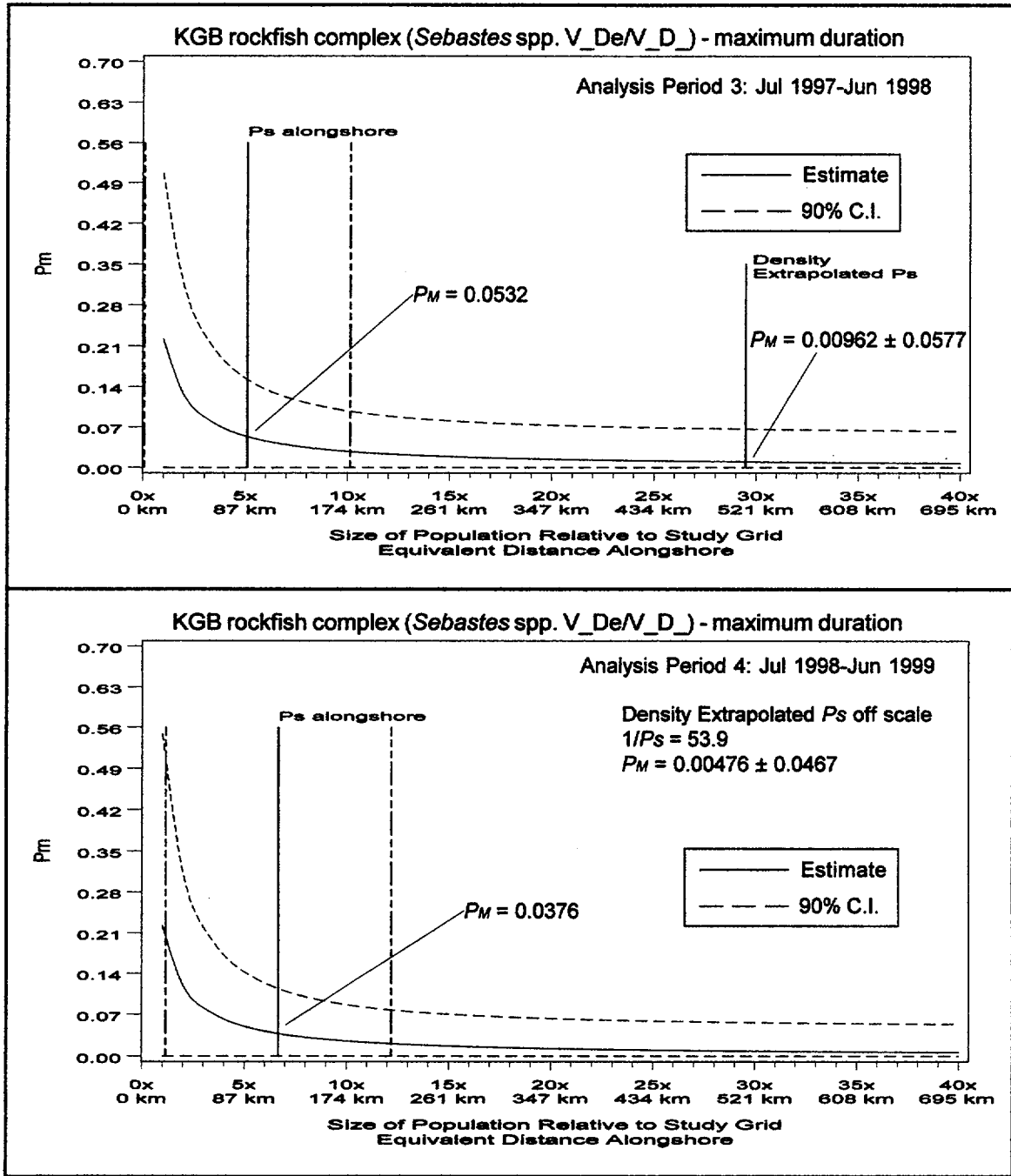


Figure 5.2.4-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

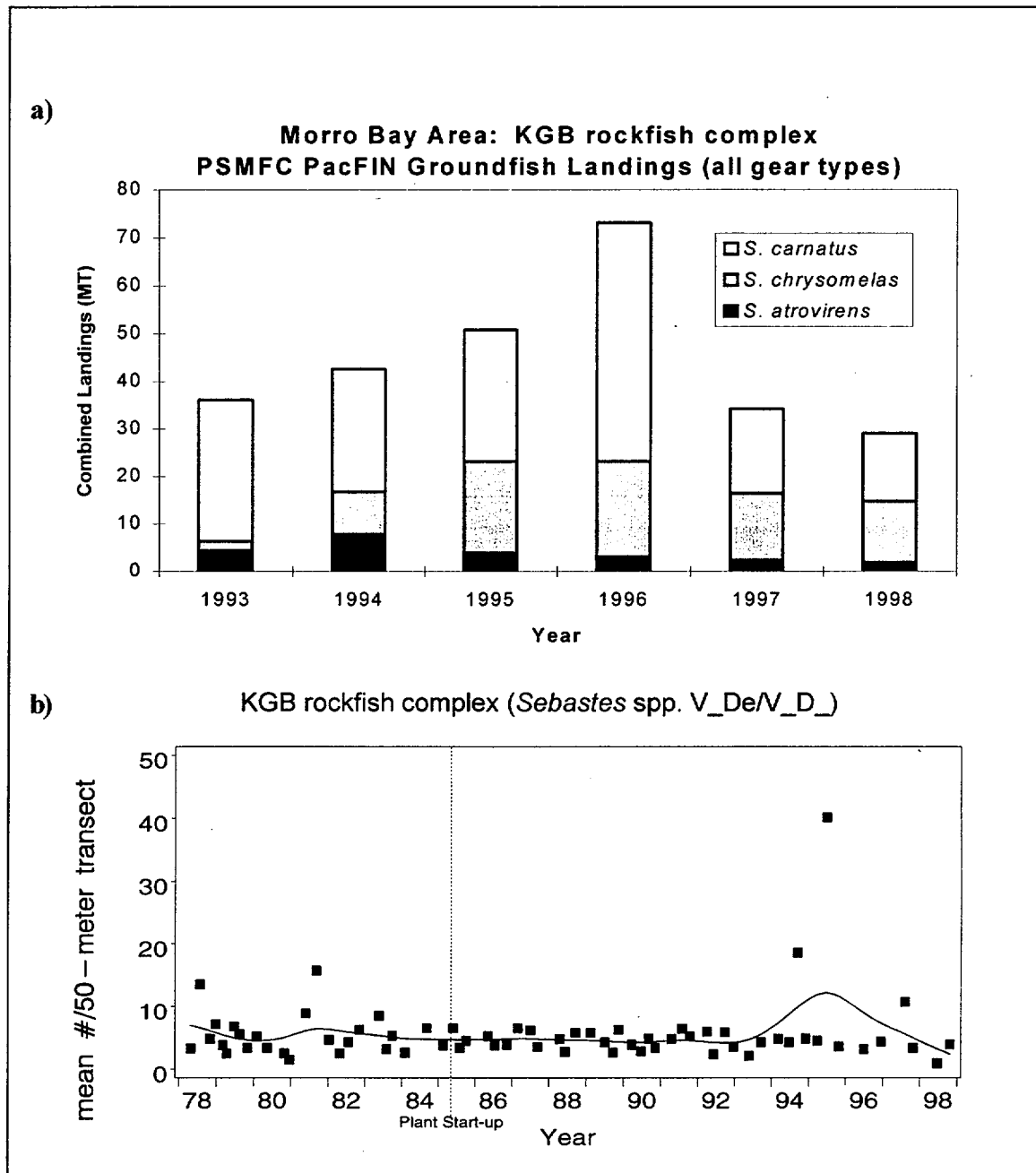


Figure 5.2.4-7. Yearly abundance of KGB rockfish complex measured by two independent methods: a) Commercial fishery landings of adults from Morro Bay area and, b) Mean number of adults and YOY observed per 50-meter subtidal benthic transect in the DCP R WMP South Control area. Spline smoothing algorithm used to fit curve through points.

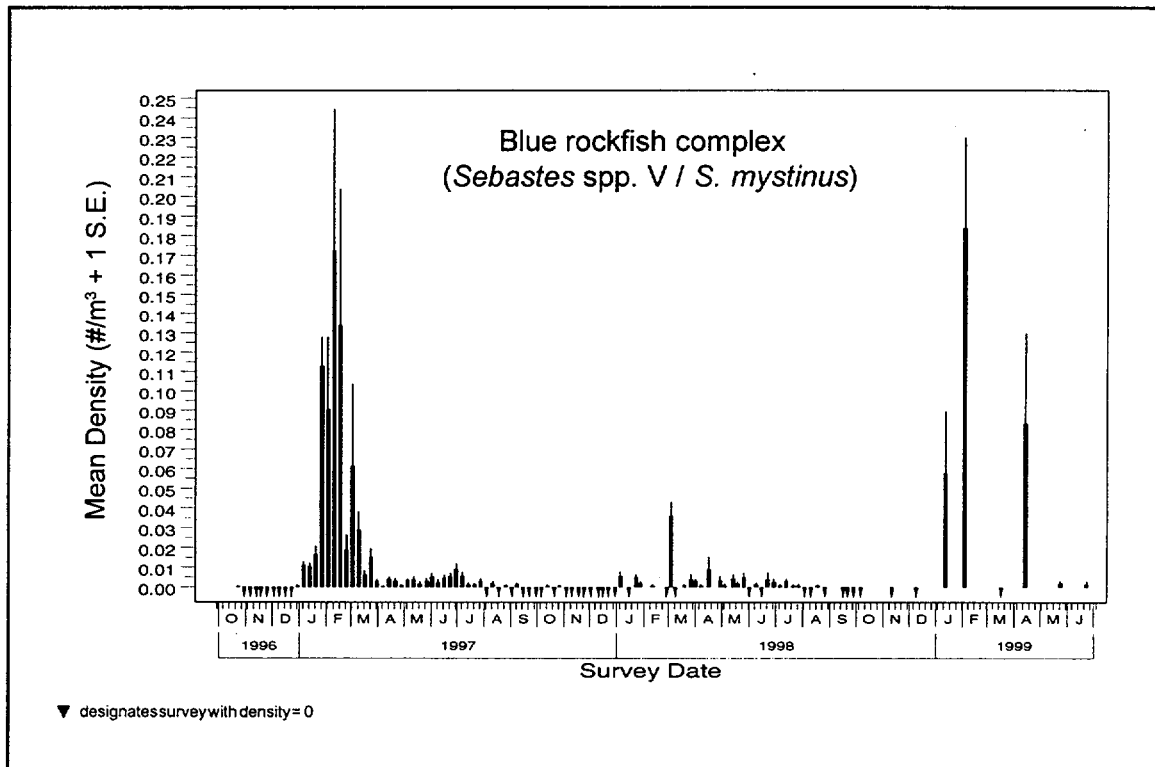


Figure 5.2.4-8. Weekly mean larval density (#/m³ + 1 S.E.) at the DCPD intake.

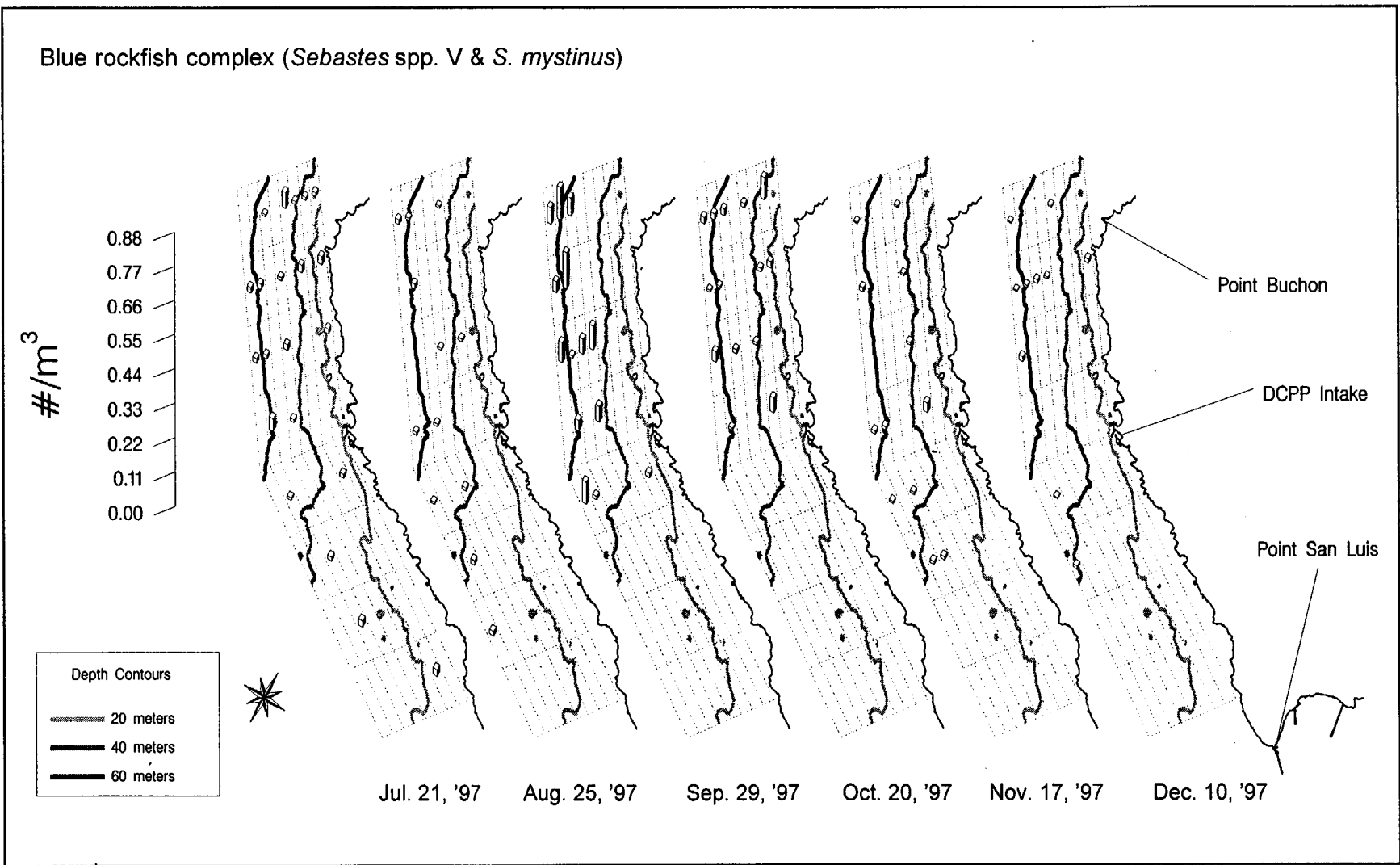


Figure 5.2.4-9a. Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

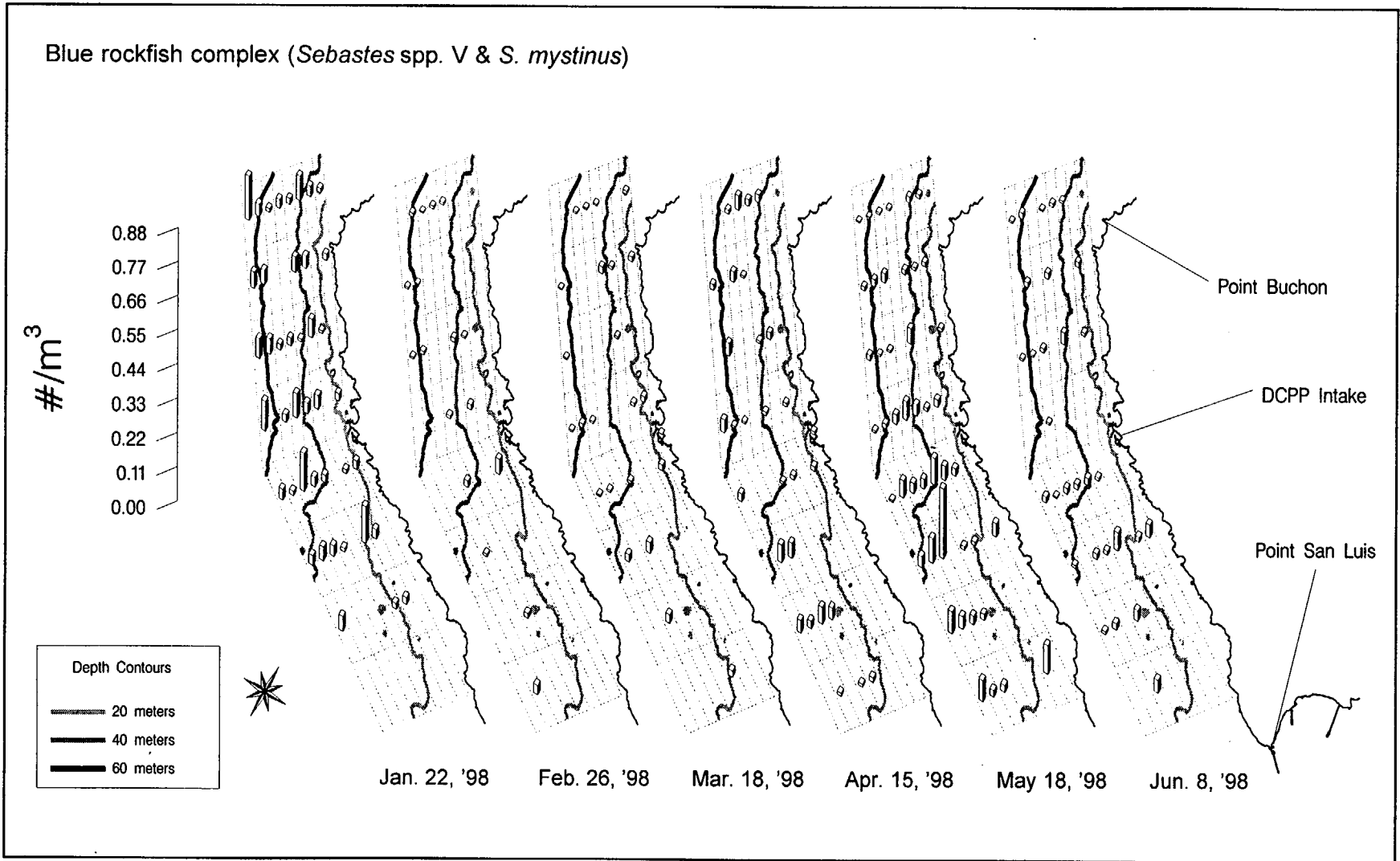


Figure 5.2.4-9b (continued). Mean larval density ($\#/m^3$) collected in the DCPP study grid cells and at the entrainment sampling location.

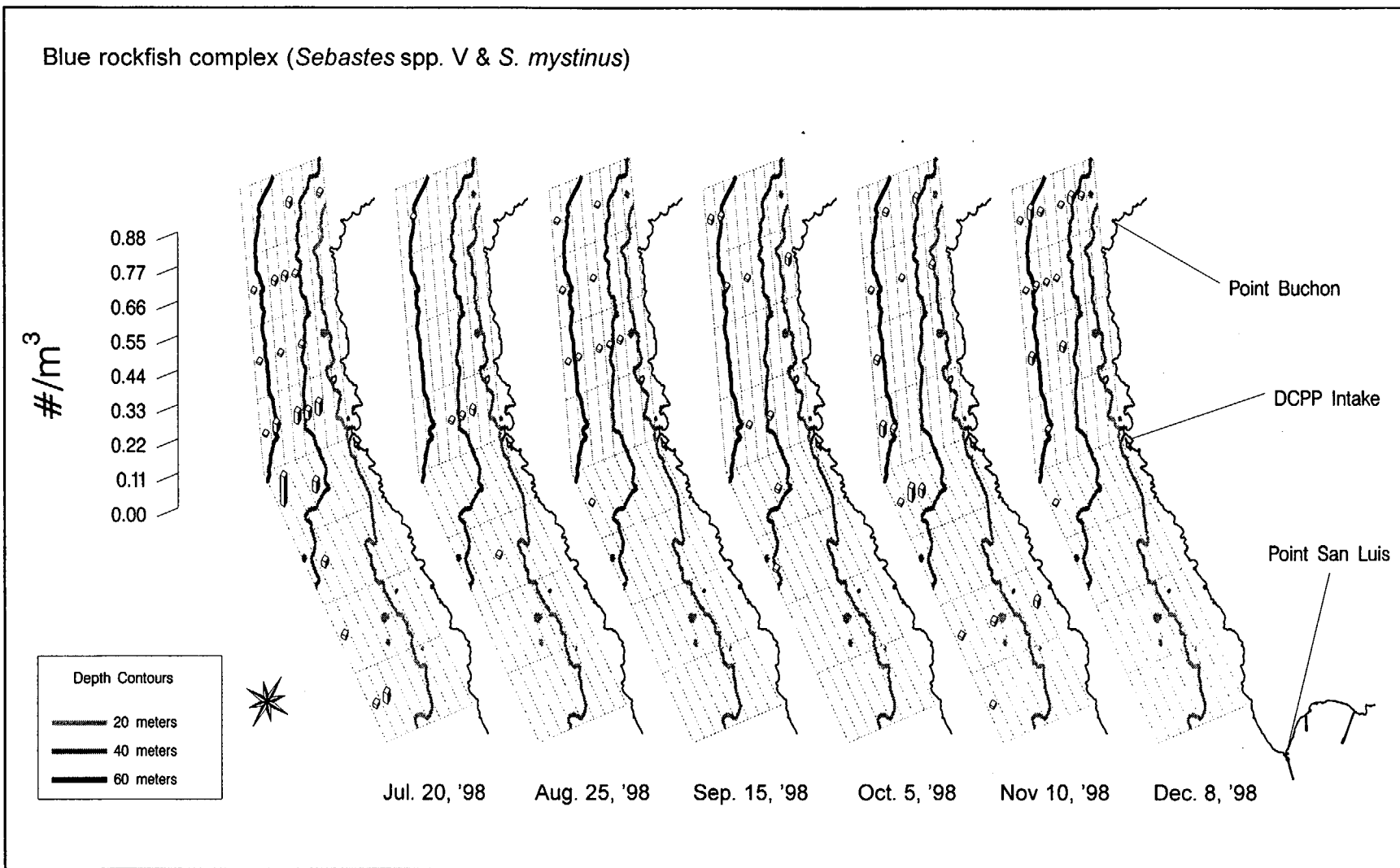


Figure 5.2.4-9c (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

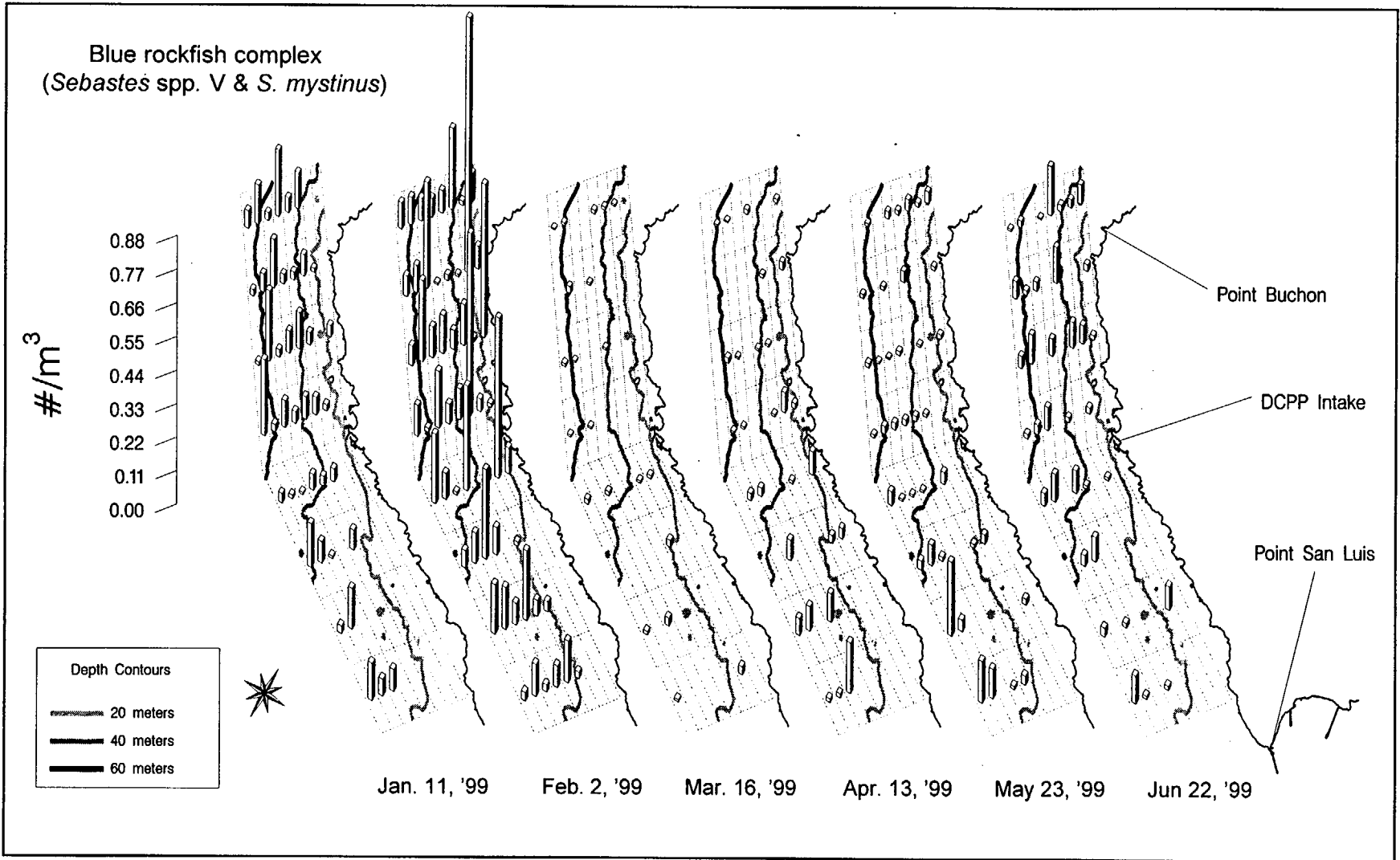


Figure 5.2.4-9d (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

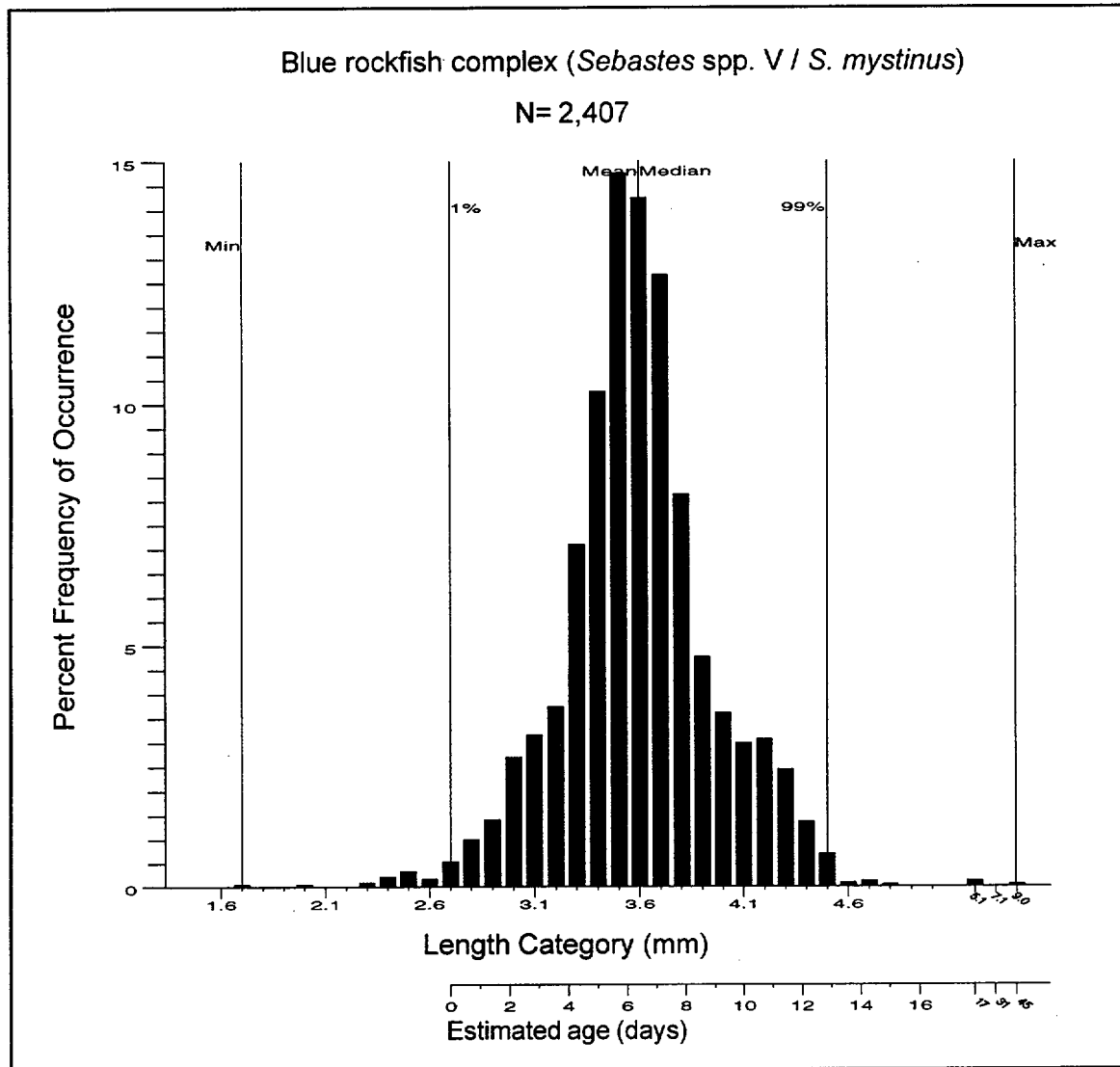


Figure 5.2.4-10. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

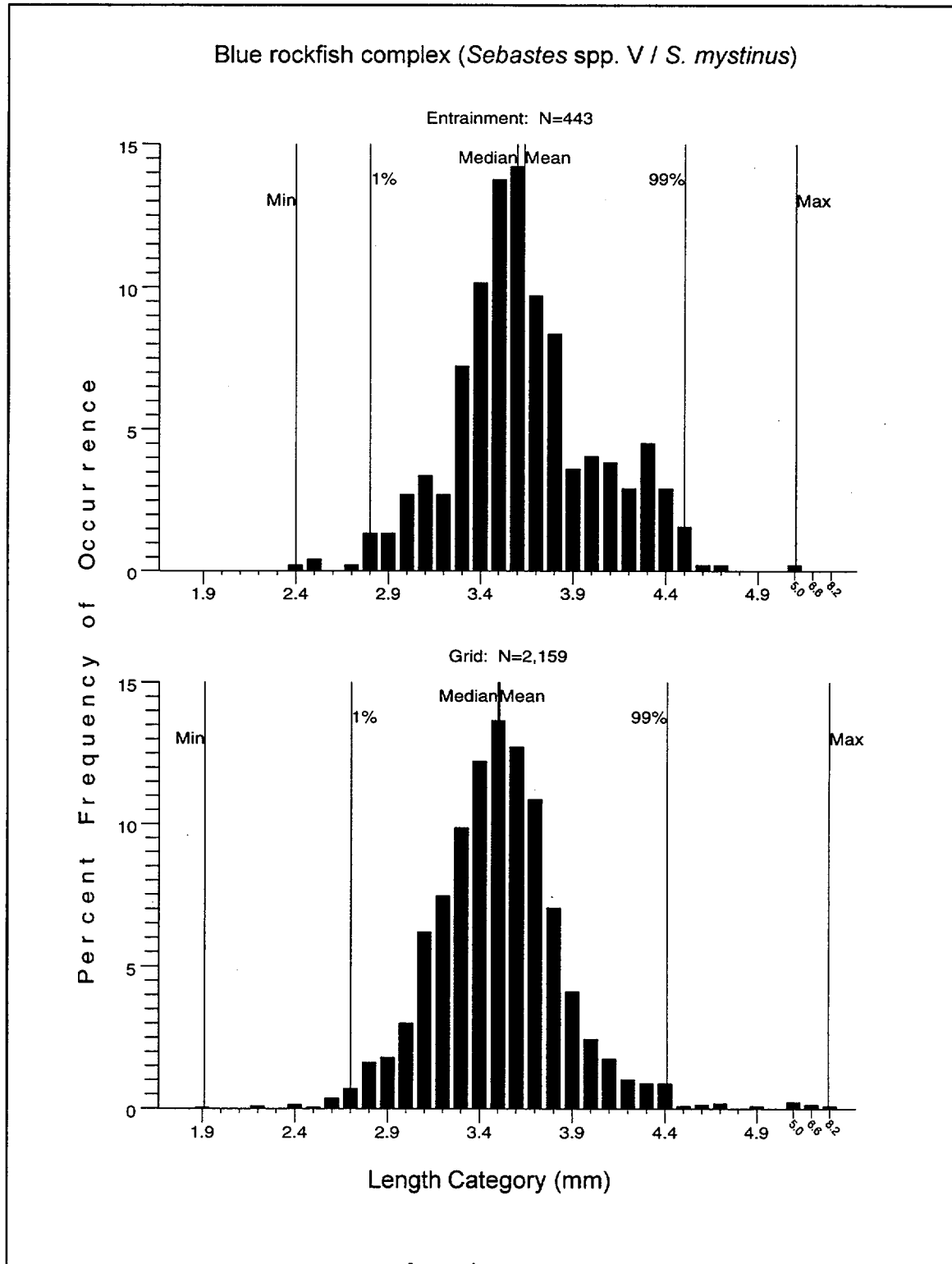


Figure 5.2.4-11. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

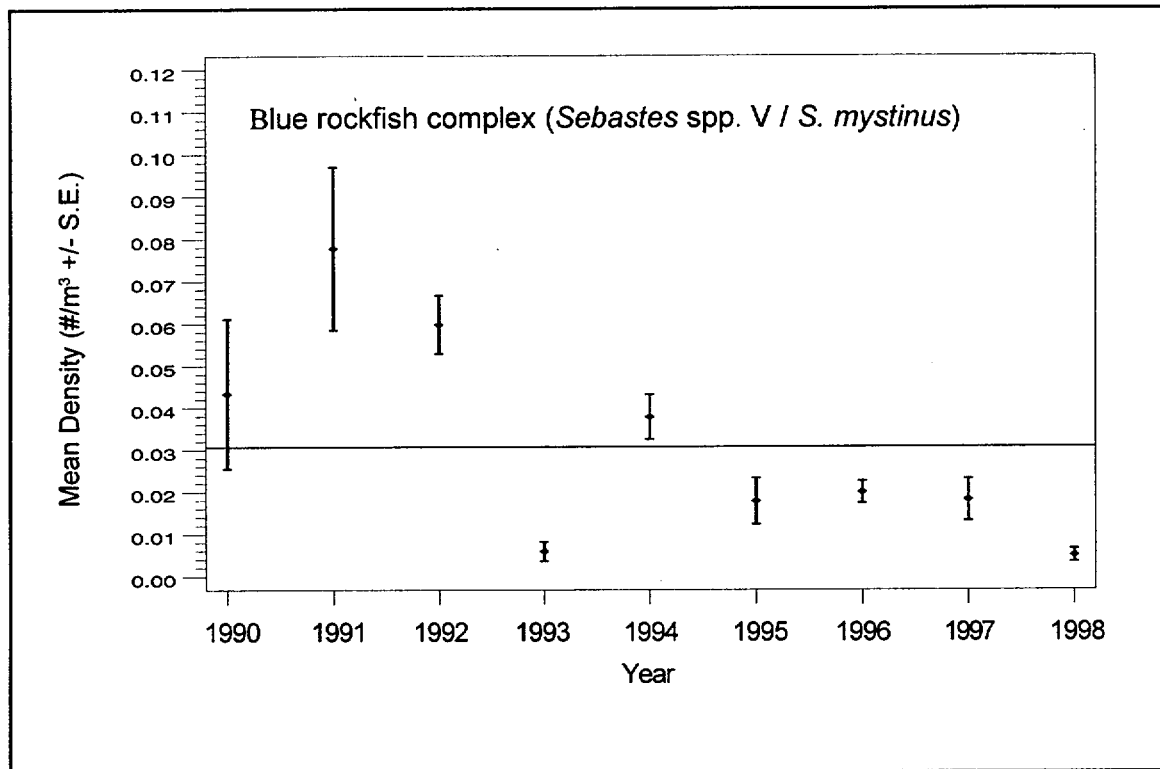


Figure 5.2.4-12. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

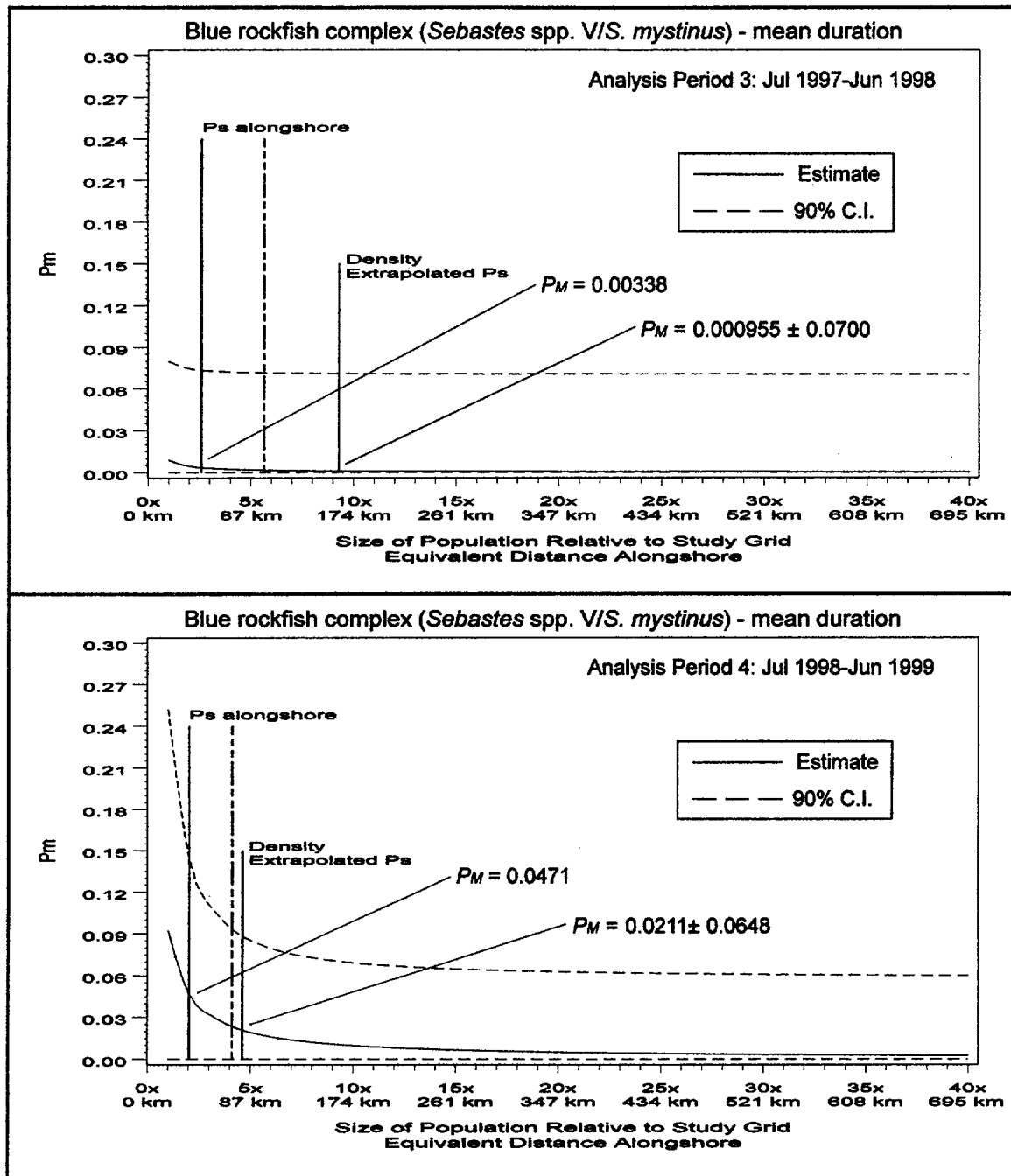


Figure 5.2.4-13a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

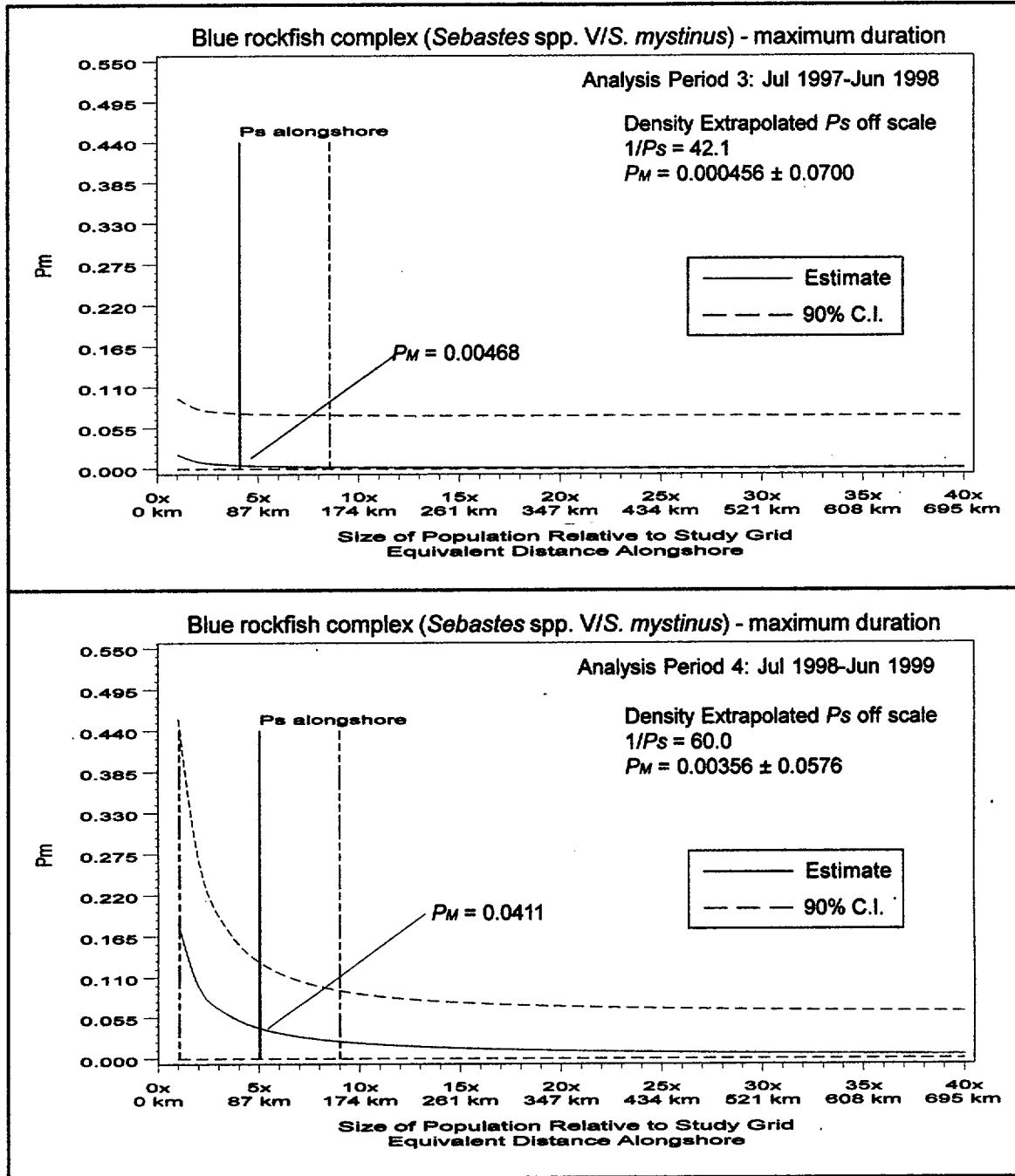


Figure 5.2.4-13b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_s) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

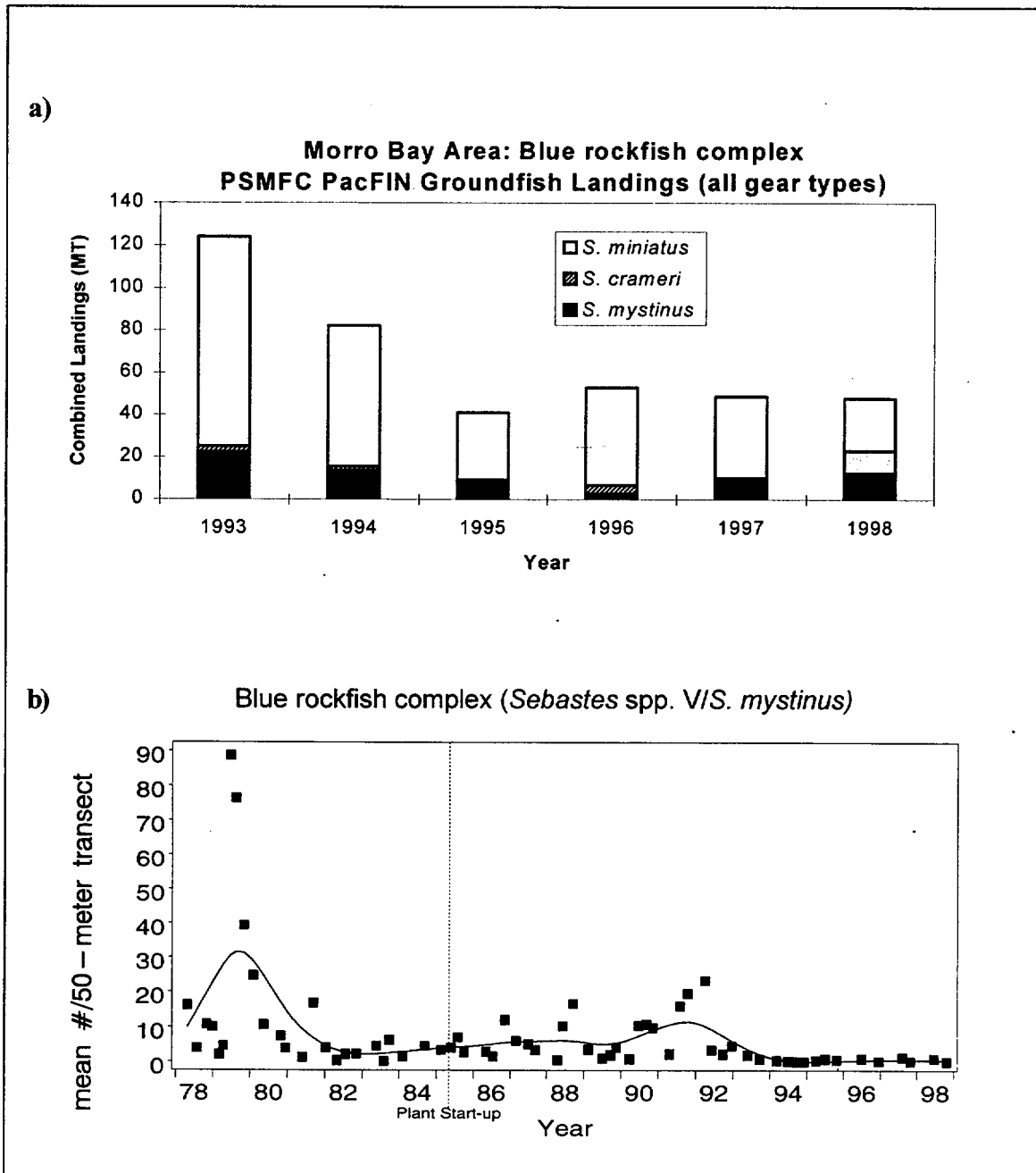
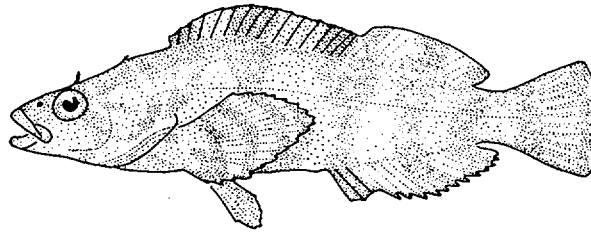


Figure 5.2.4-14. Yearly abundance of blue-rockfish complex measured by two independent methods: a) Commercial fishery+landings of adults from Morro Bay area and, b) Mean number of adults and YOY observed per 50-meter subtidal benthic transect in the DCPW RWMP South Control area. Spline smoothing algorithm used to fit curve through points.

5.2.5 Assessment of Painted Greenling (*Oxylebius pictus*)



Oxylebius pictus Gill 1862; painted greenling; length to 26 cm; Prince William Sound, Alaska to Islas San Benito, central Baja California; intertidal to 94 m; grayish to brown, sometimes white spotted; throat usually spotted and three dark bands radiate from eye; dark spots on caudal, pectoral and pelvic fins (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996).

The painted greenling (*Oxylebius pictus*) is a member of the family Hexagrammidae, which is found exclusively in the northern Pacific Ocean (Nelson 1994). Three of the four subfamilies occur along the California coast: Hexagramminae (one genus, *Hexagrammos*), Ophiodontinae (one species, *Ophiodon elongatus*), and Oxylebiinae (one species, *O. pictus*; Nelson 1994). Painted greenling are solitary bottom dwellers that inhabit the intertidal zone down to depths of 94 m among or near cobble and boulder substrata, tending to mingle with the benthic flora in areas of surge (Miller and Lea 1972; Burge and Schultz 1973; Eschmeyer et al. 1983; Love 1996). Crustaceans and polychaetes are important food items (Burge and Schultz 1973; Love 1996). In turn, painted greenling are an important food item of Brandt's cormorant (Love 1996). Painted greenling was one of the most common fish in surveys of Diablo Cove and the vicinity in 1970 and 1971 (Burge and Schultz 1973). In southern California they are most abundant at depths ranging from 15 to 31 m, but in central California the peak distribution moves inshore to a range of 5 to 22 m (Love 1996). Painted greenling are territorial and seem to have high site affinity (Love 1996).

Painted greenling are oviparous and lay adhesive batches of demersal eggs on exposed rock surfaces with low lying algae, with males guarding the eggs (Fitch and Lavenberg 1975; Love 1996). Reports of the spawning period and duration vary among sources with Moser (1996) reporting spawning activity from October–July and Fitch and Lavenberg (1975) indicating

spawning takes place February–November. Females collected from Diablo Cove and the surrounding area in May and September contained developing and mature eggs (Burge and Schultz 1973). Females spawn three times during a 3 mo (summer) season in Puget Sound and at least three times over 7 mo (September–March) in Monterey Bay, California (DeMartini and Anderson 1980). The number of eggs produced annually ranges from ca. 12,000–28,500 (DeMartini and Anderson 1980; Love 1996). Larvae are planktonic and can remain in the water column for 1–3 mo (DeMartini and Anderson 1980; Moser 1996). The larvae transform to juveniles at a size of approximately 15 mm (Kendall and Vinter 1984).

Scientific literature gives no estimates of natural mortality rates for either early life stages or later (juvenile or adult) stages of painted greenling. Mortality rates have not been calculated for adults using age-frequency analyses because age distributions in the populations sampled were not stationary (DeMartini and Anderson 1980). Hatching success per brood ranged from $31\% \pm 9\%$ to $72\% \pm 6\%$ (DeMartini 1987). Laboratory mortality rates during the yolk-sac stage for another family member, the greenling (*Hexagrammos otakii*), were calculated from survival curves as 0.001–0.003 (Hamai and Kyushin 1964). Survival rates at the end of the yolk absorption period ranged from 13% to 38%. During the feeding period of the larvae, the mortality rate (0.018–0.083) depends on temperature, with higher temperatures corresponding to higher mortality rates (Hamai and Kyushin 1964). These laboratory-derived mortality rates were measured in the absence of natural mortality (e.g., predation) and, therefore, were not appropriate to use as the larval mortality rates of painted greenling.

Longevity and age at maturation of painted greenling appear to vary with location. Their longevity was estimated at 8 yr from a 173 mm total length (TL) specimen collected in the vicinity of Diablo Canyon (Burge and Schultz 1973). In Monterey Bay, California the maximum longevity was estimated as 5 yr at 160 mm TL for males and 6 yr at 175 mm TL for females. Fish in Puget Sound had a maximum longevity of 6 yr at 200 mm TL for males and 8 yr at 215 mm TL for females (DeMartini and Anderson 1980). Age at 50% maturity was 3 yr for females and 2 yr for males in Monterey Bay (DeMartini 1976; DeMartini and Anderson 1980).

Painted greenling have limited fishery value. They are typically taken incidentally by recreational and commercial fisheries while targeting other fishes (Fitch and Lavenberg 1975; Love 1996). Thus there are no stock assessments or catch records with which to compare losses attributable to power plant entrainment.

5.2.5.1 Summary of Field Collections

Painted greenling larvae were collected almost year round at the DCPD intake structure during the years 1996–1999 (**Appendix H**), with their highest abundance occurring in late March and May 1997 (**Figure 5.2.5-1**). It appears there were fewer painted greenling larvae during 1998 than during either 1997 or 1999, especially during February and March 1998. This might have been due to the El Niño event that was detected along the central California coast in the fall of 1997 (Lynn et al. 1998; NOAA 1999). There were 1,133 larval painted greenling in 553 bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999 representing 12% of the subsamples collected and processed from that location during that period.

Painted greenling larvae occurred in the DCPD study grid during most months except September 1997, and August and September 1998 (**Appendix H**). The highest density occurred during May and June 1999 (**Figure 5.2.5-2**) and in the grid cells closest to shore. There were 372 larval painted greenling identified from 261 bongo net subsamples representing 9% of the study grid subsamples collected and processed from July 1997–June 1999.

Standard lengths of all painted greenling larvae collected at the DCPD intake structure between October 1996 and June 1999 ranged from a minimum of 2.1 mm to a maximum of 7.9 mm (**Figure 5.2.5-3**). The central 98% of this length-frequency distribution resulted in minimum and maximum lengths for the analyses of 3.2 mm and 5.2 mm, respectively. The mean larval length in this distribution was 4.1 mm. The growth rate of larval painted greenling (0.083 mm/d) reported by Freeman et al. (1985) was used to estimate ages of entrained larvae. We assumed that the shortest larva of the central 98% of the length-frequency distribution was immediately post-hatch and aged zero days. Consequently, the estimated ages of larvae entrained ranged from zero

days up to 24–70 d post-hatching for the largest larvae measured. On average, the estimated ages of painted greenling larvae entrained at DCPD ranged from 10–24 d post-hatching. Reported hatching size for painted greenling is less than 3.5 mm (Moser 1996). The fact that we observed some larvae smaller than the reported hatching lengths may be partly explained by natural variation of hatch lengths within the population and partly by the phenomenon of shrinkage following preservation (Theilacker 1980).

Significant differences were detected between mean lengths (t -test: $p \leq 0.041$) and between length-frequency distributions (Kolmogorov-Smirnov test: $p \leq 0.002$) of larval painted greenling from the DCPD intake structure and study grid despite the appearance of similarity between the two distributions (Figure 5.2.5-4). The mean standard lengths from the intake and study grid were 4.1 mm and 4.0 mm, respectively. The maximum difference between the length-frequency distributions detected by the Kolmogorov-Smirnov goodness of fit test occurred at 4.1 mm, indicating that smaller individuals were collected from the DCPD intake. While these differences were statistically detectable and significant, we believe that the biological significance of these differences was low.

5.2.5.2 Estimating Total Annual Entrainment

The annual estimated mean entrainment for painted greenling larvae ranged from a minimum of 8,410,000 ($\widehat{SE} = 800,000$) in Analysis Period 2 to a maximum of 22,000,000 ($\widehat{SE} = 1,600,000$) in Analysis Period 1 (Table 5.2.5-1). Values of $2 \cdot \widehat{SE}(\widehat{E}_T)$ can be used to approximate 95% confidence intervals around the point estimates. These values for October 1996–September 1997 and October 1997–September 1998 would not overlap, indicating that the differences between them is statistically significant.

Estimates of Annual estimates of entrained painted greenling larvae adjusted to a long-term mean based on annual indices using weekly Intake Cove surface plankton tows (Figure 5.2.5-5) ranged from a minimum of 9,610,000 ($\widehat{SE} = 914,000$) in Analysis Period 2 to a maximum of 24,200,000 ($\widehat{SE} = 1,760,000$) in Analysis Period 1 (Table 5.2.5-2). The average index for the years 1997 and 1998 were 0.0023 and 0.0022 larvae/m³, respectively. The long-term average index was 0.0025

larvae/m³ for the years 1990–1998, yielding the ratio (\bar{I}/I_i) of 1.0990 for 1997 and 1.143 for 1998 and indicating that larval greenling abundance was lower than the long-term average during 1997 and 1998. The adjustment increased the differences between the estimates for Analysis Periods 1 and 2.

NOTE: Entrainment estimates for painted greenling were not used to calculate *FH* or *AEL* models because no demographic data (e.g., larval survivorship) were available to parameterize these approaches.

5.2.5.3 Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) in each i th survey from the two years sampled ranged from a minimum of zero to a maximum of 0.0423 ± 0.0393 ($\pm 1 SE(\widehat{PE}_i)$) in February 1998 (Table 5.2.5-3). This maximum \widehat{PE}_i was not associated with the maximum \hat{f}_i (0.252) which occurred in July 1997 and thus was proportionally less important during that analysis period. No larvae were collected at either the DCP intake or from the study grid when both \widehat{PE}_i and the proportion of larvae present in the i th survey period (\hat{f}_i) were equal to zero. When $\widehat{PE}_i = 0$ but $\hat{f}_i > 0$, it indicated that larvae were collected at the DCP intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. During the Analysis Period 3, the highest \widehat{PE}_i 's were all approximately 0.04, but only January 1998 had a relatively large \hat{f}_i weighting factor (0.17) which meant it had proportionally greater influence on the annual entrainment mortality estimate. In Analysis Period 4, one of the lowest \widehat{PE}_i values carried the greatest weighting factor $\hat{f}_i = 0.23$.

Estimates of \widehat{P}_M between analysis periods and for both larval durations are relatively similar and ranged from 0.032–0.067 (Figure 5.2.5-6). Since painted greenling larvae were dispersed throughout the study grid during most surveys (Figure 5.2.5-2), P_s was calculated using alongshore current movement and extrapolating study grid abundance offshore using onshore current movement. The estimates calculated using offshore extrapolation of study grid abundance were also similar between the two analysis periods and two larval durations and ranged from 0.004–0.011. Estimates of P_M for both analysis periods using either mean or maximum length in

calculating larval duration either declined or remained approximately the same when $1/\widehat{P}_S$ increased.

5.2.5.4 Interpretation of Assessment Results

Painted greenling has very little commercial or recreational fishery value. Because of the absence of any commercial fishery for this species, there are no catch data or stock assessments with which to compare entrainment mortality rates (\widehat{P}_M). Results of the *ETM* modeling show that the power plant may annually entrain approximately 4–5% of the painted greenling larvae over an area 6 to 7 times the area of the study grid (Figure 5.2.5-6).

Abundance of adult painted greenling was examined using data from the DCPD Receiving Water Monitoring Program studies on subtidal fishes (Figure 5.2.5-7). There was considerable variation in greenling abundance over the period of observation with one obvious decline in abundance from 1992 through 1994. This may have resulted from the extended El Niño events that occurred from 1991 through 1993 (Yoklavich et al. 1996) and again in 1994 (NOAA 1999). Annual mean density of painted greenling larvae from Intake Cove surface plankton tows show high larval production in 1992 and 1995, but no coherent trends (Figure 5.2.5-5). The absence of any evidence of long-term effects (>5 yr) on painted greenling abundance from these two sources indicates that entrainment of larvae by the power plant CWS is only removing excess larval production that does not affect local adult abundance or larval production.

The lack of evidence of declining trends in adult abundance or larval production could also be the result of compensation for the additional larval mortality resulting from entrainment. If, as reported, painted greenling larvae transform into juveniles at a size of 15 mm and are planktonic for 1–3 mo (DeMartini and Anderson 1980; Moser 1996), then our results indicate that the larvae are only subject to entrainment for a very limited period of time. The mean of the size frequency distribution for entrained larvae was 4.0 mm, and 99% of all the larvae ranged from 3.2 to 5.3 mm (Figure 5.2.5-3). The period of time represented by this size range is much less than the reported larval duration (up to 90 d) and may even be shorter if, as suspected, the lower sizes represent variation in hatch size. Only one larva was collected that was within the range of

Moser's (1996) reported length at flexion (7–9 mm). The absence of flexion and post-flexion length larvae in the samples may indicate that more developed larvae are able to avoid capture or that behavioral changes result in the larvae moving out of the plankton and into other habitats where they are not subject to capture or entrainment. These observations may also indicate that painted greenling larvae quickly settle out of the plankton and may have mechanisms in later stages that compensate for mortality of planktonic larvae since there do not appear to be declines in larval abundance through time.

Table 5.2.5-1. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for painted greenling (*Oxylebius pictus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	22,000,000	1,600,000
2) Oct 1, 1997–Sep 30, 1998	8,410,000	800,000
3) Jul 1, 1997–Jun 30, 1998	11,100,000	970,000

Table 5.2.5-2. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for painted greenling (*Oxylebius pictus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	24,200,000	1,760,000
2) Oct 1, 1997–Sep 30, 1998	9,610,000	914,000
3) Jul 1, 1997–Jun 30, 1998	12,100,000	1,110,000

Table 5.2.5-3. Painted greenling (*Oxylebius pictus*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.00894	0.00593	0.252	0.016
Aug 25, 1997	0.00954	0.0134	0.0329	0.0046
Sep 29, 1997	0	0	0	0
Oct 20, 1997	0.0398	0.0474	0.0310	0.0041
Nov 17, 1997	0.00751	0.0106	0.0191	0.0037
Dec 10, 1997	0.0125	0.0144	0.0333	0.0050
Jan 22, 1998	0.0405	0.0206	0.1703	0.0118
Feb 26, 1998	0.0423	0.0393	0.0296	0.0035
Mar 18, 1998	0.0361	0.0255	0.0345	0.0044
Apr 15, 1998	0.00440	0.00341	0.101	0.0112
May 18, 1998	0.00780	0.00318	0.089	0.0075
Jun 8, 1998	0.0162	0.00515	0.207	0.0123

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.00285	0.00305	0.0262	0.00366
Aug 26, 1998	0	0	0	0
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0.00741	0.00827	0.0108	0.00196
Jan 12, 1999	0.0153	0.00478	0.124	0.00499
Feb 3, 1999	0.0181	0.00464	0.168	0.00562
Mar 17, 1999	0.0116	0.00362	0.236	0.00960
Apr 14, 1999	0.00924	0.00450	0.0775	0.00524
May 24, 1999	0.00997	0.00338	0.233	0.00962
Jun 23, 1999	0.00747	0.00208	0.125	0.00601

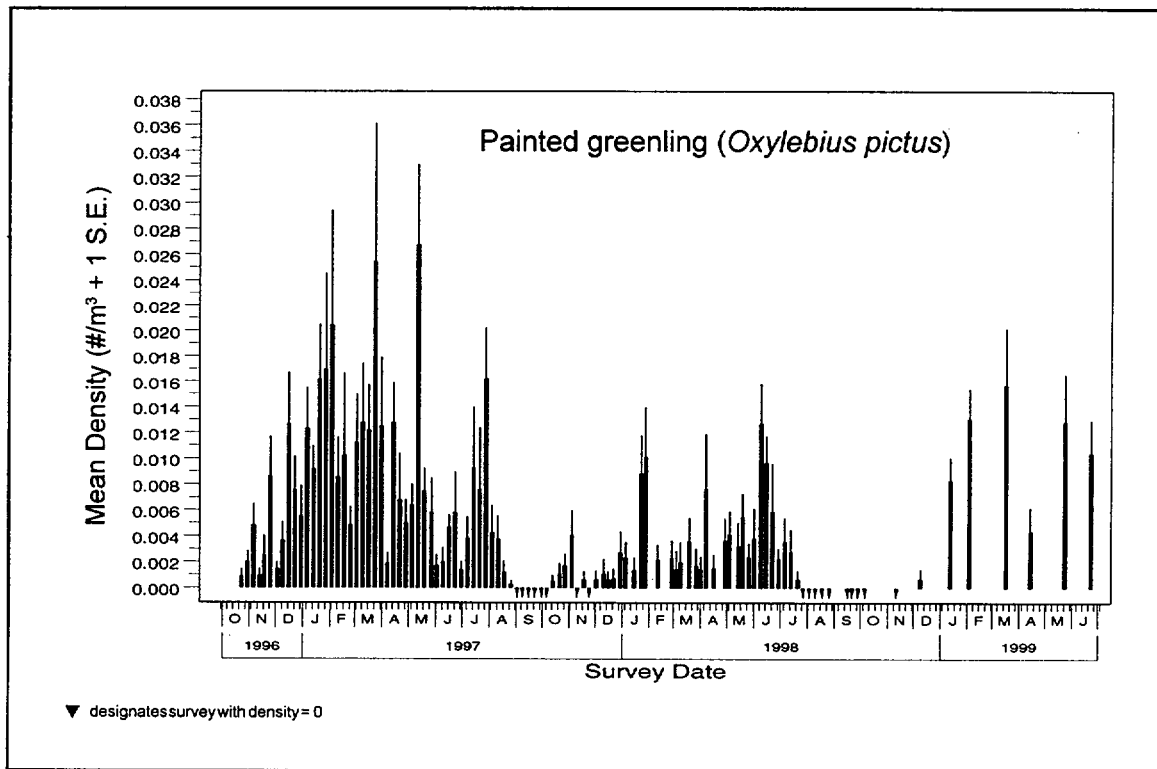


Figure 5.2.5-1. Weekly mean larval density (#/m³ + 1 S.E.) at the DCPD intake.

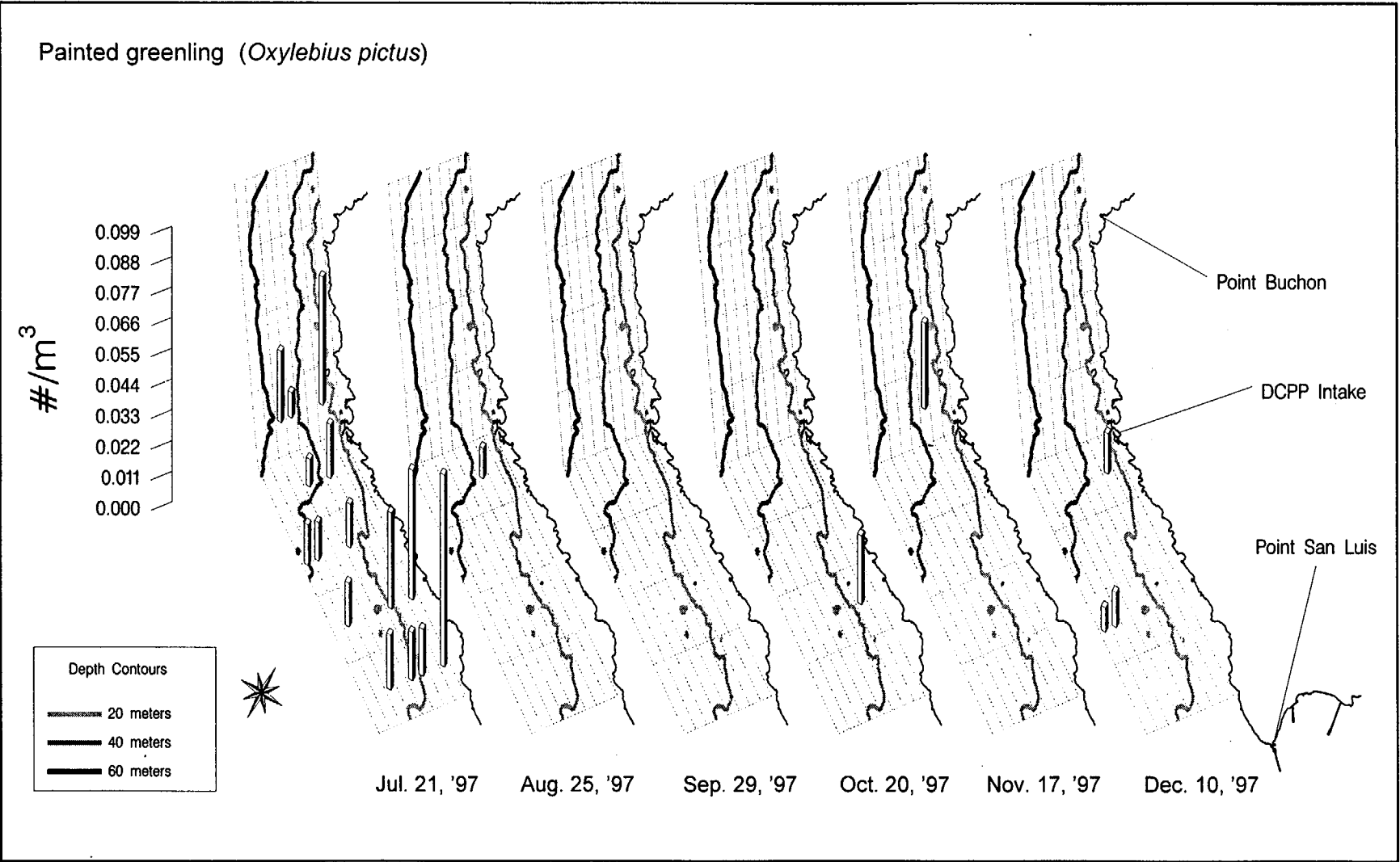


Figure 5.2.5-2a. Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

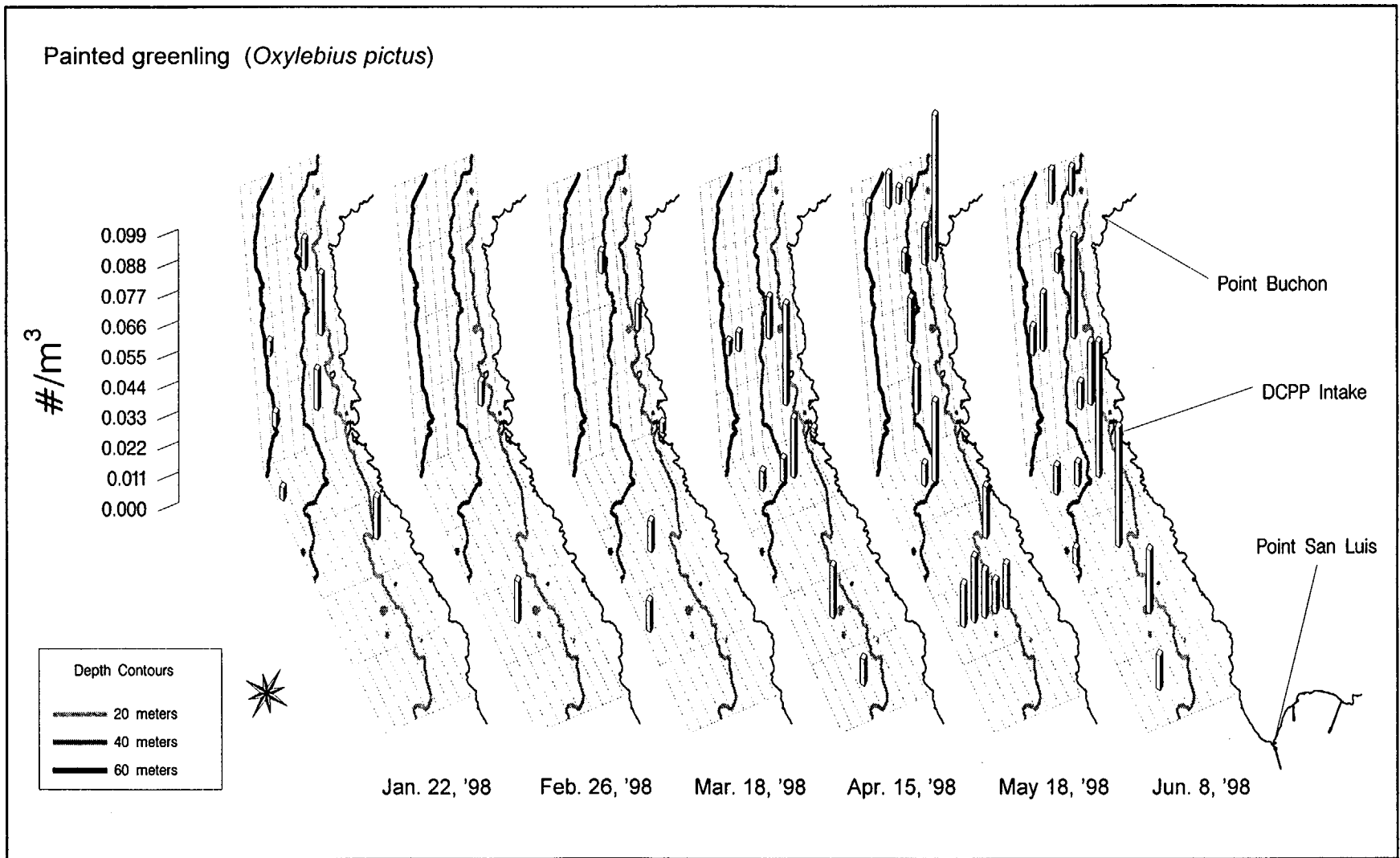


Figure 5.2.5-2b (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

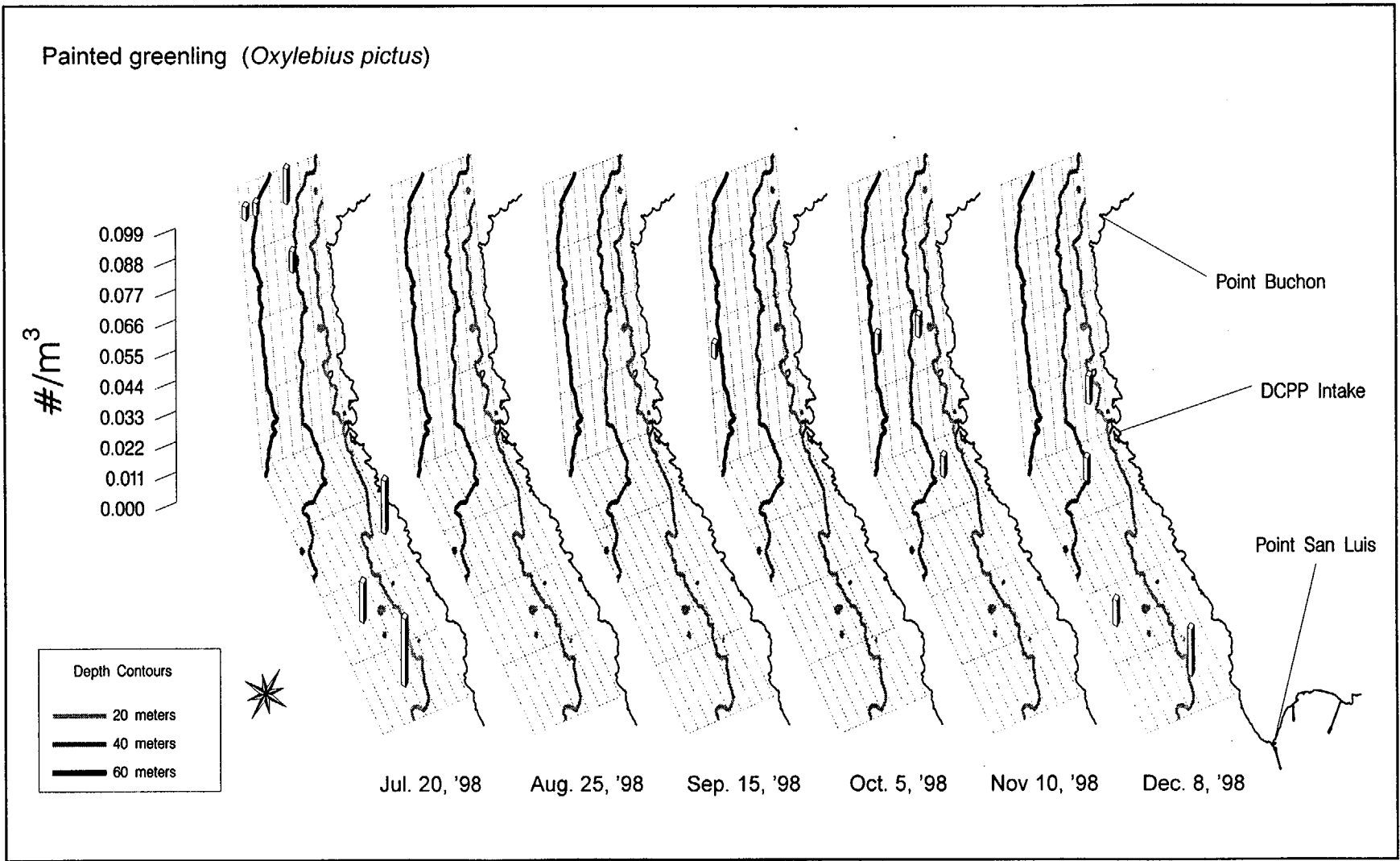


Figure 5.2.5-2c (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

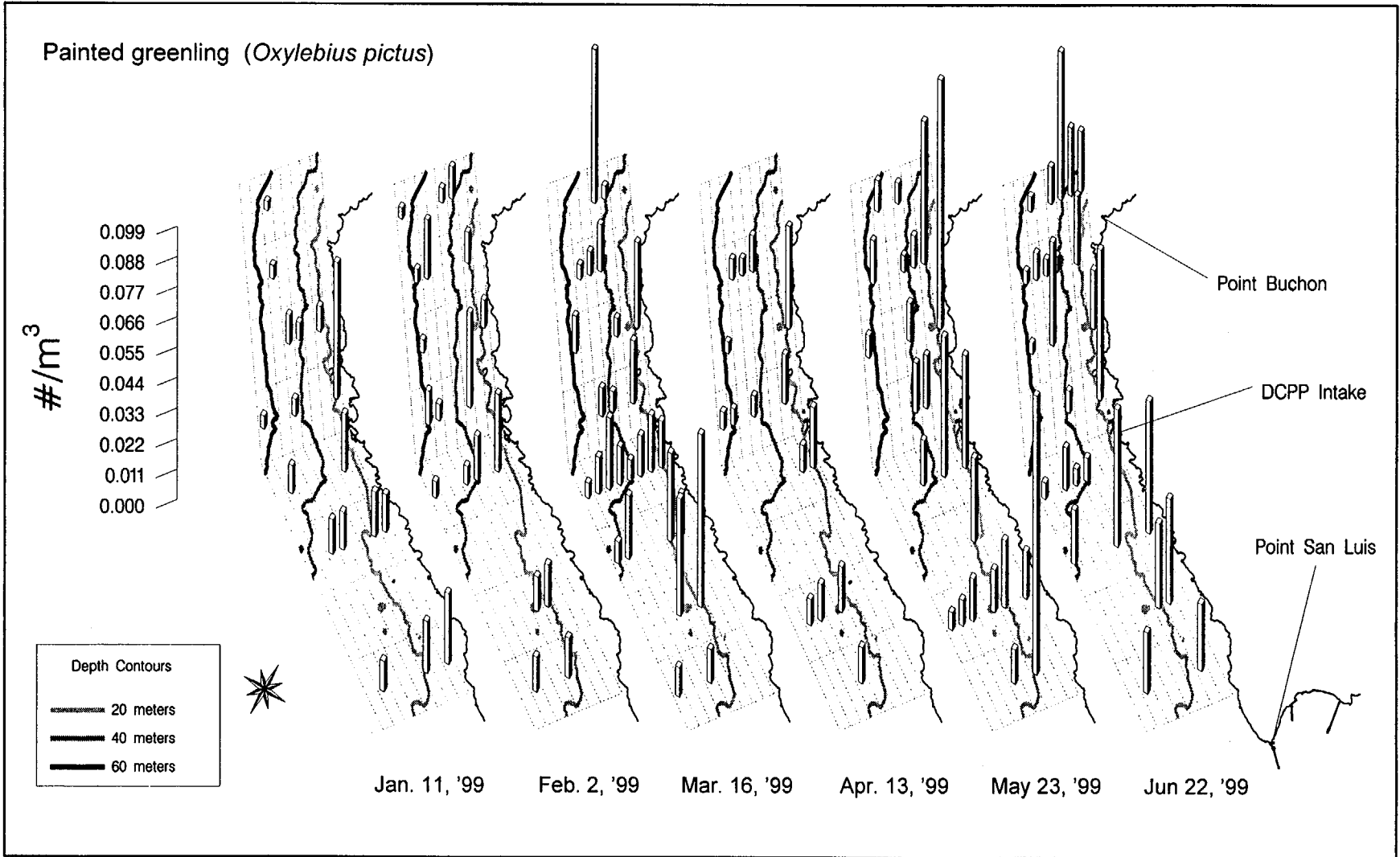


Figure 5.2.5-2d (continued). Mean larval density ($\#/m^3$) collected in the DCPP study grid cells and at the entrainment sampling location.

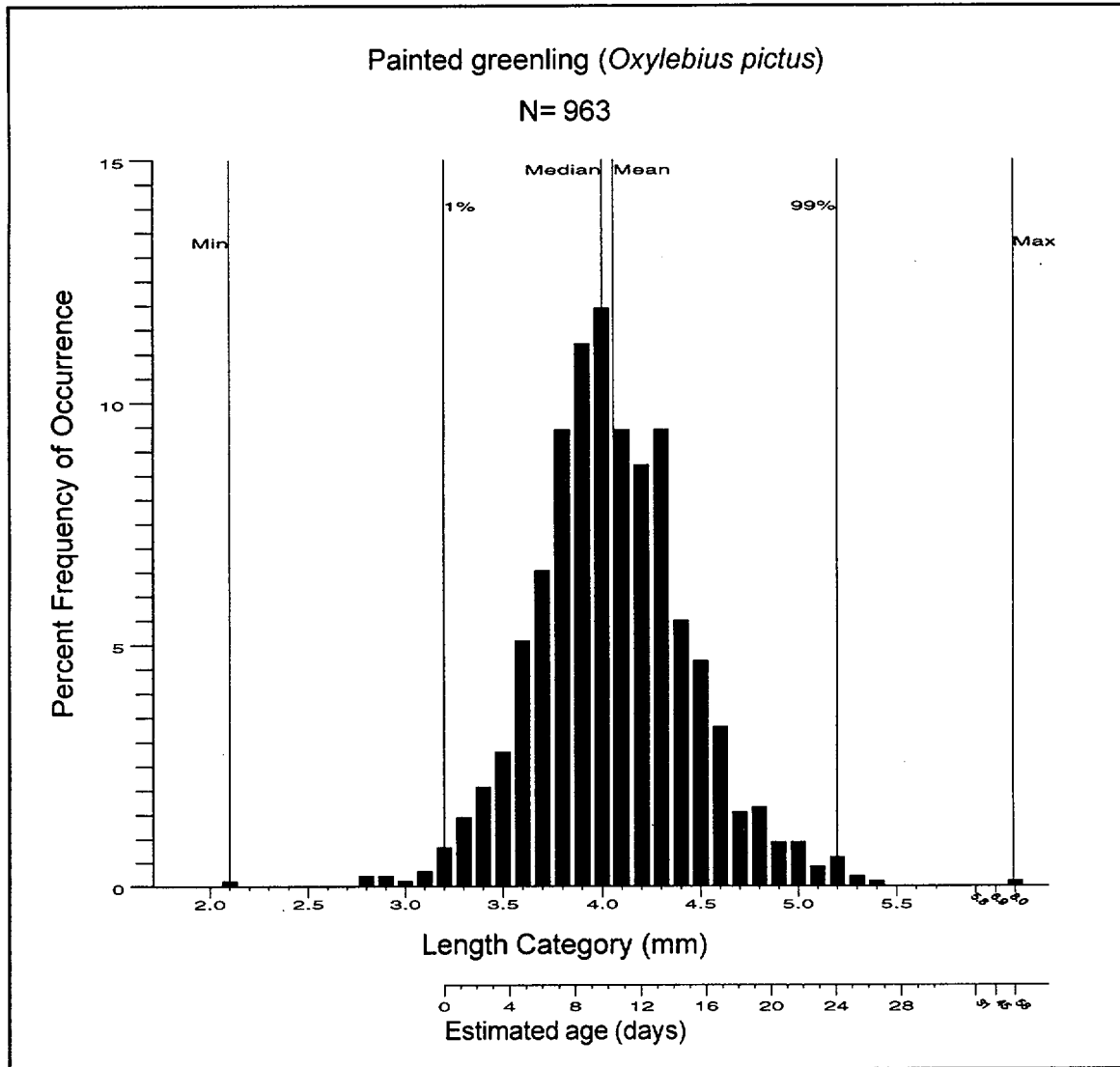


Figure 5.2.5-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

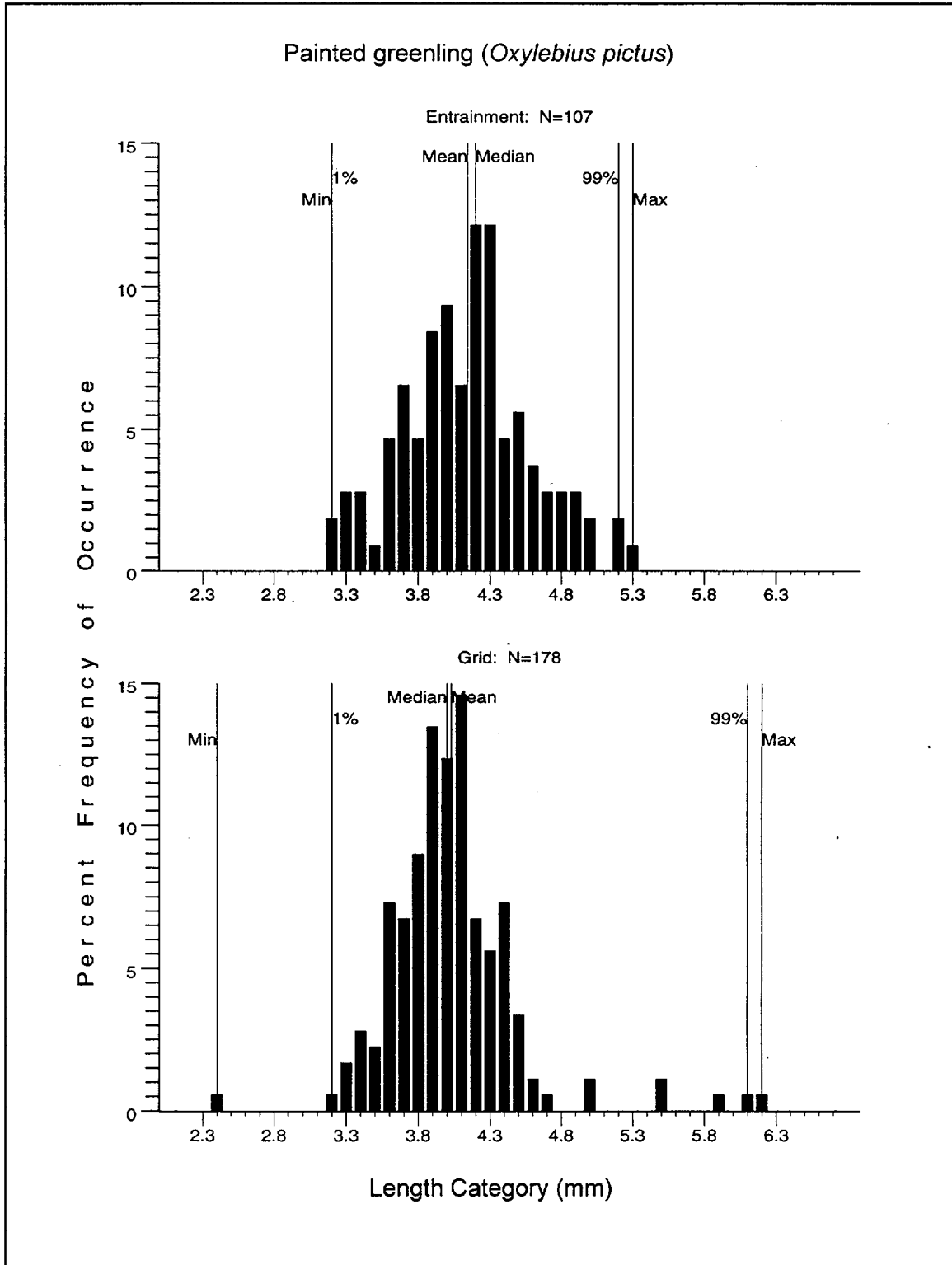


Figure 5.2.5-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

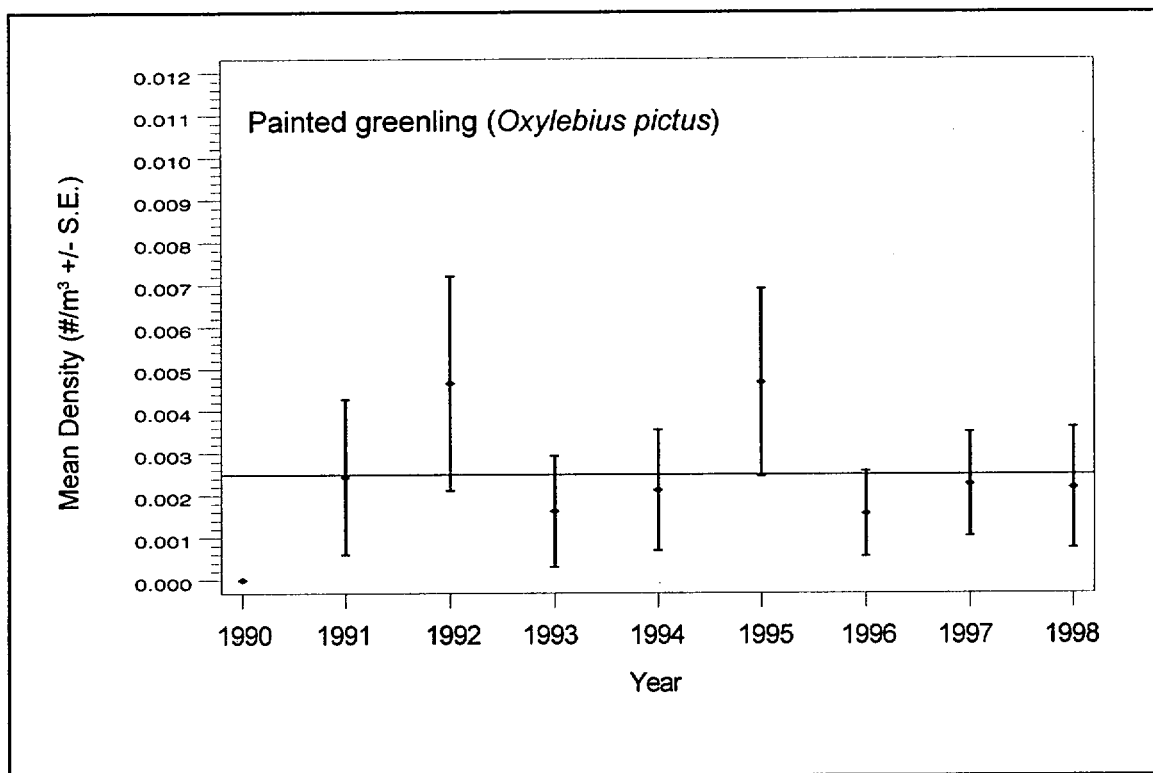


Figure 5.2.5-5. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

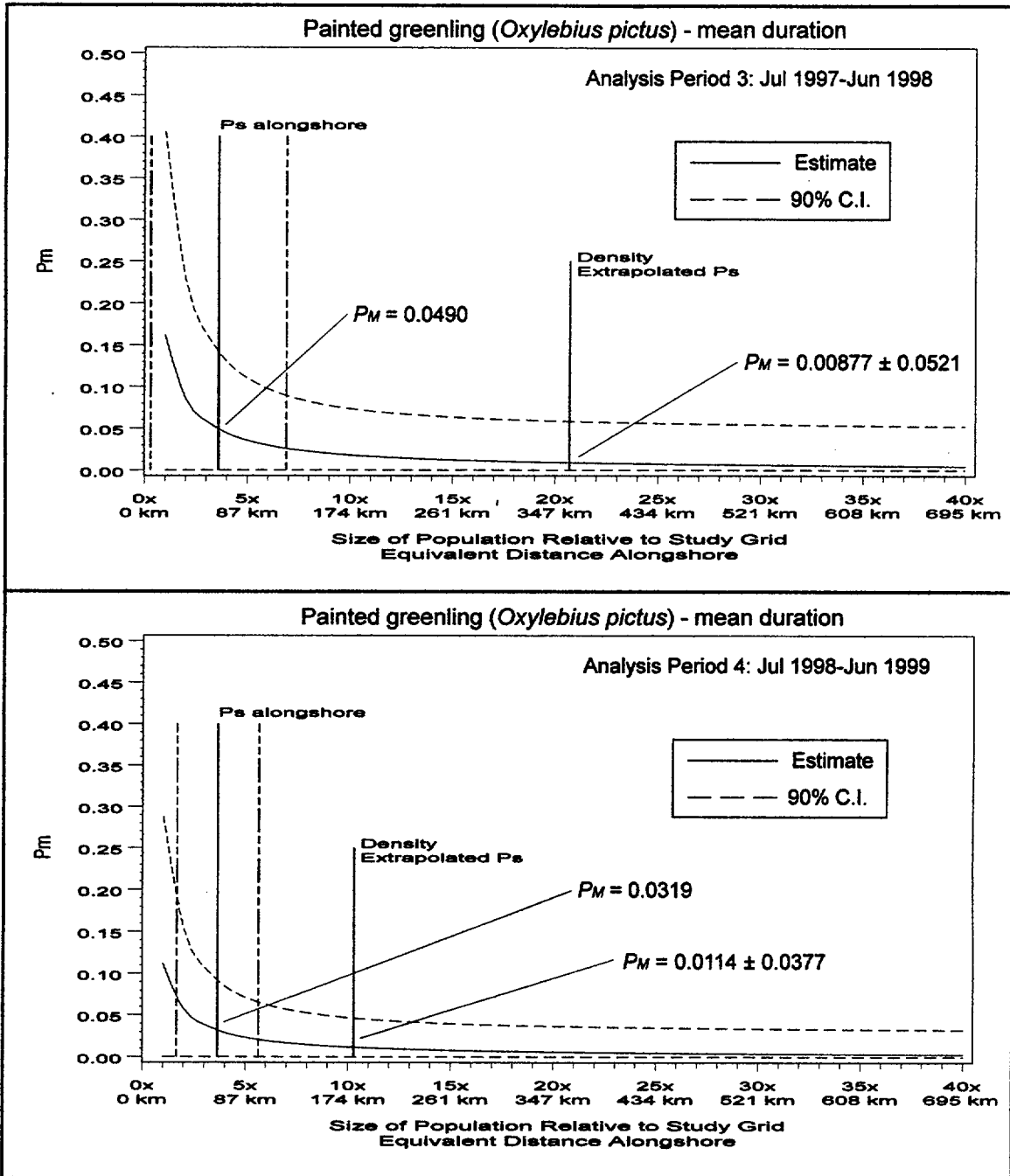


Figure 5.2.5-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

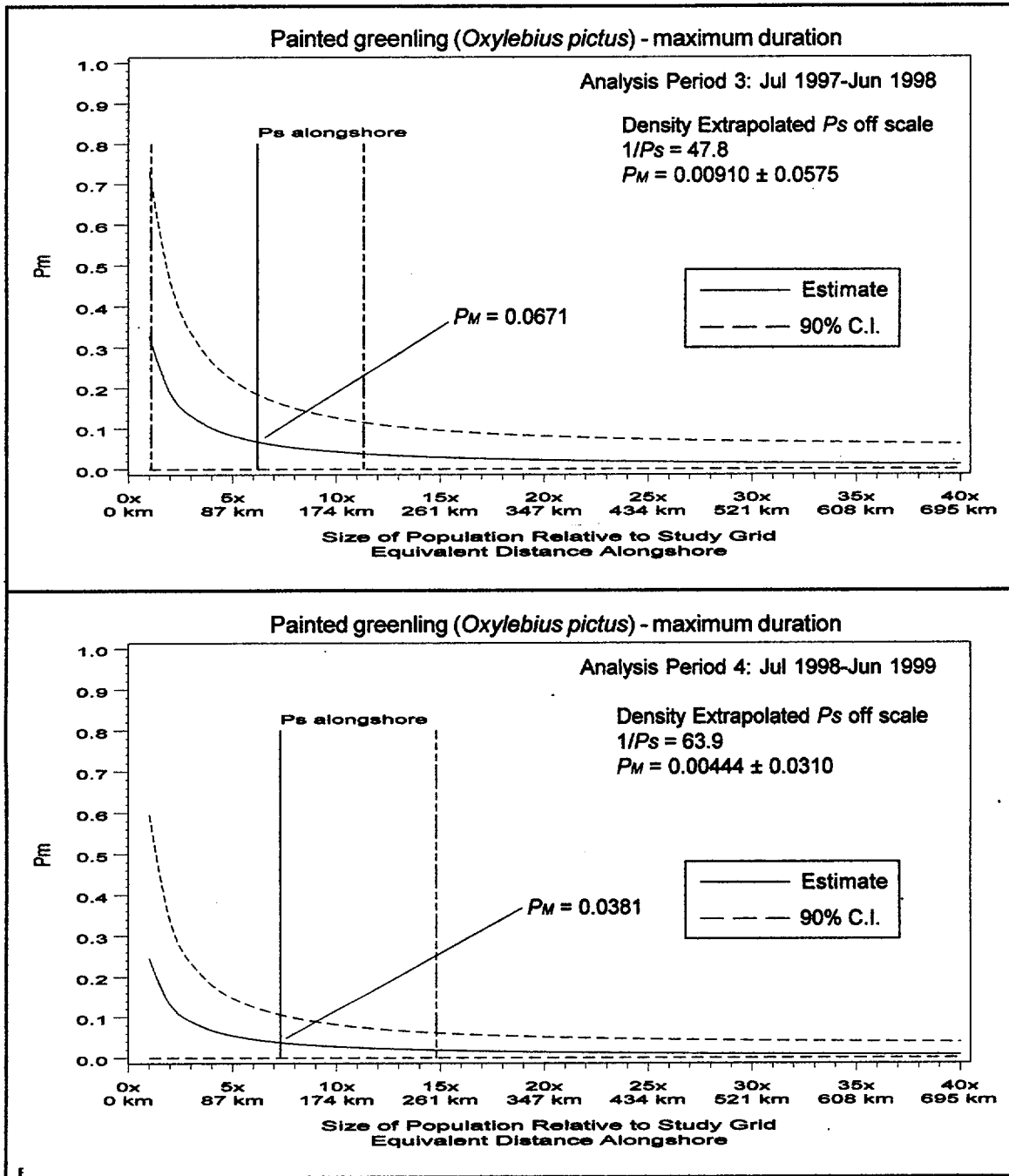


Figure 5.2.5-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

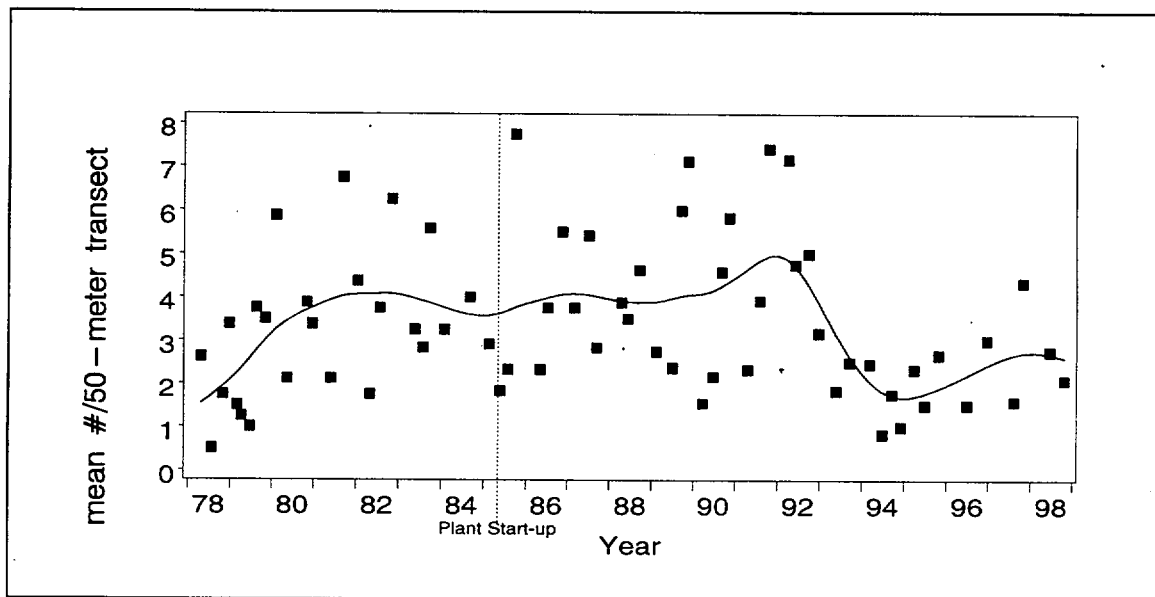


Figure 5.2.5-7. Mean number of painted greenlings observed per 50-meter subtidal benthic transect in the DCP R WMP South Control area. Spline smoothing algorithm used to fit curve through points.

5.2.6 Assessment of Sculpins (Family Cottidae)

Cottidae is a scorpaeniform family 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 ETWG selected three cottid species for assessment in the DCPD entrainment study: smoothhead sculpin (*Artedius lateralis*), snubnose sculpin (*Orthonopias triacis*), and cabezon (*Scorpaenichthys marmoratus*).

Intertidal and shallow subtidal fishes, including the cottids, display a wide range of life histories that defy broad demographic generalization. Species within the family Cottidae display a variety of life history patterns ranging from relatively short-lived to longer-lived species (Gibson 1969, 1982; Miller 1979). The large staghorn sculpin (*Leptocottus armatus*), common in Pacific coast bays and estuaries, is known to live to 3 yr and reach sexual maturity after 1 yr (Jones 1962; Tasto 1975). The fluffy sculpin (*Oligocottus snyderi*) and the tidepool sculpin (*O. maculosus*) have short lifespans and early maturation. This conclusion is based on growth rate data coupled with the scarcity of individuals older than 1.5 yr and on data showing early maturation and high reproductive output for fluffy sculpin (deVlaming et al. 1982). Cabezon, the largest of the North American cottids, may live 13 yr but only inhabits tidepools during its first or second year of life (O'Connell 1953). The demography of cottids is not well known.

A detailed review of the demography of several species of cottids closely related to smoothhead sculpin (*Artedius lateralis*) will show why substitution of early life history characteristics from related taxa is not possible for target taxa from the Cottidae. Begle (1989) proposed a phylogenetic classification placing the genera *Oligocottus* and *Clinocottus* as the nearest relatives to the genus *Artedius*. As with smoothhead sculpin, sculpins in the genera *Oligocottus* and *Clinocottus* are oviparous; lay demersal, adhesive egg batches; show varying degrees of parental care of the eggs; and produce pelagic larvae.

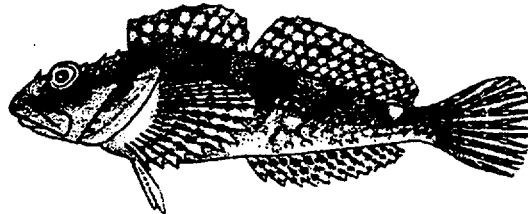
Though the demography of local species from these closely related genera (i.e., tidepool sculpin, fluffy sculpin, and woolly sculpin [*Clinocottus analis*]) is similar in many respects to that of smoothhead sculpin, information necessary to compute *AEL* and *FH* for this latter species is

lacking (Table 5.2.6-1). The tidepool sculpin achieves a maximum size of 8.9 cm, becomes sexually mature by 12 mo (Pierce and Pierson 1990), and primarily occurs in the intertidal zone. Using unvalidated ages, Pierce and Pierson (1990) reported mean annual fecundity ranges from 103 eggs for an age class I female to 699 eggs for an age class III female. The fluffy sculpin also reaches a maximum size of ca. 8.9 cm (Eschmeyer et al. 1983) and a maximum age of 1.5 yr at Dillon Beach, California (Freeman et al. 1985). It may spawn more than once during its approximately 8 mo reproductive period (Grossman and deVlaming 1984) and is found in tidepools and shallow rocky areas from Sitka, Alaska to Rio Socorro, northern Baja California (Miller and Lea 1972). Instantaneous growth rates of wild-caught fluffy sculpin adults, estimated by length-frequency analyses, varied between males and females and range from 0.063 for an age 1+ female to 1.059 for an age 0+ male (Freeman et al. 1985).

The wooly sculpin (*Clinocottus analis*) is larger and longer lived than either the smoothhead sculpin or the two representatives of the genus *Oligocottus*. It attains a maximum size of 18 cm (Eschmeyer et al. 1983) and a maximum age of 8 yr for males and 6 yr for females (Wells 1986). This sculpin is found from the intertidal zone to 18 m depths and from Cape Mendocino, northern California to Punta Asunción, central Baja California (Miller and Lea 1972). It spawns in tidepools at Point Fermin, southern California from September through November. Young-of-the-year (YOY) recruit to tidepools in southern California from November to February (Wells 1986). Egg incubation takes ca. 18–30 d in the laboratory (Eigenmann 1892; Budd 1940; Hubbs 1966). Wells (1986) indicates that all specimens over 60 mm TL and between zero and 1 yr of age appear sexually mature with batch fecundity described by the linear function $F=11.6TL-620.6$ ($n=45$; $r=0.940$; $P\leq 0.01$). Males of this species appear to grow faster and to a larger size than females (Wells 1986). The largest female collected (110 mm) contained 784 eggs; the mean number of eggs was 242 per average reproductive female (74 mm; Wells 1986). Number of spawns per season is unknown, but multiple spawns are implied by tri-modal size distribution of ova present in gonads (Wells 1986). Based on Budd (1940) examining wooly sculpin and Morris (1951) examining bald sculpins, 11–25 mm fishes were surmised to be newly settled from the pelagic larval phase and hatched approximately 6–8 wk prior (Wells 1986). Despite these life

history descriptions, there are no estimates of larval survivorship with which to parameterize the *FH* or *AEL* models for members of the Cottidae.

5.2.6.1 Smoothhead sculpin (*Artedius lateralis*)



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

The smoothhead sculpin is a common nearshore, intertidal cottid (Miller and Lea 1972). Spawning varies between locations: winter–spring in British Columbia (Marliave 1977) and June in Puget Sound (Matarese et al. 1989). Their eggs hatch into pelagic larvae in about 16 d at 15.5°C (Budd 1940; Matarese et al. 1989). Larvae of this species have been collected in DCP entrainment samples nearly year-round (Figure 5.2.6-1). Love (1996) indicates that these sculpins likely mature within their first year of life and probably live as long as 3 yr.

The demographic data available for smoothhead sculpin and its close relatives (Table 5.2.6-1) do not provide sufficient information to compute *AEL* or *FH*. Estimates of fecundity and spawning periodicity are available for closely related species that likely compare favorably with *A. lateralis* based on their similar ecological roles, adult habitats, and close phylogenetic relationships. However, in the absence of any estimates of egg or larval survivorship, *FH* or *AEL* cannot be computed for this species.

Recreational and commercial fisheries do not target most small intertidal and shallow subtidal cottids. This is one reason that the literature on these species is limited. The absence of any

population estimates from fishery management plans or other sources will make assessment of impacts on the smoothhead sculpin population difficult.

Summary of Field Collections

Estimates of smoothhead sculpin larval abundance showed distinct seasonal peaks at the DCPD intake structure during the years 1996–1999 (**Appendix H**), with greatest abundance occurring between April and July (**Figure 5.2.6-1**). There were 5,598 larval smoothhead sculpin identified from 1,320 bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999 representing 28% of the samples collected and processed from the intake structure during that period. With the exception of one very high peak density in April 1998, the distribution of abundance and magnitude of density did not appear to be different between 1997 and 1998. Although only entrainment surveys that were paired with study grid surveys were processed after September 1998, the abundance patterns appear to be similar to previous years.

Larval smoothhead sculpin generally occurred with similar seasonality in the DCPD study grid and at the DCPD intake structure (**Appendix H**). The largest densities in the study grid occurred in July 1997, April 1999, and May 1999 (**Figure 5.2.6-2**). There were 676 smoothhead larvae identified from 312 bongo net subsamples representing 10% of the study grid samples collected and processed from July 1997–June 1999. Larval abundance appeared to track the 20 m isobath, with larvae likely concentrated inshore of this contour (Marliave 1986). Apparently, the higher density of this species in the southern portion of the study grid results from the fact that more of the area in the southern half of the grid is within the 0–20 m depth range.

Standard lengths of 4,929 smoothhead sculpin larvae measured from samples collected at the DCPD intake structure between October 1996 and June 1999 ranged from 1.6 mm to 11.8 mm (**Figure 5.2.6-3**). The central 98% of this length-frequency distribution resulted in minimum and maximum lengths of 2.4 mm and 5.3 mm, respectively. The mean larval length in this distribution was 3.1 mm. Reported hatch size for this species ranged from 3.9–4.5 mm (Moser 1996). The fact that we observed some larvae smaller than the reported hatching lengths can be explained partly by natural variation of hatch lengths within the population and partly by the phenomenon

of shrinkage following preservation (Theilacker 1980). The growth rate applied to this species (0.08 mm/d) from Freeman et al. (1985) was used to estimate ages of entrained larvae. Assuming that the shortest larvae (either 1.6 or 2.4 mm) were immediately post-hatch and aged zero days, the estimated ages of larvae entrained could range from zero days up to 35–123 d post-hatching for the largest larvae measured. The average estimated ages of smoothhead sculpin larvae entrained at DCPD ranged from 9–19 d post-hatching.

Significant differences exist between mean lengths (t -test: $p < 0.001$) and between length-frequency distributions (Kolmogorov-Smirnov test: $p < 0.001$) of larval smoothhead sculpin from the DCPD intake structure and study grid, despite the appearance of similarity between the two distributions (**Figure 5.2.6-4**). The mean standard lengths from the intake and study grid were 3.1 mm and 3.7 mm, respectively. The large sample size (655 larvae from the intake and 280 larvae from the study grid) causes the t -test to be highly sensitive to small differences between the means (Zar 1984). Median lengths were similar at 3.1 mm and 3.2 mm at the intake structure and in the grid, respectively. The maximum difference between the length-frequency distributions detected by the Kolmogorov-Smirnov goodness of fit test occurred at 3.9 mm, indicating that more large individuals were collected from the grid. While these differences were statistically detectable and significant, we believe that the biological significance of these differences is low.

Estimating Total Annual Entrainment

Annual mean entrainment estimates for smoothhead sculpin larvae ranged from 88,900,000 ($\widehat{SE} = 3,660,000$) in 1996–97 Analysis Period 1 to 96,100,000 ($\widehat{SE} = 9,410,000$) in 1997–98 Analysis Period 2 (**Table 5.2.6-2**). The estimates for 1997–98 Analysis Period 3 were slightly different than Analysis Period 2 because smoothhead sculpin larvae were collected during the summer and fall months of 1997 when the two periods did not overlap. Values of $2 \cdot \widehat{SE}(\widehat{E}_T)$ can be used to approximate 95% confidence intervals around the point estimates. Confidence intervals for the 1996–97 and 1997–98 estimates would overlap, indicating that the differences among them were probably not significant.

Annual entrainment estimates for smoothhead sculpin larvae adjusted to a long-term mean based on annual indices using weekly Intake Cove surface plankton tows (**Figure 5.2.6-5**) ranged from 57,700,000 ($\widehat{SE}=2,370,000$) in Analysis Period 1 to 115,000,000 ($\widehat{SE}=11,300,000$) in Analysis Period 2 (**Table 5.2.6-3**). The average index values for 1997 and 1998 were 0.0734 and 0.0397 larvae/m³, respectively, while the long-term average index was 0.0476 larvae/m³ for the years 1990–1998, yielding the ratio \bar{I}/I_i of 0.649 for 1997, and 1.20 for 1998. Thus, the adjusted values increase the differences between the 1996–1997 and the 1997–1998 analysis periods.

NOTE: Estimates of *FH* or *AEL* for smoothhead sculpin using annual entrainment were not calculated because no demographic data exists for this species.

Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) in the surveys from the two analysis periods ranged from a minimum of zero to a maximum of 0.0729 ± 0.0181 ($\pm 1SE(\widehat{PE}_i)$) in June 1999 (**Table 5.2.6-4**). Both April and June 1999 demonstrated similar \widehat{PE}_i values around 0.07, but the proportional entrainment estimate in April had greater weight with an annual proportion of larvae hatched in the *i*th survey period (\hat{f}_i) equal to 0.30 as compared with an $\hat{f}_i=0.18$ from June of 1999. When both \widehat{PE}_i and \hat{f}_i were equal to zero, there were no larvae collected at either the DCP intake or the study grid. When $\widehat{PE}_i = 0$ but $\hat{f}_i > 0$ (e.g., Sept.–Nov. 1997), larvae were collected at the DCP intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. The largest values of \hat{f}_i occurred April through June in both analysis periods indicating that these were times of peak hatching for this species.

Smoothhead sculpin adults are found in the shallow nearshore area (Miller and Lea, 1972). Study grid samples showed that the larvae were also distributed primarily in nearshore areas (**Figure 5.2.6-2**). Therefore, P_s was calculated using only alongshore current movement to calculate point estimates of \widehat{P}_M . Results for smoothhead sculpin show how large differences in estimated larval durations (9 vs. 35 d) can affect estimates of \widehat{P}_M (**Figures 5.2.6-6**). Estimates of total

entrainment mortality increased about 5% with increasing larval transport duration in both periods (Period 3, mean duration $\widehat{P}_M \cong 11\%$ and max. duration $\widehat{P}_M \cong 15\%$; Period 4, mean duration $\widehat{P}_M \cong 15\%$ and max. duration $\widehat{P}_M \cong 20\%$) with the second year being higher overall. Values for \widehat{P}_M were greater in the second analysis period. The probability of entrainment is less for the shorter duration in both analysis periods because of the reduced time over which larval transport occurred. Estimates from longer larval durations showed that weaker alongshore currents resulting from the El Niño conditions during the 1997–98 analysis period resulted in a larger estimate of \widehat{P}_S and smaller areas of inference compared to the 1998–99 analysis period.

Interpretation of Assessment Results

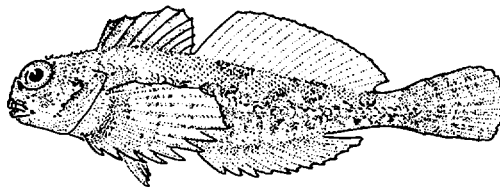
Smoothhead sculpin has neither commercial nor recreational fishery value, and there is little information on its ecological role in the community. Because of the absence of any fishery for this species, no catch data can be used to compare harvest mortality rates to entrainment mortality rates (\widehat{P}_M). There are also no estimates of stock size or density that could be used to convert \widehat{P}_M into an estimate of adult equivalent loss, assuming no compensatory mortality.

Annual mean densities of smoothhead sculpin larvae from Intake Cove surface plankton tows did not show any long-term trends in abundance from 1990–1998 (**Figure 5.2.6-5**). Although the estimate for 1998 is close to the long-term mean density, the data overall show a large amount of variation among years. The data do not provide any evidence of a reduction in larval production that would affect recruitment and eventually adult population density. Trends in adult populations of smoothhead sculpin were examined using data from the DCPD Receiving Water Monitoring Program studies on subtidal fishes. Mean abundance from three 50 m transects in an area approximately 1 km south of Diablo Cove and not contacted by the plant's thermal discharge combine data for smoothhead sculpin with data for other cottids because of the difficulties in identifying these small, cryptic fishes underwater (**Figure 5.2.6-7**). The data vary considerably among years, but the fitted curve shows a declining trend from 1992 through 1998. Although these data are variable the timing of the apparent decline is consistent with the life-span (~3 yr)

and age of sexual maturity (~1–2 yr) for this species, since any reductions in adult density of smoothhead sculpin would only be expected to be detectable after several generations.

The sizes of the majority of the entrained larvae ranged from 2.0 mm to 4.5 mm (Figure 5.2.6-3). Although larvae as large as 11.9 mm were entrained, there were few larvae greater than the reported size at flexion of 5.0–6.3 mm (Moser 1996). In fact, most of the larvae were less than the maximum hatch size of 4.5 mm reported by Moser (1996). This may indicate that smoothhead sculpin larvae are only subject to entrainment over a limited period of their larval development. It may also indicate that larger larvae are avoiding capture or that behavioral changes result in the larvae moving out of the plankton and into other habitats where they are not subject to entrainment or capture using our sampling methods. The considerable variation in adult densities, the absence of a decreasing trend in larval abundance, and the relatively short developmental period over which larvae are entrained indicates that the removal of approximately 10–20% of the smoothhead sculpin larvae from an area 7–8 times that of the study grid does not negatively affect local adult populations or larval abundance.

5.2.6.2 Snubnose sculpin (*Orthonopias triacis*)



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

Despite the common occurrence of snubnose sculpin in nearshore rocky subtidal and intertidal habitats, their life history remains relatively undescribed. Females are oviparous and spawn year round with peaks between February and October. The eggs are demersal and adhesive and hatch planktonic larvae (Feeney 1992; Moser 1996). Bolin (1941) conducted studies of the embryology

and development of early larval stages of *O. triacis* in laboratory rearing experiments. Egg incubation took 16–19 d at about 13°C, after which the larvae hatched at sizes ranging from 2.9–3.8 mm. All larvae died within 10 d of hatching despite several regimes of aeration and nutrition, increasing by about 0.2 mm in length over that time (i.e., growth rate of 0.02 mm/d). Yolk sacs were exhausted by about 5 d. The growth described above, representing the first 5–6 d of life until the yolk stores were exhausted, probably underestimates the growth rate in the wild where they can feed successfully. The growth rate of 0.083 mm/d used to estimate larval age of entrained *O. triacis* is from Freeman et al.'s (1985) description of the early life history of another intertidal cottid (*O. snyderi*).

The demographic data available for *O. triacis* do not provide sufficient information for computation of *AEL* or *FH*. Phylogenetic analyses indicate that the relationship of *O. triacis* to sister cottids found in similar habitats remains unresolved (Begle 1989). Recreational and commercial fisheries do not target small intertidal and shallow subtidal cottids. This is one reason that the literature on these species is limited. In the absence of egg or larval survivorship estimates, the impact of entrainment on the smoothhead sculpin population will be assessed using only the *ETM*.

Summary of Field Collections

Estimates of snubnose sculpin larval abundance showed seasonal peaks in late spring and early summer at the DCPD intake structure during the years 1997 and 1998 (Figure 5.2.6-8). There were 4,533 snubnose sculpin larvae identified from 1,422 bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999 representing 31% of the samples collected and processed from the intake structure during that period. There appeared to be a relatively compressed period of larval abundance in April through July of 1998 compared to a more protracted spawning season in 1997 that lasted from February through September. This may have been related to the El Niño event that occurred during late 1997 (Lynn et al. 1998; NOAA 1999) as substantial increases in water temperatures and lowered productivity negatively affected

larval production and survival. Monthly samples collected in 1999 show larval densities similar in timing with 1997.

Larval snubnose sculpin generally occurred in the DCPD study grid with similar seasonality to that observed at the DCPD intake structure (**Appendix H**). The 447 snubnose larvae identified from 201 bongo net subsamples represented 7% of the fishes collected and processed from July 1997–June 1999 study grid samples. Thus, snubnose larvae were less common in the study grid than at the intake structure where their larvae were found in 31% of the samples. The peak abundances in the study grid occurred in July 1997 (**Figure 5.2.6-9**). During July 1997 and other surveys, snubnose sculpin larvae were typically more abundant in the nearshore areas of the grid. Similar to smoothhead sculpin, spatial distribution of larval snubnose abundance appeared to follow the 20 m isobath. Marliave (1986) found that larvae of rocky intertidal and nearshore fishes may resist offshore transport, and possibly even alongshore transport, to remain concentrated against the shore. Larvae of this species occurred more often in the southern portion of the study grid because more of the area in the southern half of the grid is within the 0–20 m depth range.

Standard lengths of all measured snubnose sculpin larvae collected at the DCPD intake structure between October 1996 and June 1999 (3,750 larvae) ranged from 1.7 mm to 8.5 mm (**Figure 5.2.6-10**). The central 98% of this length-frequency distribution resulted in minimum and maximum lengths used for analyses of 2.6 mm and 6.1 mm, respectively. The mean larval length in this distribution was 3.6 mm. Reported hatching size for this species ranged from 2.6–3.8 mm (Moser 1996). The fact that we observed some larvae smaller than the reported hatching lengths can be explained partly by natural variation of hatch lengths within the population and partly by the phenomenon of shrinkage following preservation (Theilacker 1980). The growth rate applied to this species (0.08 mm/d) from Freeman et al. (1985) was used to estimate ages of entrained larvae. Assuming that the shortest larvae (either 1.7 or 2.6 mm) were immediately post-hatch and aged zero days, then the estimated ages of larvae entrained could range from zero days up to 42–82 d post-hatching for the largest larvae measured. The average estimated ages of snubnose larvae entrained at DCPD ranged from 11–22 d post-hatching.

Distributions of snubnose sculpin larval lengths at the DCPD intake structure and in the study grid were compared using a Kolmogorov-Smirnov test (Figure 5.2.6-11). The test did not detect a significant difference between the two distributions ($p > 0.14$). Larvae in the study grid showed a bimodal size distribution, with a greater proportion of larger individuals represented in the grid relative to collections at the intake structure. A t -test detected a significant difference ($p \leq 0.0134$) between mean lengths for the two locations: 3.5 mm at the DCPD intake and 3.7 mm in the study grid. The large sample size (380 larvae from the intake and 161 larvae from the study grid) causes the t -test to be highly sensitive to small differences between the means (Zar 1984). While the difference between the means was statistically significant, we believe that the biological significance of the difference is low.

Estimating Total Annual Entrainment

The annual estimated mean entrainment of snubnose sculpin larvae ranged from a minimum of 59,800,000 ($\widehat{SE} = 4,120,000$) in 1997–98 Analysis Period 2 to a maximum of 85,600,000 ($\widehat{SE} = 3,490,000$) in 1996–97 Analysis Period 1 (Table 5.2.6-5). The estimates for 1997–98 Analysis Period 3 were slightly different than Analysis Period 2 because snubnose sculpin larvae were collected during the summer and fall months of 1997 when the two periods did not overlap. Values of $2 \cdot \widehat{SE}(\widehat{E}_T)$ can be used to approximate 95% confidence intervals around the point estimates. These confidence intervals for October 1996–September 1997 and October 1997–September 1998 would not overlap, indicating that the differences between them were probably statistically significant.

The adjusted estimates of annual entrainment of snubnose sculpin larvae ranged from 83,500,000 ($\widehat{SE} = 5,750,000$) in 1997–98 Analysis Period 2 to 110,000,000 ($\widehat{SE} = 4,480,000$) in 1996–97 Analysis Period 1 (Table 5.2.6-6) based on annual indices using weekly Intake Cove surface plankton tows (Figure 5.2.6-12). The average index values for the years 1997 and 1998 are 0.028 and 0.025 larvae/m³, respectively, while the long-term average index is 0.036 larvae/m³ for the years 1990–1998, yielding the ratio \bar{I}/I_i of 1.28 for 1997 and 1.40 for 1998. The adjustments

increased the estimates for all three periods but did not decrease the relative differences among them.

NOTE: Estimates of *FH* or *AEL* for snubnose sculpin using annual entrainment were not calculated because no demographic data exists for this species.

Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) in the surveys from the two analysis periods ranged from a minimum of zero to a maximum of 0.859 ± 0.911 ($\pm 1SE(\widehat{PE}_i)$) in December 1997 (Table 5.2.6-7). However, this maximum value was accompanied by a relatively low estimate of the annual proportion of larvae hatched in the i th survey period (\hat{f}_i) indicating that relatively few snubnose sculpin larvae were collected at the intake during this month. When both \widehat{PE}_i and \hat{f}_i were equal to zero, no larvae were collected at either the DCPD intake or from the study grid. When $\widehat{PE}_i = 0$ but $\hat{f}_i > 0$, larvae were collected at the DCPD intake during the monthly survey period but not during the entrainment survey paired with the 72-hour study grid survey. The largest values of \hat{f}_i occurred during April through July in both analysis periods. During the 1996–1997 analysis period, the largest values of \widehat{PE}_i occurred during periods when the \hat{f}_i were lowest, indicating that the high \widehat{PE}_i values resulted from low entrainment densities used to estimate abundance in nearshore areas of the study grid. During the 1997–1998 analysis period these surveys were also associated with the largest values of \widehat{PE}_i .

Results of *ETM* for snubnose sculpin showed how differences in estimated larval durations (11 vs. 42 d) can affect estimation of \widehat{P}_M (Figures 5.2.6-13). Study grid samples showed that snubnose sculpin larvae were primarily distributed in nearshore areas (Figure 5.2.6-9) despite the fact that adults have been found from the intertidal zone out to depths of 30 m (Miller and Lea 1972). Based on observed larval and reported adult distributions, P_S was calculated using both alongshore current movement and extrapolating study grid abundance offshore using onshore current movement before extending alongshore. The probability of entrainment was typically less for the shorter duration within an extrapolation class because of the reduced time period over which larval transport occurred. Estimates of \widehat{P}_M using alongshore transport were larger for the

1998–1999 analysis period (0.24; **Figure 5.2.6-13b**) than for the 1997–1998 analysis period (0.14) and were greater than within-period differences between estimates based on different larval durations. Estimates of \widehat{P}_M using offshore abundance extrapolation and maximum transport duration were very similar between periods (i.e., 0.021 for 1998–1999 and 0.023 for 1997–1998). The increased onshore transport caused by the El Niño conditions during the 1997–1998 period reduced the differences in the estimates by compensating for the large differences in alongshore transport between the two periods.

Interpretation of Assessment Results

Snubnose sculpin has neither commercial nor recreational fishery value and there is little information on its ecological role in the community. Because of the absence of any fishery for this species, no catch data can be used to compare harvest mortality rates to entrainment mortality rates (\widehat{P}_M). There also are no stocks or adult density estimates that could be used to convert \widehat{P}_M into equivalent adult losses (assuming no compensatory mortality).

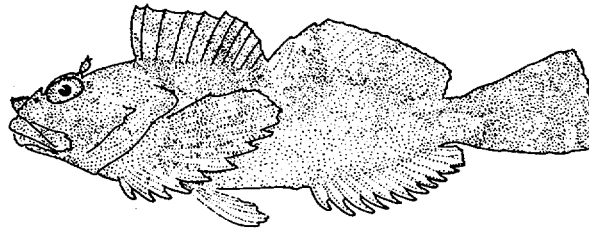
Annual mean density of snubnose sculpin larvae from Intake Cove surface plankton tows shows a declining trend in abundance over time, although the estimates for 1997 and 1998 appear to have leveled off (**Figure 5.2.6-12**). Reduced larval production may affect recruitment and eventually adult population densities. Reductions in adult density due to entrainment of snubnose sculpin larvae could be expected to appear only after several generations. There were no estimates in the scientific literature of the life-span or age at sexual maturity for snubnose sculpin, though they are likely to be similar to other small, nearshore cottids: 1–3 yr for sexual maturity and 2–7 yr for longevity (Gibson 1969; Miller 1979; deVlaming et al. 1982; Grossman and deVlaming 1984; Freeman et al. 1985; Wells 1986; Pierce and Pierson 1990).

Adult abundance of snubnose sculpin observed in the DCPD Receiving Water Monitoring Program (RWMP) studies on subtidal fishes varies considerably through time, but shows a downward trend from the early 1990s through 1998 (**Figure 5.2.6-14**). These data were collected along three 50 m transects in an area approximately 1 km south of Diablo Cove not contacted by the plant's thermal discharge. Since the potential life-span and age at sexual maturity of snubnose

sculpin are less than the time since power plant operation began, there has been sufficient time for losses in the adult population to occur as a result of a decrease in larvae. Thus, it appears that larval entrainment mortality of snubnose sculpin may be a factor in the reduction of adult abundance in the vicinity of DCP.

Snubnose sculpin have a smaller geographical distribution (Farallon Islands, northern California to Isla San Geronimo, northern Baja California) than other central California sculpins (Eschmeyer et al. 1983; Love et al. 1996). Although the results of the *ETM* evaluated using extrapolated abundance implying a large population area, the more restricted distribution of this taxon indicates that an estimate of P_M closer to the values estimated using alongshore transport alone may be more appropriate. These estimates range from approximately 10% to over 20%, depending upon larval duration and sampling period (Figures 5.2.6-13). Based on Moser's (1996) reported size at flexion of 4.2–4.7 mm, the length range of larvae entrained shows that post-flexion larvae are still subject to entrainment (Figure 5.2.6-10). This also indicates that snubnose sculpin larvae have a prolonged exposure to entrainment. The prolonged exposure period and the levels of entrainment mortality estimated by P_M may partially explain other results that show long-term declines in larval abundance in intake samples (Figure 5.2.6-12) and declines in local adult abundance (Figure 5.2.6-14).

5.2.6.3 Cabezon (*Scorpaenichthys marmoratus*)



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

The cabezon (*Scorpaenichthys marmoratus*) is the largest North American species of marine cottid and occurs over the nearshore continental shelf from depths of 85 m up to the intertidal zone (O'Connell 1953; Matarese et al. 1989). Cabezon are a popular sport fish and are also landed commercially (Fitch and Lavenberg 1971; Lamb and Edgell 1986). Females are oviparous and lay demersal, adhesive eggs in rocky crevices or on algae; males guard the egg nest until the pelagic larvae hatch (Burge and Schultz 1973; Feder et al. 1974; Matarese et al. 1989). Moser (1996) indicates that cabezon larvae hatch at 3–6 mm.

Larvae appear in the water column around November or December and recruit to tidepools at around 40 mm SL in March off Moss Beach, California (R.R. Harry unpubl. data cited in O'Connell 1953), implying a 3–4 mo planktonic duration. Females begin to mature in their third year between 25–48 cm 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 SL specimen and 95,000 eggs for a 65 cm SL specimen (Hart 1973); mean fecundity of 48,700 eggs for a 1.4 kg female and 97,600 eggs for a 4.6 kg female (O'Connell 1953; Bane and Bane 1971); and up to 152,000 eggs from a 76 cm 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 yr and males to 9 yr (O'Connell 1953).

As with other members of the Cottidae, there are insufficient data to parameterize the *FH* and *AEL* approaches for impact assessment. No independent estimates of survivorship for early life stages prior to entrainment or later life stages are available from the literature. Thus, the impact of entrainment on this species' population will be assessed using only the *ETM*.

Summary of Field Collections

Estimates of cabezon larval abundance showed distinct seasonal peaks at the DCPD intake structure during the years 1996–1999 (**Appendix H**) with an apparent trend of decreasing abundance at the intake over the same period (**Figure 5.2.6-15**). There were 1,938 larval cabezon identified from 575 bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999 representing 12% of the entrainment samples collected and processed during that period. The spawning period for cabezon in winter 1996–1997 was longer and had higher abundances than the winter 1997–1998 spawning period. This difference may have been related to the El Niño event that occurred during late 1997 (Lynn et al. 1998; NOAA 1999) as substantial increases in water temperatures and lowered productivity negatively affected larval production and survival. The limited samples available from the winter 1998–1999 spawning period appear to show similar timing as previous years.

The seasonality of larval cabezon in the DCPD study grid was similar to the timing observed from the samples at the DCPD intake structure (**Figure 5.2.6-16**). There were 887 cabezon larvae identified from 326 bongo net subsamples (**Appendix H**) representing 11% of the study grid samples collected and processed from July 1997–June 1999. The spatial distribution of larval cabezon abundance in the study grid during 1997–1998 Analysis Period 3 appeared primarily constrained against the shoreward side of the study grid. During 1998–1999 Analysis Period 4, cabezon larvae appeared to be more widely distributed in the study grid. The stronger alongshore currents during the second analysis period may account for this difference. Larval dispersal may have been more limited during the El Niño conditions present during the 1997–1998 analysis period due to weaker alongshore and stronger onshore currents.

Standard lengths of all cabezon larvae collected at the DCPD intake structure between October 1996 and June 1999 and measured (1,537 larvae) ranged from a minimum of 2.3 mm to a maximum of 8.4 mm (Figure 5.2.6-17). The central 98% of this length-frequency distribution resulted in minimum and maximum lengths of 3.7 mm and 6.1 mm, respectively, that were used for calculating larval duration. The mean length of this distribution was 4.8 mm. Reported hatching size for this species ranged from 3–6 mm (Moser 1996). The fact that we observed some larvae smaller than the reported hatching lengths can be explained partly by natural variation of hatch lengths within the population and partly by the phenomenon of shrinkage following preservation (Theilacker 1980). The growth rate applied to this species (0.3 mm/d) was derived from O'Connell (1953) and Moser (1996) and was used to estimate ages of entrained larvae. Assuming that the shortest larvae (either 2.3 or 3.7 mm) were immediately post-hatch and aged zero days, the estimated ages of larvae entrained could range from zero days up to 8–20 d post-hatching for the largest larvae measured. The average estimated ages of cabezon larvae entrained at DCPD ranged from 4–8 d post-hatching.

Distributions of cabezon larval lengths at the DCPD intake structure and in the study grid were compared using a Kolmogorov-Smirnov test (Figure 5.2.6-18). The test detected a significant difference between the two distributions ($p \leq 0.001$). Larvae in the study grid had a greater proportion of smaller individuals relative to collections at the intake structure. A *t*-test also detected a significant difference ($p \leq 0.002$) between the mean lengths for the two locations: 4.7 mm at the DCPD intake and 4.8 mm in the study grid. While these differences were statistically significant, we believe that the biological significance of these differences was low.

Estimating Total Annual Entrainment

The annual estimated mean entrainment of cabezon larvae ranged from 14,700,000 ($\widehat{SE} = 1,460,000$) in 1997–98 Analysis Periods 2 and 3 to 35,700,000 ($\widehat{SE} = 2,720,000$) in 1996–97 Analysis Period 1 (Table 5.2.6-8). Values of $2 \cdot \widehat{SE}(\widehat{E}_T)$ can be used to approximate 95% confidence intervals around the point estimates. The confidence intervals for the 1996–97 and 1997–98 periods would not overlap, indicating that the differences between them were probably

statistically significant. The estimates for Analysis Period 3 are the same as Analysis Period 2 because all of the cabezon were collected during the October–June period when the two periods overlapped (Figure 5.2.6-15).

Annual estimates of entrained cabezon larvae, adjusted to a long-term mean based on annual indices using weekly Intake Cove surface plankton tows (Figure 5.2.6-19) ranged from 36,300,000 ($\widehat{SE}=3,600,000$) in Analysis Periods 2 and 3 to 51,900,000 ($\widehat{SE}=3,950,000$) in Analysis Period 1 (Table 5.2.6-9). The average index for the years 1997 and 1998 are 0.0076 and 0.0045 larvae/m³, respectively, while the long-term average index is 0.011 larvae/m³ for the years 1990–1998, yielding the ratio \bar{I}/I_i of 1.45 for 1997 and 2.47 for 1998. The adjustments increases the estimates of abundance and decreases the differences among them.

NOTE: Estimates of *FH* or *AEL* for cabezon using annual entrainment were not calculated because there were no demographic data available for this species.

Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) in the surveys from the two analysis periods ranged from a minimum of zero to a maximum of 0.106 ± 0.103 ($\pm 1\widehat{SE}(\widehat{PE}_i)$) in October 1997 (Table 5.2.6-10). However, this maximum \widehat{PE}_i value was not accompanied by a maximal estimate of the annual proportion of larvae hatched in the i th survey period (\hat{f}_i) so it was proportionally less important to the estimate of annual entrainment mortality than other values with higher \hat{f}_i 's. Periods when both \widehat{PE}_i and \hat{f}_i were equal to zero indicated that no larvae were collected at either the DCP intake or from the study grid. When $\widehat{PE}_i = 0$ but $\hat{f}_i > 0$, larvae were collected at the DCP intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. The largest values of \hat{f}_i occurred from December–February in both analysis periods indicating that these were times of high larval abundance at the intake structure.

Estimates of \widehat{P}_M for either alongshore current transport or offshore abundance extrapolation during both analysis periods were relatively similar and ranged from 0.006 to 0.03 (Figures

5.2.6-20). Cabezon adults have been found to depths of 75 m (Miller and Lea 1972) and their larvae were distributed throughout the study grid (Figure 5.2.6-16). Therefore, P_s was calculated using both alongshore current movement and extrapolating study grid abundance offshore using onshore current movement before extending it alongshore. Larval durations calculated using the mean and maximum larval lengths (central 98% of length distribution) only differed by 4 d (4 vs. 8 d). This similarity in duration resulted in relatively small values of \widehat{P}_M and rapid decline in their value with increasing P_s . Thus, it appears that cabezon larvae were entrainable over a relatively short period of their development.

Interpretation of Assessment Results

Cabezon has both commercial and recreational fishery value. Combined reported landings at the ports of San Luis and Morro Bay have varied during 1975–1998 from zero in 1975 to a high of 78 MT in 1997 with an average of 9.7 MT (Figure 5.2.6-21). From 1995–1998, the combined average catch increased dramatically to over 60 MT/yr as a result of increased fishing effort stimulated by a high demand for cabezon in the ‘live-fish’ fishery. Juvenile and adult cabezon abundance examined using data from the DCPD Receiving Water Monitoring Program (RWMP) studies on subtidal fishes appears to be a declining since 1993 (Figure 5.2.6-21). Mean abundance of juvenile and adult cabezon was estimated from three 50 m transects in an area approximately 1 km south of Diablo Cove and not contacted by the plant’s thermal discharge. This decline likely reflects the increased ‘live-fish’ fishery activity targeting young, nearshore species. Increases in the activity of fisherman in the ‘live-fish’ fishery near DCPD has been noted since approximately 1995. There does not appear to be a similar long-term abundance decline for cabezon larvae from the Intake Cove surface plankton tows; mainly due to high abundance in 1995 (Figure 5.2.6-19). In addition, the narrow size range of larvae entrained by the power plant (central 98% of length-frequency distribution ranged from 3.7–6.1 mm) indicates that cabezon larvae are exposed to entrainment for a relatively short period of time (Figure 5.2.6-17). Additionally, most larvae entrained were shorter than the reported length at flexion of 7.0 mm (Moser 1996). While it remains unclear whether local cabezon populations are in decline after

examining these data, the size range of entrained larvae and relatively low estimates of \widehat{P}_M can lead to the conclusion that larval entrainment mortality is not affecting local adult populations.

Empirical transport modeling results indicate that the power plant may annually entrain approximately 1.5–3.5% of the cabezon larvae in an area 2–3 times the size of the study grid (assuming alongshore transport only) but less than 1% of larvae in an area from 4–22 times the size of the study grid (assuming both alongshore and offshore transport). Using this range of values, an estimate of $\widehat{P}_M = 0.015$ or 1.5% was used to estimate entrainment effects on cabezon landings assuming no compensatory mortality. Based on landings and revenues of cabezon in the Morro Bay area from 1998 (75.2 MT and \$592,300; PSMFC PacFIN database), the average dollar loss to the cabezon fishery (assuming a 1.5% proportional loss) due to larval entrainment at DCPD would be approximately \$9,000/yr.

Table 5.2.6-1. Summary of known demography for four closely related cottid species; X indicates data available from published sources; * indicates length-frequency data to estimate total adult mortality is available from this study; — indicates no data available.

Species	S_{egg}	S_{larvae}	S_{adult}	Fecundity	Age @ maturity	Spawning	Longevity	Age & Growth	Stage Duration
<i>A. lateralis</i>	—	—	—	—	X	—	X	—	X ¹
<i>O. maculosus</i>	—	—	*	X	X	—	—	—	—
<i>O. snyderi</i>	—	—	*	—	—	X	X	X	—
<i>C. analis</i>	—	—	—	X	X	X	X	X	X ^{1,2}

¹ Egg stage duration

² Planktonic larval duration

Table 5.2.6-2. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for smoothhead sculpin (*Artedius lateralis*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	88,900,000	3,660,000
2) Oct 1, 1997–Sep 30, 1998	96,100,000	9,410,000
3) Jul 1, 1997–Jun 30, 1998	107,000,000	9,490,000

Table 5.2.6-3. Estimated total annual adjusted entrainment (\hat{E}_{Adj-T}) and standard error ($\widehat{SE}(\hat{E}_{Adj-T})$) for smoothhead sculpin (*Artedius lateralis*) larvae from the three analysis periods.

Analysis Period	\hat{E}_{Adj-T}	$\widehat{SE}(\hat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	57,700,000	2,370,000
2) Oct 1, 1997–Sep 30, 1998	115,000,000	11,300,000
3) Jul 1, 1997–Jun 30, 1998	129,000,000	11,400,000

Table 5.2.6-4. Smoothhead sculpin (*Artedius lateralis*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.00600	0.00248	0.112	0.00534
Aug 25, 1997	0.0236	0.00797	0.0175	0.00111
Sep 29, 1997	0	0	0.00235	0.000440
Oct 20, 1997	0	0	0.00016	0.0000900
Nov 17, 1997	0	0	0.00022	0.000110
Dec 10, 1997	0	0	0	0
Jan 22, 1998	0	0	0.00251	0.000440
Feb 26, 1998	0	0	0.00173	0.000240
Mar 18, 1998	0.0166	0.00453	0.0317	0.00165
Apr 15, 1998	0.0431	0.0115	0.453	0.0163
May 18, 1998	0.0354	0.00750	0.161	0.00646
Jun 8, 1998	0.0380	0.00685	0.219	0.00861

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.00466	0.00229	0.0301	0.00155
Aug 26, 1998	0.00583	0.00619	0.00198	0.000360
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0	0	0	0
Jan 12, 1999	0.0194	0.0104	0.0157	0.00133
Feb 3, 1999	0.0284	0.010	0.0511	0.00214
Mar 17, 1999	0.0165	0.00483	0.0915	0.00351
Apr 14, 1999	0.0716	0.0222	0.300	0.00759
May 24, 1999	0.0440	0.00973	0.329	0.00788
Jun 23, 1999	0.0729	0.0181	0.180	0.00471

Table 5.2.6-5. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for snubnose sculpin (*Orthonopias triacis*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	85,600,000	3,490,000
2) Oct 1, 1997–Sep 30, 1998	59,800,000	4,120,000
3) Jul 1, 1997–Jun 30, 1998	75,500,000	4,094,000

Table 5.2.6-6. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for snubnose sculpin (*Orthonopias triacis*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	110,000,000	4,480,000
2) Oct 1, 1997–Sep 30, 1998	83,500,000	5,750,000
3) Jul 1, 1997–Jun 30, 1998	105,000,000	5,720,000

Table 5.2.6-7. Snubnose sculpin (*Orthonopias triacis*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.0139	0.00482	0.246	0.00837
Aug 25, 1997	0.0182	0.00671	0.0589	0.00296
Sep 29, 1997	0.859	0.288	0.0322	0.00173
Oct 20, 1997	0.859	0.527	0.00588	0.000700
Nov 17, 1997	0.00474	0.00625	0.00343	0.000510
Dec 10, 1997	0.859	0.911	0.00303	0.000510
Jan 22, 1998	0.0143	0.00760	0.0133	0.00108
Feb 26, 1998	0	0	0.00472	0.000500
Mar 18, 1998	0	0	0.00648	0.000810
Apr 15, 1998	0.0556	0.0201	0.216	0.0106
May 18, 1998	0.0323	0.00894	0.117	0.00480
Jun 8, 1998	0.0467	0.0132	0.293	0.00877

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.0129	0.00582	0.148	0.0112
Aug 26, 1998	0.00885	0.00783	0.00908	0.00109
Sep 16, 1998	0.00445	0.00293	0.00420	0.000600
Oct 6, 1998	0.0199	0.0103	0.0148	0.00121
Nov 11, 1998	0.0292	0.0270	0.0160	0.00175
Dec 9, 1998	0.00470	0.00509	0.00375	0.000680
Jan 12, 1999	0.0726	0.0407	0.0257	0.00218
Feb 3, 1999	0.0532	0.0255	0.0439	0.00297
Mar 17, 1999	0.123	0.0414	0.168	0.00570
Apr 14, 1999	0.104	0.0420	0.251	0.00736
May 24, 1999	0.0357	0.00896	0.143	0.00448
Jun 23, 1999	0.150	0.0527	0.173	0.00745

Table 5.2.6-8. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for cabezon (*Scorpaenichthys marmoratus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	35,700,000	2,720,000
2) Oct 1, 1997–Sep 30, 1998	14,700,000	1,460,000
3) Jul 1, 1997–Jun 30, 1998	14,700,000	1,460,000

Table 5.2.6-9. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for cabezon (*Scorpaenichthys marmoratus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	51,900,000	3,950,000
2) Oct 1, 1997–Sep 30, 1998	36,300,000	3,600,000
3) Jul 1, 1997–Jun 30, 1998	36,300,000	3,600,000

Table 5.2.6-9. Cabezon (*Scorpaenichthys marmoratus*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0	0	0	0
Aug 25, 1997	0	0	0	0
Sep 29, 1997	0	0	0	0
Oct 20, 1997	0.106	0.103	0.0935	0.00830
Nov 17, 1997	0.00608	0.00340	0.0596	0.00605
Dec 10, 1997	0.0140	0.00395	0.289	0.0139
Jan 22, 1998	0.00317	0.00244	0.428	0.0185
Feb 26, 1998	0	0	0.108	0.00854
Mar 18, 1998	0	0	0.00924	0.00197
Apr 15, 1998	0	0	0.0107	0.00219
May 18, 1998	0	0	0.00280	0.00115
Jun 8, 1998	0	0	0	0

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0	0	0	0
Aug 26, 1998	0	0	0	0
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0.00140	0.00072	0.104	0.00895
Jan 12, 1999	0.00630	0.00209	0.587	0.0175
Feb 3, 1999	0.00359	0.00127	0.177	0.0112
Mar 17, 1999	0.00380	0.00181	0.103	0.00768
Apr 14, 1999	0.00679	0.00774	0.028	0.00486
May 24, 1999	0	0	0	0
Jun 23, 1999	0	0	0	0

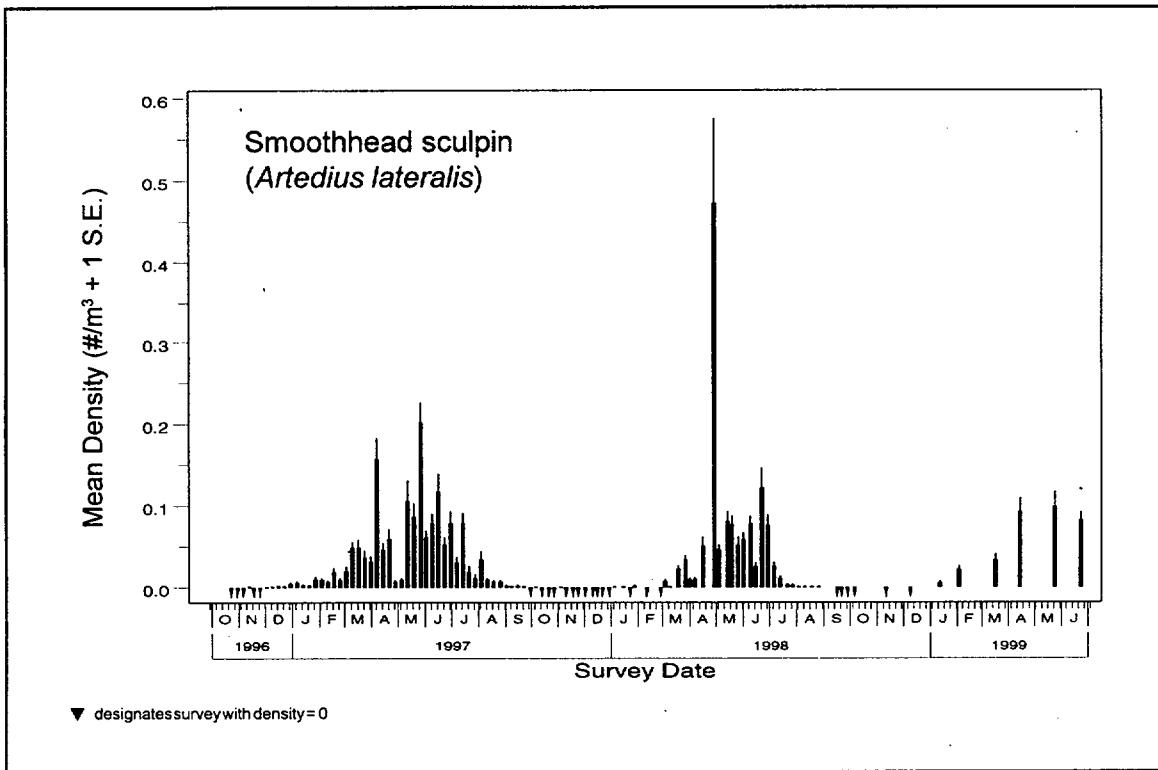


Figure 5.2.6-1. Weekly mean larval density (#/m³ + 1 S.E.) at the DCPPI intake.

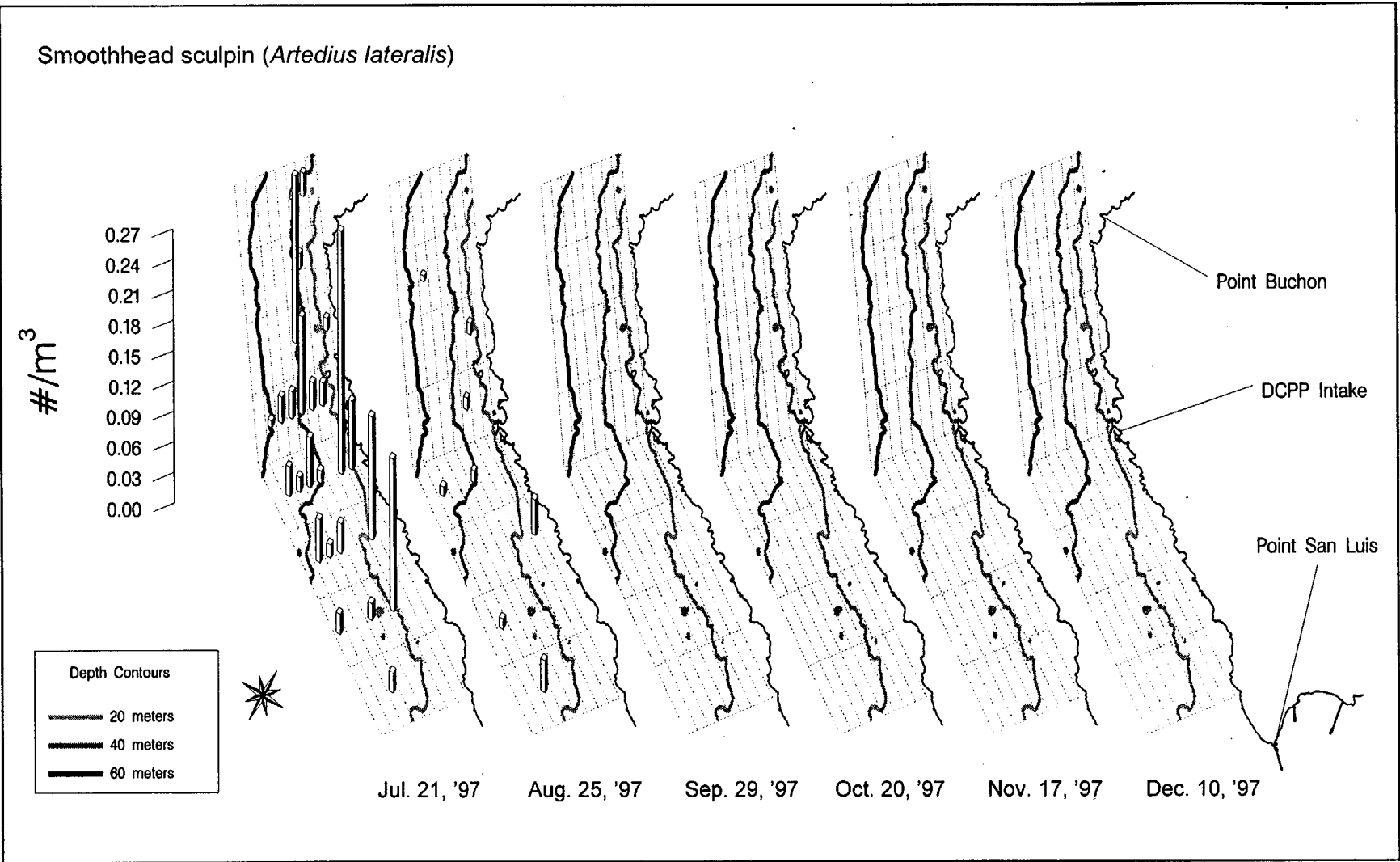


Figure 5.2.6-2a. Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

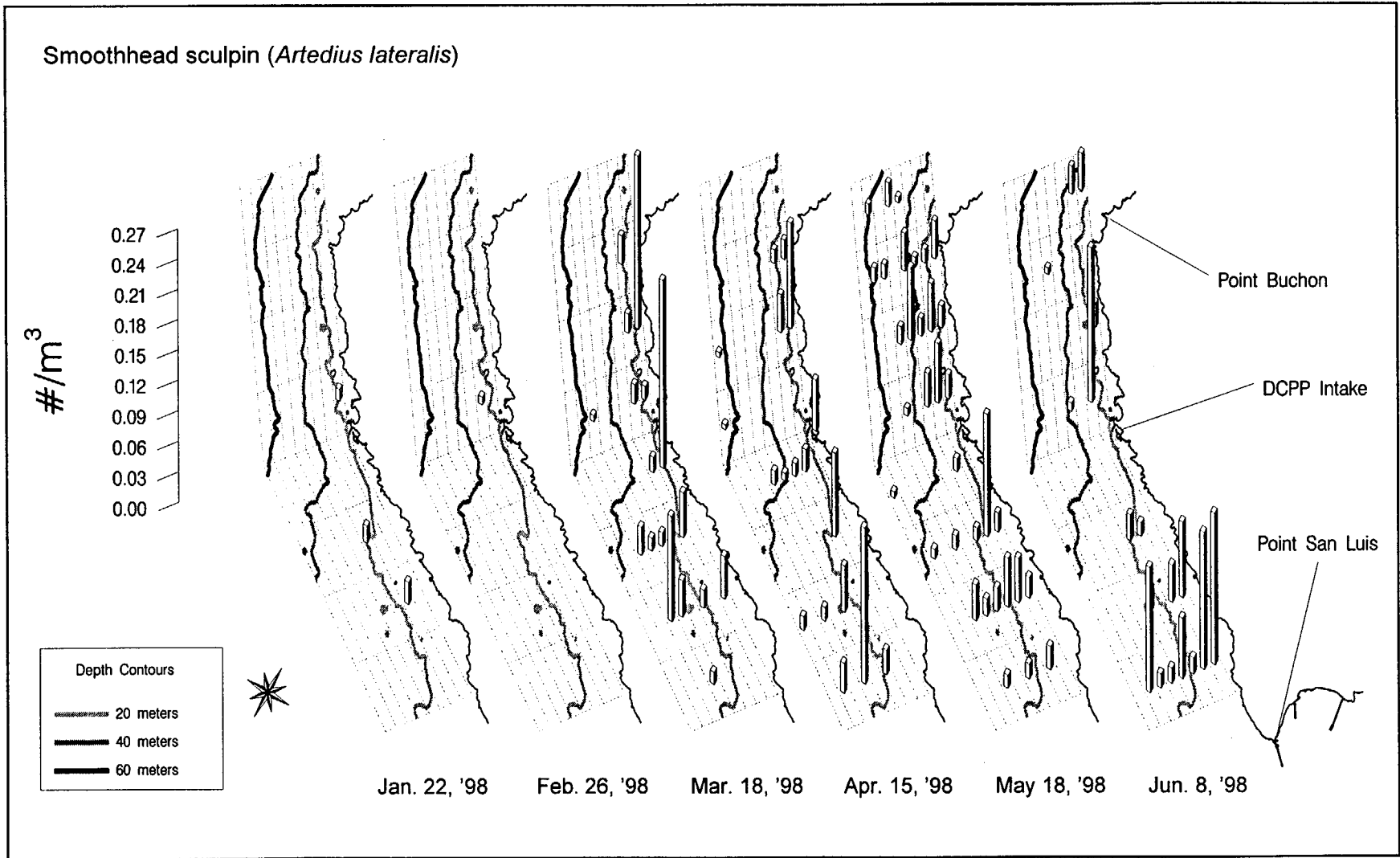


Figure 5.2.6-2b (continued). Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

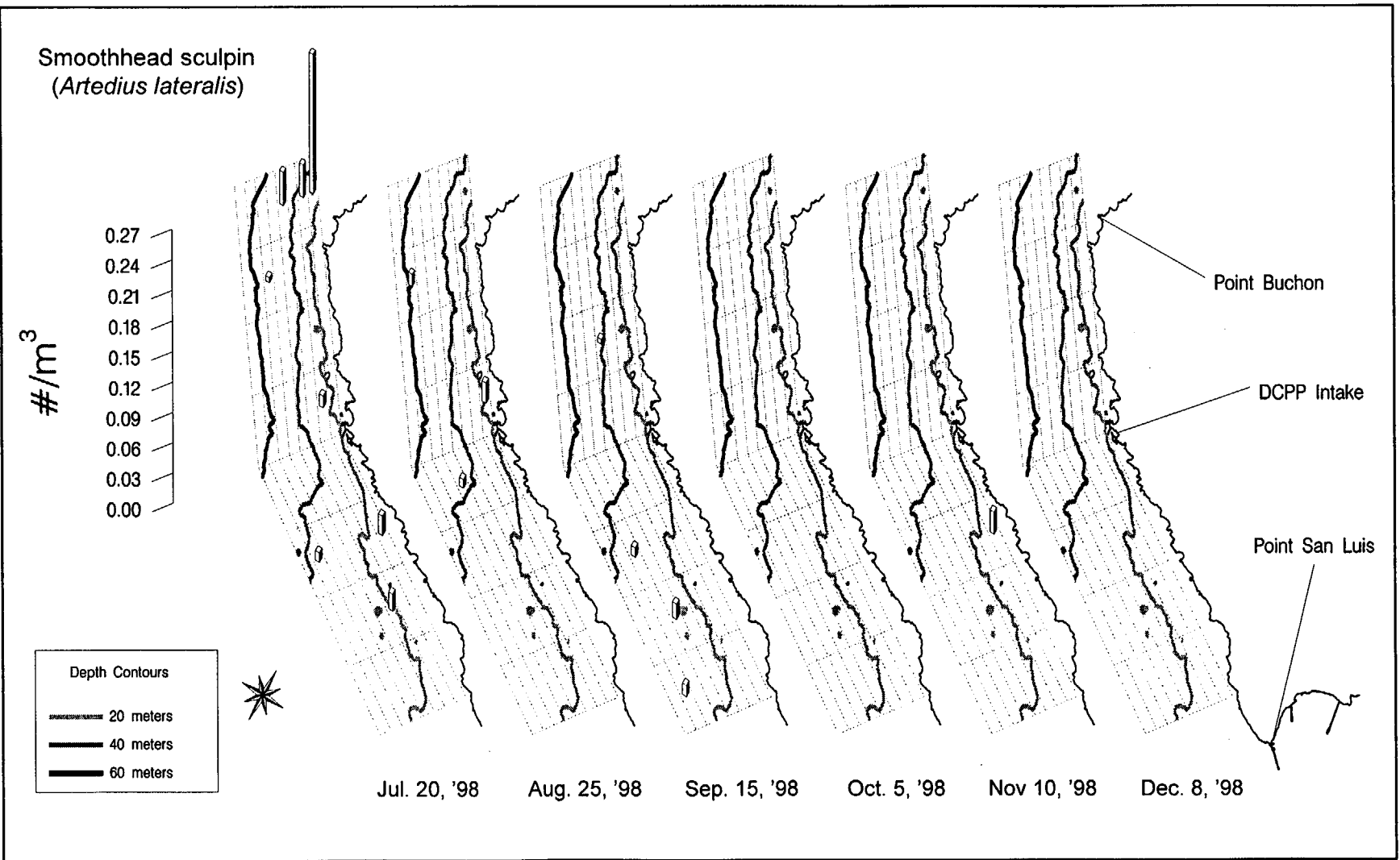


Figure 5.2.6-2c (continued). Mean larval density ($\#/m^3$) collected in the DCPP study grid cells and at the entrainment sampling location.

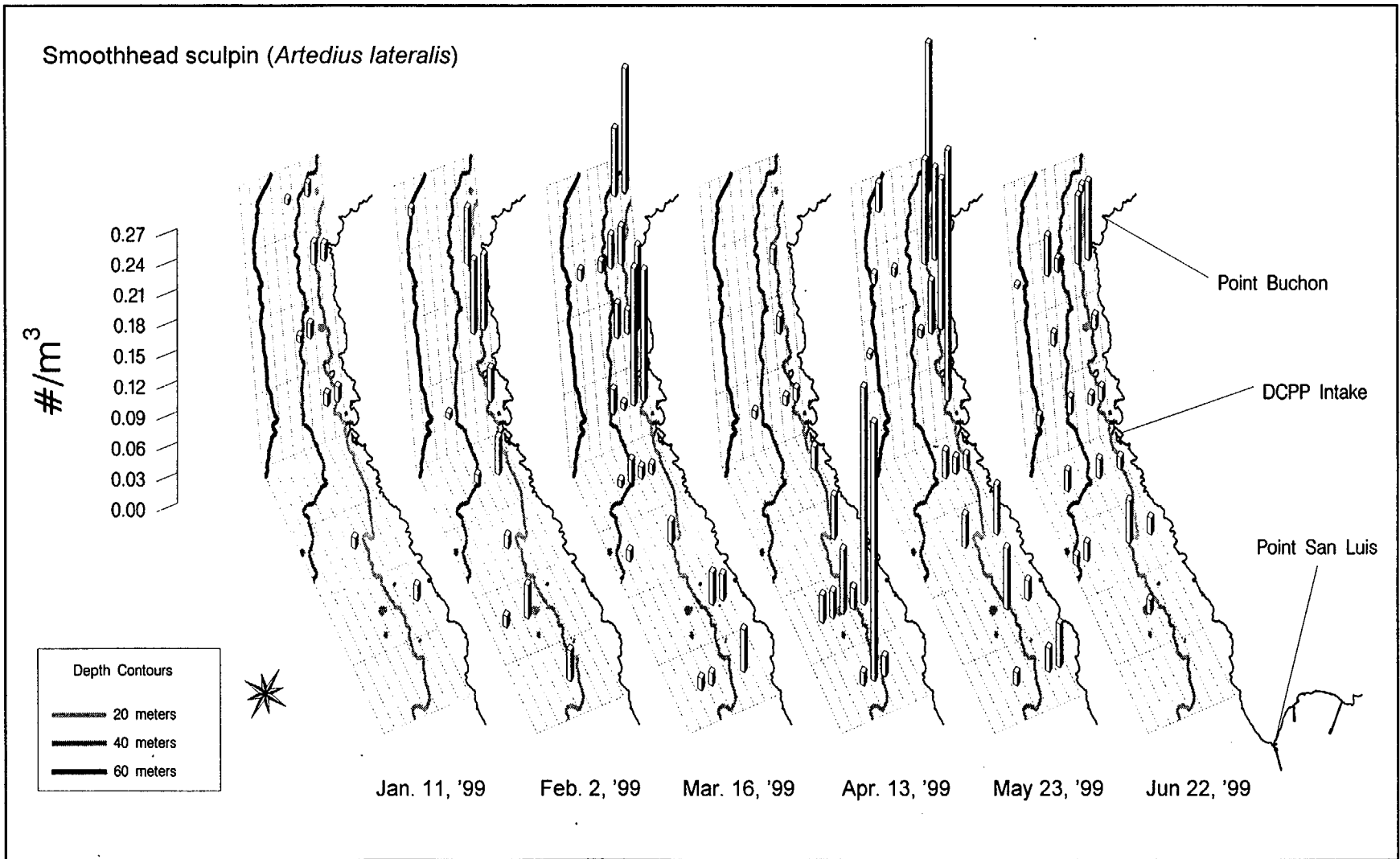


Figure 5.2.6-2d (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

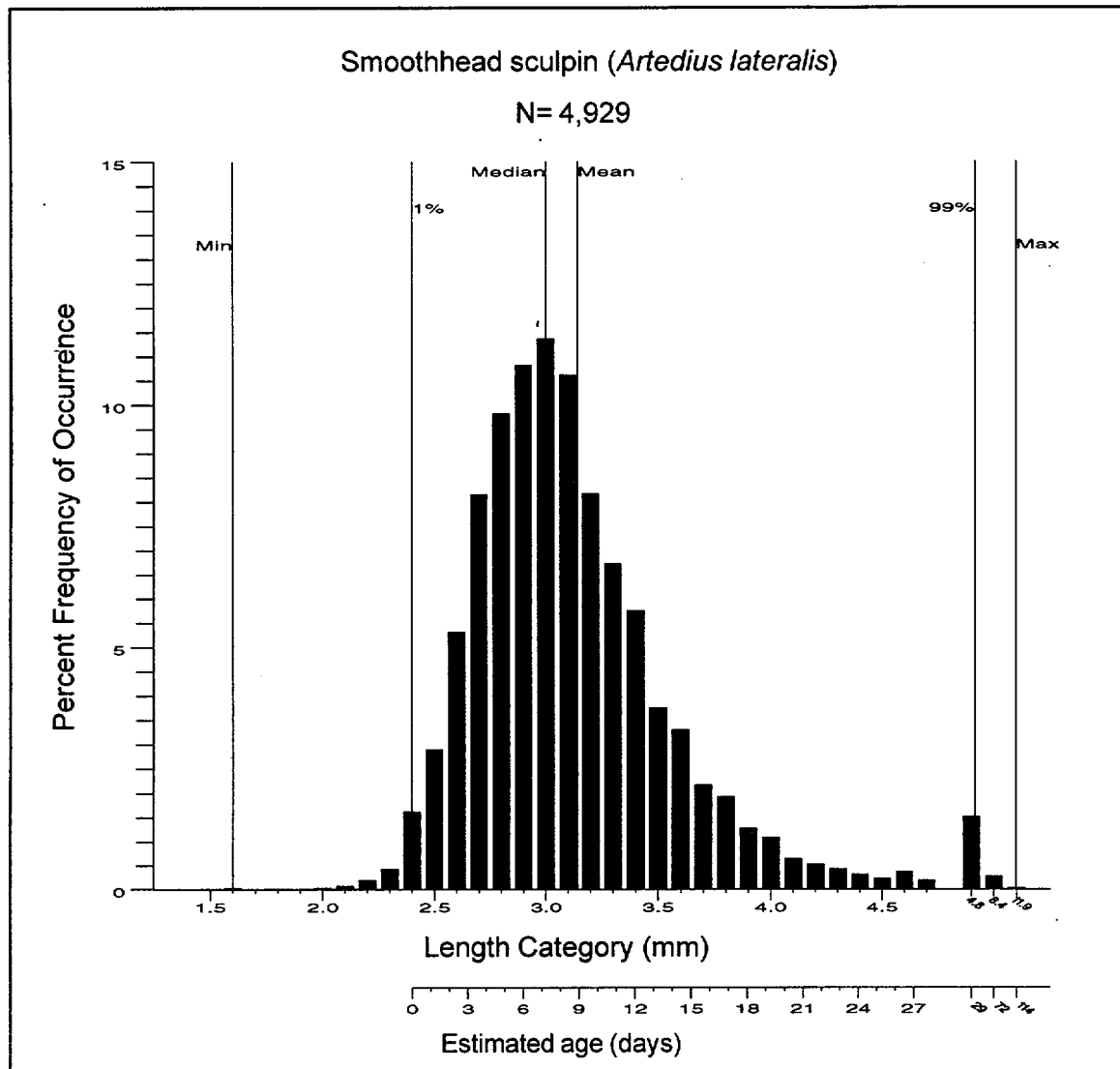


Figure 5.2.6-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

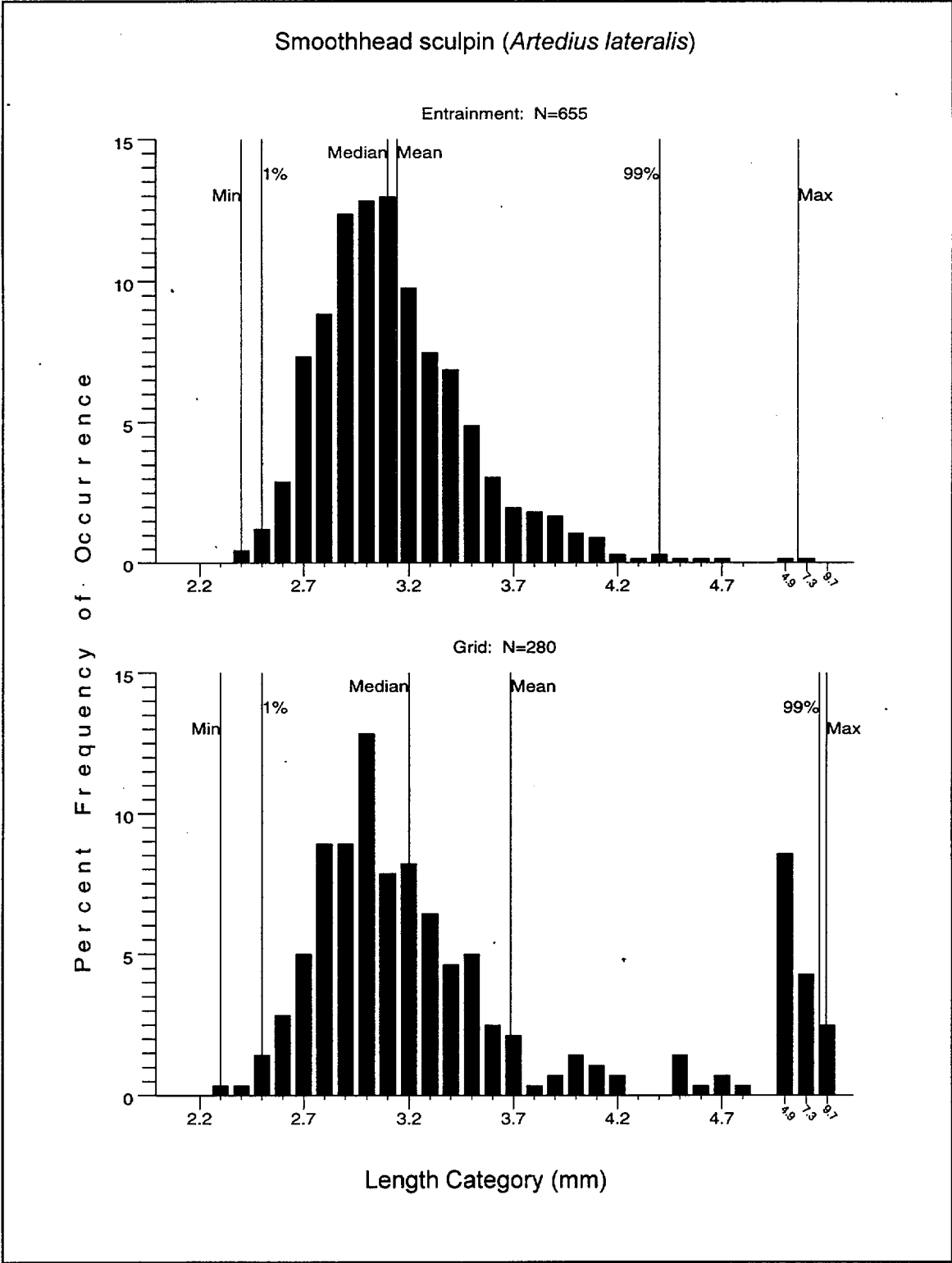


Figure 5.2.6-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

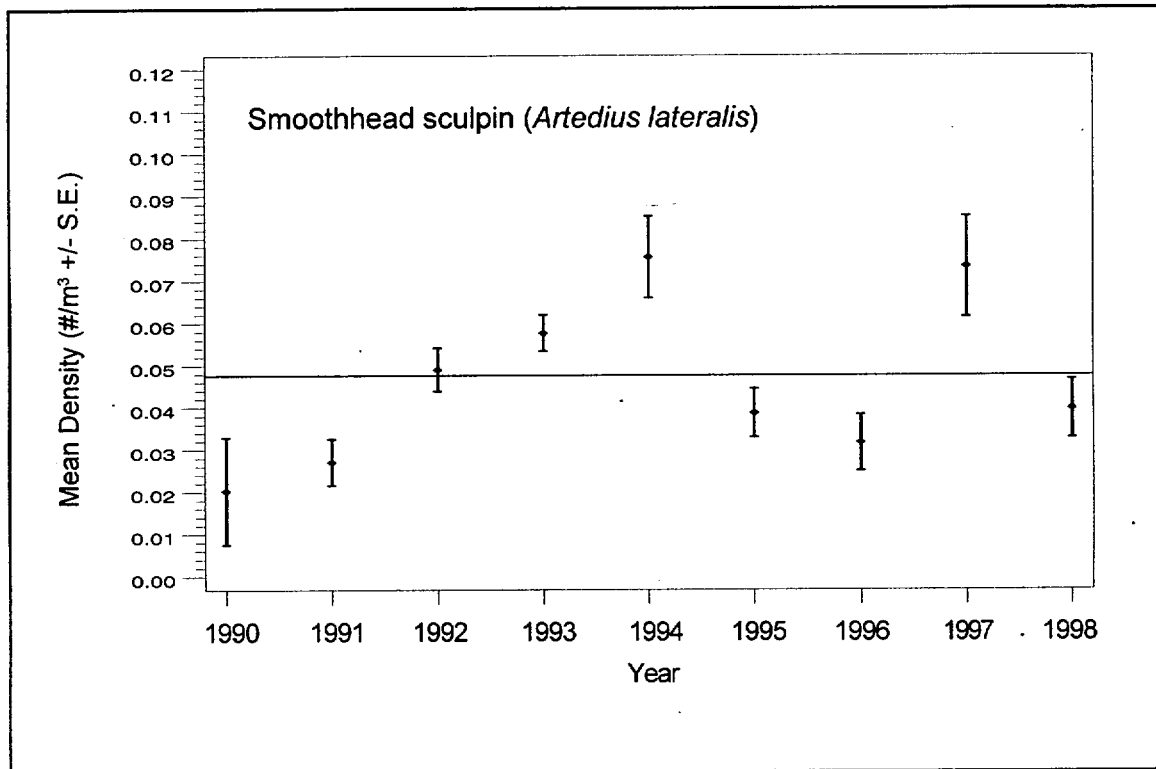


Figure 5.2.6-5. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

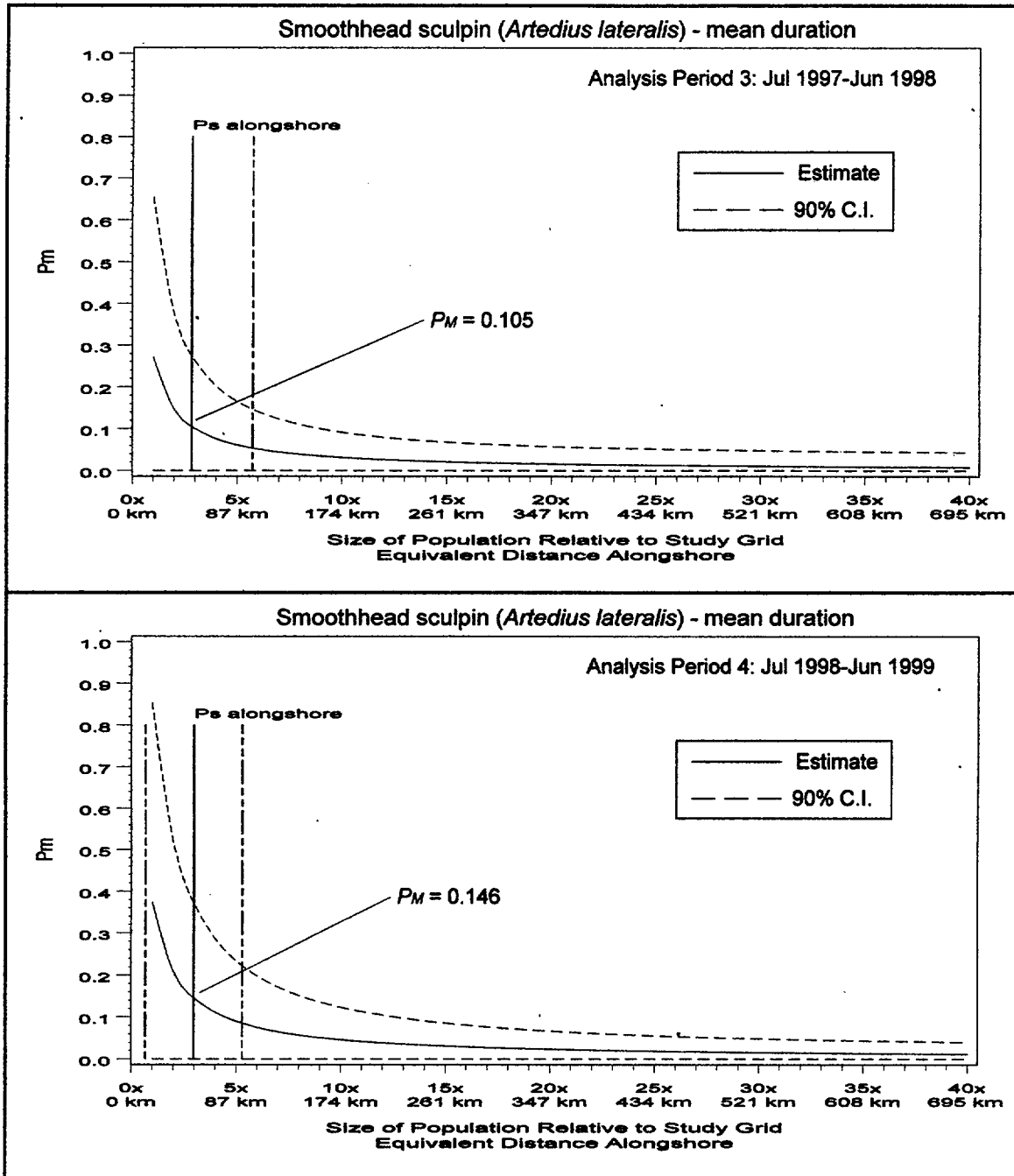


Figure 5.2.6-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements with the 90% C.I. indicated.

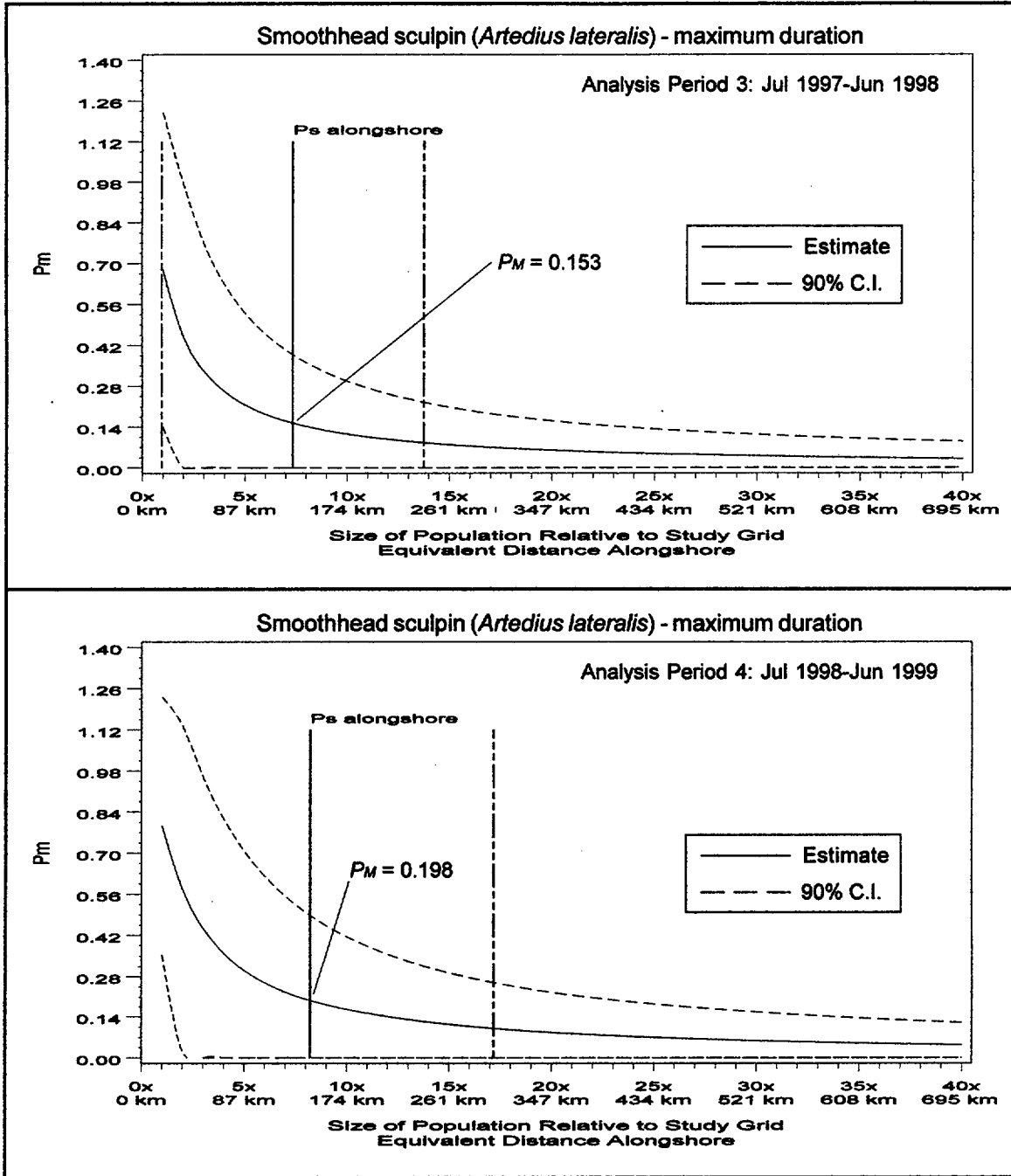


Figure 5.2.6-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements with the 90% C.I. indicated.

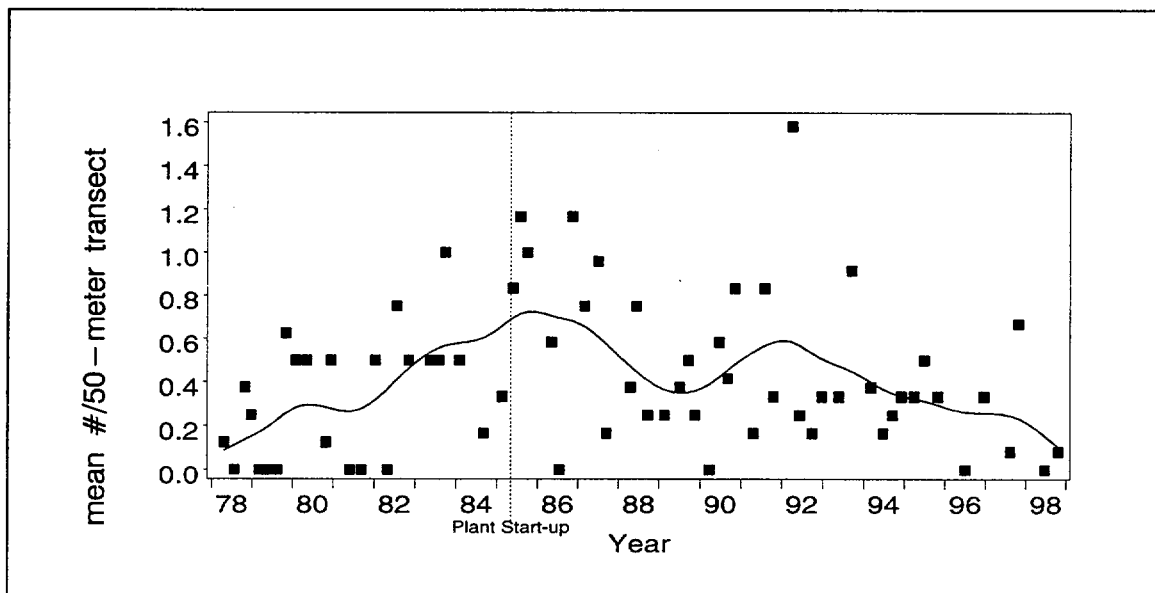


Figure 5.2.6-7. Mean number of sculpins (*Cottidae*) observed per 50-meter subtidal transect in the DCPW RWMP South Control area. Spline smoothing algorithm used to fit curve through points.

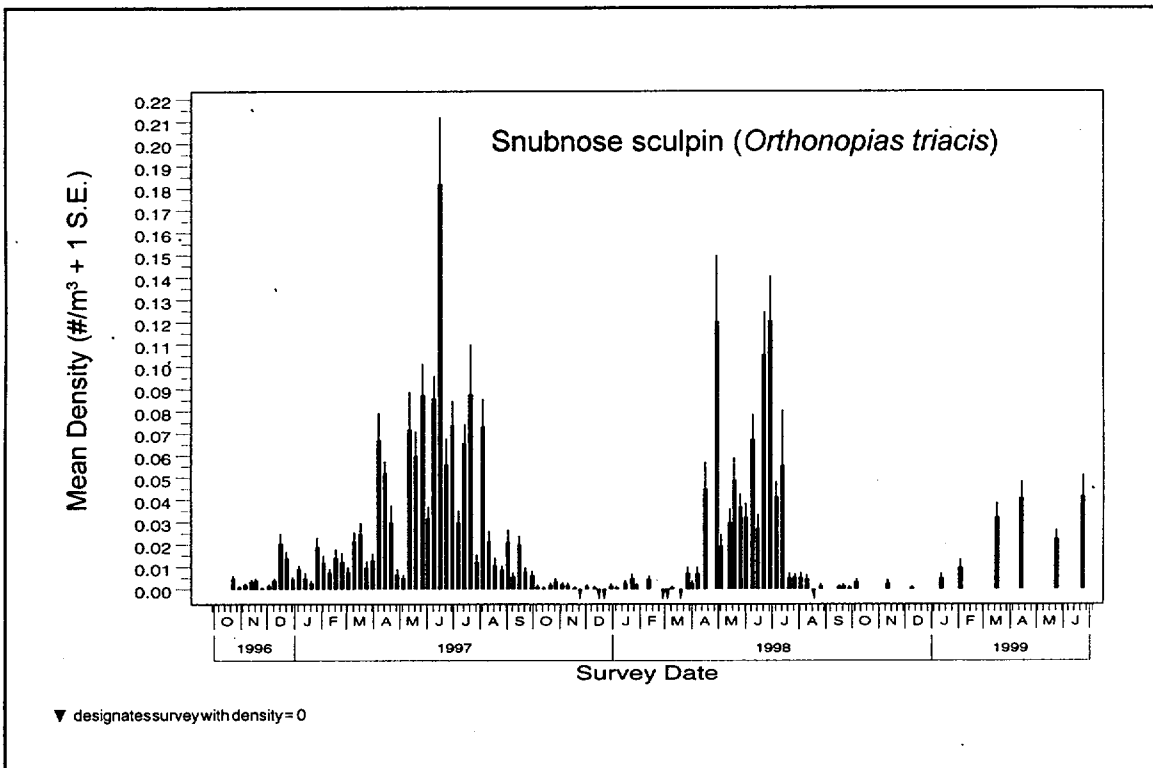


Figure 5.2.6-8. Weekly mean larval density (#/m³ + 1 S.E.) at the DCP intake.

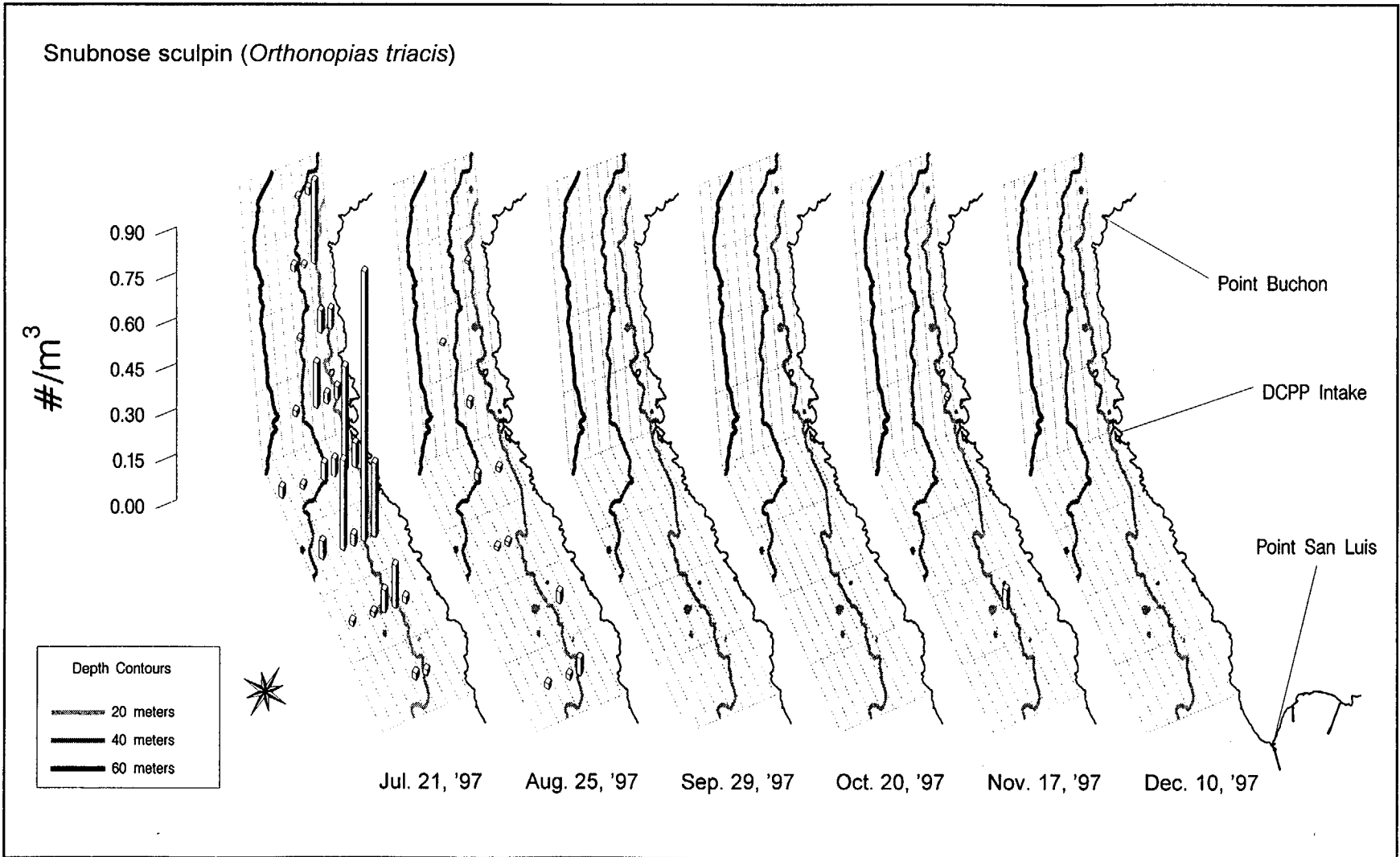


Figure 5.2.6-9a. Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

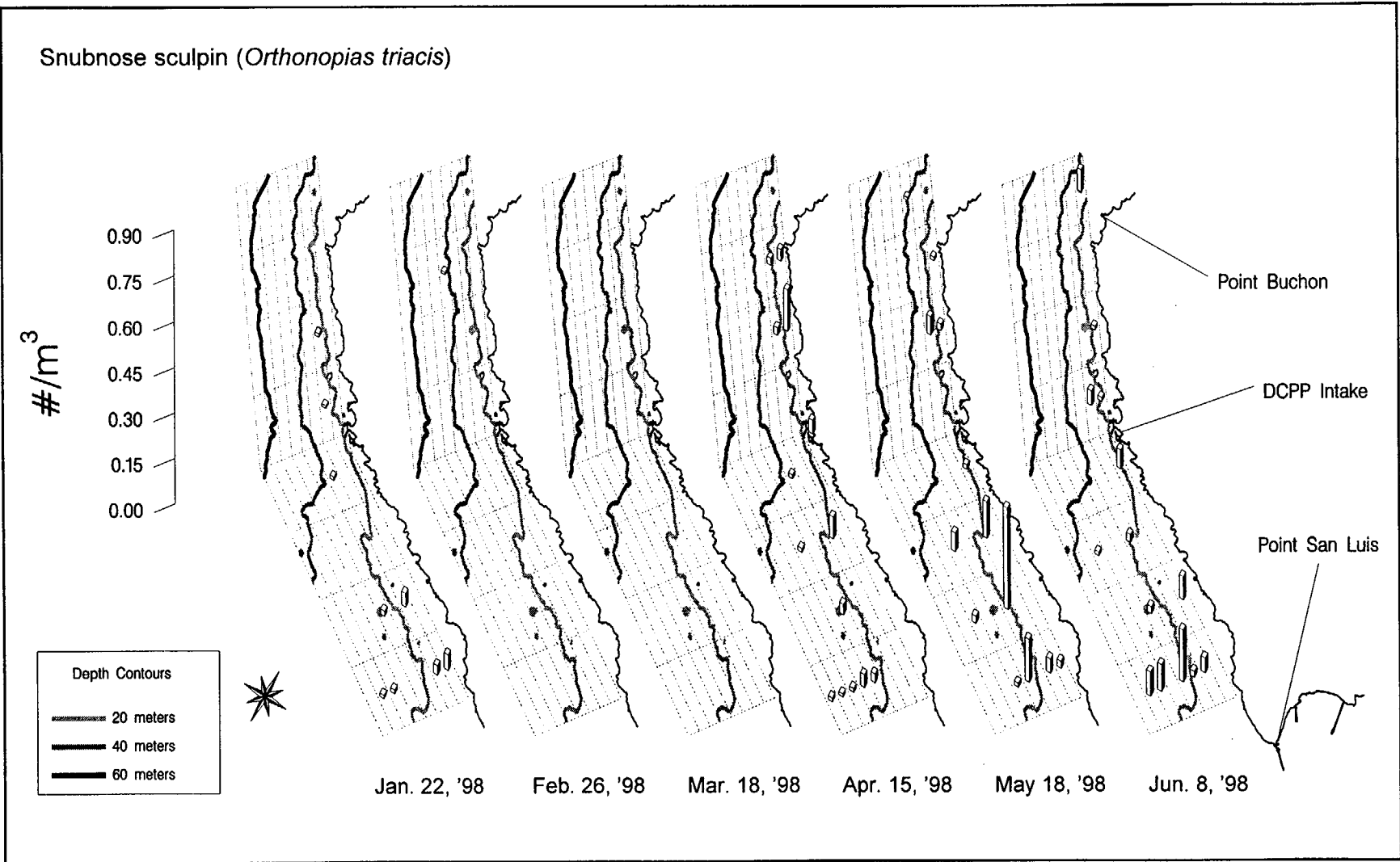


Figure 5.2.6-9b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

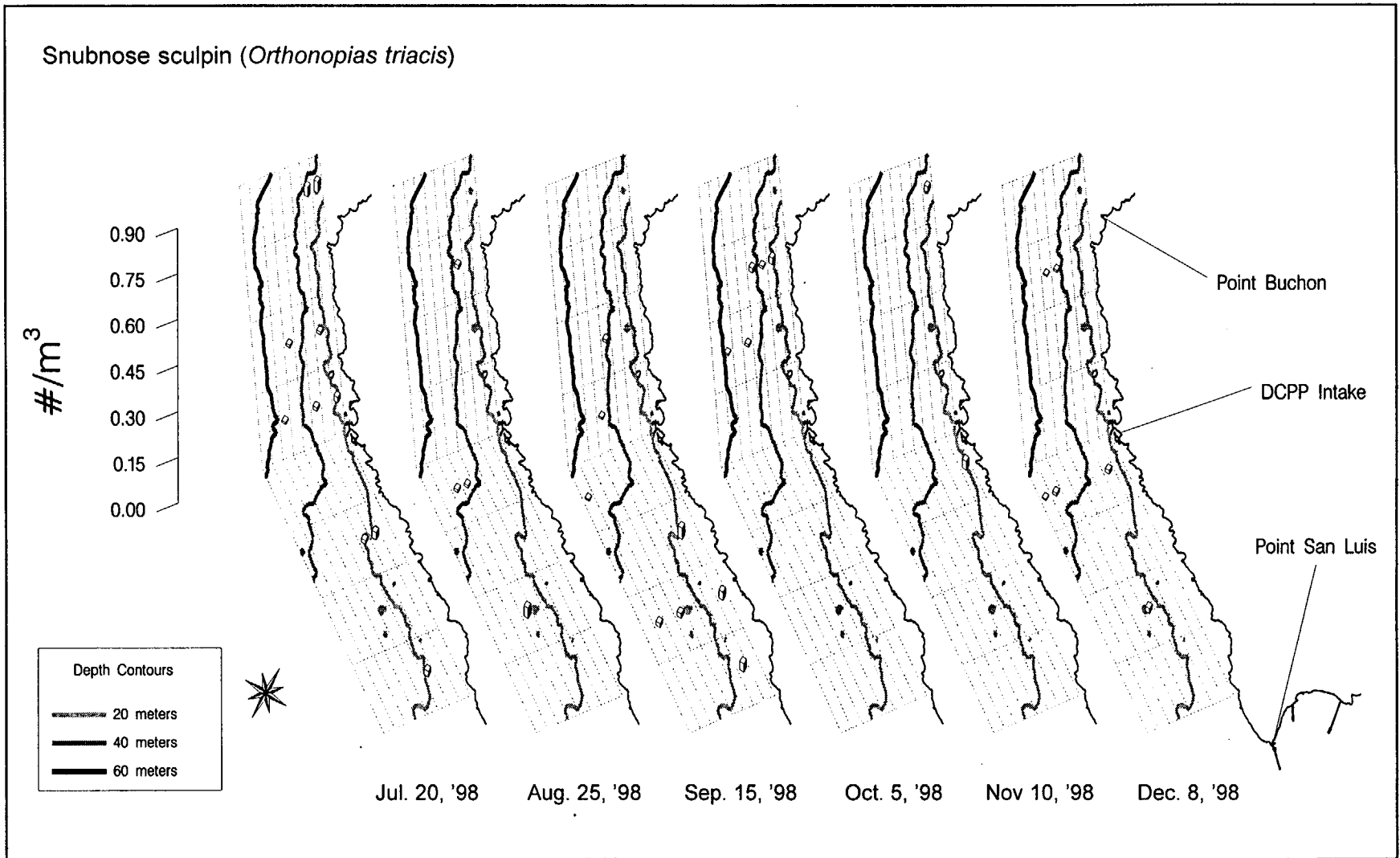


Figure 5.2.6-9c (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

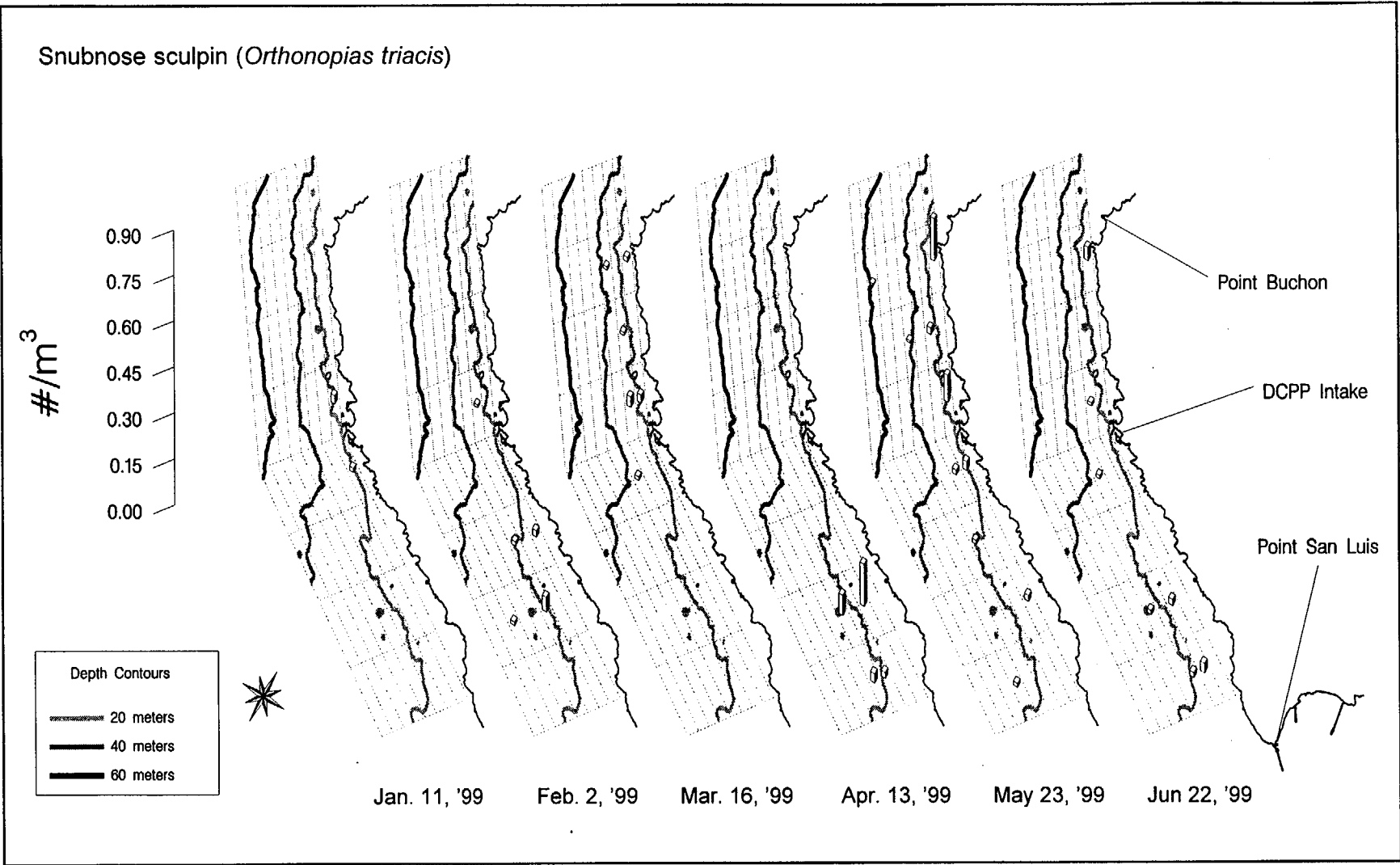


Figure 5.2.6-9d (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

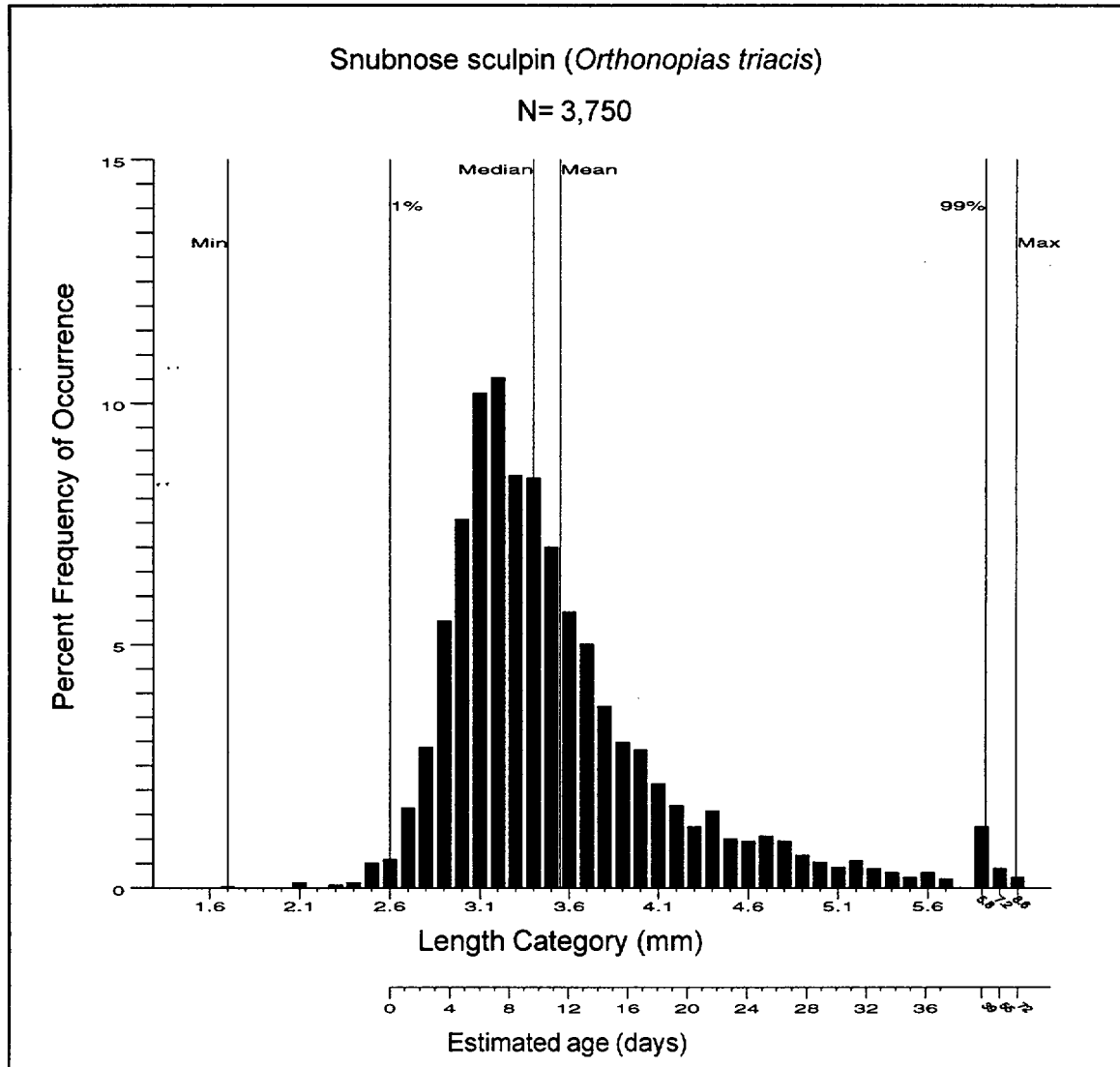


Figure 5.2.6-10. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

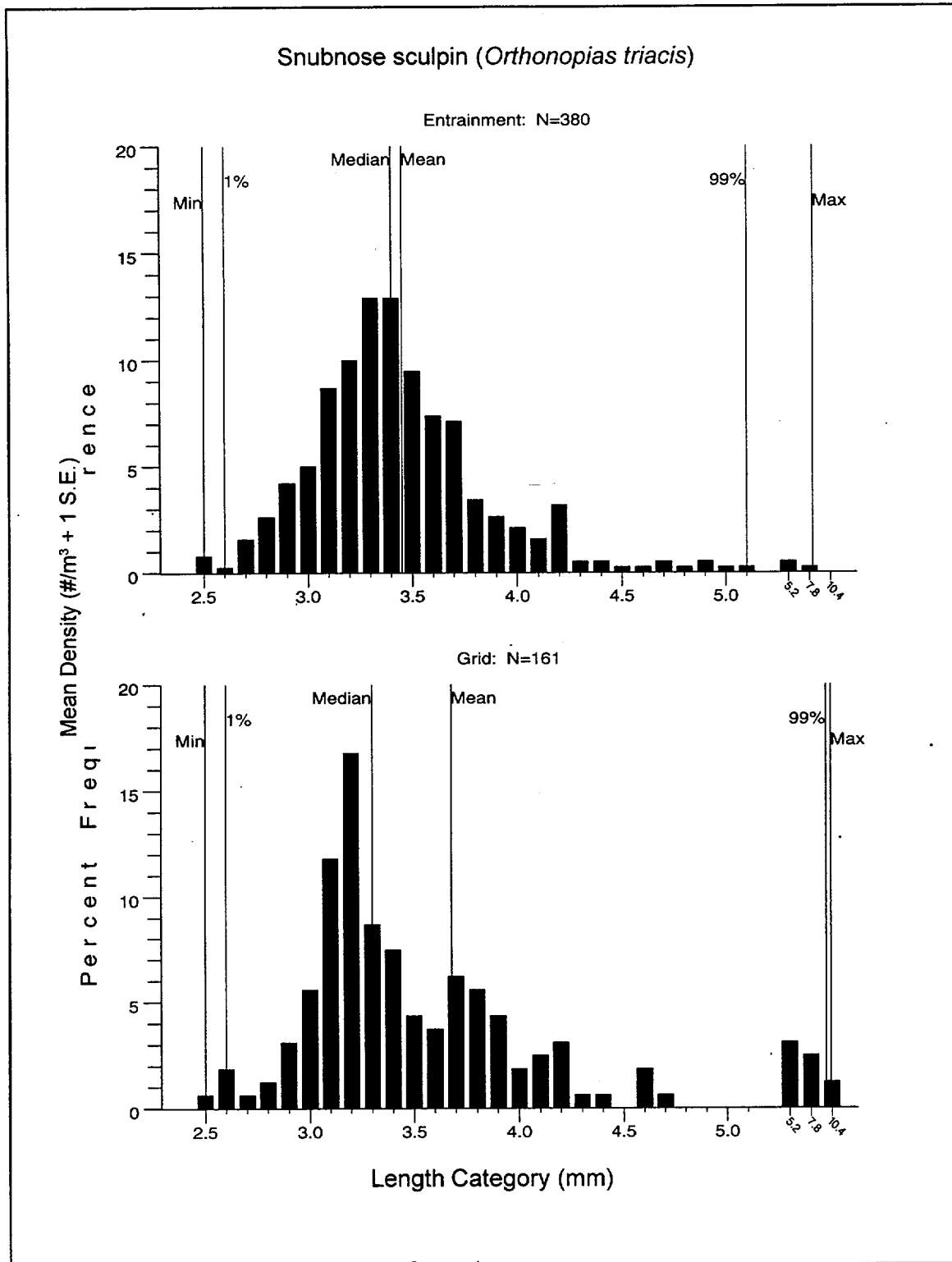


Figure 5.2.6-11. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

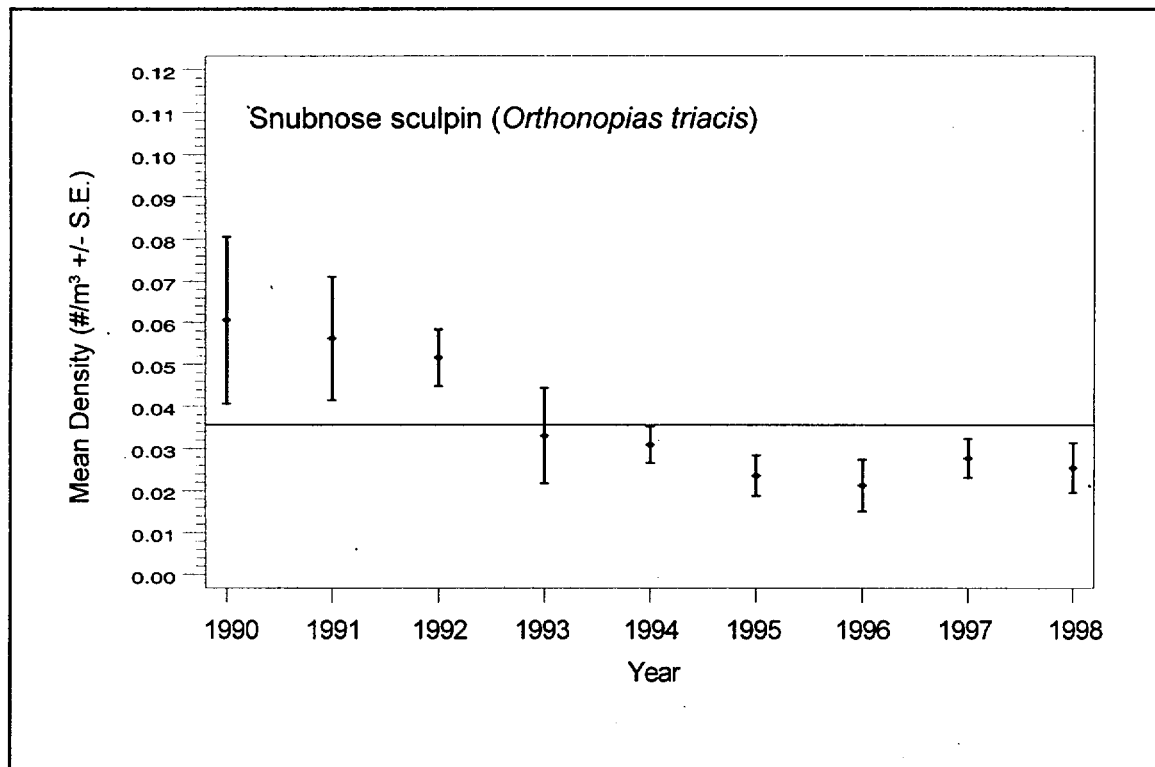


Figure 5.2.6-12. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

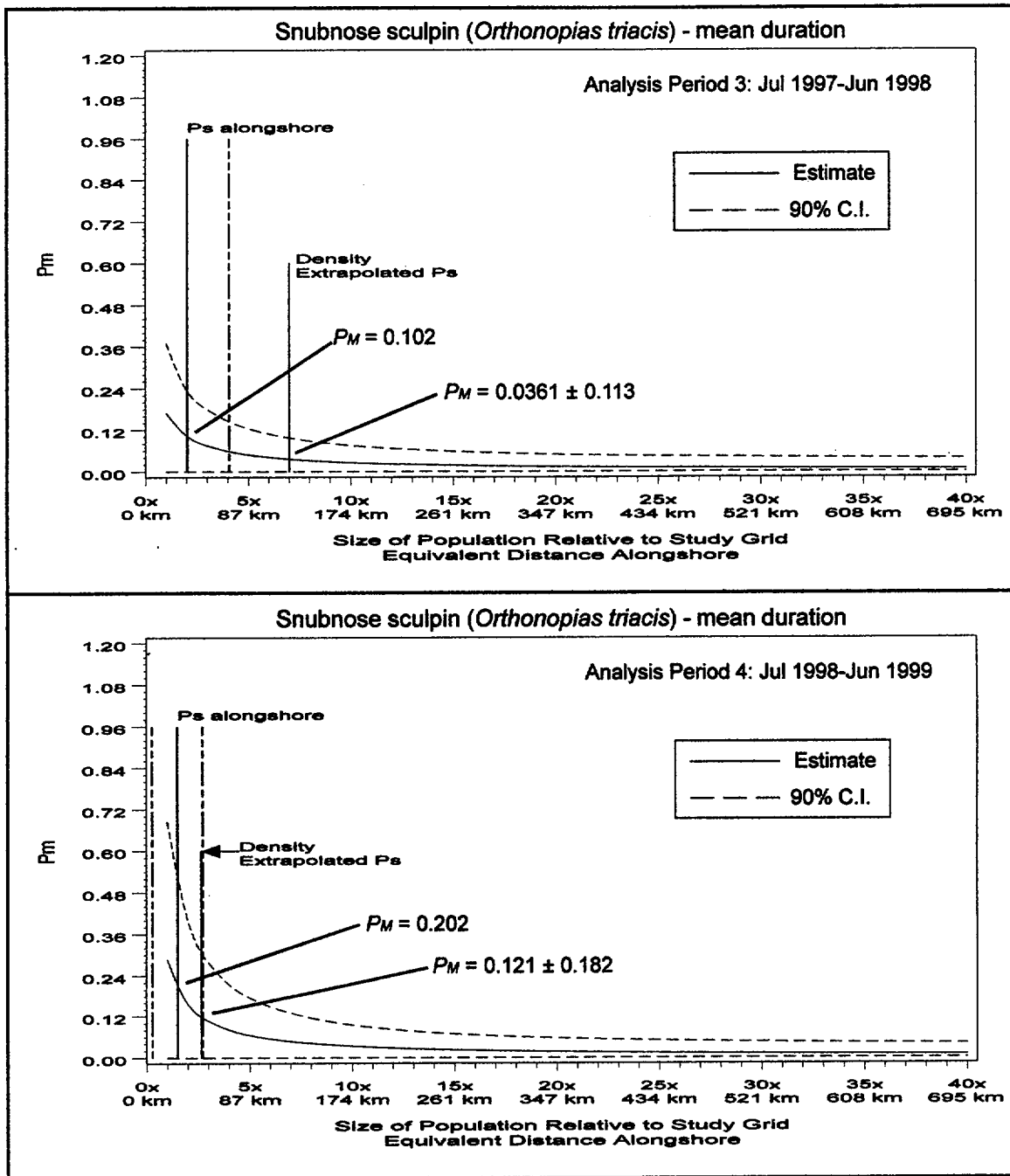


Figure 5.2.6-13a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

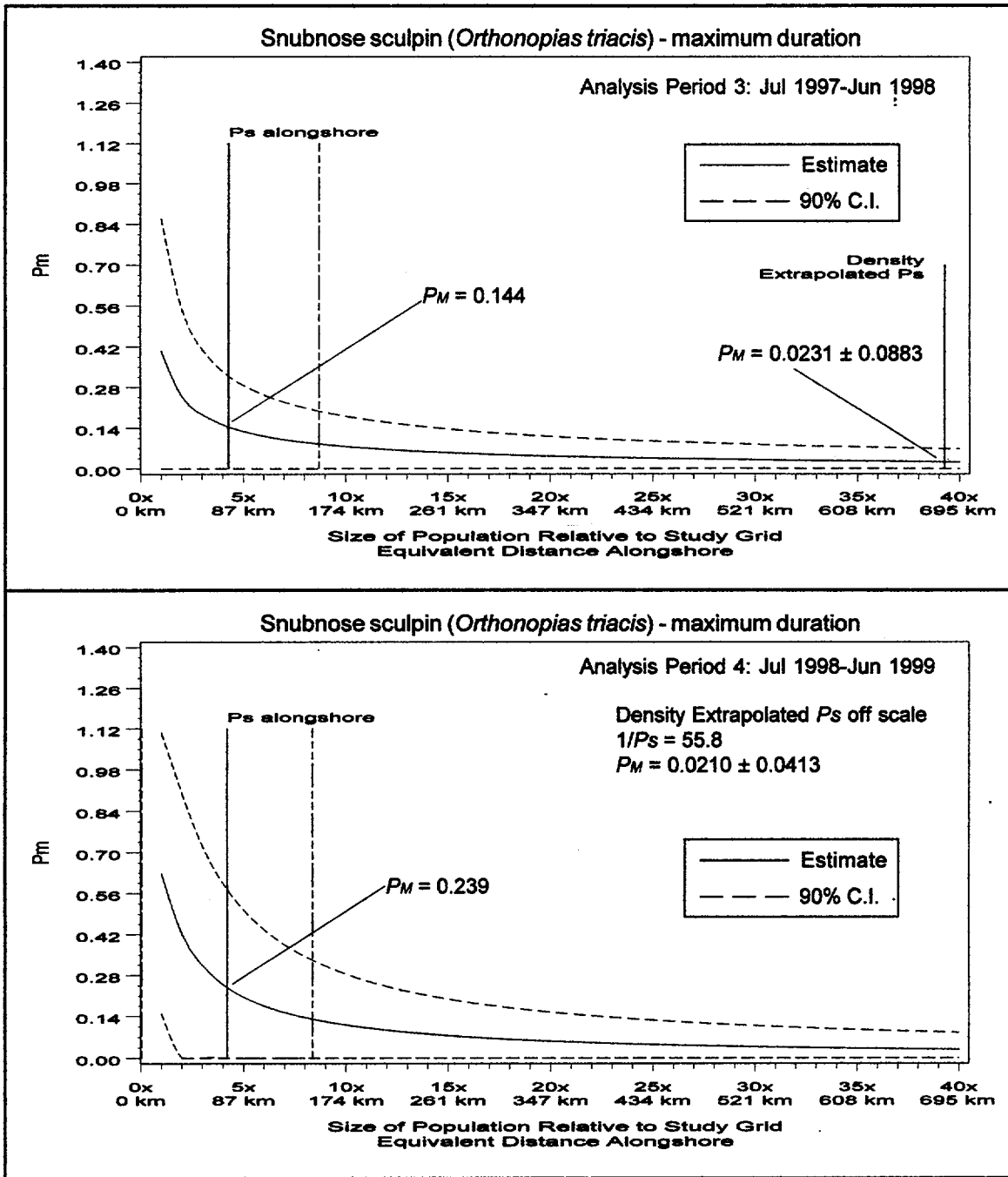


Figure 5.2.6-13b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

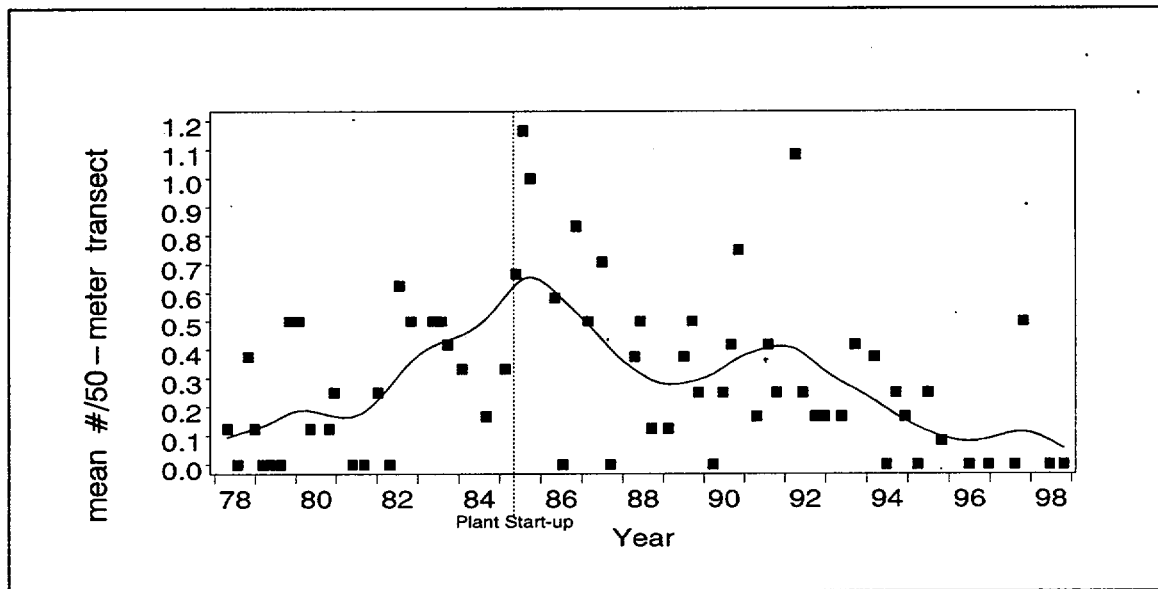


Figure 5.2.6-14. Mean number of snubnose sculpins observed per 50-meter subtidal transect in the DCPW RWMP South Control area. Spline smoothing algorithm used to fit curve through points.

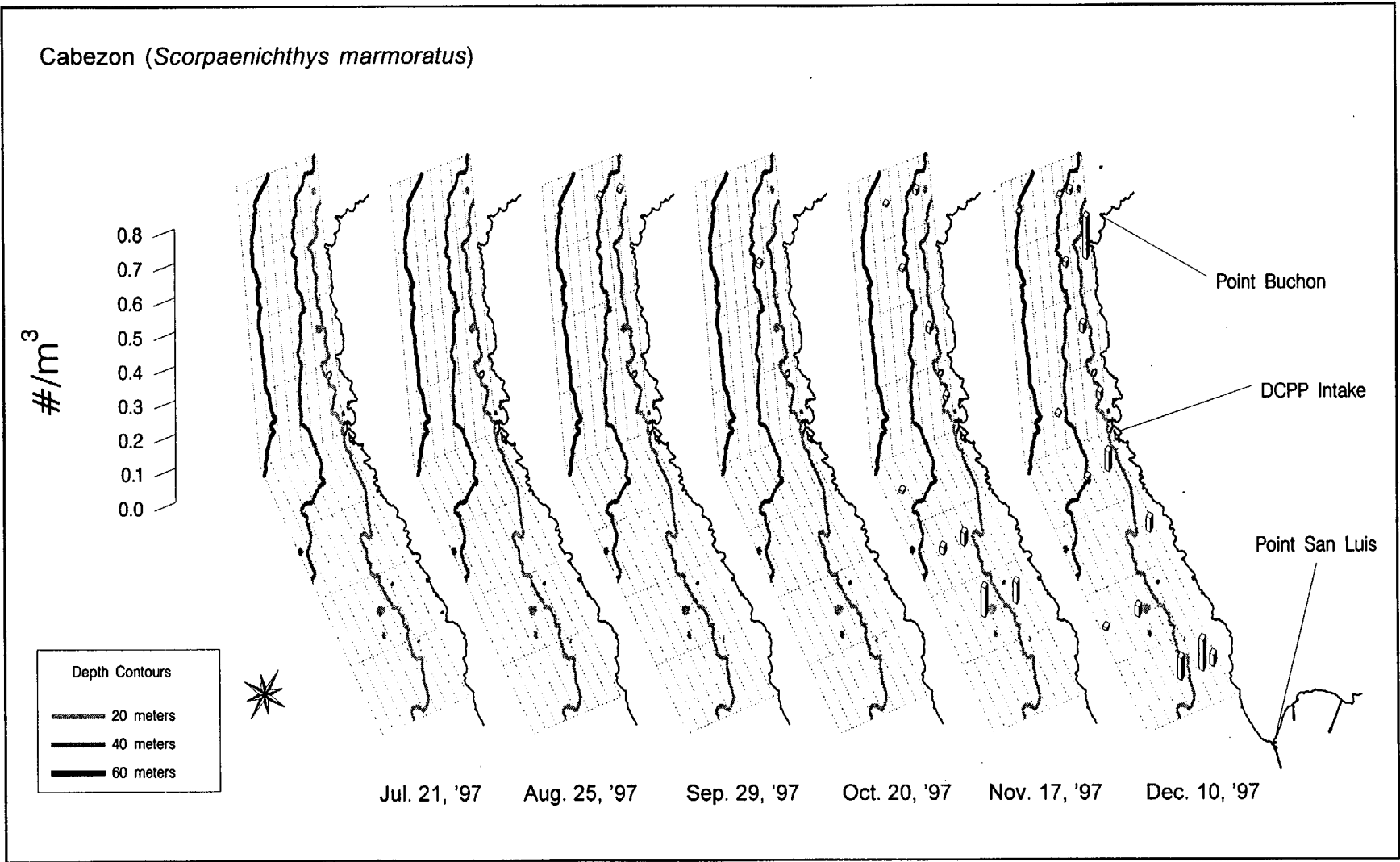


Figure 5.2.6-16a. Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

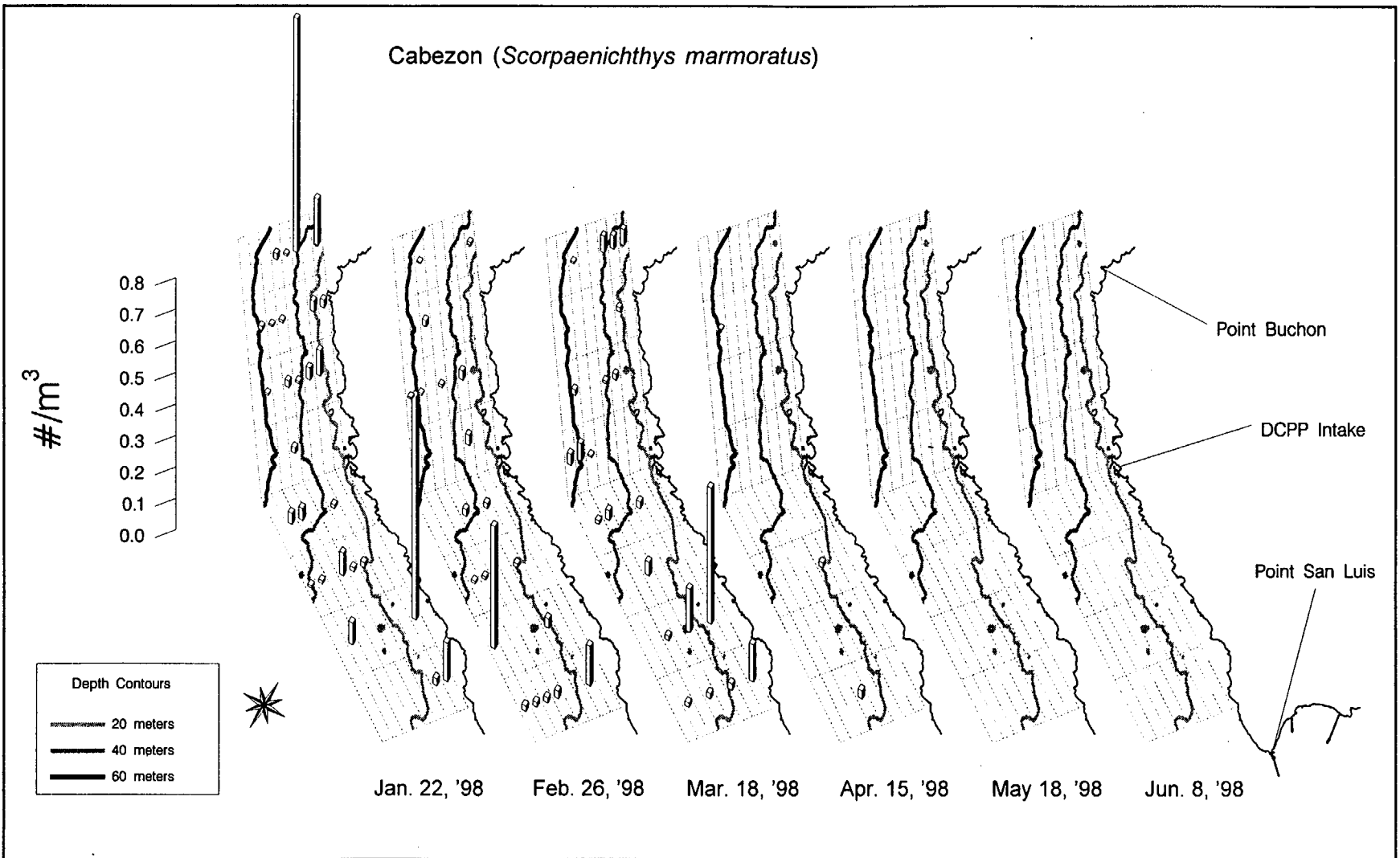


Figure 5.2.6-16b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

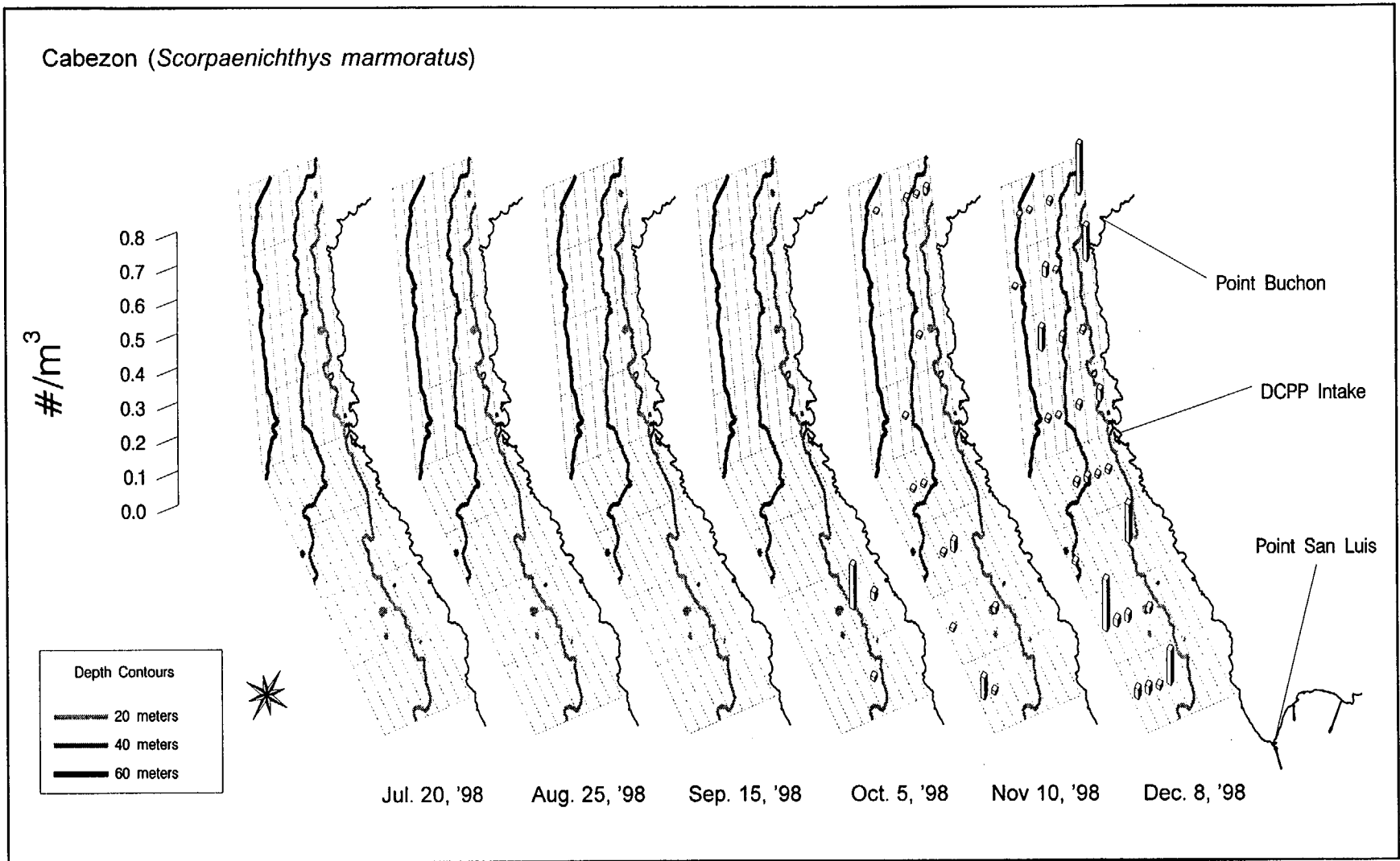


Figure 5.2.6-16c (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

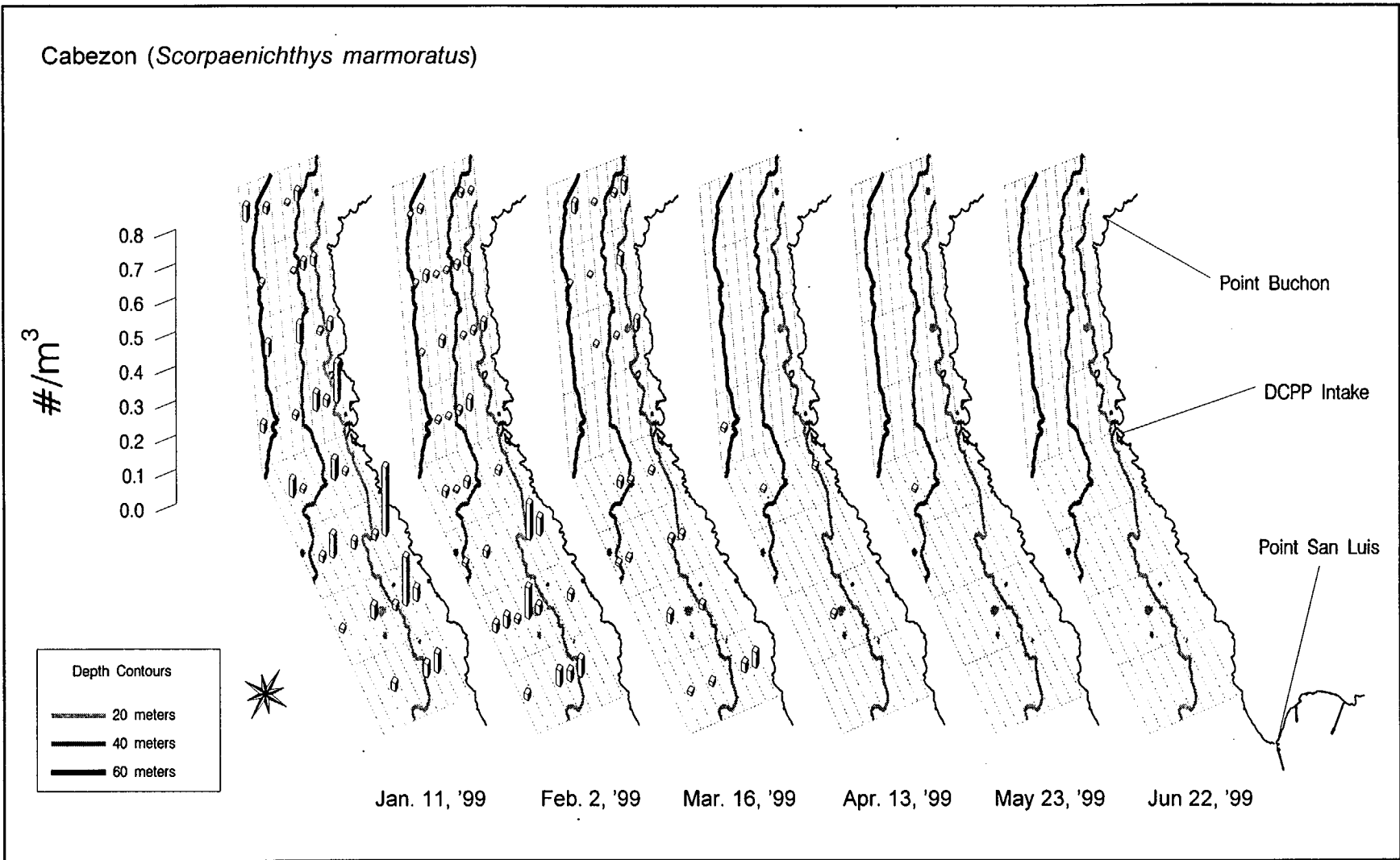


Figure 5.2.6-16d (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

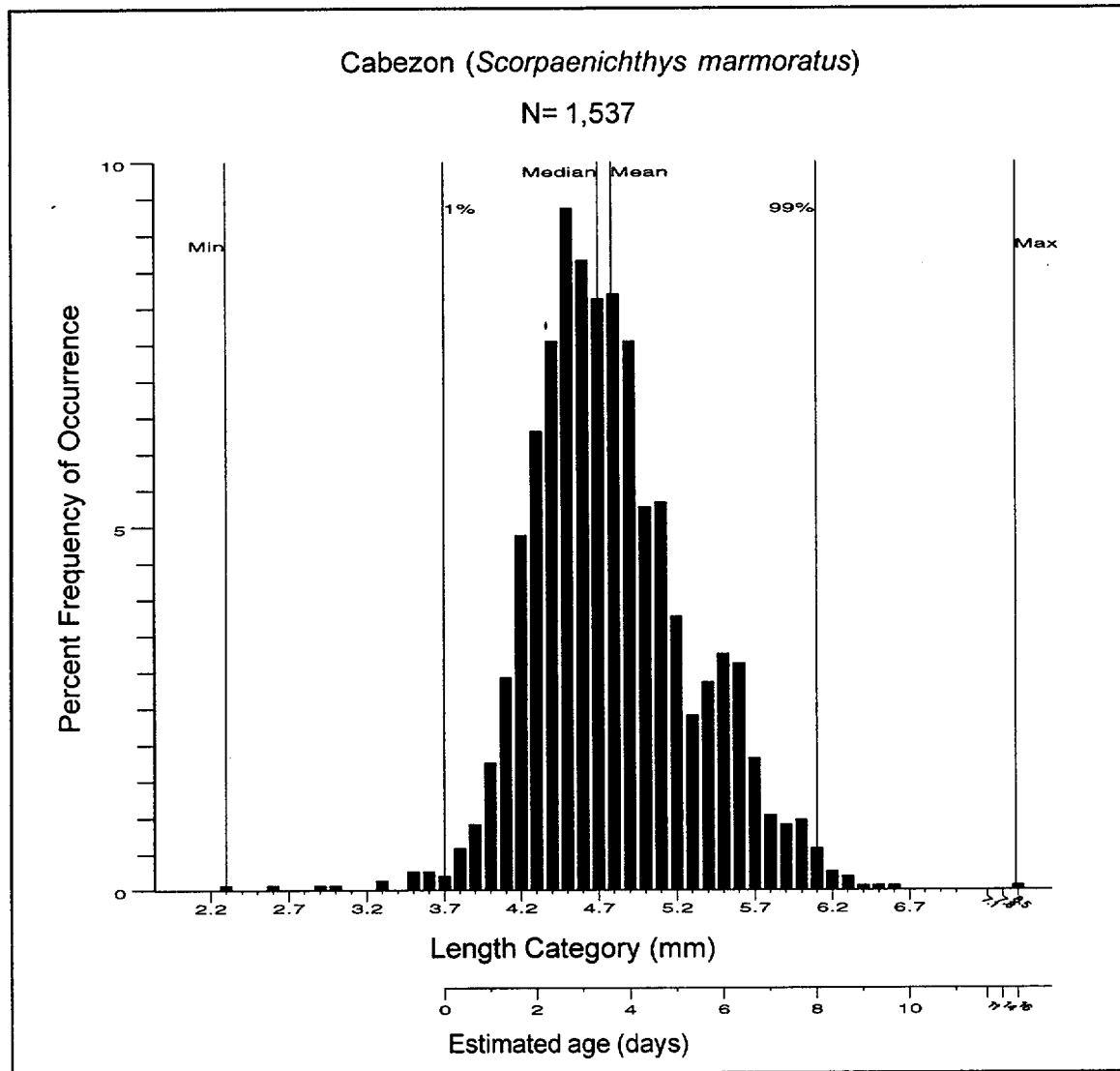


Figure 5.2.6-17. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

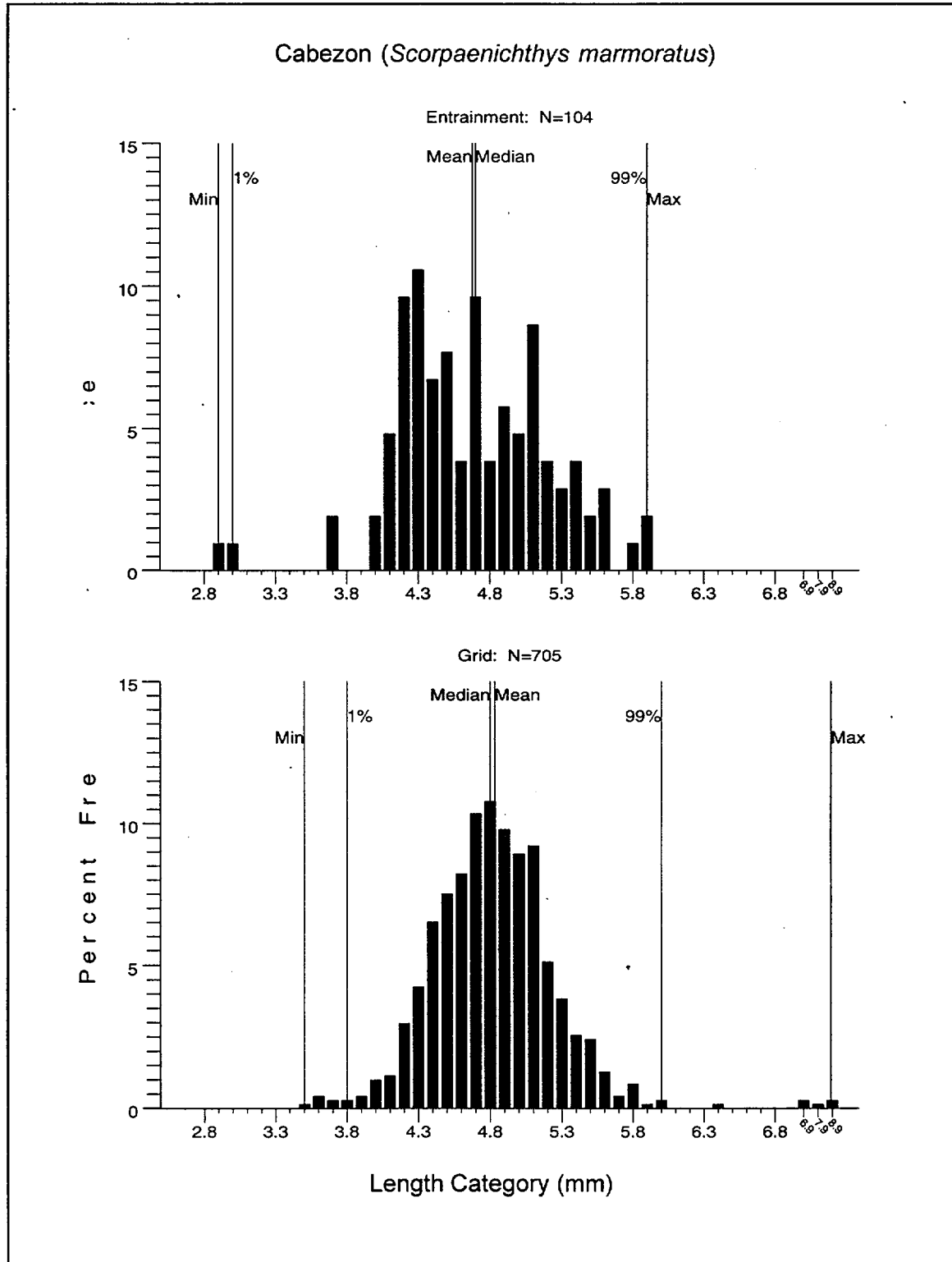


Figure 5.2.6-18. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

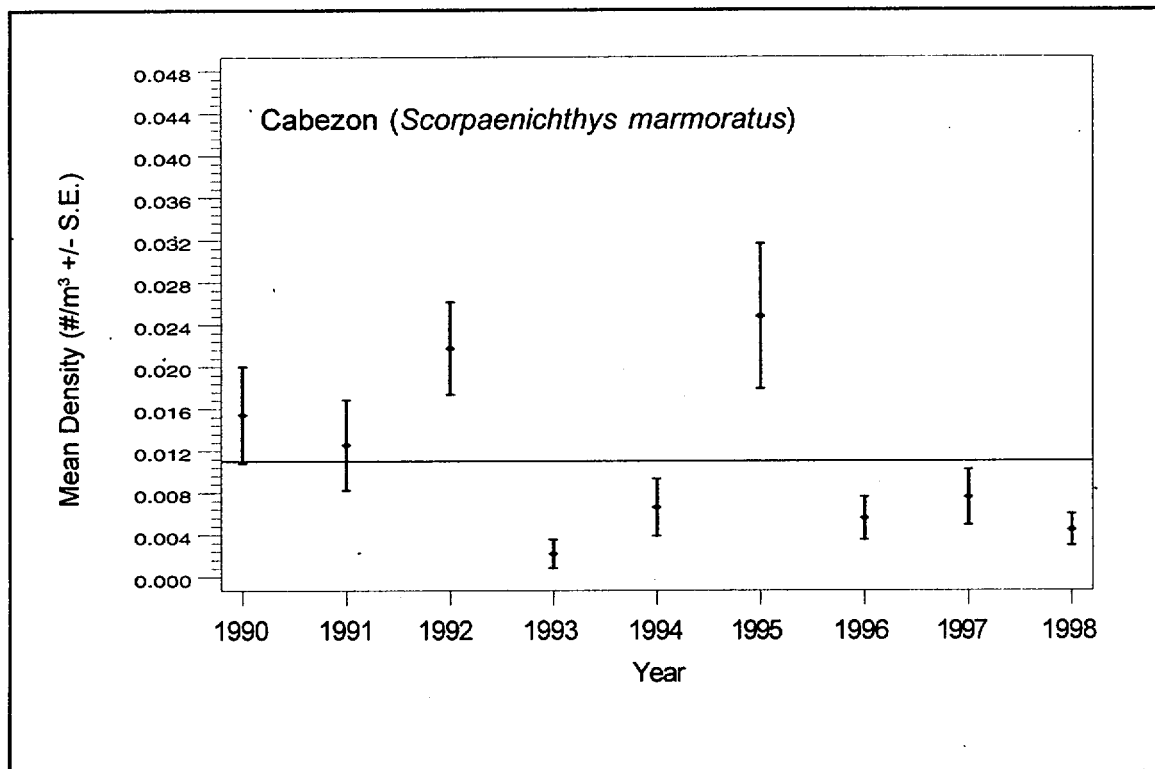


Figure 5.2.6-19. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

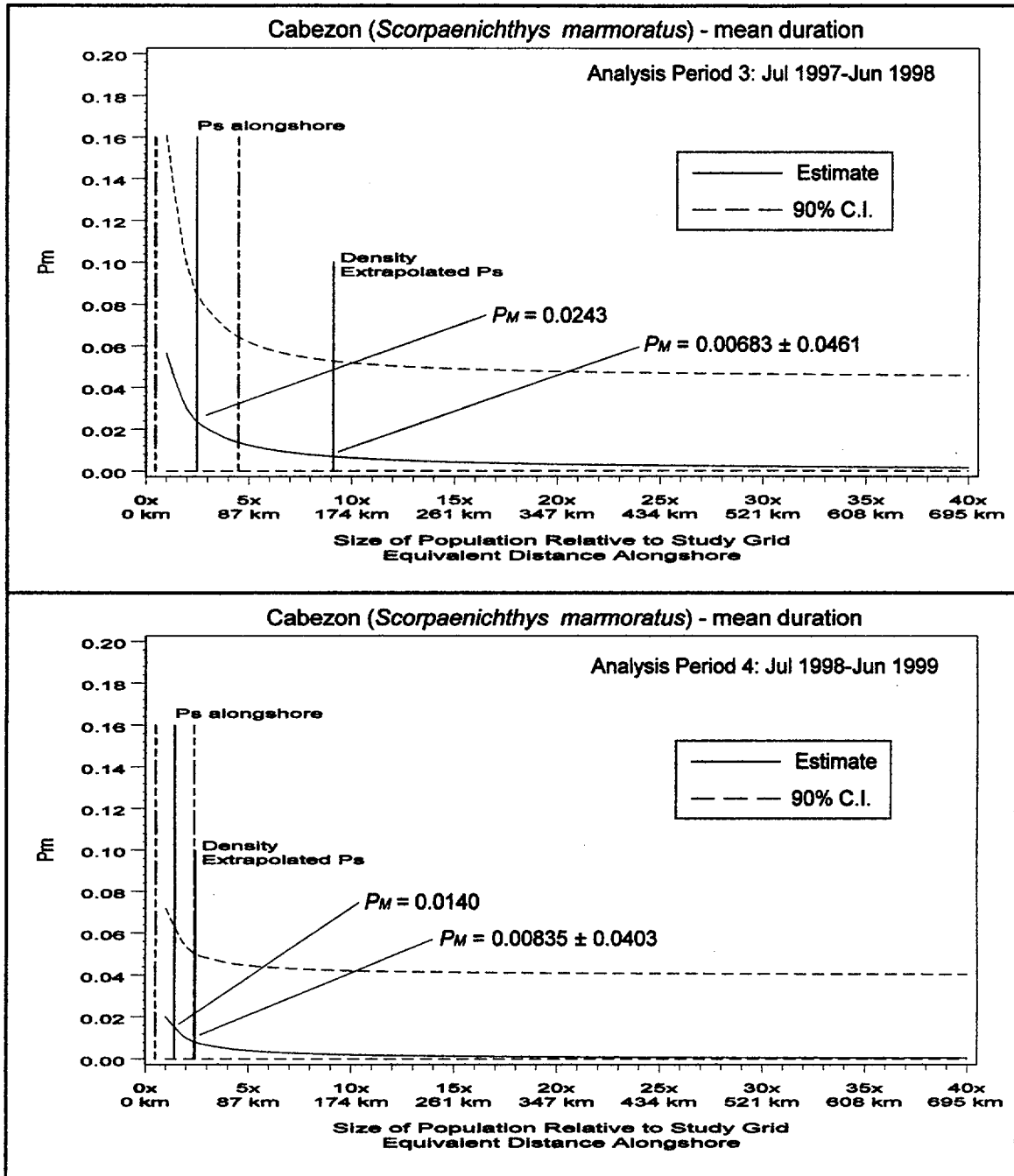


Figure 5.2.6-20a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

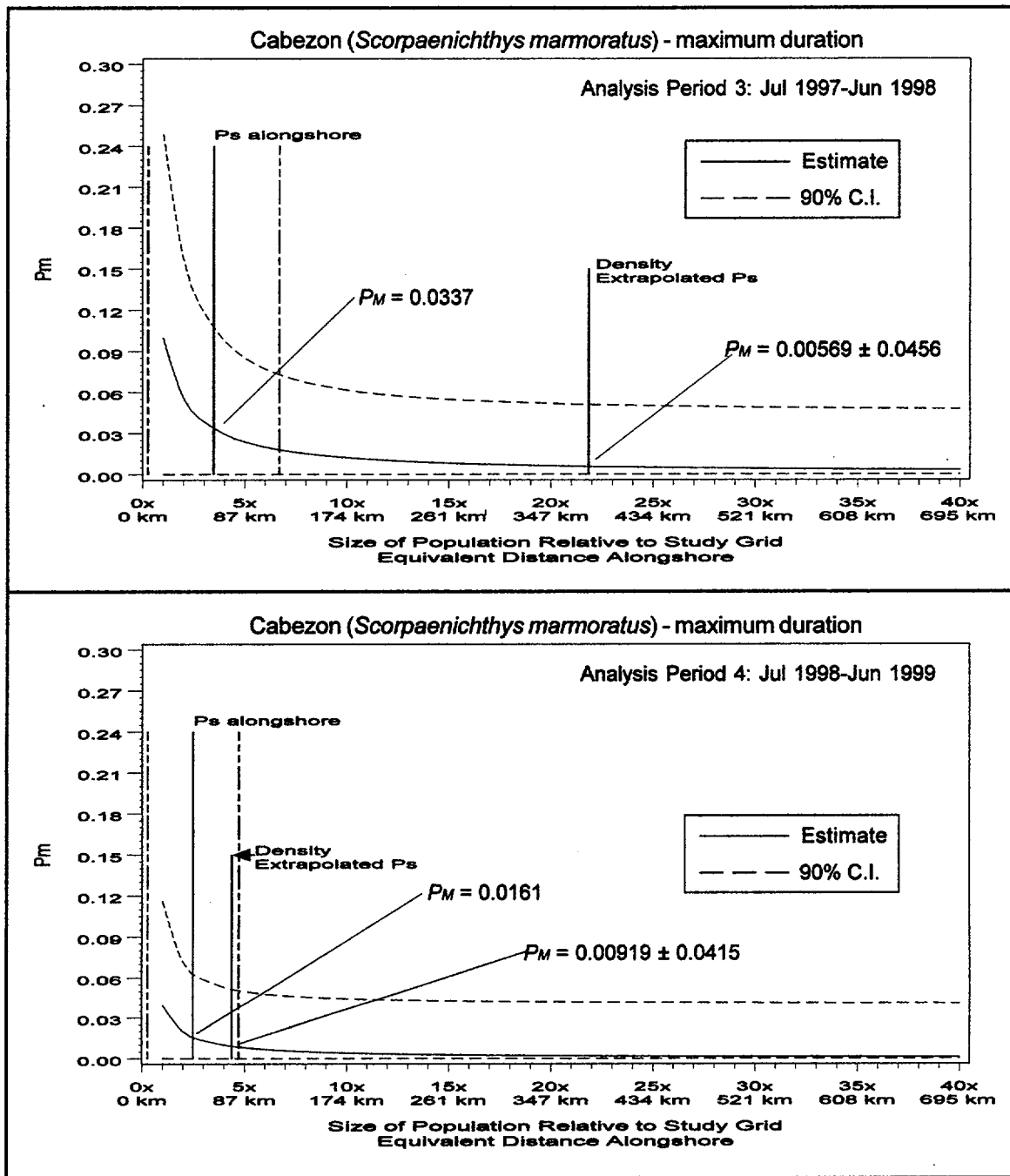


Figure 5.2.6-20b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

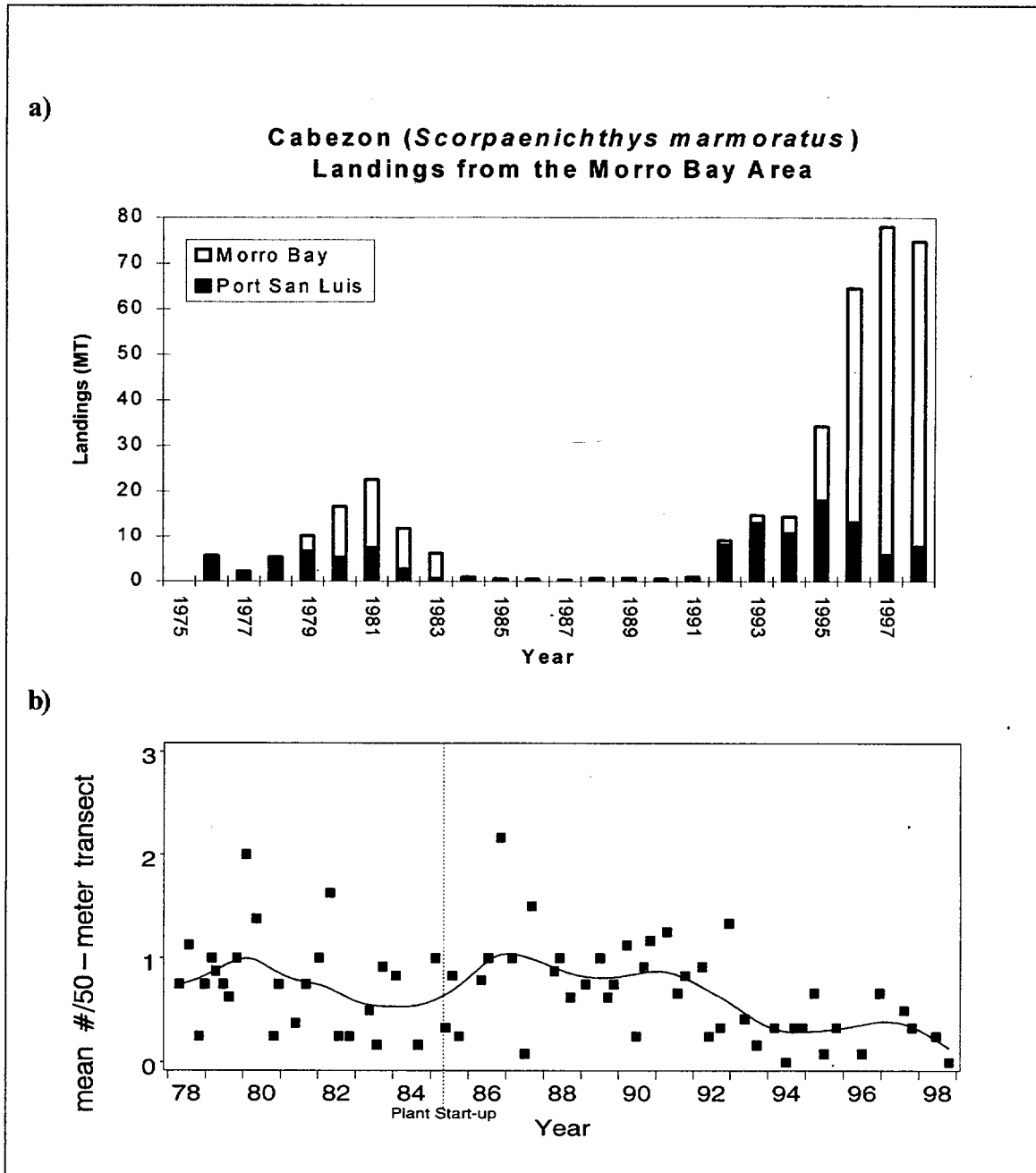
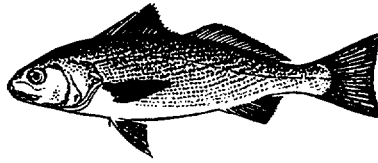


Figure 5.2.6-21. Yearly abundance of cabezon measured by two independent methods: a) Commercial landings of adults from Morro Bay area and, b) Mean number of adults and juveniles observed per 50-meter subtidal benthic transect in the DCPW RWMP South Control area. Spline smoothing algorithm used to fit curve through points.

5.2.7 Assessment of White Croaker (*Genyonemus lineatus*)



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

White croaker is one of eight species in the family Sciaenidae (the drums) occurring in California coastal waters. Other representatives of this family are white seabass (*Atractoscion nobilis*), shortfin corvina (*Cynoscion parvipinnis*), black croaker (*Cheilotrema saturnum*), spotfin croaker (*Roncador stearnsi*), California corbina (*Menticirrhus undulatus*), queenfish (*Seriphus politus*), and yellowfin croaker (*Umbrina roncadore*). Two of these, shortfin corvina and black croaker, are neither commercially nor recreationally important fishes in California.

White croaker are most abundant in southern and central California at depths from 6 m to 75 m (Love 1996). They tend to form schools, often over sand or mud bottoms. White croaker spawn year-round in central California. Love et al. (1984) state that

Batch fecundities ranged from 800 eggs in a 15.5 cm long female to 37,200 eggs in a 26 cm long female. During the spawning period about 19% of all mature female white croaker sampled contained hydrated eggs, implying that a female spawned about once every 5 d. Females of ages 1 and 2 (13–18 cm) have a spawning season of 3 mo and spawn about 18 times per season, whereas older fish (19 cm and larger) spawn over a period of 4 mo, about 24 times per season.

Love et al. (1984) also indicate that eggs and larvae are pelagic, and post-flexion larvae settle to the bottom as they develop. Juveniles are found near the bottom in 3–6 m of water, then migrate to deeper water as they mature. By one year after settlement, half of all male and female white

croaker are reproductively mature, with 100% cohort maturity attained by the third to fourth year. White croakers live 12–13 yr.

Studies conducted at the San Onofre Nuclear Generating Station (SONGS) provided estimates of adult equivalent losses for white croaker that were entrained and impinged by the cooling water intake system (Murdoch et al. 1989). They estimated the duration of each larval stage (e.g., yolk-sac, pre-flexion, flexion, post-flexion) at risk by dividing the range in body length of a larva in a given stage by the estimated daily growth rate of 0.20 mm/d (Murdoch et al. 1989). This method assumed linear growth rates throughout the larval stages. In the present study we used the same growth rate with the same assumption.

5.2.8.1 Summary of Field Collections

White croaker larvae were found seasonally at the DCPD intake structure during the years 1996–1999, with their highest densities occurring during the winter and spring (**Appendix H**). There were 4,300 larval white croaker identified from 1,114 bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999 representing 24% of the subsamples collected and processed from that location during that period. The highest densities of larval croaker occurred in March 1997 and May 1998 (**Figure 5.2.7-1**). The density of this species was variable between weeks, with one or two weeks of rather high density followed by several consecutive weeks of lower density. The highest entrainment densities of white croaker larvae in 1998 occurred in May, while only a few were seen during that month in 1997. This shift in abundance peaks between years may have been affected by the El Niño event that began during the fall/winter season of 1997–98 (Lynn et al. 1998; NOAA 1999).

White croaker larvae generally occurred in the DCPD study grid during December through May of each year (**Appendix H**), with their highest recorded abundance occurring during March 1998 (**Figure 5.2.7-2**). When present, the highest white croaker larval densities occurred in the southern half of the nearshore grid sampling area. There were 1,710 larval white croaker identified from 422 bongo net subsamples representing 14% of the study grid subsamples collected and processed from July 1997–June 1999.

Standard lengths of all white croaker larvae collected at the DCPD intake structure between October 1996 and June 1999 ranged from a minimum of 0.90 mm to a maximum of 8.2 mm (Figure 5.2.7-3). The central 98% of this length-frequency distribution resulted in minimum and maximum lengths for the analyses of 1.1 mm and 5.5 mm, respectively. The mean larval length in this distribution was 2.4 mm. Hatching size for white croaker is reported between 1.5 and 1.8 mm (Moser 1996). The fact that we observed larvae smaller than the reported hatching lengths can be explained by natural variation of hatch lengths within the population and by the phenomenon of shrinkage following preservation (Theilacker 1980).

The growth rate of larval white croaker (0.20 mm/d) reported by Murdoch et al. (1989) was used to estimate ages of entrained larvae. Assuming that the shortest larvae were immediately post-hatch and aged zero days, then the estimated ages of larvae entrained could have ranged from zero days up to 22–37 d post-hatching for the longest larvae measured. On average, the estimated ages of white croaker larvae entrained at DCPD ranged from 7–8 d post-hatching.

Differences between the distributions of white croaker larval lengths at the DCPD intake structure and the study grid (Figure 5.2.7-4) were tested using a Kolmogorov-Smirnov test. The test detected a significant difference between the two distributions ($p < 0.001$). The largest difference between the distributions was detected at a length of approximately 2.7 mm, the size separating two modes of the distribution from the DCPD intake. A single mode predominated in the study grid distribution. A *t*-test also detected a significant difference ($p < 0.001$) between the mean lengths for the two locations: 2.7 mm at the DCPD intake and 2.3 mm in the study grid.

Differences in the mean are partly due to a larger differences in sample size between the study grid ($n=1,263$) and the intake location ($n=150$). A large sample size also causes the *t*-test to be highly sensitive to small differences between the means (Zar 1984). The length frequency of white croaker ($n=3,529$) in all entrainment subsamples (Figure 5.2.7-3) yielded a distribution similar to that of the nearshore grid subsamples. While these differences were statistically detectable and significant, both distributions were heavily weighted with recently hatched (yolk-sac) and pre-flexion larvae. Therefore, we believe that the entrainment subsamples and grid subsamples represent the same population of available larvae.

5.2.7.2 Estimating Total Annual Entrainment

The annual estimated mean entrainment white croaker larvae ranged from a minimum of 65,100,000 ($\widehat{SE}=3,880,000$) in Analysis Period 2 to a maximum of 70,500,000 ($\widehat{SE}=2,620,000$) in Analysis Period 1 (Table 5.2.7-1). A 95% confidence interval around these estimates approximated by $2 \cdot \widehat{SE}(\widehat{E}_T)$ does not overlap indicating that the estimates were probably not statistically different.

Annual estimates of the number of white croaker larvae entrained, adjusted to a long-term mean based on annual indices using weekly Intake Cove surface plankton tows (Figure 5.2.7-5), ranged from a minimum of 305,000,000 ($\widehat{SE}=11,300,000$) in Analysis Period 1 to a maximum of 447,000,000 ($\widehat{SE}=26,300,000$) in Analysis Period 3 (Table 5.2.7-2). The average index for the years 1997 and 1998 are 0.0251 larvae/m³ and 0.0161 larvae/m³, respectively, while the long-term average index is 0.109 larvae/m³ for the years 1990–1998, yielding the ratio \bar{I}/I_t of 4.33 for 1997 and 6.77 for 1998. The adjustment increases the difference between the estimates. A 95% confidence interval, approximated by $2 \cdot \widehat{SE}(\widehat{E}_{Adj-T})$ would show a statistically significant difference between the 1996–1997 estimates and the two 1997–1998 estimates.

5.2.7.3 Fecundity Hindcasting (FH)

Fecundity hindcasting requires age-specific fecundity and mortality to assess entrainment effects. White croaker spawn multiple times within a year. Females of 1–2 yr (i.e., 13–18 cm) undergo a 3 mo spawning season and spawn ca. 18 times per season. Older fish (i.e., 19 cm and larger) spawn over a period of 4 mo, ca. 24 times per season (Love et al. 1984). In our calculations we will assume an average of 21 egg batches per yr. The average number of eggs per batch will be based on Love et al. (1984) who showed a modal age of 3 yr for fish lengths of 18–18.9 cm. This permits extrapolation to a batch fecundity of approximately 5,000 eggs for age 3 yr.

Love et al. (1984) found that adult white croaker have a maximum longevity of 12 yr, and Love (1996) stated that the species matures between 1 and 4 yr, with half spawning after 1 yr. The expected average age of maturation for the purpose of calculations was estimated as 2 yr.

Love (1996) reported that white croaker eggs hatch in 2 d, while Murdoch et al. (1989) suggested an instantaneous egg mortality rate of $Z = 0.25$ (survival $\approx 78\%$ /day). Egg survival can therefore be estimated as

$$S_{Egg} = e^{-2(0.25)} = 0.6065.$$

An estimate of survival for larvae from the time of egg hatching to entrainment was based on information on larval lengths collected from DCPD entrainment subsamples. The central 98% lengths of the larvae ranged from 1.1–5.5 mm with a mean of 2.44 mm. Murdoch et al. (1989) states that white croaker larvae grow at a rate of approximately 0.2 mm per day. The average time to entrainment from hatching (hatch length is assumed to be the shortest length recorded in DCPD subsamples) is then estimated as 6.7 d. Assuming that the instantaneous larval survival rate is the same as for eggs, larval survival is estimated as

$$S_{Larvae} = e^{-6.7(0.25)} = 0.1873.$$

It is likely that the larval survival rate is equal to or greater than the survival rate of eggs. Thus, the survival rate for larvae is probably underestimated, resulting in an overestimate of FH .

As an example of the FH calculation, when these parameters are modeled for the period October 1, 1997 through September 30, 1998, the resulting number of adult females that would have produced the number of entrained larvae is given as

$$\widehat{FH} = \frac{440,198,000}{(0.6065)(0.1873)(5,000 \cdot 21) \left(\frac{12-2}{2} \right)} = 7,380 \text{ adult females per yr.}$$

Estimates of FH were different between the two years of sampling (Table 5.2.7-3). Numbers of hindcast adult females from the three analysis periods ranged from 5,000–7,500. The least number of hindcast individuals were estimated from Analysis Period 1 (October 1996–September 1997) while the greatest were estimated from Analysis Period 3 (July 1997–June 1998).

Sensitivity Analysis

Longevity had the greatest leverage on recalculated values of \widehat{FH} (Table 5.2.7-4). Varying this parameter in the model resulted in an \widehat{FH} range of 2,320–237,000 adult females for the three periods, compared to the original estimate of 5,110–7,500 adult females. Survivorship had the next greatest amount of leverage on recalculated \widehat{FH} .

5.2.7.4 Adult Equivalent Loss (AEL)

For white croaker, no independent estimate of survival from entrainment to age of adult recruitment was found in the literature. To calculate \widehat{AEL} as $2 \cdot \widehat{FH}$, we must first align the ages at maturity (~5 yr) and recruitment into the fishery (3–4 yr) so that the FH females are of the same age as the AEL recruits. As such, \widehat{AEL} ranged from 14,700 to 21,600 adult white croaker per year across the three analysis periods.

5.2.7.5 Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) in each i th survey from the two years sampled ranged from a minimum of zero to a maximum of 0.0340 ± 0.008 ($\pm 1SE(\widehat{PE}_i)$) in January 1998 (Table 5.2.7-5). No larvae were collected at either the DCP intake or from the study grid when both \widehat{PE}_i and the proportion of larvae present in the i th survey period (\hat{f}_i) were equal to zero (e.g., August–November 1998 and April–June 1999). When $\widehat{PE}_i = 0$ and $\hat{f}_i > 0$, larvae were collected at the DCP intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. Since \widehat{PE}_i was weighted by \hat{f}_i , some of the larger \widehat{PE}_i values were less important to the annual estimate of entrainment mortality.

The lengths of entrained white croaker larvae, excluding the largest 1% and smallest 1% of all measurements, ranged from 1.1 to 5.5 mm. Assuming a growth rate of 0.2 mm/day (Murdoch et al. 1989), larvae may be susceptible to entrainment by the plant for approximately 22 days. The frequent, repeated breeding of white croaker suggests that the entrainment at Diablo Canyon occurs over multiple larval batches. Literature on the life history of white croaker would support this contention (Love et al. 1984; Love 1996).

Estimates of \widehat{P}_M differed markedly when calculated using the mean and maximum larval durations and were generally higher during the second year of sampling (Figures 5.2.7-6). The larval durations calculated using the mean and maximum larval lengths differed by 15 d (7 vs. 22 d). For \widehat{P}_S calculated using only alongshore currents, differences in duration did not cause much change in \widehat{P}_M between mean and maximum duration; ca. 2–3% in Analysis Period 3 and ca. 4–6% in Analysis Period 4. Although white croaker larvae were more common in the southern half of the study grid when they were abundant (March 1998), they generally occurred throughout the study grid and were not restricted to the nearshore grid cells. Therefore, P_S was calculated using both alongshore current movement and extrapolating study grid abundance offshore based on onshore current movement. For \widehat{P}_S calculated using alongshore currents and offshore abundance extrapolation, changing larval duration did not change \widehat{P}_M much in Analysis Period 3 (ca. 0.1–0.3% for both durations), but yielded a change from 2% (mean duration) to 1% (maximum duration) in Analysis Period 4.

5.2.7.6 Interpretation of Assessment Results

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

Payment to the fishermen in 1990 was ca. \$0.19/kg depending on catch size and fish condition (Leet et al. 1992). The total recreational catch in both northern and southern California in 1998 was estimated at 443,000 fishes (PSMFC RecFIN database). Data from the California Department of Fish & Game show that local commercial landings of white croaker during the period 1975–1998 averaged 9.1 MT at Port San Luis and 3.8 MT at Morro Bay (Figure 5.2.7-7). Because of the low economic value of the species in comparison to other targeted species, some

of the white croaker landings probably represent incidental catches as a result of these other fisheries.

Love et al. (1984) gives the length mode for white croaker caught in the commercial gillnet fishery (28 cm SL) and from skiff sportfishing (22.5 cm SL). The weight of a 28 cm white croaker is approximately 200–225 g, depending on gender, with females generally heavier. Assuming a daily natural mortality rate of 0.0005 (Ricker 1975), we can align the approximately 5-yr old *FH* females to an age of recruitment to the fishery of 3.5 yr (Love et al. 1984). In this manner, assuming a 50:50 sex ratio in the population, $2 \cdot FH$ becomes equivalent to *AEL*. Thus, the approximate *AEL* based on *FH* ranged from 14,700 3.5-yr old adults in 1996–1997 to a maximum of 21,600 in 1997–1998. Using an average weight of 0.213 kg/adult in the fishery derived from Love et al. (1984), the price per kg from Leet et al. (1992), and assuming 100% catchability, these equivalent adult losses could equate to 3.1–4.6 MT annually, approximately \$594–872/yr. Alternatively, this conservative estimate of loss represents 24–36% of the average annual catch from the Morro Bay area between 1975–1998. However, estimates of annual proportional larval entrainment mortality (\widehat{P}_M) that assume no compensation, suggest losses of 0.1% to perhaps as high as 6% of the local population (over areas 4–41 times the study grid area), providing a lower limit to these proportional effects.

Adult white croaker are widely distributed over sand and mud bottoms in shelf waters and are not typically found in association with rock substratum. Combining this fact with the fact that white croaker adults are rarely observed in the vicinity of the power plant (Tenera 1997c) leads to the conclusion that their abundance is centered elsewhere than around Diablo Canyon. Therefore, the greater abundance of soft bottom habitat relative to rock substrata in the Morro Bay and Avila areas, combined with relatively low larval mortality probabilities of \widehat{P}_M (0.001–0.06), suggests that entrainment impacts on local white croaker populations are not appreciable.

Table 5.2.7-1. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for white croaker (*Genyonemus lineatus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	70,500,000	2,620,000
2) Oct 1, 1997–Sep 30, 1998	65,100,000	3,880,000
3) Jul 1, 1997–Jun 30, 1998	66,100,000	3,890,000

Table 5.2.7-2. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for white croaker (*Genyonemus lineatus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	305,000,000	11,300,000
2) Oct 1, 1997–Sep 30, 1998	440,000,000	26,300,000
3) Jul 1, 1997–Jun 30, 1998	447,000,000	26,300,000

Table 5.2.7-3. Estimated number of white croaker adult females (\widehat{FH}) whose reproductive output was equivalent to the adjusted number of larvae entrained per year (\hat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{FH})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	5,110	12,300	268,000	97
2) Oct 1, 1997–Sep 30, 1998	7,380	17,800	387,000	141
3) Jul 1, 1997–Jun 30, 1998	7,500	18,100	394,000	143

Table 5.2.7-4. White croaker (*Genyonemus lineatus*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: Oct 1, 1996–Sept 30, 1997

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 5,110$				
\hat{E}_{Adj-T}	305,000,000	4,800	5,430	626
\hat{S}_{egg}	0.607	3,100	26,500	23,400
\hat{S}_{larvae}	0.187	987	26,500	25,500
# Eggs/yr	105,000	987	26,500	25,500
Longevity	12	2,320	162,000	159,000
Maturation	2	4,650	6,390	1,740

Table 5.2.7-4. White croaker (*Genyonemus lineatus*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%

b) Analysis Period 2: Oct 1, 1997–Sept 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 7,380$				
\hat{E}_{Adj-T}	440,000,000	6,660	8,110	1,450
\hat{S}_{egg}	0.607	4,480	38,200	33,800
\hat{S}_{larvae}	0.187	1,420	38,200	36,800
# Eggs/yr	105,000	1,420	38,200	36,800
Longevity	12	3,360	233,000	230,000
Maturation	2	6,710	9,230	2,520

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 7,500$				
\hat{E}_{Adj-T}	447,000,000	6,780	8,230	1,450
\hat{S}_{egg}	0.607	4,550	38,900	34,300
\hat{S}_{larvae}	0.187	1,450	38,900	37,400
# Eggs/yr	105,000	1,450	38,900	37,400
Longevity	12	3,410	237,000	234,000
Maturation	2	6,820	9,380	2,560

Table 5.2.7-5. White croaker (*Genyonemus lineatus*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.0244	0.0293	0.00704	0.000890
Aug 25, 1997	0	0	0.00447	0.000620
Sep 29, 1997	0	0	0.00584	0.000690
Oct 20, 1997	0	0	0.000570	0.000220
Nov 17, 1997	0	0	0.00135	0.000370
Dec 10, 1997	0	0	0.0628	0.00457
Jan 22, 1998	0.0340	0.00858	0.139	0.00489
Feb 26, 1998	0.000630	0.000450	0.00780	0.000750
Mar 18, 1998	0.000390	0.000120	0.0532	0.00277
Apr 15, 1998	0.00203	0.000720	0.293	0.00932
May 18, 1998	0.00526	0.00146	0.425	0.0107
Jun 8, 1998	0.00948	0.0116	0.000590	0.000200

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0	0	0.00221	0.000810
Aug 26, 1998	0	0	0	0
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0.00545	0.00325	0.0348	0.00338
Jan 12, 1999	0.00492	0.000830	0.673	0.00931
Feb 3, 1999	0.0122	0.00558	0.104	0.00606
Mar 17, 1999	0.0302	0.0104	0.186	0.00728
Apr 14, 1999	0	0	0	0
May 24, 1999	0	0	0	0
Jun 23, 1999	0	0	0	0

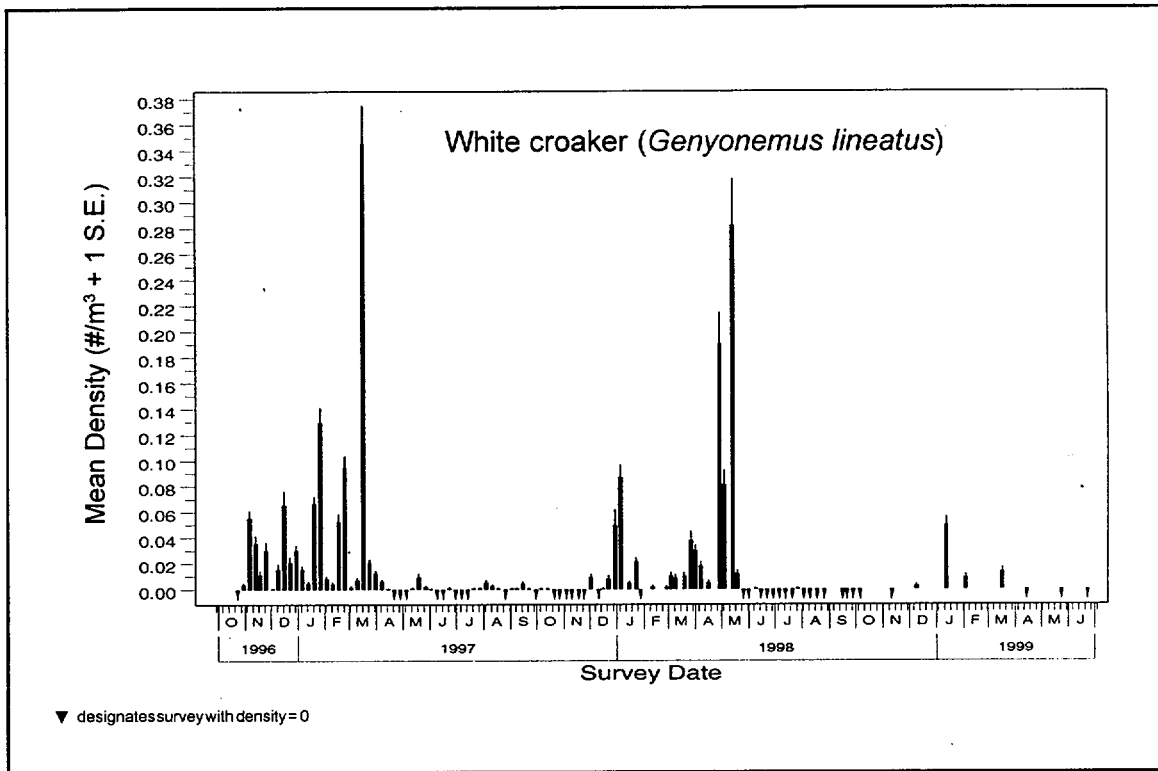


Figure 5.2.7-1. Weekly mean larval density (#/m³ + 1 S.E.) at the DCP intake.

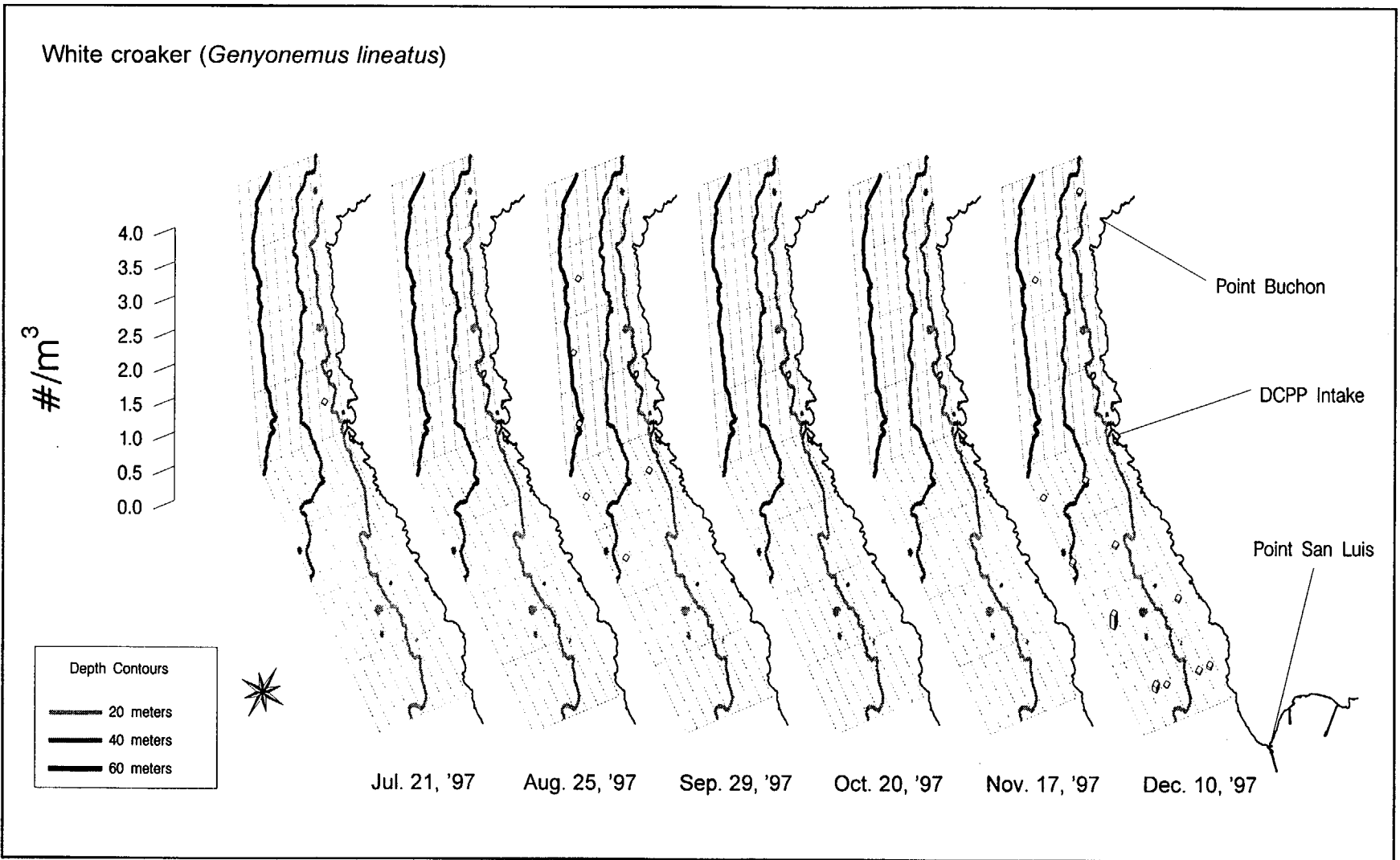


Figure 5.2.7-2a. Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

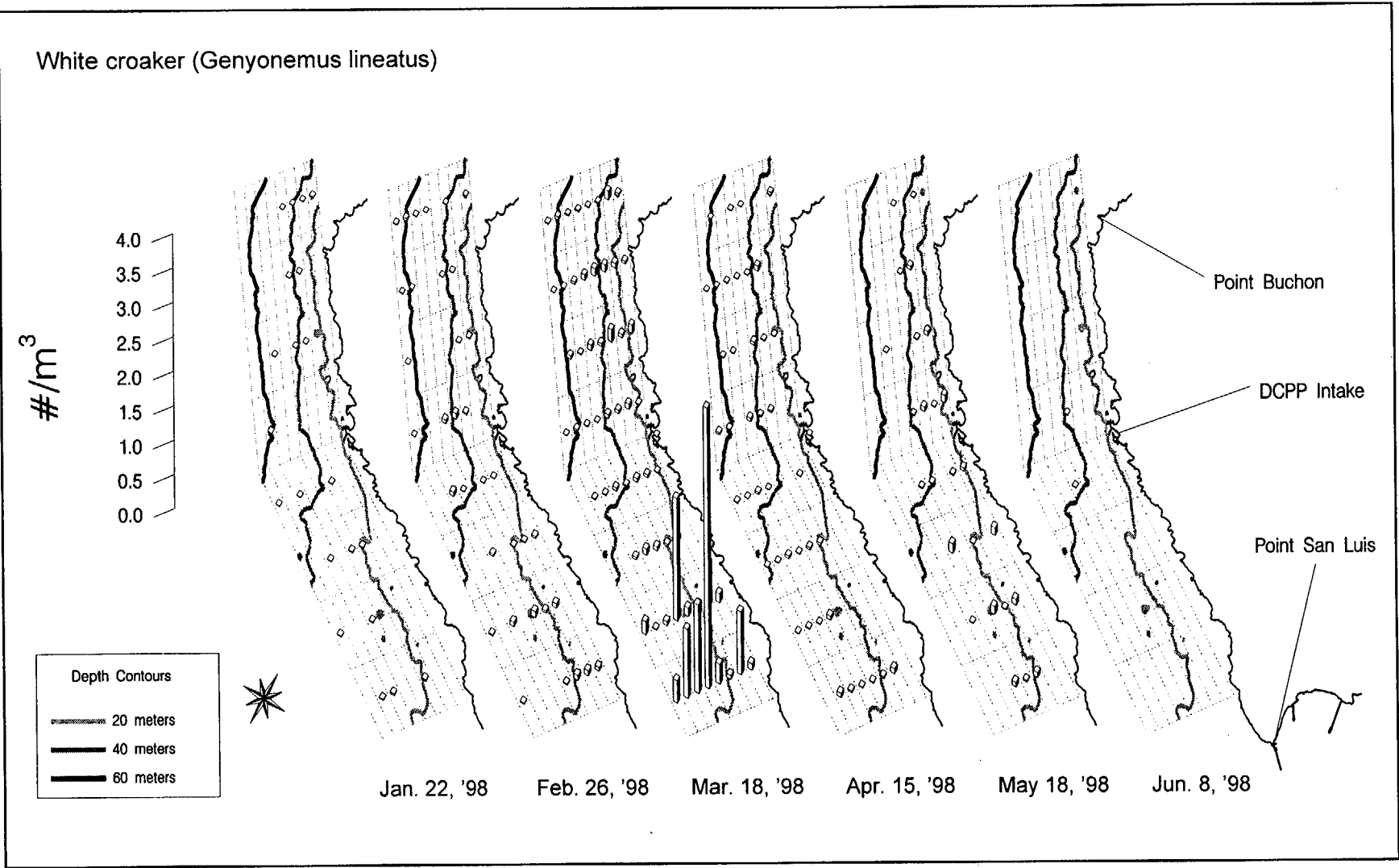


Figure 5.2.7-2b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

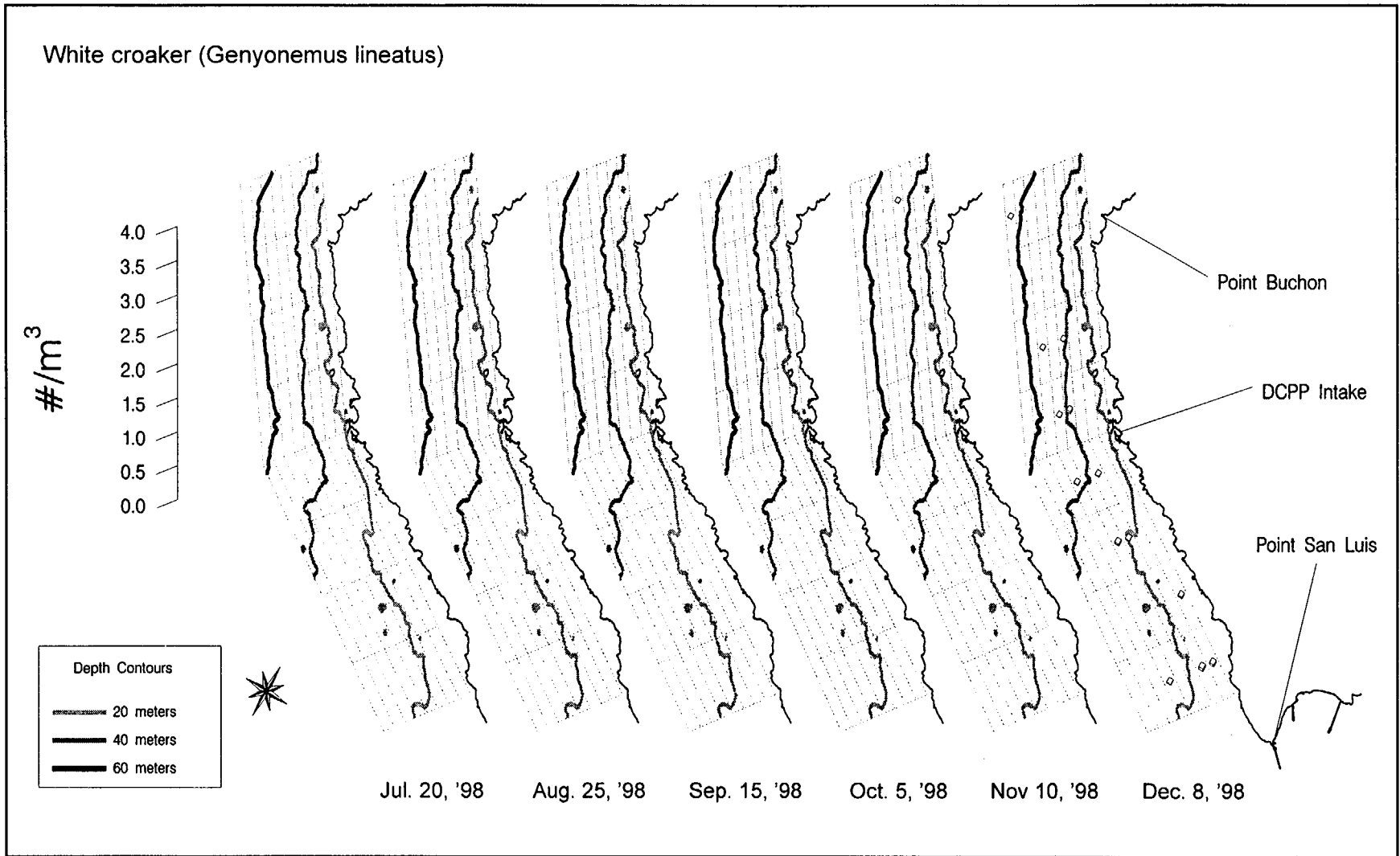


Figure 5.2.7-2c (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

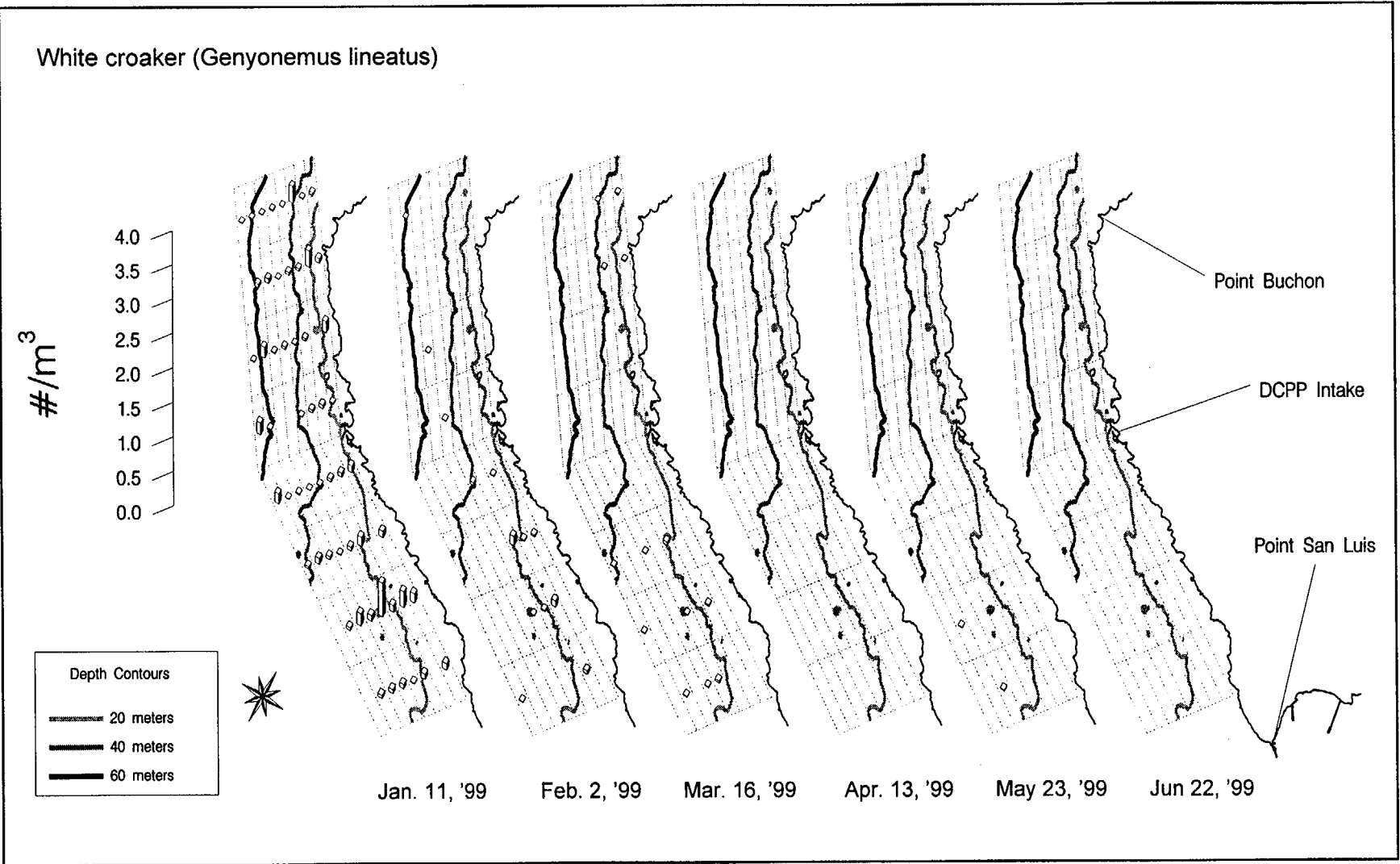


Figure 5.2.7-2d (continued). Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

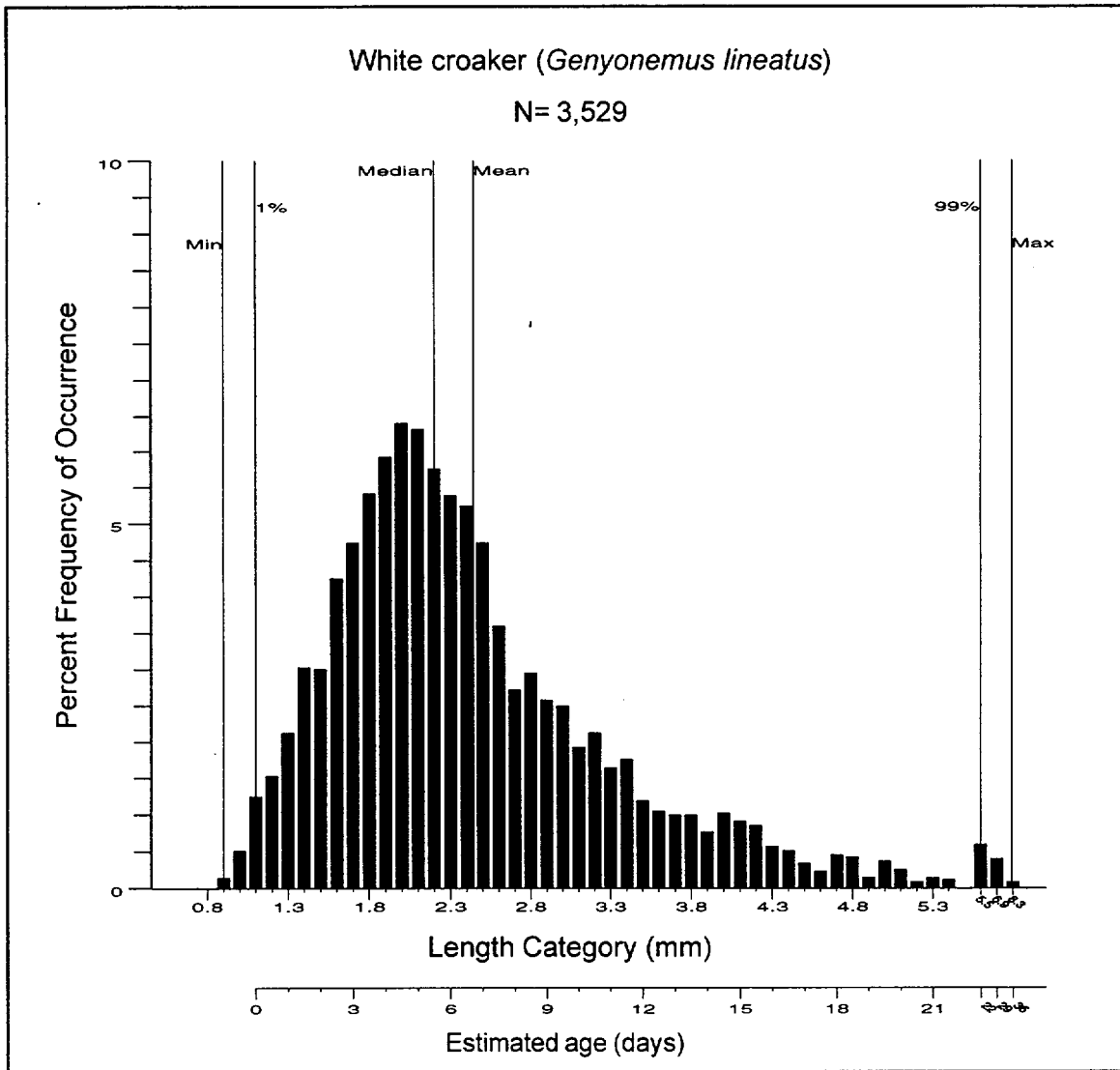


Figure 5.2.7-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

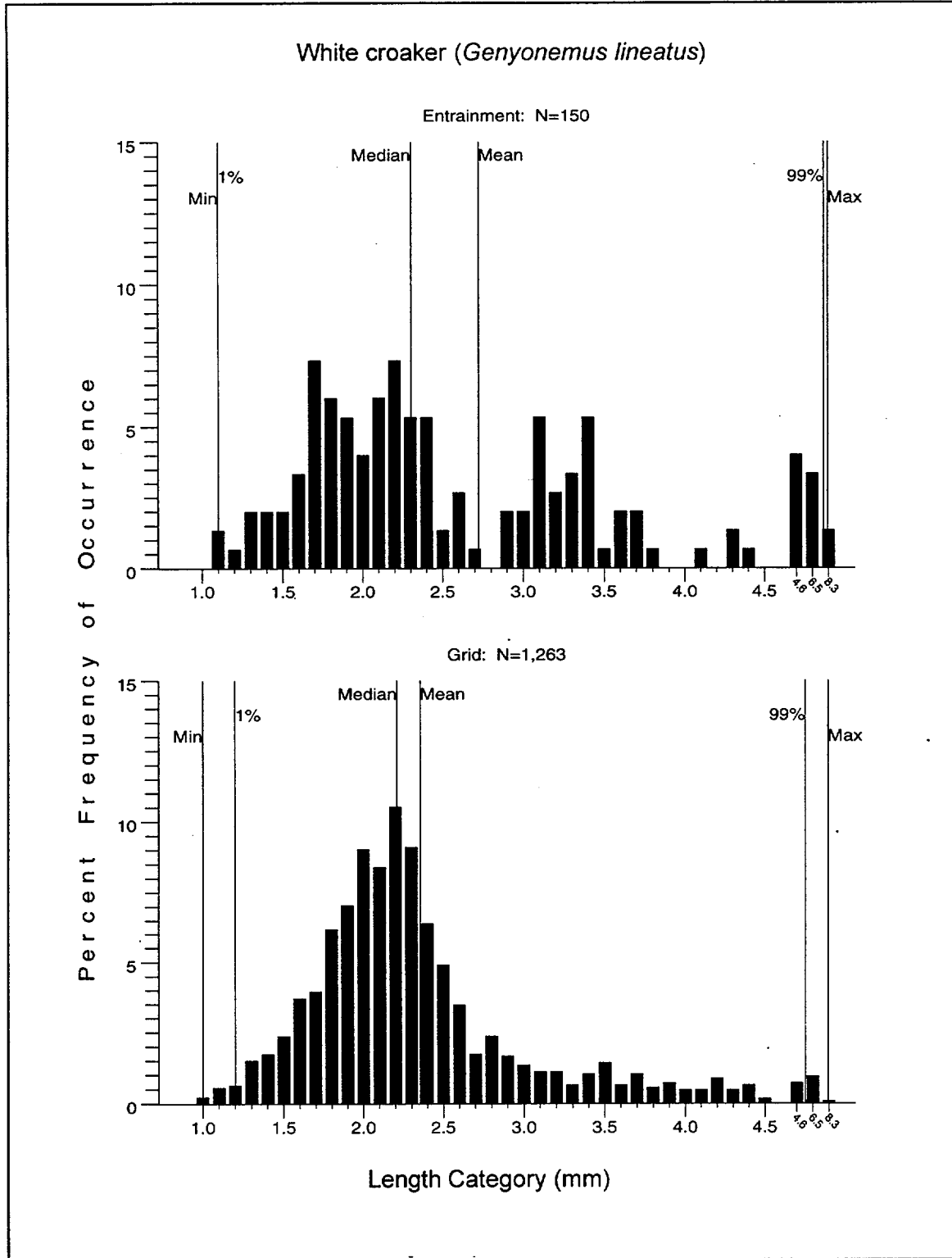


Figure 5.2.7-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

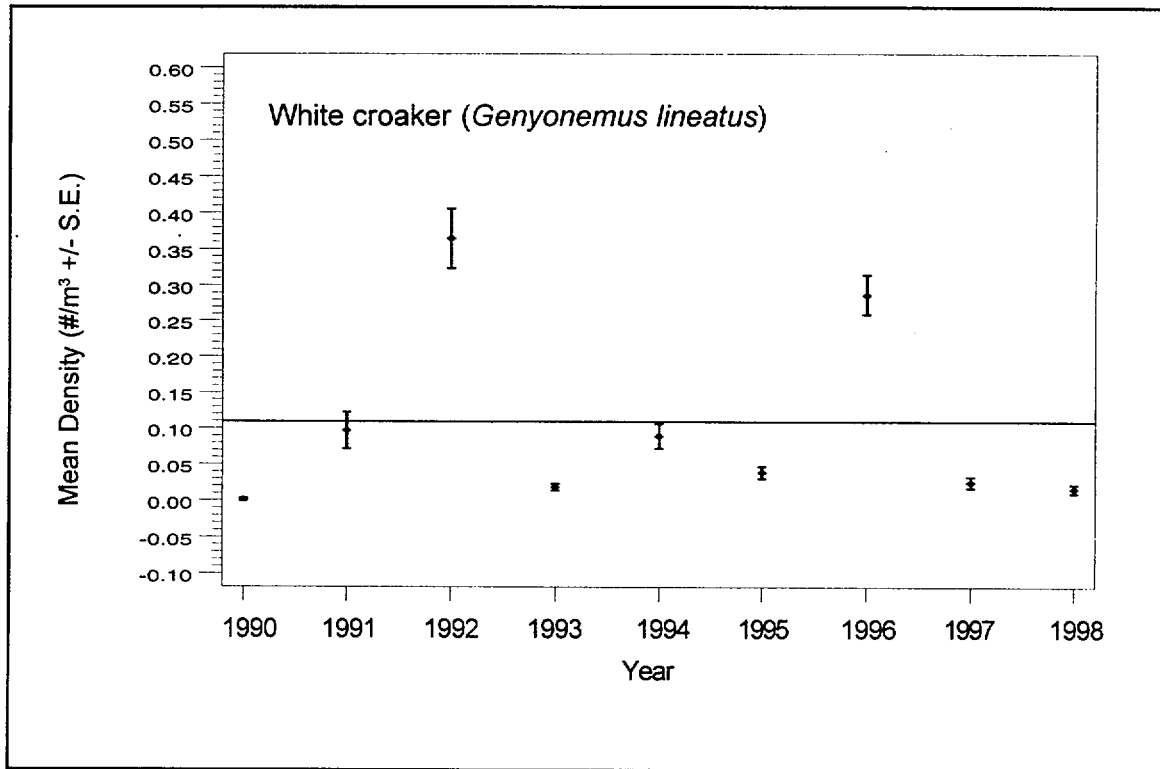


Figure 5.2.7-5. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

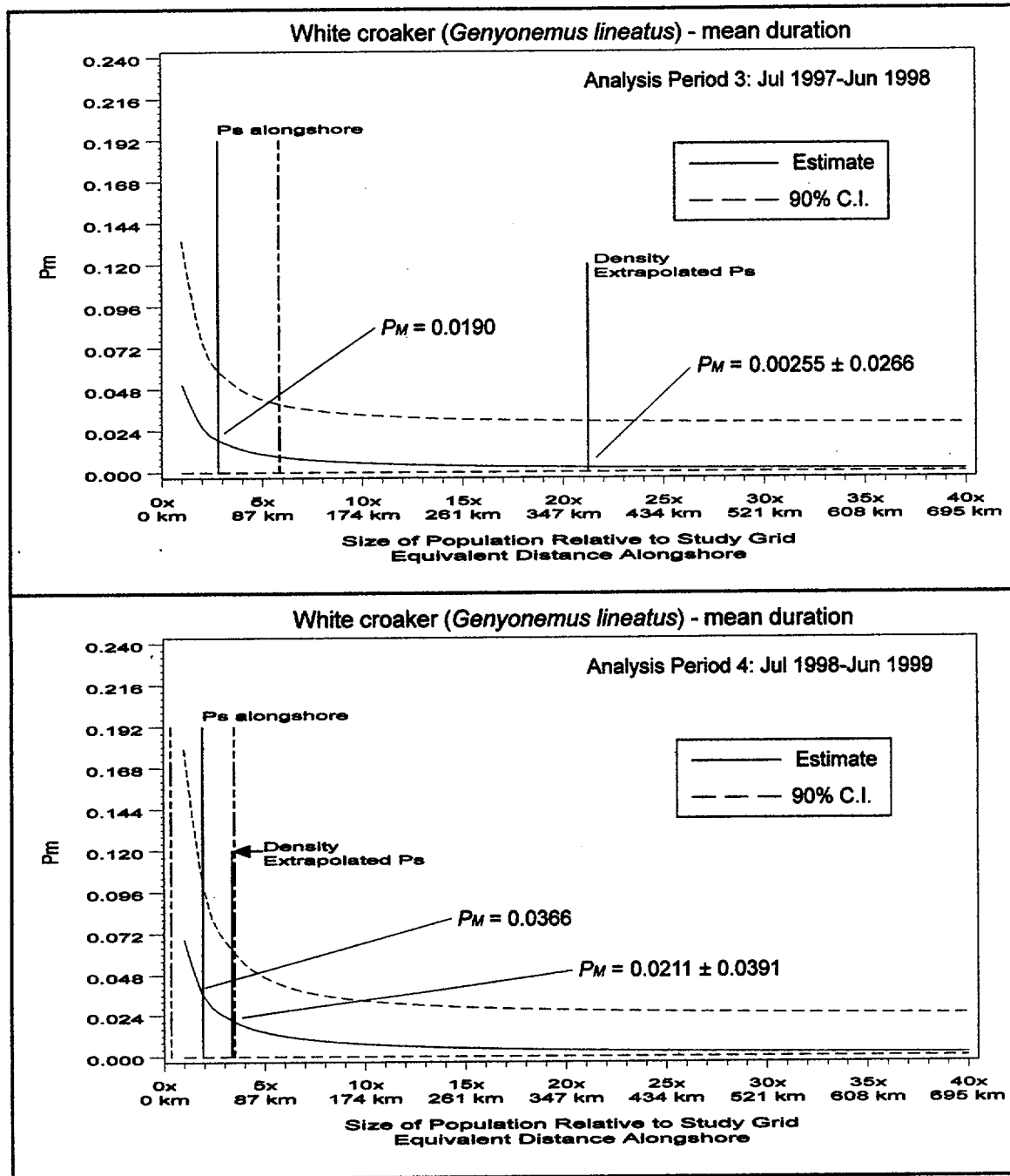


Figure 5.2.7-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

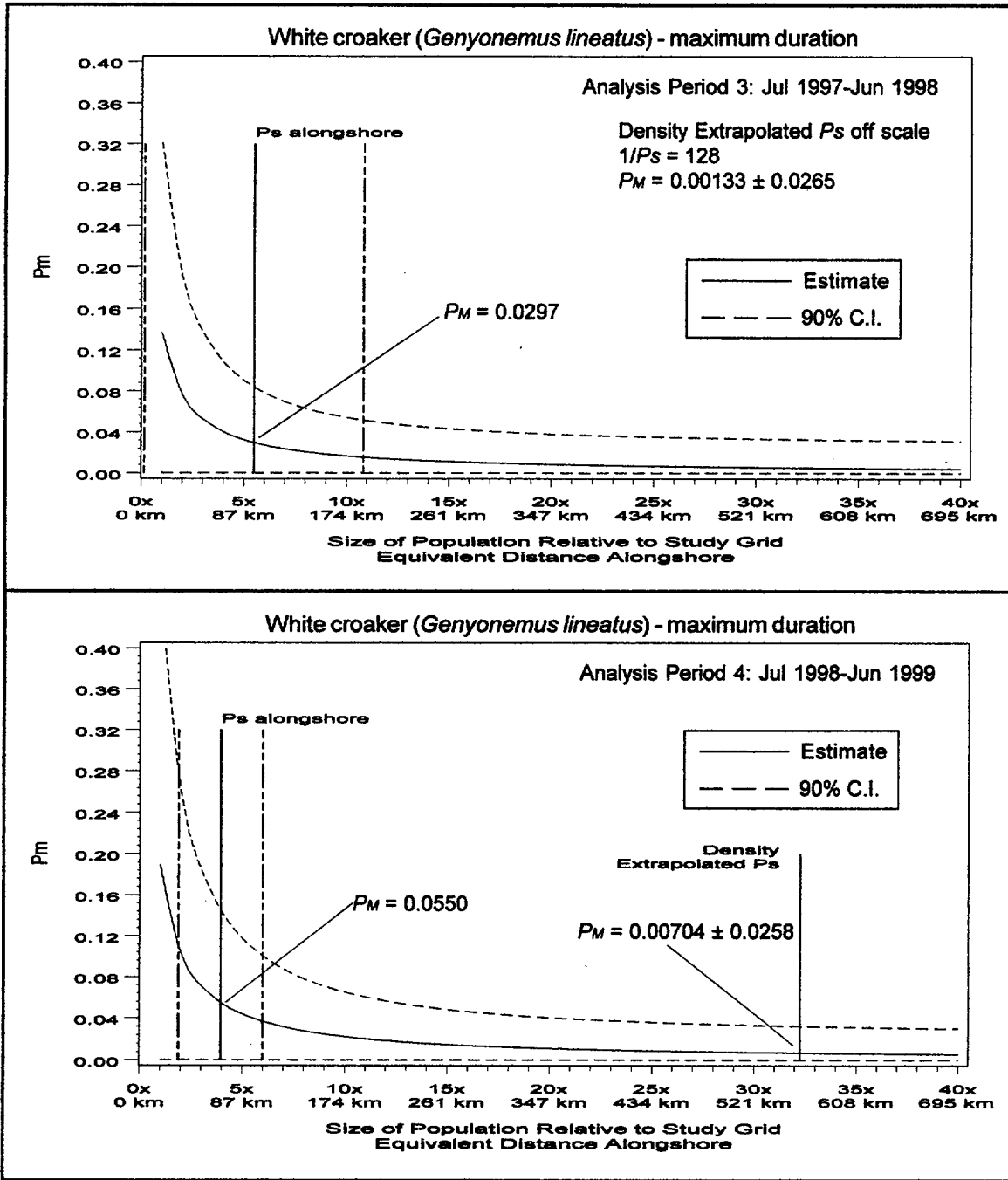


Figure 5.2.7-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

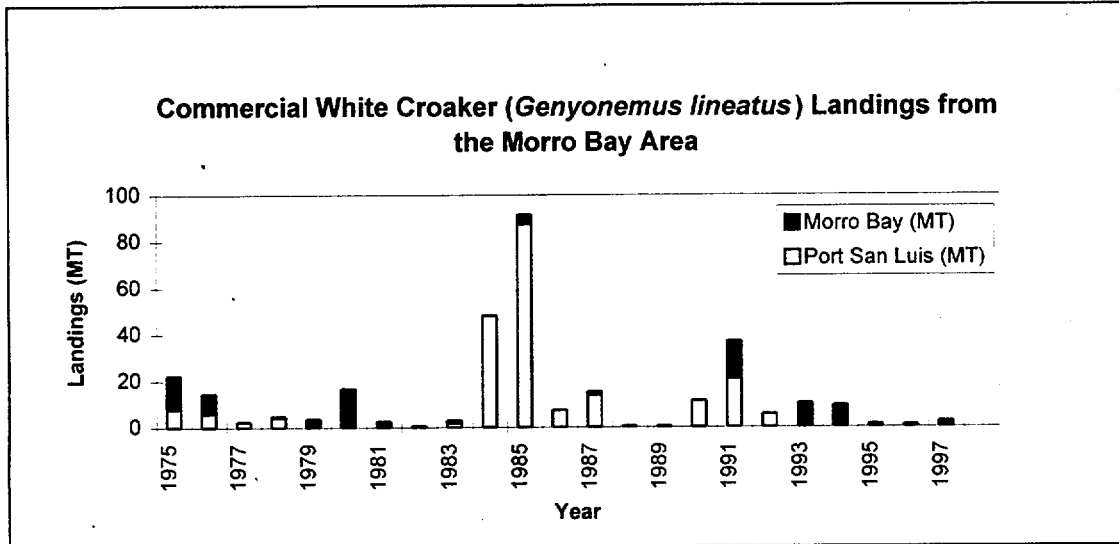
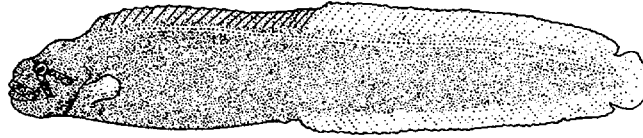


Figure 5.2.7-7. Annual commercial landings (MT) of white croaker (*Genyonemus lineatus*) at ports in the Morro Bay area (source: California Department of Fish and Game Database).

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5.2.8 Assessment of Monkeyface Prickleback (*Cebidichthys violaceus*)



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

The monkeyface prickleback (*Cebidichthys violaceus*) is a member of the family Stichaeidae, which is primarily distributed in the northern Pacific Ocean (Nelson 1994). The family consists of three subfamilies, 31 genera, and about 60 species (Nelson 1994). The monkeyface prickleback belongs to the subfamily Xiphisterinae, which contains 15 species, several of which are common to the California coast (Miller and Lea 1972; Nelson 1984). The monkeyface prickleback is found as far south as central Baja California, Mexico but is rare south of Point Conception (Burge and Schultz 1973; Love 1996). They are common in crevices and rocks from the upper intertidal to shallow rocky reefs at depths of about 24 m and appear to be highly territorial (Wang 1986; Love 1996). They are not commonly sighted subtidally because of their cryptic nature (Burge and Schultz 1973). In central California, juveniles are most abundant in water about 0.5 m above mean lower low water (MLLW) tidal height and commonly found under rocks at low tide (Love 1996). Investigations into the diet of this fish in Diablo Cove reveal it is an herbivore feeding largely on red algae (Burge and Schultz 1973).

Monkeyface prickleback lay demersal, adhesive eggs (Wang 1986; Fitch and Lavenberg 1971; Baxter 1974) and exhibit parental egg-guarding behavior (Fitch and Lavenberg 1971; Bane and Bane 1971). Spawning has been reported from January to May (Fitch and Lavenberg 1971; Baxter 1974; Wang 1986; Love 1996). In Diablo Cove, females were full of eggs in January, contained small undeveloped eggs in July, and had spent ovaries in September (Burge and Schultz 1973). This evidence, coupled with the presence of young-of-the-year (YOY) in fall, suggests late summer spawning (Burge and Schultz 1973). Additionally, maturing ovaries were

observed from December through June, mature ovaries from March through May, and spent ovaries from February through August with one in December. Older fish appear to spawn earlier in the season than younger fish (Marshall and Wyllie Echeverria 1991).

Fecundity increases with age and length. Smaller fish produce 6,000 to 8,000 eggs (Fitch and Lavenberg 1971; Baxter 1974) while larger females produce more. A 41 cm SL female aged 7 yr produced 17,500 eggs, and a 61 cm SL female aged 11 yr had 46,000 eggs (Marshall and Wyllie Echeverria 1991).

Monkeyface prickleback larvae are planktonic (Wang 1986), but little else is known about the early life history of this species. A family member, the black prickleback (*Xiphister atropurpureus*), was shown to have marked positive phototaxis (attraction to light) for 3–5 d, after which time they become negatively phototactic (Peppar 1965 in Coleman 1992). There were no data on monkeyface prickleback larval growth rates in the literature. The larval growth rate (Stepien 1986) for an ecologically similar species, the giant kelpfish (*Heterostichus rostratus*, family Clinidae), was substituted for the missing *C. violaceus* growth rate. The accuracy of this growth rate as it applies to monkeyface prickleback is unknown, but it represents the best available data from the current scientific literature.

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

The fishery for monkeyface prickleback is largely recreational although some are sold commercially (Wang 1986; Love 1996). They are usually caught using a fishing method called

“poke-poling” among intertidal rocks. A small commercial fishery has been underway in the Morro Bay area since 1993 (California Department of Fish and Game Database).

5.2.8.1 Summary of Field Collections

Abundances of monkeyface prickleback larvae at the DCPD intake structure were seasonal during the years 1996–1999 (**Appendix H**), with highest densities occurring during the spring and summer (**Figure 5.2.8-1**). Few larvae of this species were collected during the months of August through December. It appears that the initiation of reproduction in monkeyface prickleback might have been delayed by a month or two during 1998. This might have been due to the El Niño event that began in 1997 (Lynn et al. 1998; NOAA 1999). There were 7,090 larval monkeyface prickleback identified from 1,253 bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999 representing 27% of the intake subsamples collected and processed during that period.

Monkeyface prickleback larvae were generally present in the DCPD study grid during January through July of each year (**Appendix H**), with their highest abundance occurring during May 1998 and April–May 1999 (**Figure 5.2.8-2**). They were distributed in higher density in the cells closest to shore in the southern half of the grid. There were 904 larval monkeyface prickleback identified from 294 bongo net subsamples representing 10% of the study grid subsamples collected and processed from July 1997–June 1999.

Standard lengths of all monkeyface prickleback larvae collected at the DCPD intake structure between October 1996 and June 1999 ranged from a minimum of 2.8 mm to a maximum of 24.6 mm; corresponding age estimates ranged from zero days (just hatched) to about 88 d (**Figure 5.2.8-3**). The growth rate of larval giant kelpfish (0.25 mm/d) reported by Stepien (1986) was used to estimate ages of these monkeyface prickleback larvae. The central 98% of this length-frequency distribution resulted in minimum and maximum lengths for the analyses of 5.7 mm and 12 mm, respectively. The mean larval length in this distribution was 7.33 mm, which corresponded to an estimated age of 6.5 d. We assumed that larvae shorter than the minimum length of the central 98% of the distribution had just hatched and were aged zero days. Subsequent ages were estimated

from this assumed hatch length. No reported hatching length for monkeyface prickleback was found in the scientific literature. Reported hatching size for bluebarred prickleback (*Plectobranchnus evides*) is <7.4 mm (Moser 1996). Individuals that appeared to be different ages based on length might be the same age as a result of natural variation in hatching size or variable shrinkage after preservation. Thus, it is possible that at least some of the smaller-sized larvae, at least up to 5.7 mm and possibly larger, had just hatched before being caught.

Distributions of monkeyface prickleback larval lengths at the DCP intake structure and in the study grid were compared using a Kolmogorov-Smirnov test (Figure 5.2.8-4). The test did not detect a significant difference between the two distributions ($p > 0.288$). A *t*-test also did not detect a significant difference ($p > 0.75$) between the mean lengths from the two locations. On average, these larvae were estimated to be about 6.5 d old, indicating that the power plant entrains relatively young monkeyface prickleback larvae. In addition, these data indicate that the age and size structure of the population entrained is nearly identical to that of the population at risk.

5.2.8.2 Estimating Total Annual Entrainment

The annual estimates of the average entrainment for 1996–97 Analysis Period 1 ($\widehat{E}_T = 106,000,000$) and 1997–98 Analysis Period 2 ($\widehat{E}_T = 119,000,000$) were similar (Table 5.2.8-1). The small differences in the estimated entrainment numbers are not statistically significant because 95% confidence intervals approximated by $\pm 2 \cdot \widehat{SE}(\widehat{E}_T)$ would not overlap.

Annual entrainment estimates of monkeyface prickleback larvae, adjusted to the long-term average from nine years of Intake Cove plankton sampling (Figure 5.2.8-5), ranged from 61,500,000 ($\widehat{SE} = 5,580,000$) in Analysis Period 2 to 83,100,000 ($\widehat{SE} = 8,160,000$) in Analysis Period 1 (Table 5.2.8-2). The adjustment index (\bar{I}/I_i) was calculated as the ratio between the nine year average (\bar{I}) of Intake Cove sampling and the average annual index estimated from these same tows during the year being adjusted (I_i). The average index for the years 1997 and 1998 (I_i) were 0.019 and 0.029 larvae/m³, respectively, while the long-term average index (\bar{I}) was 0.0148 larvae/m³ for the years 1990–1998, yielding the ratios \bar{I}/I_i of 0.783 for 1997 and

0.517 for 1998. The differences between the adjusted estimates were not statistically significant because 95% confidence intervals approximated by $\pm 2 \cdot \widehat{SE}(\hat{E}_{Adj-T})$ did not overlap.

NOTE: Entrainment estimates for monkeyface prickleback larvae were not used to calculate annual adult losses (*FH* or *AEL*) because there were insufficient demographic data with which to parameterize these approaches.

5.2.8.3 Empirical Transport Model (*ETM*)

Monthly estimates of proportional entrainment (PE_i) in the surveys from the two analysis periods ranged from a minimum of zero to a maximum of 0.859 ± 0.464 ($\pm 1 \widehat{SE}(\widehat{PE}_i)$) in January 1999 (Table 5.2.8-3). Periods when both \widehat{PE}_i and the annual proportion of larvae hatched in the i th survey period (\hat{f}_i) were equal to zero indicated that no larvae were collected at either the DCPD intake or from the study grid. When $\widehat{PE}_i = 0$ but $\hat{f}_i > 0$, larvae were collected at the DCPD intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. The largest values of \hat{f}_i occurred between April and June in both analysis periods indicating that these were periods of high monkeyface prickleback larval abundance at the intake structure. These surveys were also associated with the largest values of \widehat{PE}_i , except for the estimate in January 1999. Since \hat{f}_i was used to weight individual estimates of PE_i , those with higher \hat{f}_i values were proportionally more important to the annual entrainment mortality estimates.

Larval monkeyface prickleback were distributed close to shore in the study grid subsamples (Figure 5.2.8.2) and similar to observed adult distributions in shallow nearshore areas up to depths of 25 m (Miller and Lea 1972). Therefore, P_S was only calculated using alongshore current movement and not offshore extrapolation of study grid abundance. *ETM* results for monkeyface prickleback show the differences in how estimated larval durations can affect calculation of \widehat{P}_M (Figures 5.2.8-6a and b). As expected, values for \widehat{P}_M increase with increasing values of \widehat{P}_S (i.e., decreasing $1/\widehat{P}_S$) for shorter larval duration between periods. The probability of entrainment is less for the shorter duration because of the reduced time period for larval transport to occur. The difference between years for \widehat{P}_M is much less for the shorter larval

duration than the longer duration (0.11 to 0.16 vs. 0.11 to 0.23). The larger confidence intervals around \widehat{P}_S for the longer larval duration reflect the larger uncertainty that results from increased alongshore transport. The point estimates for \widehat{P}_M for both larval durations are greater during 1997–1998 because of weaker alongshore currents associated with El Niño conditions.

5.2.8.4 Interpretation of Assessment Results

A limited fishery exists for monkeyface prickleback. Monkeyface prickleback landings were first recorded in 1993 at Port San Luis and Morro Bay, peaked in 1995, and declined through 1998 (Figure 5.2.8-7). Landings ranged from a low of 3 kg at Port San Luis in 1993 to a high of 180 kg at Morro Bay in 1995. The average combined annual catch between 1993 and 1998 from the Morro Bay area was 75 kg/yr. Because of the limited fishery for this species, there have been no estimates of stock size or adult density. Therefore, the catch data will not be used to compare harvest mortality rates to \widehat{P}_M .

The highest annual densities of monkeyface prickleback larvae from Intake Cove surface plankton tows occurred in 1990. Abundances in 1997 and 1998 were slightly above the long-term mean density (Figure 5.2.8-5). Adult monkeyface prickleback abundance was low and variable on the transects surveyed during the DCPD Receiving Water Monitoring Program fish observations from 1978 to 1998 (Figure 5.2.8-7). Monkeyface prickleback have a relatively long lifespan that has been estimated at up to 18 yr from a 67 cm SL fish (Marshall and Wyllie Echeverria 1991). Results of the *ETM* show that the power plant may annually entrain 11–23% of the monkeyface prickleback larvae from an area 7 to 8 times the area of the study grid (Figure 5.2.8-6). The wide range in the size of larvae entrained (<3 mm to >24 mm) indicate that monkeyface prickleback larvae are vulnerable to entrainment over a large portion of their larval life (Figure 5.2.8-3). This could indicate an increased potential for impacts from entrainment on this taxon. In the absence of other estimates of adult population abundance, there is no definitive way to determine whether this level of larval mortality is sufficient to cause a long-term local population decline. However, this species is widely distributed from southern Oregon to Baja,

and it is unlikely that larval losses from entrainment that may affect local adult abundances would affect the larger population.

Table 5.2.8-1. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for monkeyface prickleback (*Cebidichthys violaceus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sept 30, 1997	106,000,000	10,400,000
2) Oct 1, 1997–Sep 30, 1998	119,000,000	10,800,000
3) Jul 1, 1997–Jun 30, 1998	116,000,000	10,700,000

Table 5.2.8-2. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for monkeyface prickleback (*Cebidichthys violaceus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	83,100,000	8,160,000
2) Oct 1, 1997–Sep 30, 1998	61,500,000	5,580,000
3) Jul 1, 1997–Jun 30, 1998	60,200,000	5,520,000

Table 5.2.8-3. Monkeyface prickleback (*Cebidichthys violaceus*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.0247	0.00723	0.0437	0.00248
Aug 25, 1997	0	0	0	0
Sep 29, 1997	0	0	0	0
Oct 20, 1997	0	0	0	0
Nov 17, 1997	0	0	0	0
Dec 10, 1997	0	0	0	0
Jan 22, 1998	0	0	0.00320	0.000510
Feb 26, 1998	0.00621	0.00369	0.0122	0.00101
Mar 18, 1998	0.0217	0.0108	0.0379	0.00490
Apr 15, 1998	0.139	0.0481	0.403	0.0164
May 18, 1998	0.0135	0.00301	0.188	0.00981
Jun 8, 1998	0.0542	0.0123	0.313	0.0126

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.0108	0.00972	0.0580	0.00483
Aug 26, 1998	0	0	0	0
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0	0	0	0
Jan 12, 1999	0.859	0.464	0.0116	0.00114
Feb 3, 1999	0.0384	0.0245	0.0389	0.00348
Mar 17, 1999	0.0223	0.00636	0.119	0.00538
Apr 14, 1999	0.0401	0.0146	0.434	0.0140
May 24, 1999	0.0155	0.00440	0.178	0.00729
Jun 23, 1999	0.0615	0.0170	0.161	0.00667

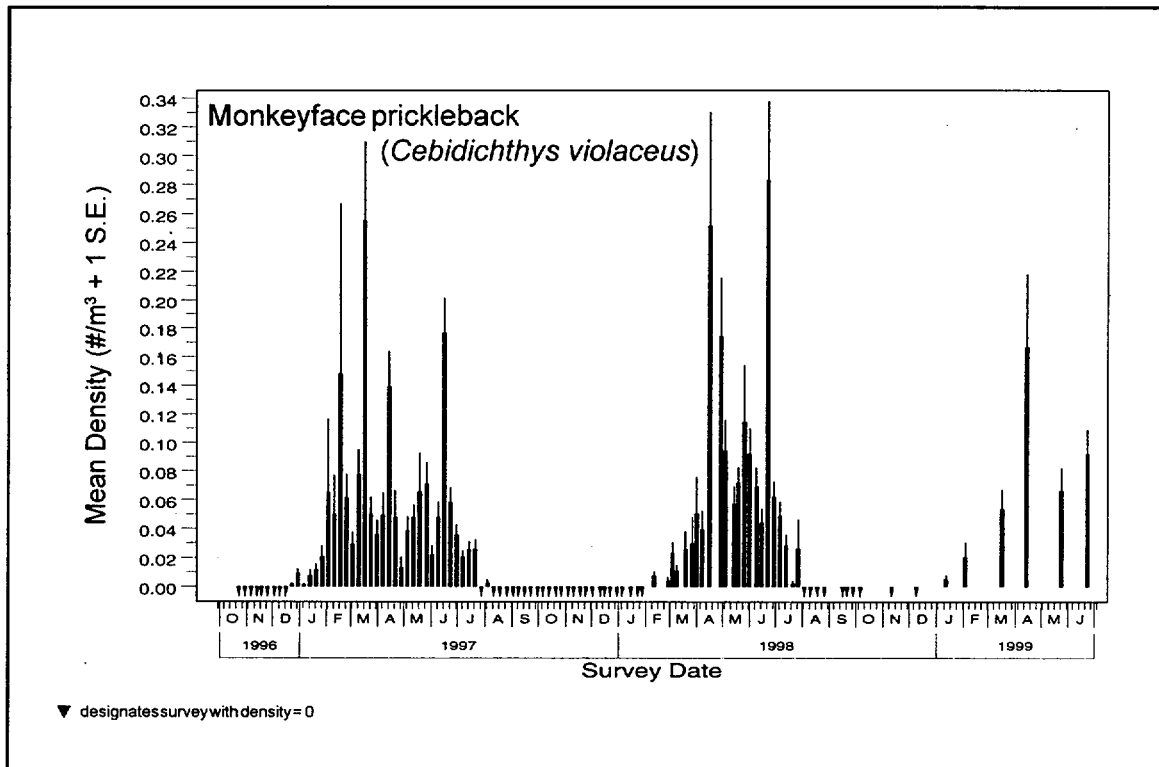


Figure 5.2.8-1. Weekly mean larval density ($\#/m^3 + 1 \text{ S.E.}$) at the DCP intake.

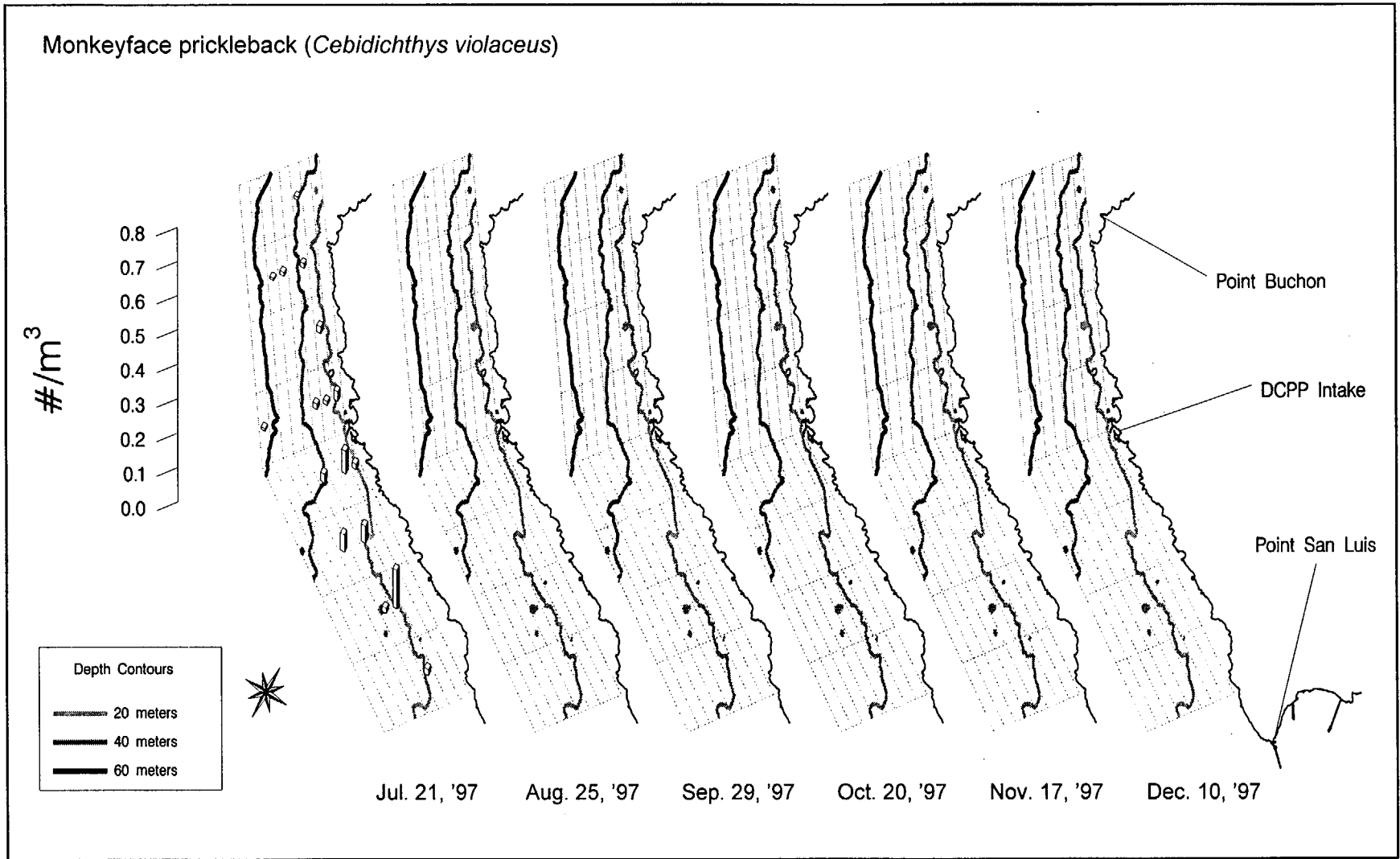


Figure 5.2.8-2a. Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

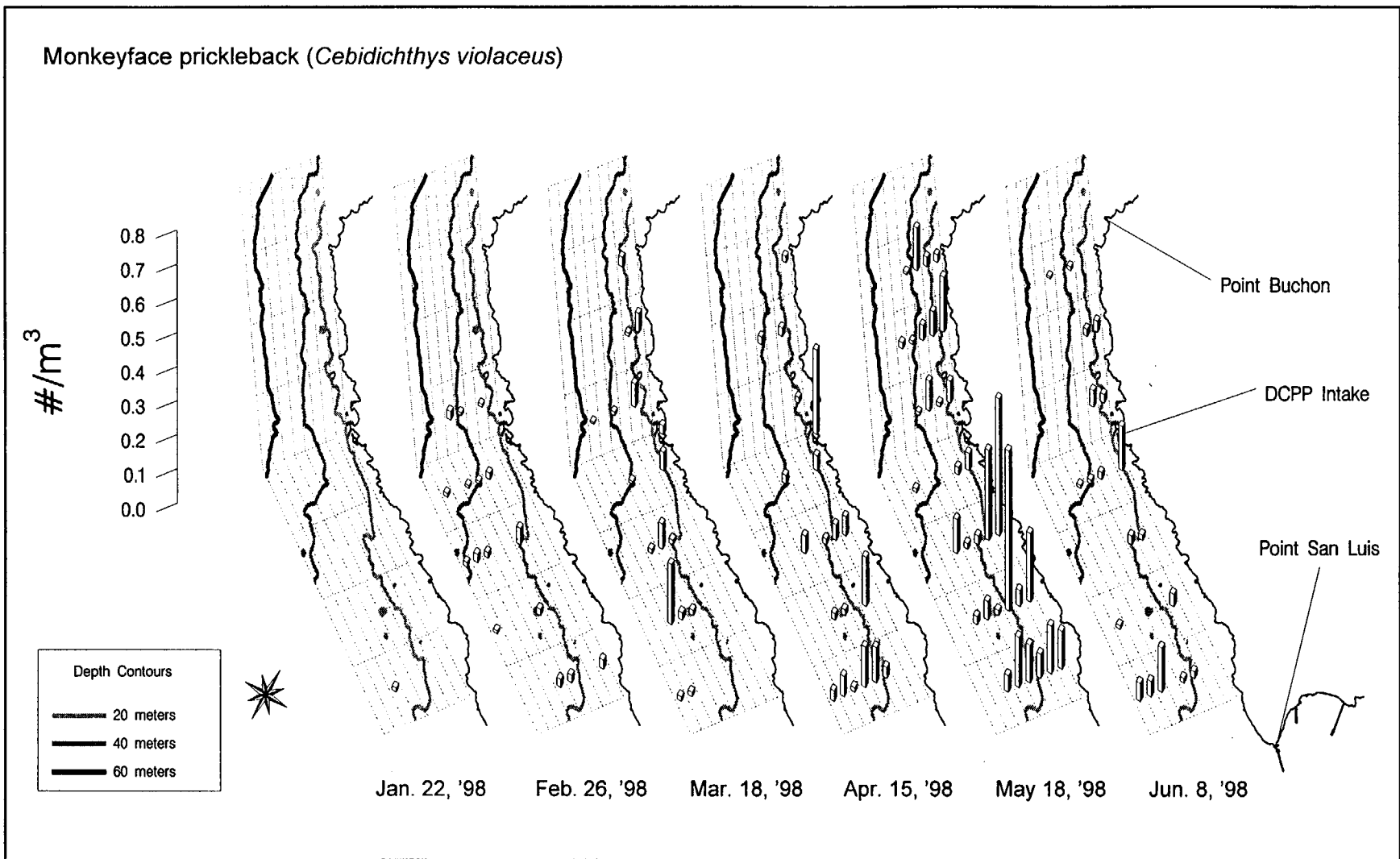


Figure 5.2.8-2b (continued). Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

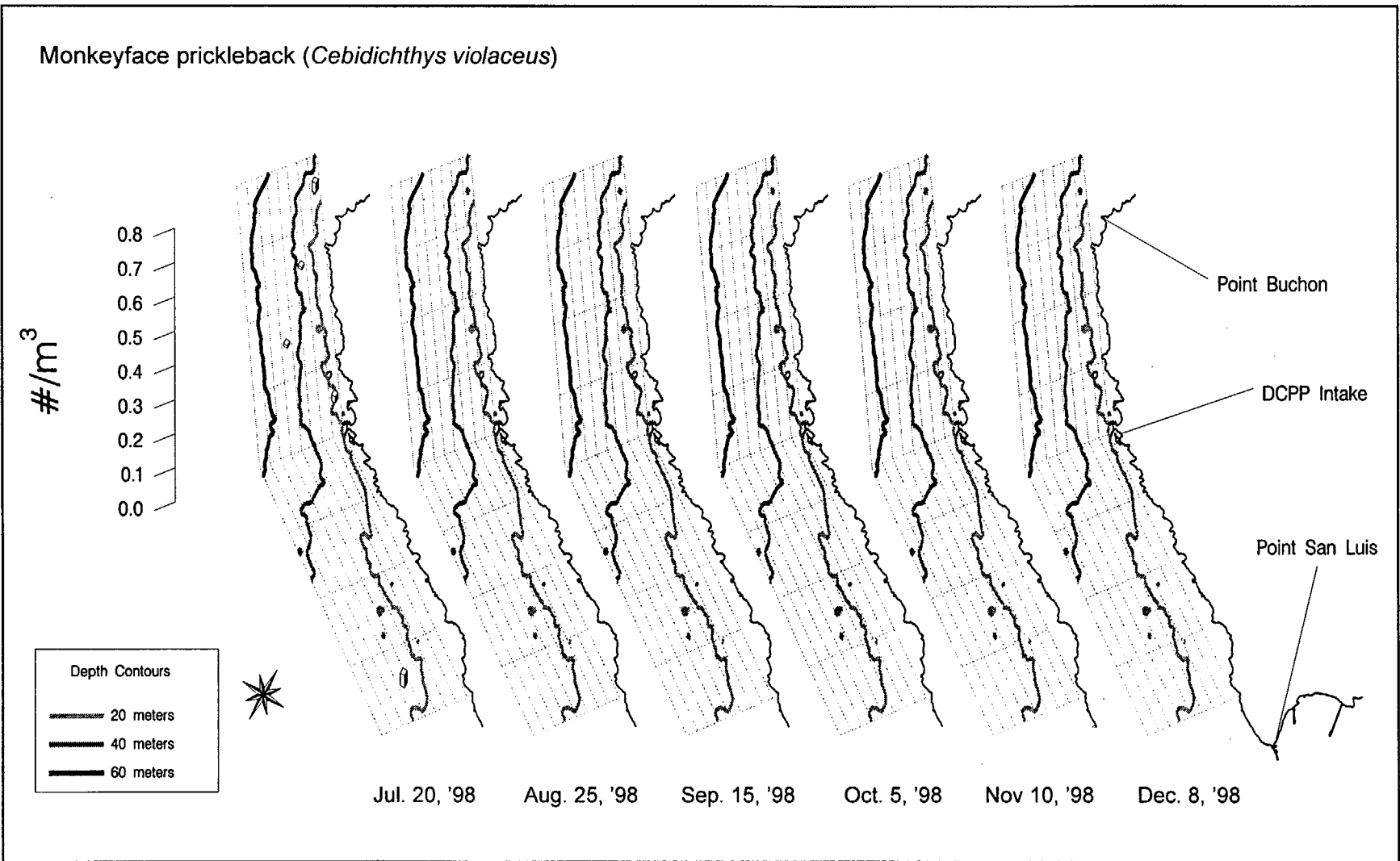


Figure 5.2.8-2c (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

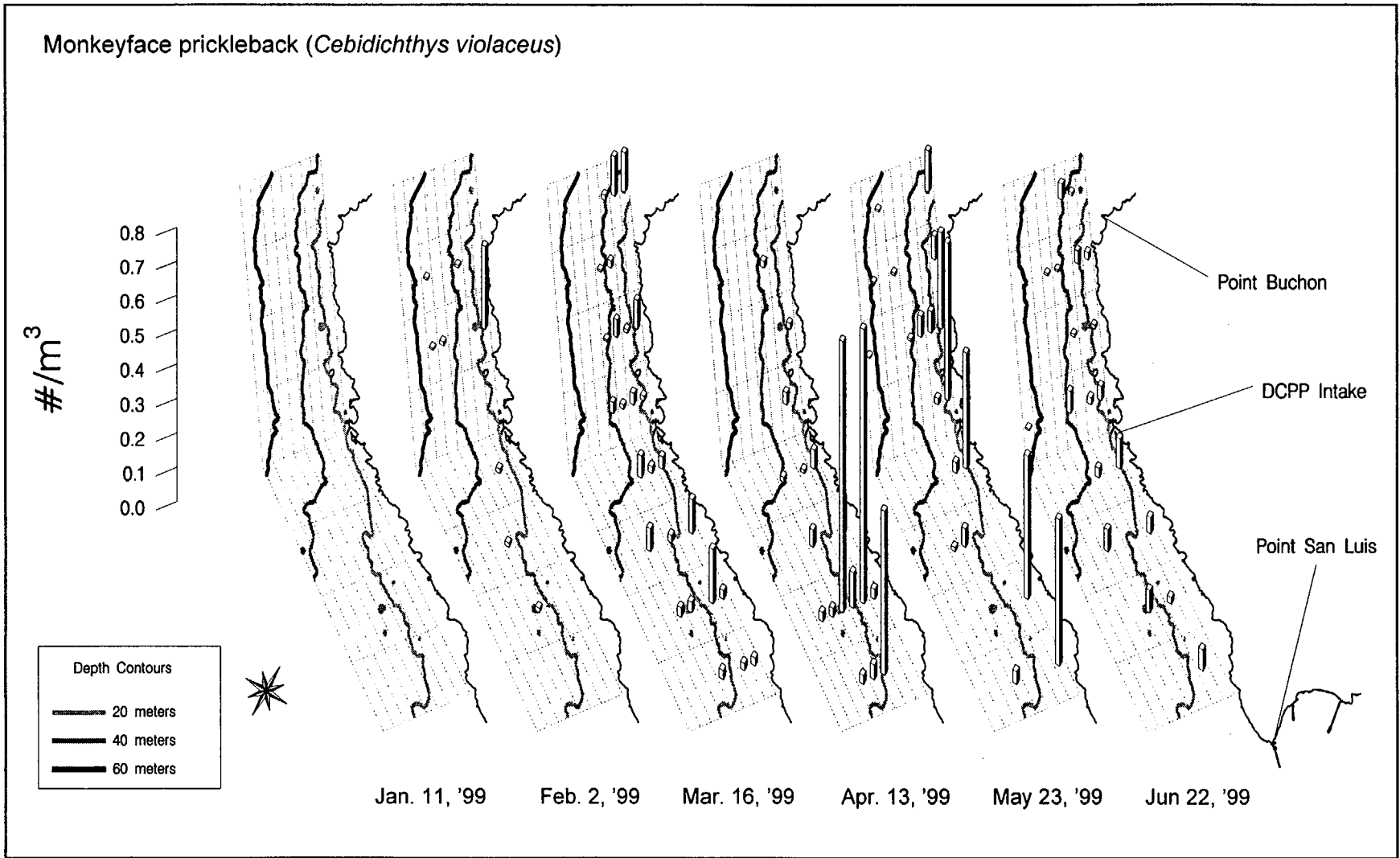


Figure 5.2.8-2d (continued). Mean larval density ($\#/m^3$) collected in the DCPP study grid cells and at the entrainment sampling location.

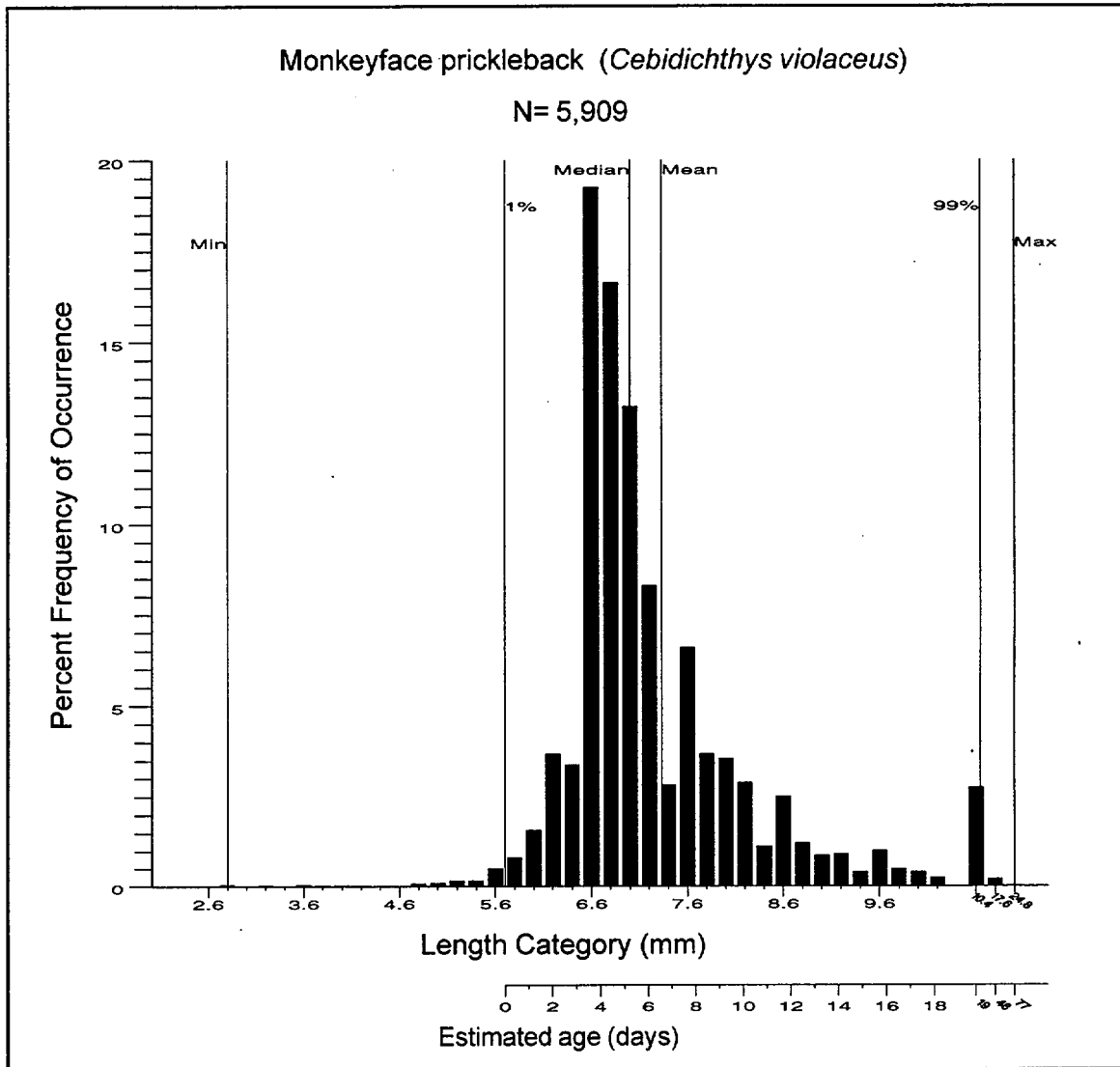


Figure 5.2.8-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

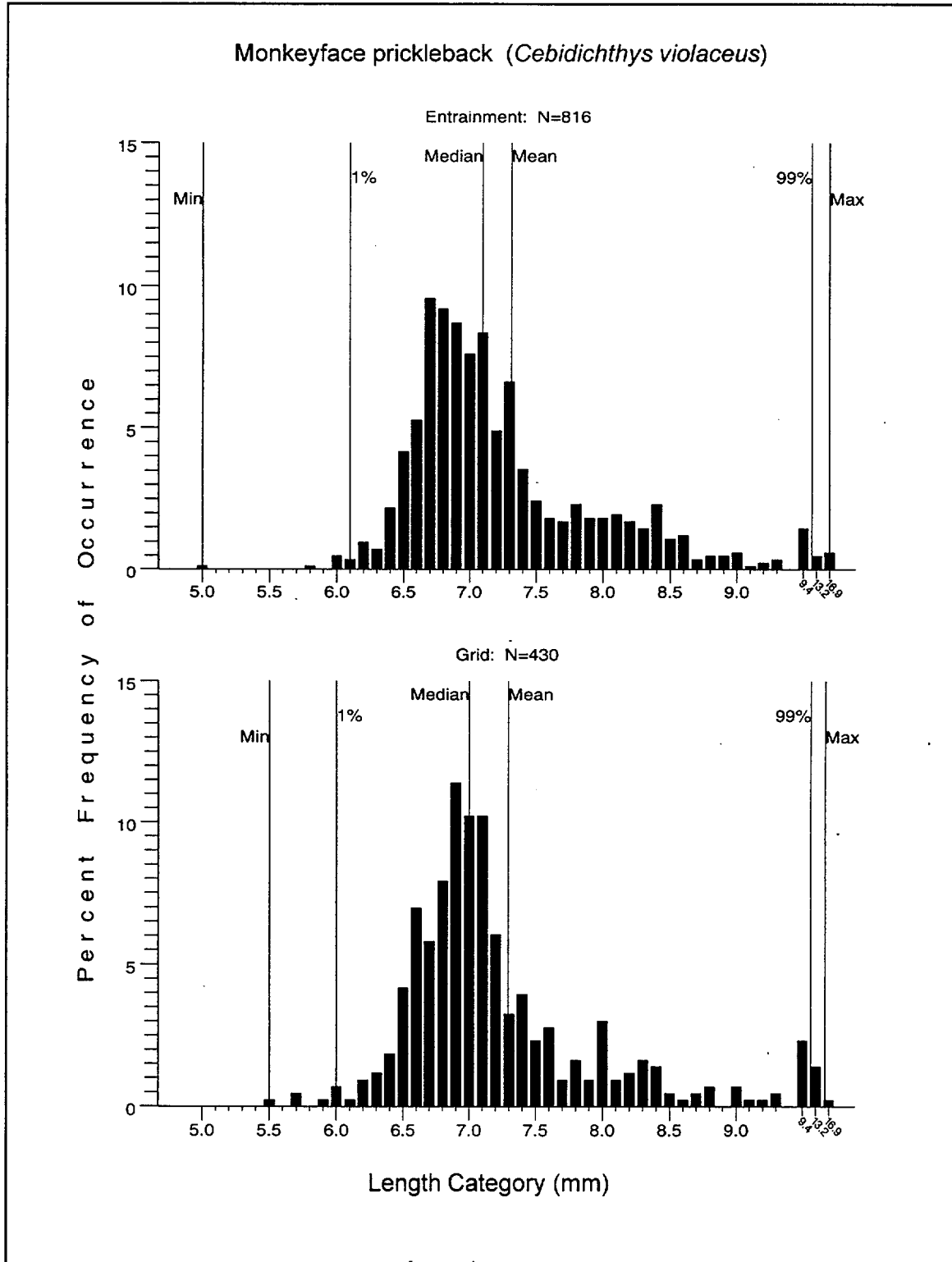


Figure 5.2.8-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

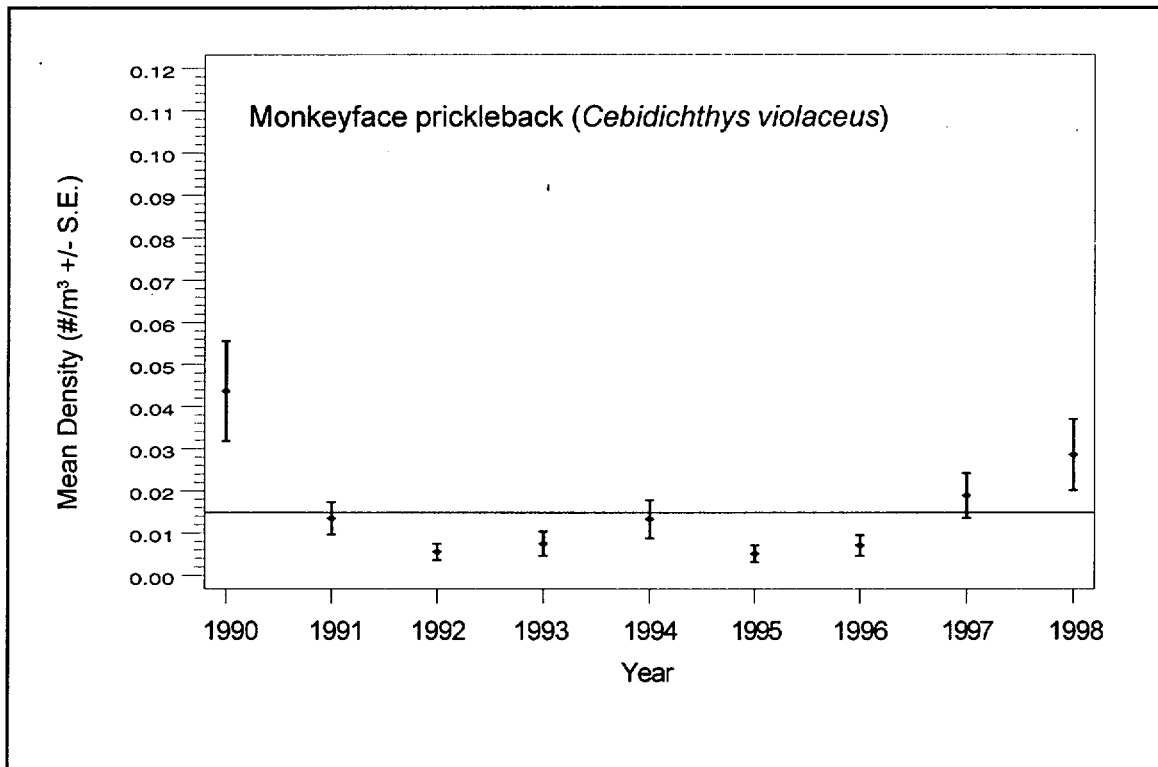


Figure 5.2.8-5. Annual mean density +/- 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

5.2.8 Monkeyface Prickleback

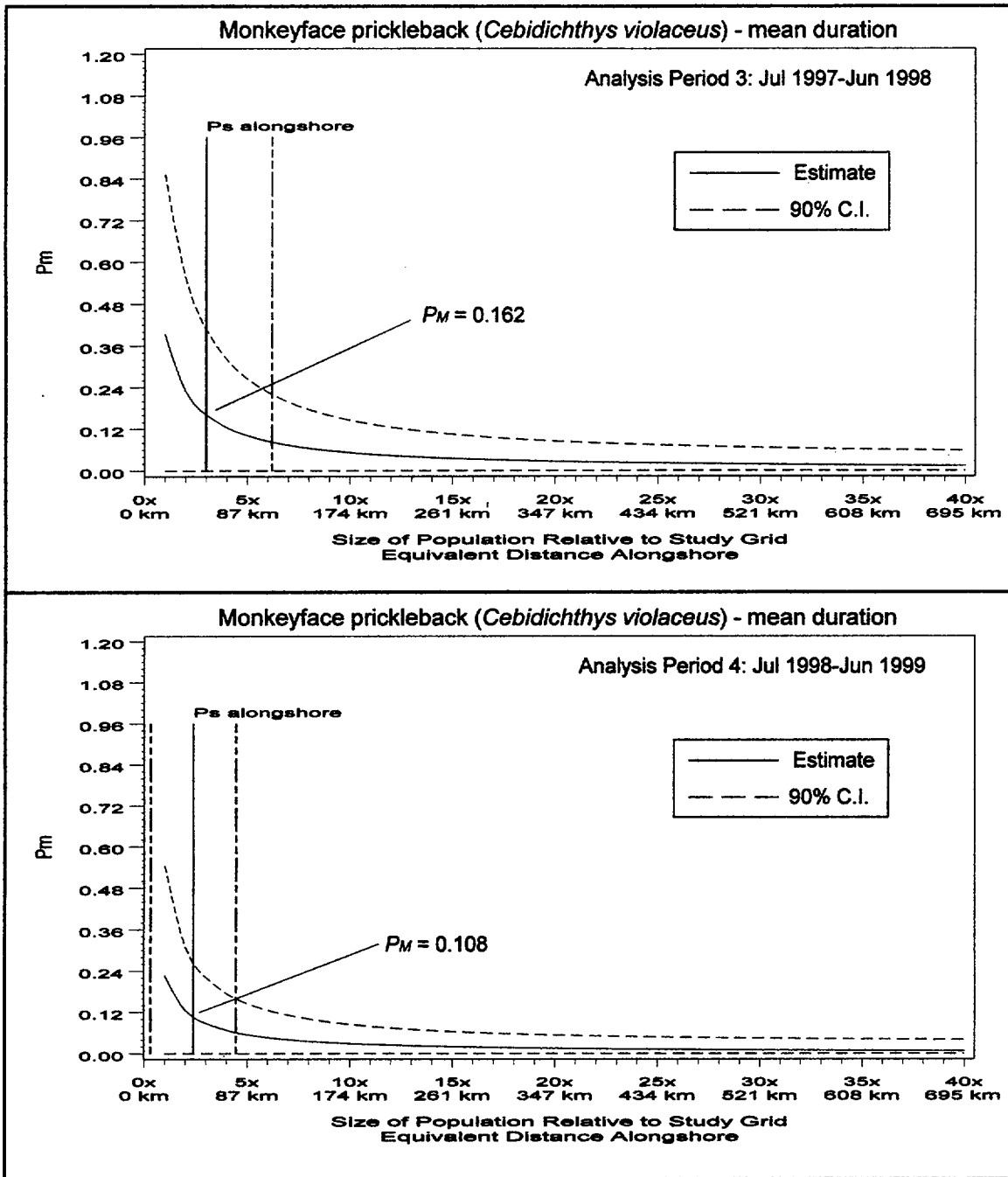


Figure 5.2.8-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements with the 90% C.I. indicated.

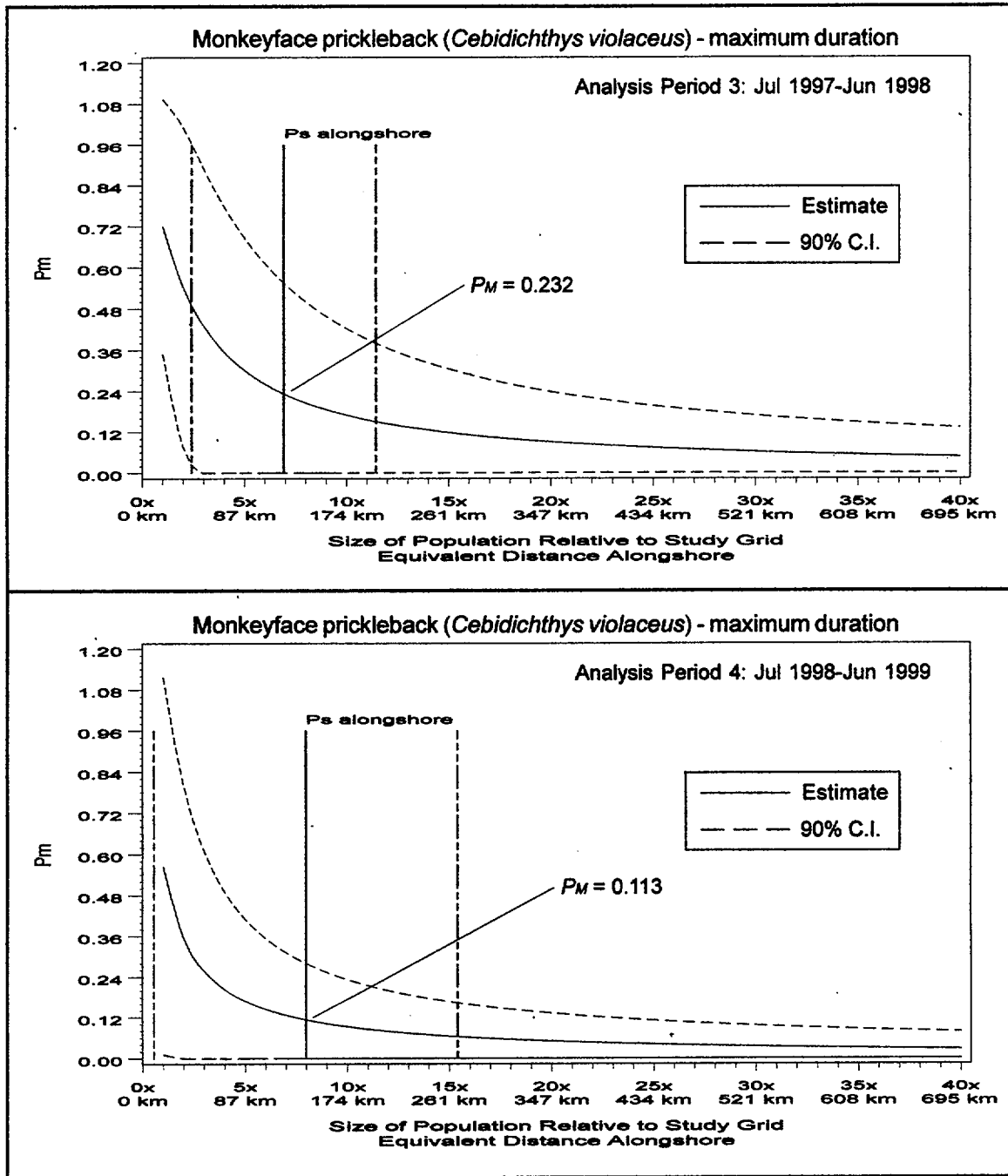


Figure 5.2.8-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements with the 90% C.I. indicated.

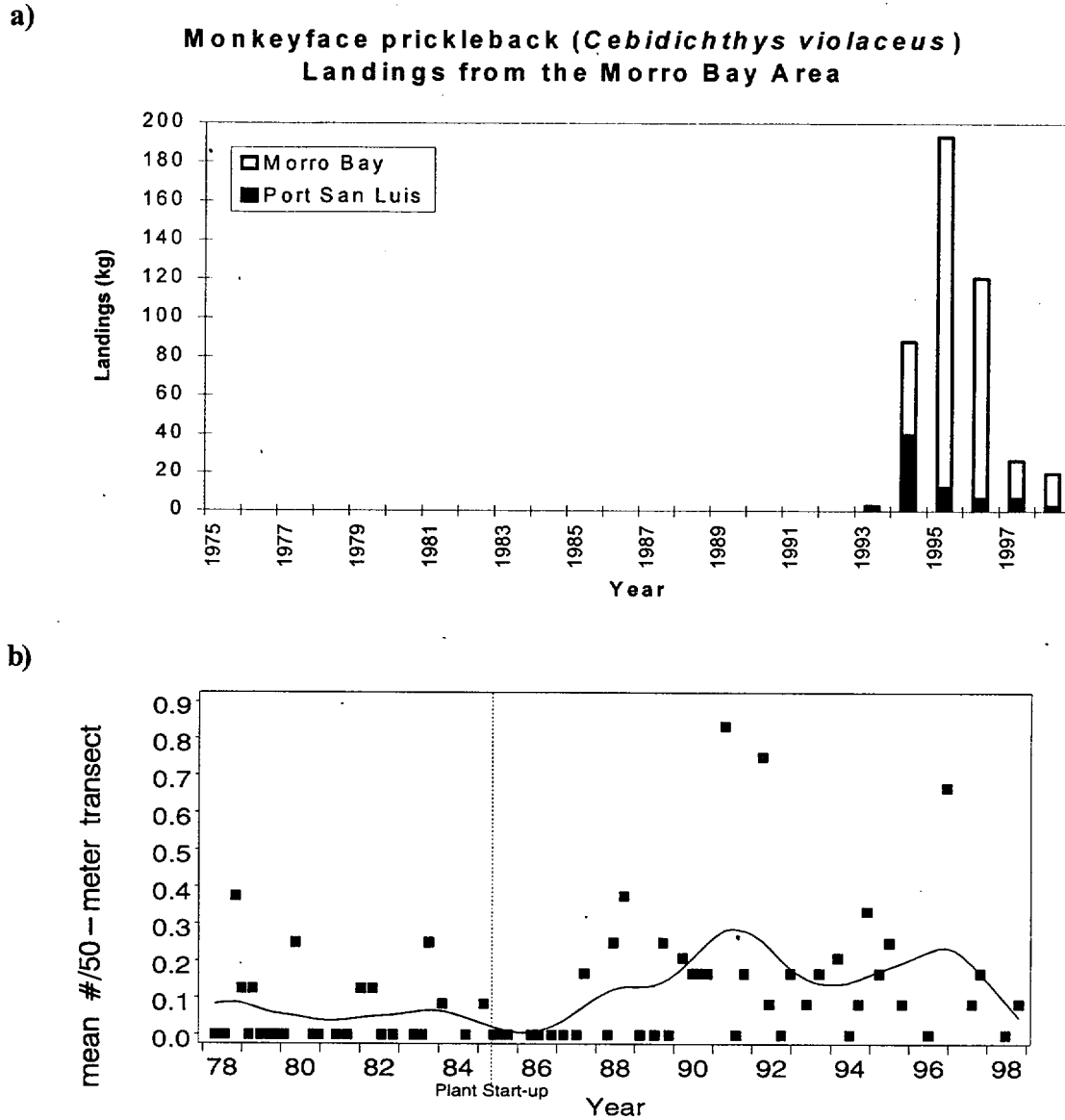
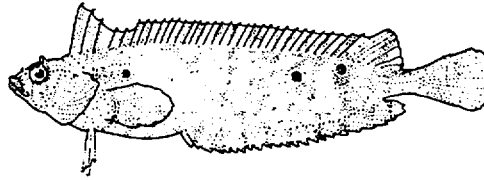


Figure 5.2.8-7. Yearly abundance of monkeyface prickleback measured by two independent methods: a) Commercial landings of adults from Morro Bay area, b) Mean number of fish observed per 50-meter subtidal benthic transect in the DCPW RWMP South Control area. Spline smoothing algorithm used to draw the curve through the points.

5.2.9 Assessment of Clinid Kelpfishes (Clinidae)



Gibbonsia elegans (Cooper 1864); spotted kelpfish; length to 16 cm; Piedras Blancas Pt., central California to Bahia Magdalena, southern Baja California, including Isla Guadalupe; to 56 m (Miller and Lea 1972; Eschmeyer et al. 1983); green to brown or tan or reddish, often blotched or streaked (Eschmeyer et al. 1983).

Gibbonsia metzi Hubbs 1927; striped kelpfish; length to 24 cm; Vancouver Is., British Columbia to Punta Rompiente, central Baja California; intertidal to 9.1 m (Miller and Lea 1972; Eschmeyer et al. 1983); reddish to light brown with stripes or darker mottling (Eschmeyer et al. 1983).

Gibbonsia montereyensis Hubbs 1927; crevice kelpfish; length to 15 cm; British Columbia to Rio Santo Tomas, northern Baja California. 15–37 m. (Miller and Lea 1972; Eschmeyer et al. 1983); reddish to brown or lavender, plain colored to spotted or striped (Eschmeyer et al. 1983). *G. erythra* is a synonym (Stepien and Rosenblatt 1991).



Heterostichus rostratus Girard 1854; giant kelpfish; length to 61 cm; British Columbia to Cabo San Lucas, southern Baja California, including Isla Guadalupe; intertidal to 40 m (Miller and Lea 1972; Eschmeyer et al. 1983); giant kelpfish come in as many as three color forms (red, brown, or green) usually associated with the plant habitats from which they were collected (Stepien 1987).

In the family Clinidae there are three species of kelpfishes in the genus *Gibbonsia* and the giant kelpfish (*Heterostichus rostratus*) that occur along the west coast of North America from Baja to British Columbia (George and Springer 1980). Nelson (1994) indicates that worldwide there are three groups of clinids with about 20 genera and 73 species. Clinids are small (generally <25 cm SL; exception *H. rostratus* ca. 60 cm SL), primarily demersal residents of nearshore rocky reefs and kelp and seaweed beds in temperate marine waters (Lamb and Edgell 1986; Moser 1996).

There are no catch statistics for these species because they are not commercially or recreationally harvested.

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

There is very little demographic information relating to the early life stages of clinids in general or specifically to the four representatives of the family found in central California. Growth of larval giant kelpfish was estimated by linear regression from data on lab-reared specimens (Stepien 1986) as $0.25 \text{ mm/d} \pm 0.013$ (slope ± 1 SE). A similar estimate of growth rate is not available for *Gibbonsia* spp., but if the growth rate for giant kelpfish is substituted for *Gibbonsia*, it allows us to estimate larval ages at entrainment and calculate *ETM* for kelpfishes. There are no available data to indicate how well the larval growth rate of giant kelpfish describes the larval growth of *Gibbonsia* spp. Therefore, using giant kelpfish larval growth is considered only as an approximation to the growth of *Gibbonsia* spp. larvae. Additionally, there are no literature estimates of early life stage survivorship for any of the clinids treated here, so *FH* and *AEL* are not calculated for the clinid kelpfishes. The relatively few identified larval giant kelpfish (42 at the DCP intake and one from the study grid) were incorporated into the clinid kelpfish group for the analyses.

5.2.9.1 Summary of Field Collections

Estimates of kelpfish larval abundance at the DCP intake structure during the years 1996–99 indicate that species in this genus are continuous spawners (**Appendix H**) exhibiting at least two peaks in larval abundance per year. During the 1996–97 season, larval abundance at the intake

structure peaked in January and again in June–August (**Figure 5.2.9-1**). In the 1997–98 season, the January peak seen in the previous year did not occur, and the later peak appeared displaced by about one month and occurred in May–June. Although there are fewer processed subsamples from the 1998–99 spawning season, the peaks appear to conform with the pattern for the 1996–97 period. There were 9,361 larval kelpfishes identified from 2,808 bongo net subsamples collected at the DCP intake structure between October 1996 and June 1999 representing 60% of the subsamples collected and processed from the intake structure during that period.

Larval kelpfishes were relatively scarce in the DCP study grid (**Appendix H**), but the temporal distribution of abundance roughly corresponded to that observed at the DCP intake structure. There were 467 kelpfish larvae identified from 213 bongo net subsamples in study grid between July 1997–June 1999 representing 7% of the study grid subsamples collected and processed. Kelpfish larval abundance was generally distributed within the 20 m isobath, and larvae were likely concentrated in unsampled areas inshore of the study grid (Marliave 1986). The apparently higher density of this species in the southern portion of the study grid results from the relationship postulated with depth above and the fact that more of the area in the southern half of the grid is within the 0–20 m depth range.

Standard lengths of the *Gibbonsia* spp. larvae (7,331 larvae) measured from subsamples at the DCP intake structure between October 1996 and June 1999 ranged from a minimum of 2.4 mm to a maximum of 23 mm (**Figure 5.2.9-3**). The minimum and maximum lengths, 4.1 mm and 12 mm, from the central 98% of this length-frequency distribution were used in calculating larval duration. A larval growth rate from giant kelpfish of 0.25 mm/d (Stepien 1986) was applied to the range of lengths to estimate the ages of the entrained larvae. The mean larval length in this distribution was 6.4 mm at approximately 9 d of age. We assumed that larvae shorter than the minimum length of the central 98% of the distribution were just hatched and aged zero days. Subsequent ages were estimated from this length and up. Other reported data for this species suggests that hatching length is approximately 4.5 mm (Moser 1996), indicating that the smallest larvae observed represent either natural variation in hatch lengths within the population or the phenomenon of shrinkage following preservation (Theilacker 1980). The possibility remains that

all larvae from the observed minimum length of 2.4 mm to the greatest reported hatching length of 4.5 mm (Moser 1996) could have just hatched, leading to overestimation of ages for all larvae <4.5 mm.

Distributions of *Gibbonsia* spp. larval lengths at the DCPD intake structure and in the study grid (Figure 5.2.9-4) were compared using a Kolmogorov-Smirnov test. The test detected a significant difference between the two distributions ($p \leq 0.001$). The length-frequency distributions in both sampling locations were unimodal, with a few larger individuals. A *t*-test did not detect a significant difference ($p > 0.786$) between mean lengths at the DCPD intake and in the study grid. The estimated age for an average length larva was about 9 d. These data indicate that entrained larvae were very young and that differences between age and length of the population entrained and the population at risk are very small.

5.2.9.2 Estimating Total Annual Entrainment

There was considerable variation of annual estimated mean entrainment of larval kelpfishes among years (Table 5.2.9-1). Approximately 186,000,000 ($\widehat{SE} = 4,740,000$) kelpfish larvae were entrained in Analysis Period 1 while entrainment estimates ranged from 83,600,000 ($\widehat{SE} = 4,150,000$) to 124,000,000 ($\widehat{SE} = 5,000,000$) between the two analysis periods in the 1997–98 sampling season. All periods appeared to be different from one another because 95% confidence intervals approximated by $2 \cdot \widehat{SE}(\widehat{E}_T)$ did not overlap.

Annual estimates of the number of kelpfish larvae entrained, adjusted to the nine year average estimated from Intake Cove surface plankton tow sampling (Figure 5.2.9-5), were 181,000,000 ($\widehat{SE} = 4,610,000$) for Analysis Period 1 and 308,000,000 ($\widehat{SE} = 15,300,000$) for Analysis Period 2 (Table 5.2.9-2). The adjustment index (\bar{I}/I_i) was calculated as the ratio between the average (\bar{I}) of Intake Cove and the average annual index estimated from these same tows during the year being adjusted (I_i). The average index for 1997 and 1998 (I_i) was 0.0682 and 0.0181 larvae/m³, respectively, while the long-term average index (\bar{I}) is 0.0664 larvae/m³ for the years 1990–1998, yielding a ratio \bar{I}/I_i of 0.974 for 1997 and 3.68 for 1998. The adjusted estimate for the 1997–1998 period is larger than the unadjusted entrainment estimate, and was significantly

greater than the 1996–1997 adjusted estimate because 95% confidence intervals approximated by $2 \cdot \widehat{SE}(\widehat{E}_{Adj-T})$ did not overlap.

NOTE: *FH* and *AEL* estimates were not calculated from the estimates of entrainment for kelpfishes because there were no demographic data available to parameterize these models.

5.2.9.3 Empirical Transport Model (*ETM*)

Monthly estimates of proportional entrainment (PE_i) for kelpfishes from the surveys during the two years sampled ranged from a minimum of 0.00144 ± 0.00156 ($\pm 1 \widehat{SE}(\widehat{PE}_i)$) in March 1998 to a maximum of 0.346 ± 0.189 in May 1998 (Table 5.2.9-3). There were other months when the \hat{f}_i was larger than the value for May 1998, which would cause the \widehat{PE}_i during that month to contribute more to the total P_M value calculated for the *ETM*. There were no periods when \widehat{PE}_i and \hat{f}_i were both equal to zero indicating that larvae were always present during the pasired entrainment and 72-hour study grid surveys.

Kelpfish larvae from the study grid subsamples were primarily distributed in nearshore areas (Figure 5.2.9-2) and similar to reported adult distributions (Miller and Lea 1972). Therefore, P_S was calculated using only alongshore current movement and not by extrapolating study grid abundance offshore. The large differences in estimated ages of larval kelpfish at entrainment (9 vs. 31 d) can affect calculation of \widehat{P}_M (Figure 5.2.9-6). As expected, values for \widehat{P}_M were less for shorter larval durations because of the reduced period of larval transport. Estimates of \widehat{P}_M for either larval duration are relatively similar within an analysis period for a given duration

5.2.9.4 Interpretation of Assessment Results

Kelpfish do not have any commercial or recreational fishery value, and there is little information on their ecological role in the community. Because of the limited fishery harvest data for these species (ca. 0.14 MT at Port San Luis in 1990), entrainment mortality rates (\widehat{P}_M) could not be compared to harvests. Additionally, there are no estimates of population size or adult density that could be used to convert \widehat{P}_M into an estimate of adult equivalent loss. Annual mean density of

kelpfish larvae from Intake Cove surface plankton tows shows considerable variation in abundance relative to the long-term mean for the period 1995–1998 (Figure 5.2.9-5). Abundance of the local adult kelpfish population appears to decline from 1993–1998 (Figure 5.2.9-7). Results of the *ETM* show that the power plant may annually entrain approximately 40% of the kelpfish larvae over an area six to seven times the area of the study grid (Figure 5.2.9-6). The length frequency distribution of entrained larvae shows a wide range of lengths, indicating that the larvae are subject to entrainment for a longer duration than other nearshore taxa (Figure 5.2.9-3). If Moser's (1996) estimate of size at flexion for spotted kelpfish *Gibbonsia elegans* is used for comparison, then the length frequency data indicates that post-flexion larvae are also being entrained. Although \widehat{P}_M for kelpfishes is likely to be overestimated because of grid sampling that is biased for nearshore taxa, the relatively high probability of entrainment by the power plant intake as well as additional evidence of declines in local adult and larval abundance indicate a high likelihood for local impacts on this taxon. Additionally, local habitat for kelpfishes (the rocky habitat between Point Buchon and Point San Luis) is bordered to the north and south by large expanses of sandy beach that do not favor adult kelpfishes and may imply a geographically constrained subpopulation. However, the extent of larval duration estimated from our data indicates that kelpfish larvae could be transported sufficient distances to connect the local rocky habitat to areas north and south of the headlands mentioned above. The most common member of this genus found locally as an adult, crevice kelpfish (*Gibbonsia montereyensis*), is distributed from British Columbia to Baja California, making it unlikely that local impacts could affect the larger population.

Table 5.2.9-1. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for kelpfish larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	186,000,000	4,740,000
2) Oct 1, 1997–Sep 30, 1998	83,600,000	4,150,000
3) Jul 1, 1997–Jun 30, 1998	124,000,000	5,000,000

Table 5.2.9-2. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for kelpfish larvae from the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	181,000,000	4,610,000
2) Oct 1, 1997–Sep 30, 1998	308,000,000	15,300,000
3) Jul 1, 1997–Jun 30, 1998	458,000,000	18,400,000

Table 5.2.9-3. Kelpfishes: Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.0347	0.0146	0.224	0.00635
Aug 25, 1997	0.250	0.122	0.172	0.00471
Sep 29, 1997	0.0298	0.022	0.0668	0.00447
Oct 20, 1997	0.0357	0.0181	0.0329	0.00162
Nov 17, 1997	0.0239	0.0117	0.0307	0.00155
Dec 10, 1997	0.0160	0.00762	0.0206	0.00116
Jan 22, 1998	0.00836	0.00291	0.0466	0.00194
Feb 26, 1998	0.0148	0.00473	0.0229	0.00100
Mar 18, 1998	0.00144	0.00156	0.00948	0.000850
Apr 15, 1998	0.168	0.114	0.0468	0.00177
May 18, 1998	0.346	0.189	0.0815	0.00372
Jun 8, 1998	0.216	0.122	0.246	0.00863

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.152	0.104	0.0847	0.00336
Aug 26, 1998	0.168	0.0937	0.0532	0.00270
Sep 16, 1998	0.0417	0.0174	0.0286	0.00199
Oct 6, 1998	0.0612	0.0241	0.0560	0.00259
Nov 11, 1998	0.116	0.0412	0.129	0.00283
Dec 9, 1998	0.0389	0.00762	0.183	0.00426
Jan 12, 1999	0.0137	0.00293	0.0946	0.00253
Feb 3, 1999	0.0802	0.0331	0.103	0.00286
Mar 17, 1999	0.0131	0.00592	0.0351	0.00140
Apr 14, 1999	0.190	0.0940	0.0762	0.00200
May 24, 1999	0.240	0.113	0.0989	0.00288
Jun 23, 1999	0.277	0.149	0.0580	0.00240

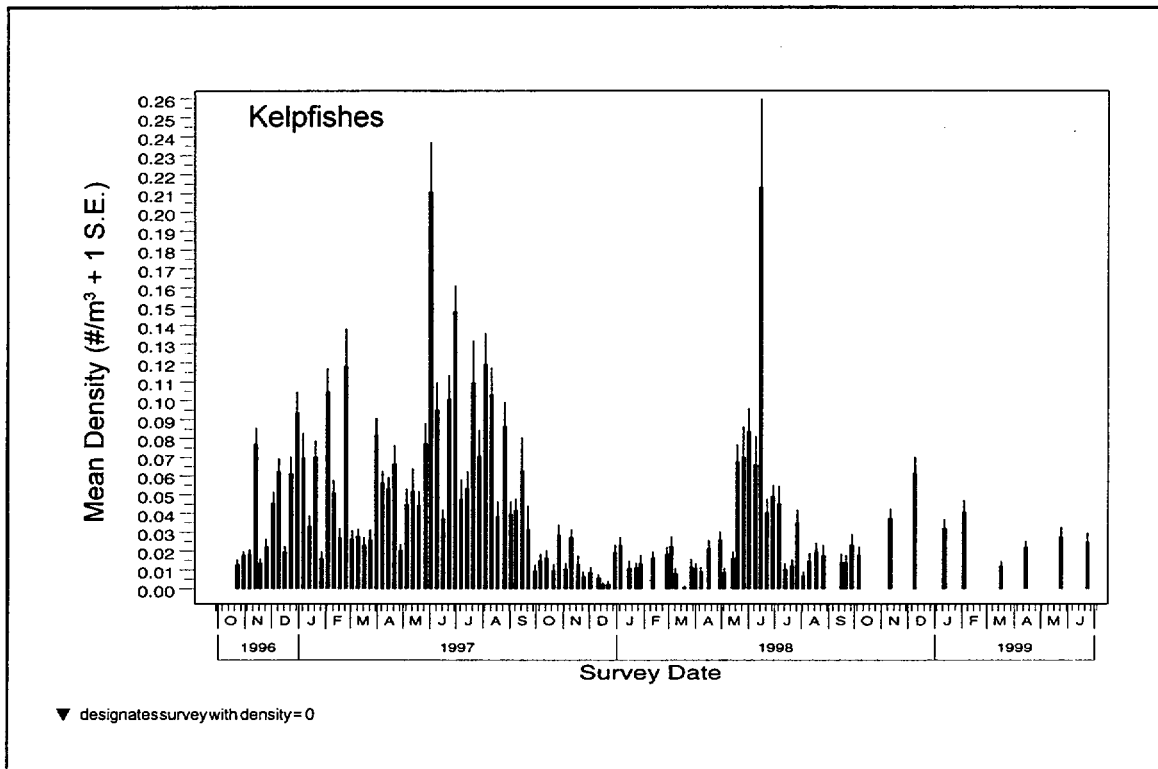


Figure 5.2.9-1. Weekly mean larval density (#/m³ + 1 S.E.) at the DCP intake.

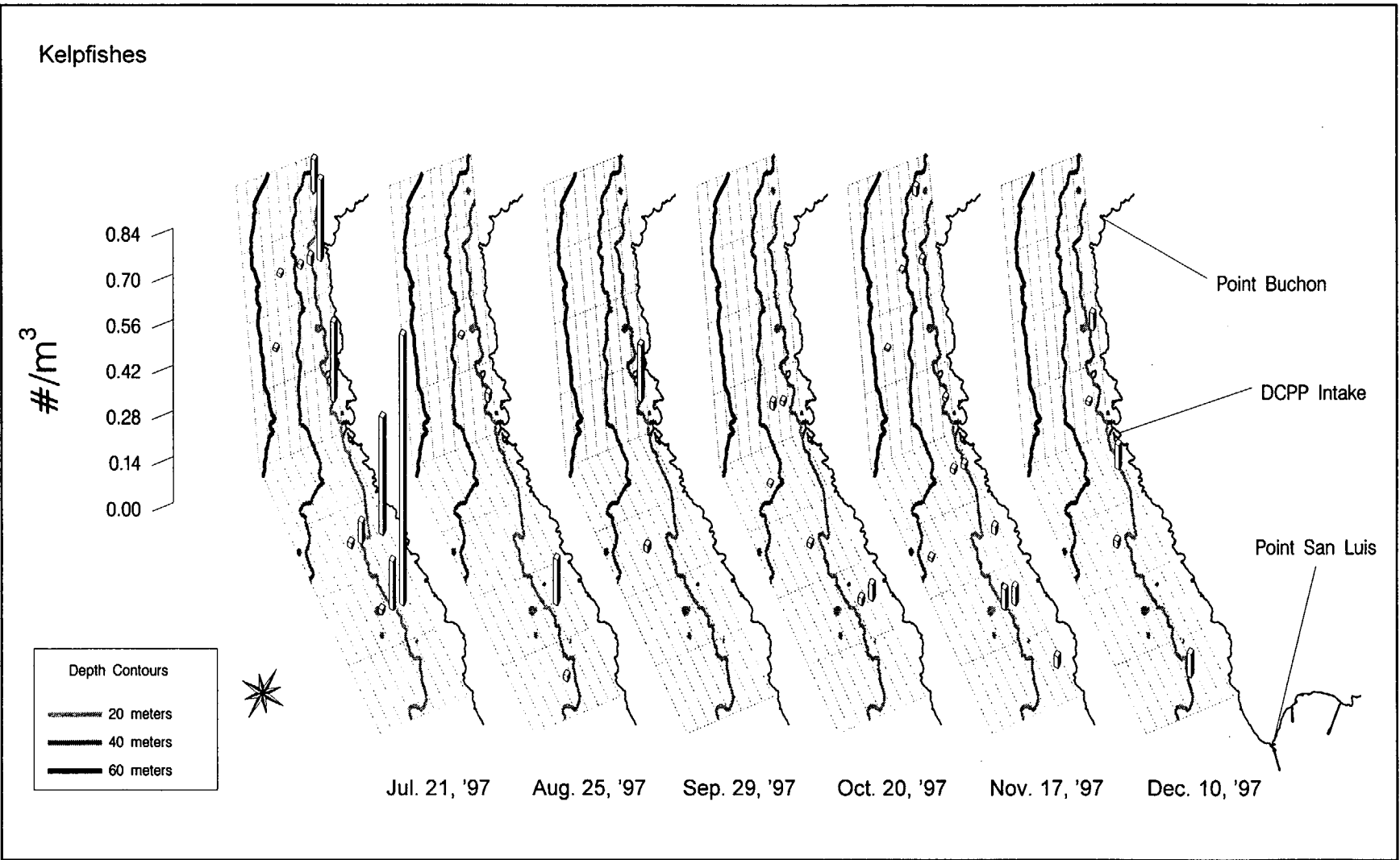


Figure 5.2.9-2a. Mean larval density (#/m³) collected in the DCCP study grid cells and at the entrainment sampling location.

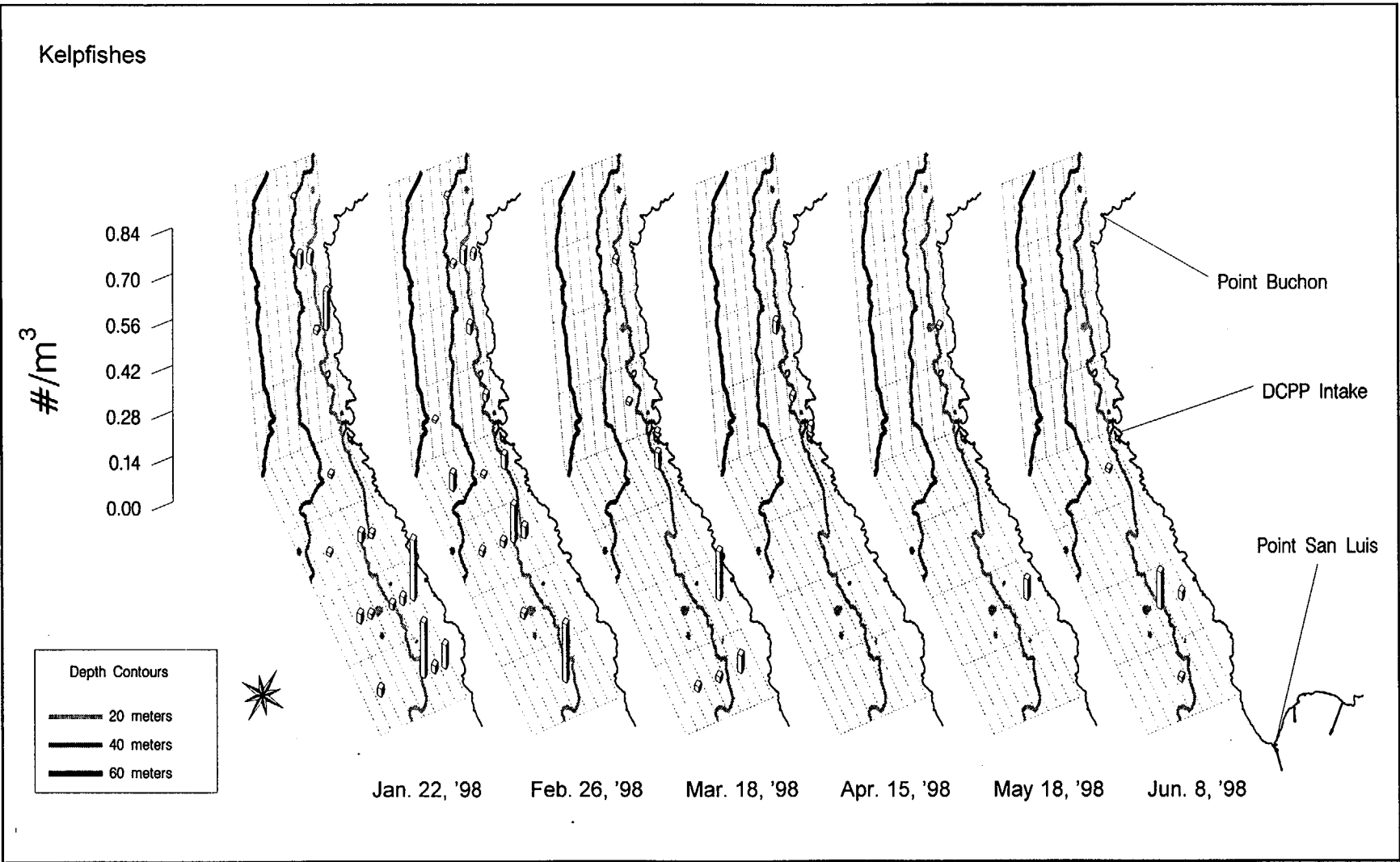


Figure 5.2.9-2b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

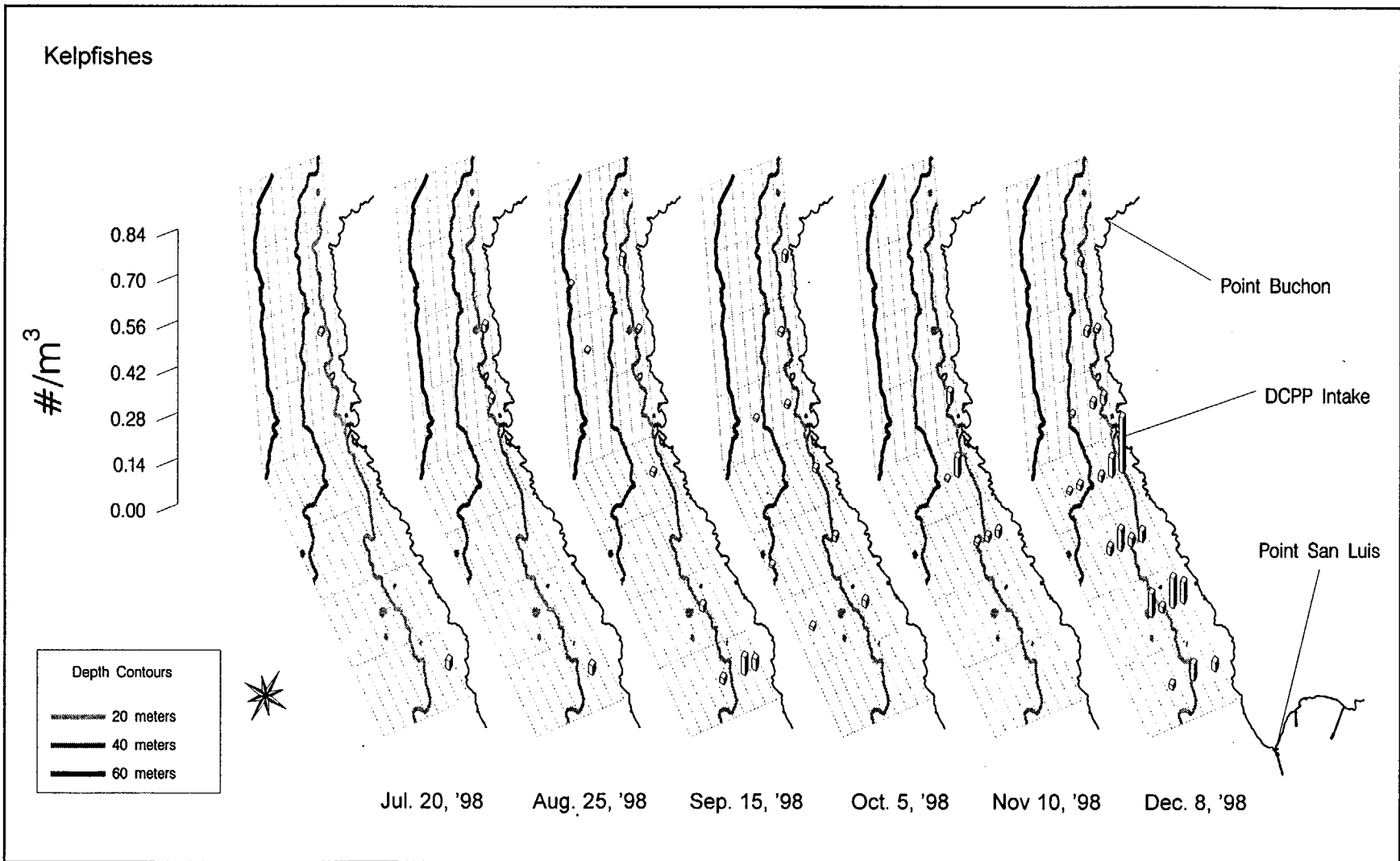


Figure 5.2.9-2c (continued). Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

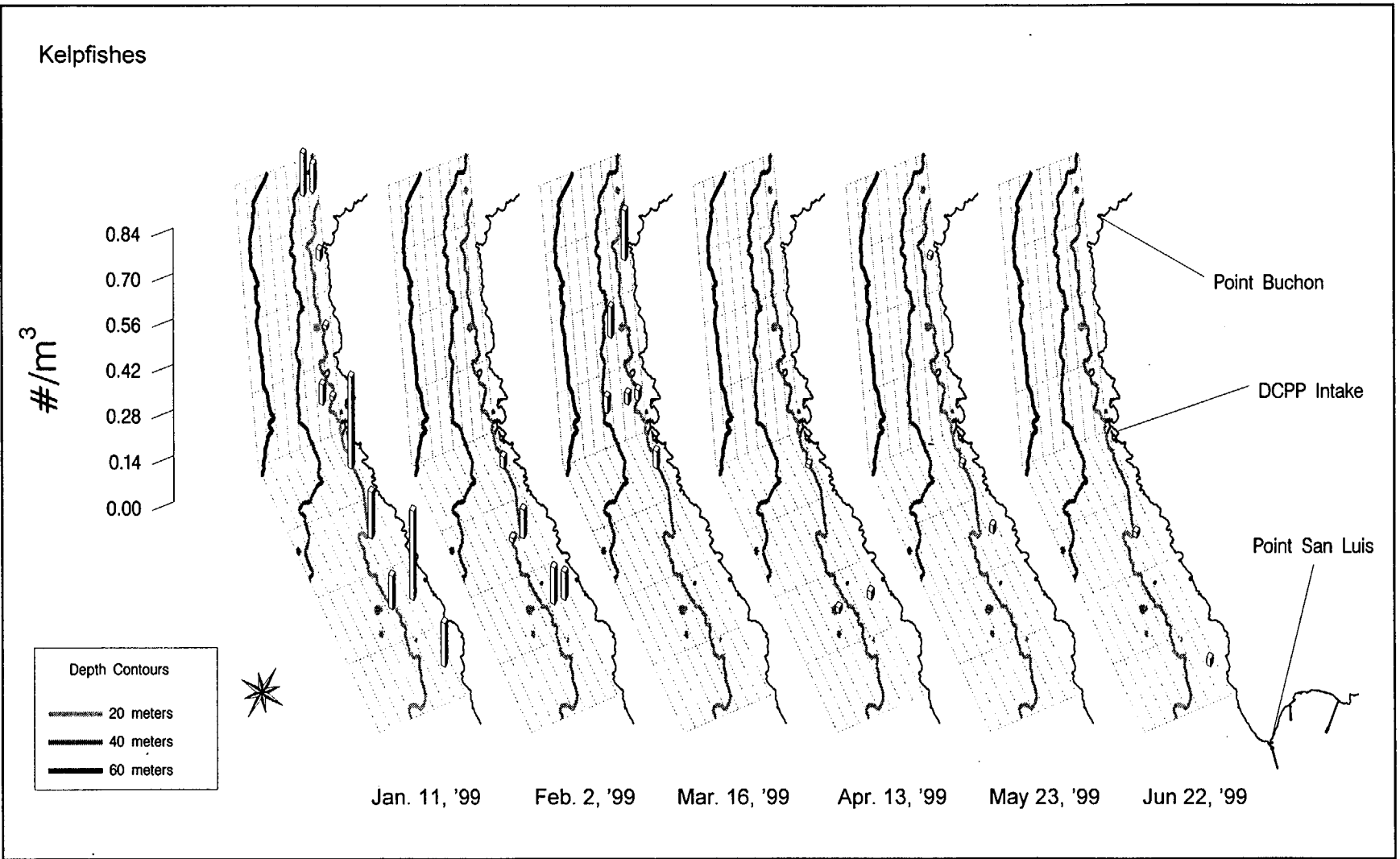


Figure 5.2.9-2d (continued). Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

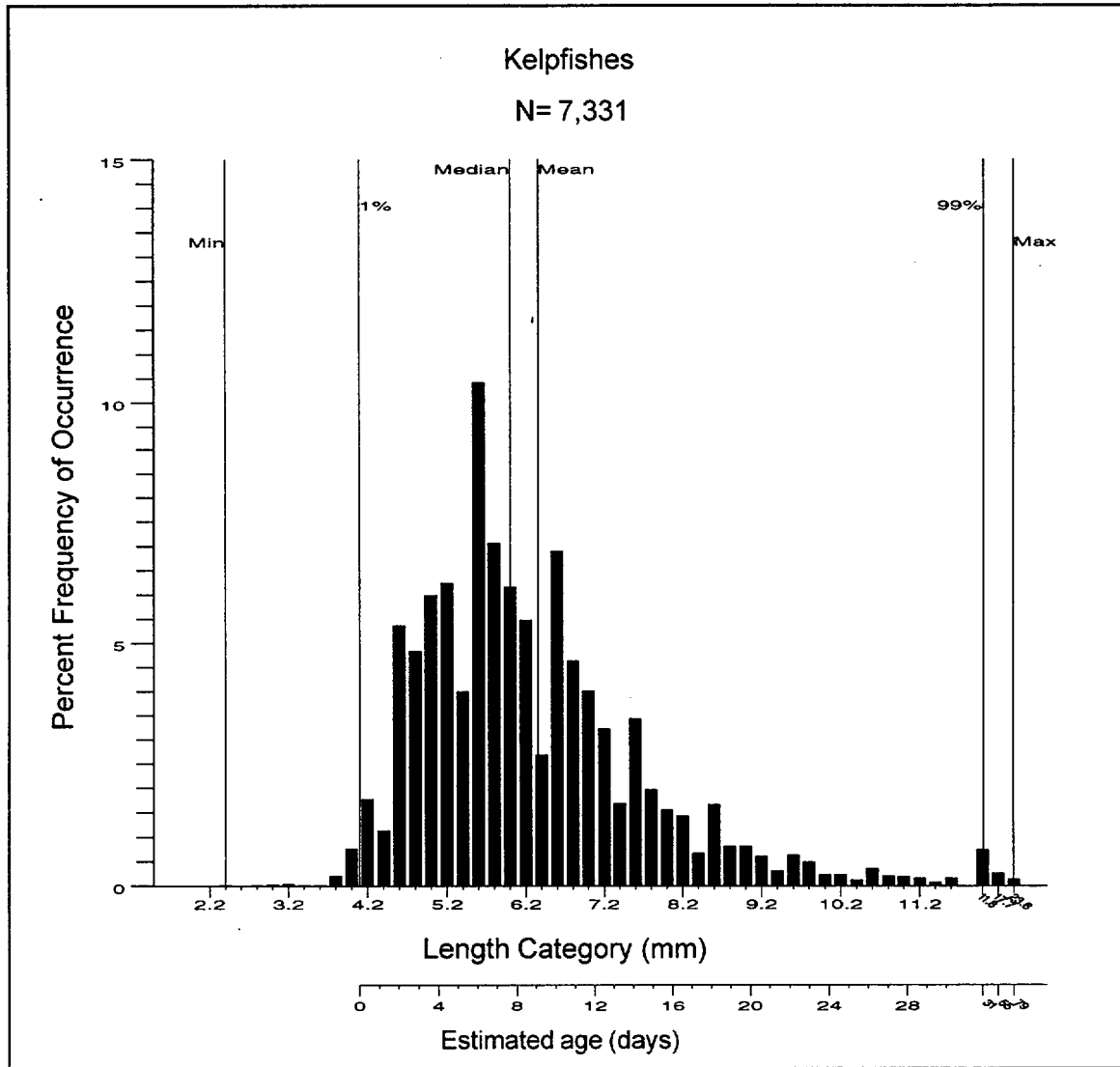


Figure 5.2.9-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

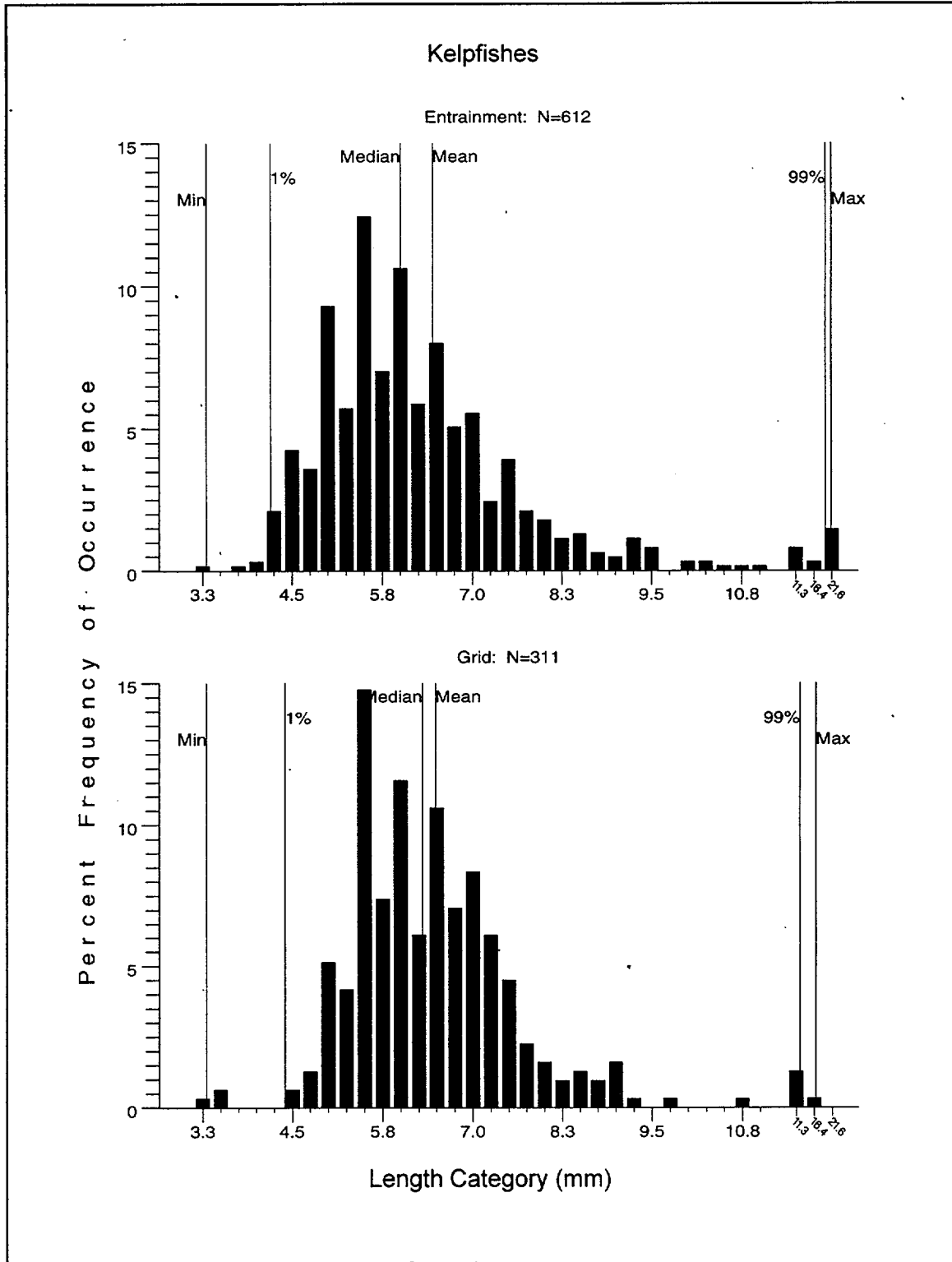


Figure 5.2.9-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

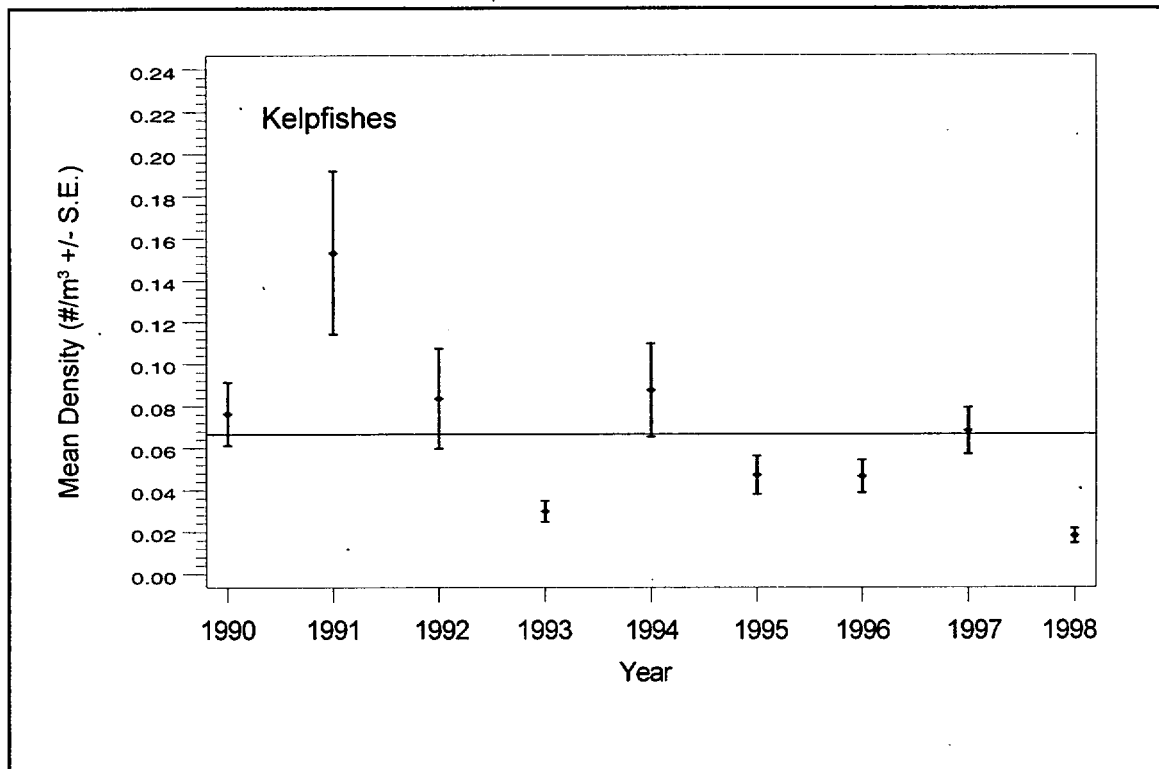


Figure 5.2.9-5. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

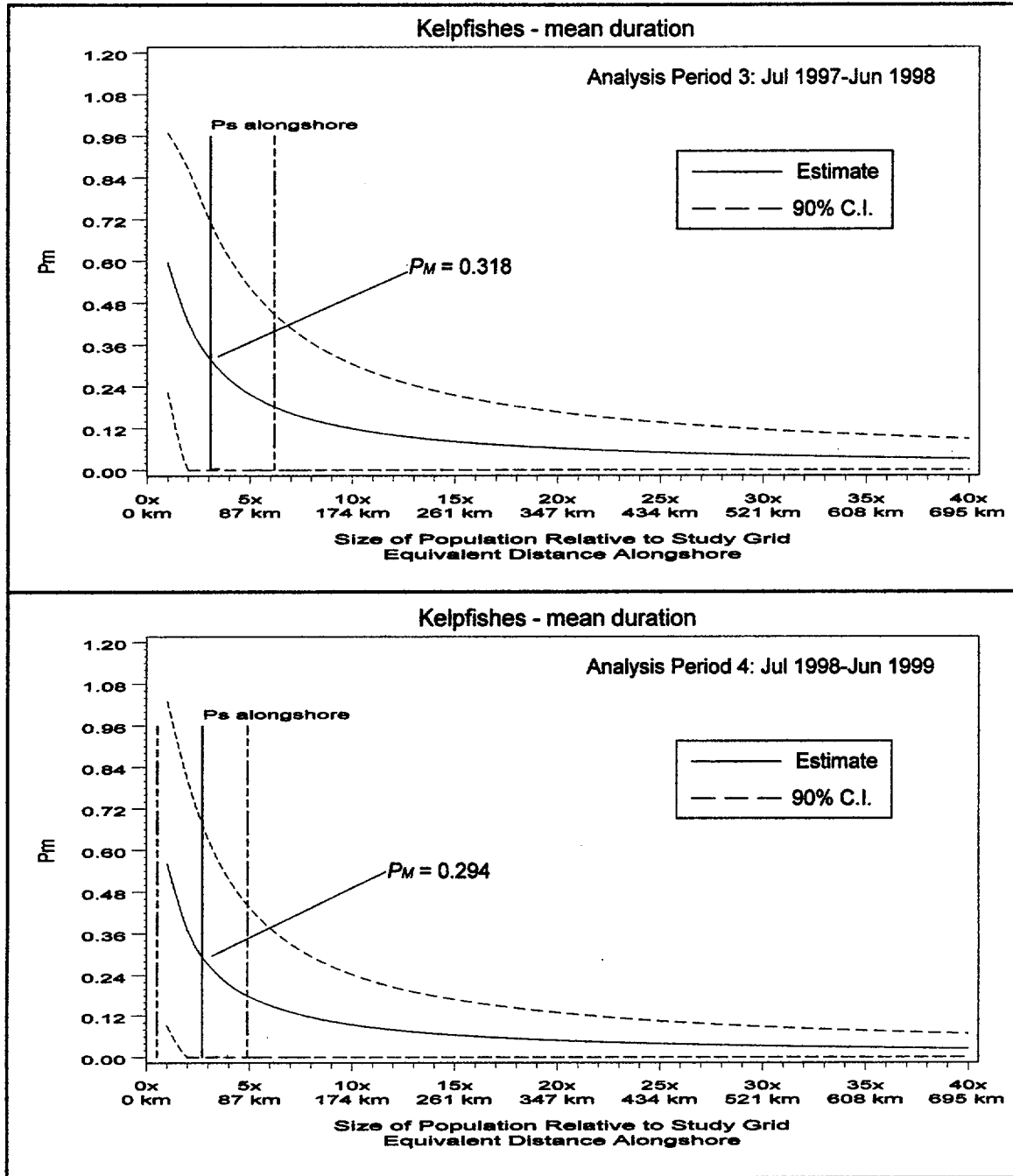


Figure 5.2.9-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements with the 90% C.I. indicated.

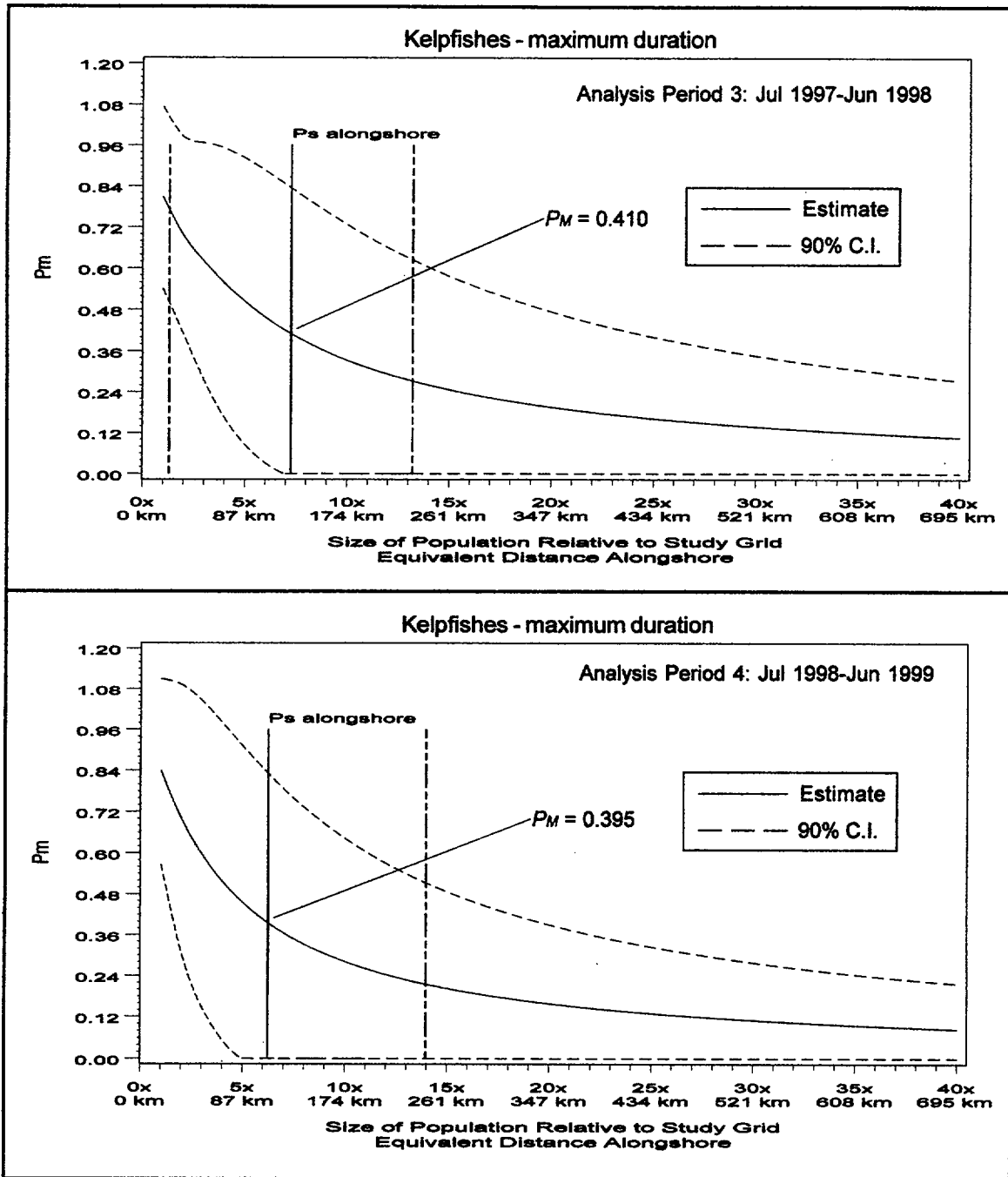


Figure 5.2.9-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements with the 90% C.I. indicated.

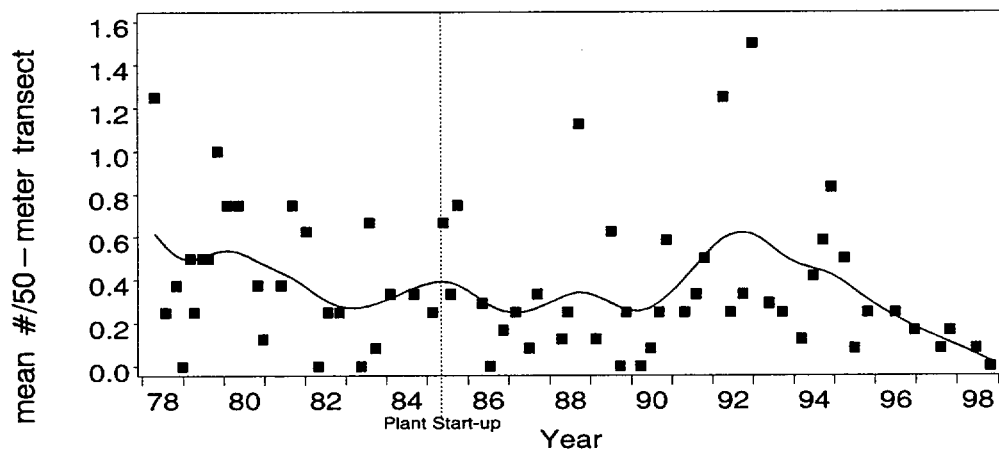
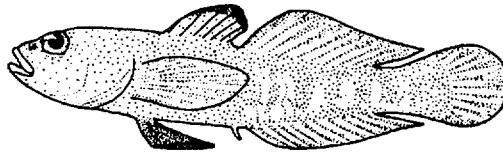


Figure 5.2.9-7. Mean number of kelpfishes observed per 50-meter subtidal transect in the DCPW RWMP South Control area. Spline smoothing algorithm used to draw the curve through the points.

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5.2.10 Assessment of Blackeye Goby (*Coryphopterus nicholsi*)



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

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

The early life history of blackeye goby is similar to other members of the family Gobiidae. Females are oviparous, laying demersal, adhesive eggs under rocks that the males guard until planktonic larvae hatch (Love 1996; Moser 1996). Nests containing eggs are found from April to August in southern California (Wiley 1973). Larvae are reported to hatch at 2.8–3 mm (Moser 1996), with planktonic durations of approximately 75 d (Steele 1997). Larval transformation occurs at 16–25 mm (Moser 1996), which is within the range of lengths at settlement (15–29 mm) reported by Steele (1997). Blackeye goby demonstrate protogynous hermaphroditism (Cole 1983; Breitburg 1987; Cole and Shapiro 1992), with all animals beginning life as females and transforming to males at around 6–7.5 cm (Love 1996). They live approximately 5 yr and mature around 0.5 yr at approximately 4.5 cm (Steele 1997). Spawning occurs year-round, peaking between February and October (Matarese et al. 1989; Moser 1996). Females may spawn several times per year with fecundity estimates ranging in southern

California from 1,700 eggs/nest (Ebert and Turner 1962) to 3,274–4,788 eggs in Orange County (Wiley 1973).

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

No species-specific larval survivorship estimates have been reported for blackeye goby. However, Brothers (1975) calculated larval mortality up to settlement (to age 0 yr) for the three sympatric gobiids (arrow goby, cheekspot goby, and shadow goby) from Mission Bay, California (Table 5.2-10-1). These estimates were used to approximate blackeye goby mortality for early life stages as well as post settlement juvenile and adult stages. Substituting the survivorship information for these closely-related species into the assessment methods allowed us to estimate the number of lost spawning females using *FH* and to project losses into the future as equivalent adults, using *AEL*.

5.2.10.1 Summary of Field Collections

Blackeye goby larvae were collected almost year round at the DCP intake structure during the years 1996–1999 (Appendix H), with their highest densities occurring primarily between May and September (Figure 5.2.10-1). Blackeye goby larvae were more abundant in 1997 than in 1998. This might have been due to the El Niño event that began during the spring of 1997 (Lynn et al. 1998; NOAA 1999). There were 7,658 larval blackeye goby identified from 1,119 bongo net subsamples collected at the DCP intake structure between October 1996 and June 1999 representing 24% of the subsamples processed from that location during that period.

Larval blackeye goby occurred in the DCPD study grid during most months except between February and March (**Appendix H**), with their highest density occurring during July 1997 (**Figure 5.2.10-2**). Blackeye goby larvae were dispersed throughout the study grid. However, during some months (e.g., October and November 1997, March 1999) blackeye goby larvae were abundant at the DCPD intake, but in low abundance in the study grid. There were 1,255 larval blackeye gobies identified from 505 bongo net subsamples representing 16% of the study grid subsamples collected and processed from July 1997–June 1999.

Standard lengths of all blackeye goby larvae collected at the DCPD intake structure between October 1996 and June 1999 ranged from a minimum of 1.5 mm to a maximum of 5.1 mm (**Figure 5.2.10-3**). The growth rate of larval blackeye goby ($0.27 \text{ mm}\cdot\text{d}^{-1}$) reported by Steele (1997) was used to estimate larval ages. Examining the central 98% of this length-frequency distribution resulted in minimum and maximum lengths for the analyses of 2 mm and 3.4 mm, respectively. The mean larval length in this distribution was 2.6 mm and was estimated to be approximately 2 d old. We assumed that larvae shorter than the minimum length of the central 98% of the distribution were just hatched and assigned an age of 0 d. Reported hatching size range for this species is 2.8–3.0 mm (Moser 1996) however, indicating that the smallest larvae observed at DCPD represented either natural variation in hatch lengths within the population or the phenomenon of shrinkage following preservation (Theilacker 1980). If the observed lengths are the result of natural variation in hatching lengths, then the possibility exists that all larvae from the observed minimum length of 1.5 mm to the greatest reported hatching length of 3.0 mm (Moser 1996) could have just hatched (aged-0 d), leading to overestimation of ages for all larvae <3.0 mm. The average estimated age at entrainment of ca. 2 d for blackeye goby larvae indicated that the power plant entrains relatively young larvae.

There were significant differences between mean lengths (t -test: $p < 0.001$) and between length-frequency distributions (Kolmogorov-Smirnov test: $p \leq 0.037$) of larval blackeye goby from the DCPD intake structure and study grid despite the apparent similarity between the two distributions (**Figure 5.2.10-4**). The mean standard lengths from the intake and study grid were 2.6 mm and 2.8 mm, respectively. The disparity between sample sizes (699 larvae from the intake

and 144 larvae from the study grid) may cause the t -test to be overly sensitive to slight differences between the means (Zar 1984). While these differences were statistically detectable and significant using the t -test and K-S test, we believe the biological significance of these differences was probably low.

5.2.10.2 Estimating Total Annual Entrainment

The annual estimated mean entrainment of larval blackeye gobies for the 1996–97 Analysis Period 1 ($\widehat{E}_T = 138,000,000$; $\widehat{SE} = 14,100,000$) and 1997–98 Analysis Period 2 ($\widehat{E}_T = 133,000,000$; $\widehat{SE} = 13,300,000$) were extremely close in value (Table 5.2.10-2). The estimate for Analysis Period 3 differs from the other estimate for 1997–98, Analysis Period 2, because larval blackeye gobies were collected throughout the year, including the time period that does overlap between the two periods (Figure 5.2.10-1). Values of $\pm 2 \cdot \widehat{SE}(\widehat{E}_T)$ can be used to approximate 95% confidence intervals around the point estimates. These approximate confidence intervals overlapped, indicating that the apparent differences between them were probably not statistically significant.

Annual estimates of the number of entrained blackeye goby larvae, adjusted to the nine year average estimated from Intake Cove surface plankton tow sampling (Figure 5.2.10-5), were 128,000,000 ($\widehat{SE} = 13,100,000$) for Analysis Period 1 and 109,000,000 ($\widehat{SE} = 10,900,000$) for Analysis Period 2 (Table 5.2.10-3). The adjustment index (\bar{I}/I_i) was calculated as the ratio between the nine year average (\bar{I}) of Intake Cove plankton samples and the average annual index estimated from these same tows during the year being adjusted (I_i). The average index for the years 1997 and 1998 (I_i) are 0.0181 and 0.0206 larvae/m³, respectively, while the long-term average index (\bar{I}) is 0.0168 larvae/m³ for the years 1990–1998, yielding the ratio $\bar{I}/I_i = 0.925$ for 1997 and 0.816 for 1998. The confidence intervals, estimated from $\pm 2 \cdot \widehat{SE}(\hat{E}_{Adj-T})$, around the adjusted entrainment abundance overlap, indicating that the differences between the estimates are probably not statistically significant.

5.2.10.3 Fecundity Hindcasting (FH)

Larval mortality rates were not available for blackeye goby, but Brothers (1975) indicates that 99% mortality over two months is reasonable for low fecundity gobies. Finite survivorship for blackeye goby larvae was estimated as $0.926 \cdot d^{-1}$ from Brothers (1975) who examined three sympatric goby species (arrow, cheekspot, and shadow goby). Average age at entrainment of blackeye gobies at DCPD was estimated as 2.12 d, calculated using minimum size of the central 98% distribution (2 mm), mean size at entrainment (2.6 mm), and a growth rate of $0.27 \text{ mm} \cdot \text{d}^{-1}$ (Steele 1997). Survival to entrainment is then estimated as $0.926^{2.12} = 0.850$. Lifetime fecundity (\widehat{TLF}) is calculated using a longevity of 3.6 yr estimated from the von Bertalanffy growth function (VBGF; Ricker 1975) described below, an age at first maturation of 0.5 yr (Steele 1997), and an estimated annual fecundity of 8,062 eggs (2 batches of 4,031 annually; Wiley 1973). The VBGF was used to estimate longevity of females at their transformation length from female to male. Steele (1997) indicates that blackeye gobies mature at 0.5 yr (ca. 4.5 cm), and Love (1996) indicates that the largest fish recorded was ca. 15 cm; longevity is five years (Wiley 1973). The VBGF can be formulated as

$$L_t = L_\infty (1 - e^{-kt}),$$

where

L_t = fish length at time t ,

L_∞ = theoretical maximum fish length (L_∞ assumed to be 15 cm), and

k = growth coefficient.

Then, using a length at maturity of approximately 4.5 cm and $L_\infty = 15$ cm, $k = 0.1724$, the VBGF estimated an age of 3.6 yr based on a length of transformation from female to male of 7 cm SL.

The adjusted total larval entrainment for blackeye goby (\hat{E}_{Adj-T}) was used to estimate the number of breeding females needed to produce the number of larvae entrained. The estimated number of breeding females (\widehat{FH}) whose fecundity equals the estimated total loss of entrained larvae is calculated assuming age of maturation of 0.5 yr and longevity value of 3.6 yr. The number of adult females hindcast from the larvae entrained at DCPD was greater for Analysis Period 1

($\widehat{FH} = 12,000$; $\widehat{SE} = 23,900$) than for Analysis Period 2 ($\widehat{FH} = 10,300$; $\widehat{SE} = 20,300$) (Table 5.2.10-4).

Sensitivity Analysis

Longevity had the greatest leverage on recalculated values of \widehat{FH} (Table 5.2.10-5). Varying this parameter in the model resulted in an \widehat{FH} range of 4,750–192,000 adult females for 1996–97 and 1997–98 analysis periods, compared to the original estimate of 10,300–12,100 adult females. Fecundity and larval survivorship had the next greatest amount of leverage on recalculated \widehat{FH} .

5.2.10.4 Adult Equivalent Loss (AEL)

No independent estimate of survival of blackeye goby from entrainment to age of adults was found in the literature. Therefore, we used survival estimates for \widehat{AEL} from two goby species (cheekspot and shadow goby) presented by Brothers (1975). Blackeye goby larval survival from entrainment up to settlement was estimated starting at estimated average entrainment age (2.12 d) to 75 d at settlement (Steele 1997), using daily survival of 0.926 derived from Brothers (1975). Larval survivorship over this period was calculated as $0.926^{72.9} \approx 0.004$. Juvenile and adult survivorship was estimated to 2 yr of age, which is the average age of adults assuming linear survival from 0.5 (age of first reproduction) to 5 yr (longevity). Daily finite survivorship was estimated as $e^{-1.02/365} = 0.997$ using annual instantaneous mortality = 1.02 (Brothers 1975). Survivorship from settlement to adulthood (2 yr less the 75 d of planktonic duration) is then $0.997^{656} \approx 0.159$.

The adjusted total larval entrainment for blackeye goby (\widehat{E}_{Adj-T}) was used to estimate the number of equivalent adults lost to the population based on the estimated number of larvae entrained (Table 5.2.10-6). The estimated number of equivalent adults corresponding to the number of larvae entrained at DCPD was 75,200 ($\widehat{SE} = 220,000$) for Analysis Period 1 and 64,100 ($\widehat{SE} = 188,000$) for Analysis Period 2. Because blackeye goby are protogynous hermaphrodites, we do not assume that AEL is related to FH by a factor of two since we cannot assume a 50:50

sex ratio in the adult population. The magnitude of the \widehat{SE} for the two estimates indicates that the differences between analysis periods are not statistically significant.

Sensitivity Analysis

Early larval and early juvenile survivorship had the greatest leverage on recalculated values of \widehat{AEL} (Table 5.2.10-7). Varying either of these parameters in the model resulted in an \widehat{AEL} range of 12,400-390,000 adult equivalents for the 1996-97 and 1997-98 analysis periods, compared to the original estimate of 64,100-75,400 adult equivalents. The range of estimates of entrainment had less effect on estimated \widehat{AEL} .

5.2.10.5 Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) for blackeye goby in each i th survey from the two years sampled ranged from a minimum of zero to a maximum of 0.859 ± 0.543 ($1 \widehat{SE}(\widehat{PE}_i)$) in February 1998 and March 1999 (Table 5.2.10-8). No larvae were collected at either the DCP intake or from the study grid when both \widehat{PE}_i and the proportion of larvae present in the i th survey period (\hat{f}_i) were equal to zero (e.g., February 1999). When $\widehat{PE}_i = 0$ and $\hat{f}_i > 0$ (e.g., March 1998), larvae were collected at the DCP intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. For blackeye goby, the relatively large \widehat{PE}_i for February 1998 and March 1999 resulted from the fact that no blackeye goby larvae were collected in the study grid. This \widehat{PE}_i was calculated using the larval density from the weekly entrainment sample (Appendix H) multiplied by the unsampled volume inshore of the two cells nearest the intake (D1 and E1) to approximate the number of larvae in this volume. This number was then added to the number of larvae found in cells D1 and E1, zero in this case as well as elsewhere in the grid, to approximate the number of larvae in the whole study grid. The low f_i values associated with these \widehat{PE}_i 's indicated that few larval blackeye gobies were collected at the intake structure during the survey period and that these estimates had low weights attributed to them in calculating the annual estimate of entrainment mortality. The greatest abundances of blackeye goby larvae at the intake structure occurred from July through September or October of each year as indicated by the higher values of f_i during those months.

Empirical transport modeling results for blackeye goby (\widehat{P}_M) show the effects of low estimated larval durations (Figure 5.2.10-6). Blackeye goby larvae were collected throughout the study grid, and thus, P_y was calculated by using alongshore and onshore current movement over estimated larval entrainment ages; study grid estimates of the number of blackeye goby larvae were extended alongshore or were extrapolated offshore, based on study grid abundance patterns offshore, and then extended alongshore. Alongshore larval transport over the short larval durations estimated from entrained larvae (average of 2 d to maximum of 5 d old at entrainment) resulted in low estimates of \widehat{P}_S . Consequently, estimates of \widehat{P}_M over these small extrapolated areas were high. Estimates of \widehat{P}_M were reasonably similar between the two analysis periods for either larval duration (mean or max.), whether extending \widehat{P}_S only alongshore or extrapolating offshore and then extending alongshore. The alongshore \widehat{P}_M value ranged from 0.174 to 0.228, while the extrapolated \widehat{P}_M values range from 0.079 to 0.179.

5.2.10.6 Interpretation of Assessment Results

Blackeye goby does not support a commercial or recreational fishery, and there is little information on their ecological role in the community. However, there are some indications of their importance as forage for other species (e.g., cormorants: Love 1996). Because of the absence of any fishery for this species, there are no catch data that can be used to compare harvest mortality rates to entrainment mortality rates (\widehat{P}_M) or to estimated *FH* and *AEL* values. Results of *ETM* modeling show that the power plant may annually entrain approximately 17–23% of the blackeye goby larvae from an area approximately twice that of the study grid. Fecundity hindcast estimates indicate that these values of \widehat{P}_M may be equal to predicted losses of the reproductive output of about 10,000–12,000 adult females. An independent estimate of *AEL* yields a predicted loss of 64,000–75,000 adults (males and females combined). Blackeye gobies are protogynous hermaphrodites (Cole 1983; Breitburg 1987; Cole and Shapiro 1992) and there is no reason to assume that the adult population for this species reflects a 50:50 sex ratio that would be required for the relationship of $AEL \equiv 2FH$. Although both of these estimates are relatively large the local population of adult blackeye goby does not exhibit any long-term declines based on DCPD Receiving Water Monitoring Program studies on subtidal fishes (Figure

5.2.10-7: Tenera 1997c). The time period since power plant operation began is much greater than the relatively short life-span (~5 yr) of blackeye gobies, indicating that there has probably been sufficient time for power plant effects to become apparent for this species.

The Intake Cove surface plankton tows were also analyzed to determine if any declining trends in larval production could be detected. These data were only analyzed for the period December through June. Blackeye goby larvae were present in the intake cove samples collected during December through June, but were also abundant in the entrainment subsamples collected from July through September. Therefore, the index based on these data that was used to adjust annual entrainment estimates to the long-term average may not be a good estimator for blackeye goby. There is no way to estimate how the index would have changed if based on an entire 12 mo period. Nonetheless, the Intake Cove surface plankton tows data do not show any declining trends in annual mean larval blackeye goby densities and larval densities in 1997 and 1998 were greater than the nine year average (Figure 5.2.10-5).

Estimates of total annual entrainment mortality (\widehat{P}_M) for this species were relatively high among the target fish taxa examined (ca. 13–23%). These values are based on extending the larval abundance within the study grid alongshore (or extrapolating that abundance offshore and then extending it alongshore) using estimated larval duration at entrainment. The short estimated larval durations for this taxa resulted in relatively small estimated areas for the population at risk. These small population areas are representative of the reflects the small size range for the majority of entrained larvae (2.0–3.4 mm). This size range is well below the reported range at flexion of 5.8–6.8 mm (Moser 1996). In fact, our observed minimum larval lengths were less than reported hatching lengths in the literature, which may be due to natural variation in hatching lengths plus an undetermined contribution of larval shrinkage due to preservation (Theilacker 1980). This may indicate that our assumption that age-0 d larvae correspond to our minimum 99% larval length is inaccurate and that all larvae less than maximum reported hatching length of 3.0 mm (Moser 1996) were aged-0 d. This would further reduce our estimate of larval duration and population area. While the small areas based on these short larval durations and alongshore and onshore current movements lead, in part, to the high estimates of entrainment mortality, the

size of the entrained larvae indicate that the time the larvae are exposed to entrainment is very short. The lack of apparent declines in the local adult and larval populations over several generations since power plant startup indicates that entrainment mortality may only be affecting surplus larval production that would not lead to a reduction in the local population. This could also indicate that compensation is occurring at some later stage in development. In either case, it does not appear the DCPD cooling water intake is causing a long-term decline in the local population of blackeye goby.

Table 5.2.10-1. Larval mortality statistics for three sympatric gobiids from Mission Bay, California (Brothers 1975).

Species	Two-Month Larval Mortality Rates (to settlement)	Annual Post- Settlement Mortality Rates	(Instantaneous)
	% (Finite)	% (Finite)	
<i>Clevelandia ios</i>	98.3	89-91	-2.39
<i>Ilypnus gilberti</i>	98.6	66-74	-1.08
<i>Quietula y-cauda</i>	99.2	62-69	-0.96

Table 5.2.10-2. Estimated total annual entrainment (\hat{E}_T) and standard error ($\widehat{SE}(\hat{E}_T)$) for blackeye goby (*Coryphopterus nicholsi*) larvae from the three analysis periods.

Analysis Period	\hat{E}_T	$\widehat{SE}(\hat{E}_T)$
1) Oct 23, 1996-Sep 30, 1997	138,000,000	14,100,000
2) Oct 1, 1997-Sep 30, 1998	133,000,000	13,300,000
3) Jul 1, 1997-Jun 30, 1998	157,000,000	14,600,000

Table 5.2.10-3. Estimated total annual adjusted entrainment (\hat{E}_{Adj-T}) and standard error ($\widehat{SE}(\hat{E}_{Adj-T})$) for blackeye goby (*Coryphopterus nicholsi*) larvae from the three analysis periods.

Analysis Period	\hat{E}_{Adj-T}	$\widehat{SE}(\hat{E}_{Adj-T})$
1) Oct 23, 1996-Sep 30, 1997	128,000,000	13,100,000
2) Oct 1, 1997-Sep 30, 1998	109,000,000	10,900,000
3) Jul 1, 1997-Jun 30, 1998	128,000,000	11,900,000

Table 5.2.10-4. Estimated number of blackeye goby adult (*Coryphopterus nicholsi*) females (\widehat{FH}) whose reproductive output was equivalent to the adjusted number of larvae entrained per year (\widehat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{FH})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	12,000	23,900	315,000	461
2) Oct 1, 1997–Sep 30, 1998	10,300	20,300	268,000	393
3) Jul 1, 1997–Jun 30, 1998	12,100	24,000	316,000	462

Table 5.2.10-5. Blackeye goby (*Coryphopterus nicholsi*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\widehat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 12,000$				
\widehat{E}_{Adj-T}	128,000,000	10,000	14,100	4,050
S larvae	0.850	10,200	62,400	52,200
# Eggs/yr	8,060	2,320	62,400	60,100
Longevity	3.60	5,570	192,000	186,000
Maturation	0.5	11,100	14,400	3,210

Table 5.2.10-5 (continued). Blackeye goby (*Coryphopterus nicholsi*): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ):

$\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 10,300$				
\hat{E}_{Adj-T}	109,000,000	8,580	11,900	3,370
<i>S larvae</i>	0.850	8,710	53,100	44,400
# Eggs/yr	8,060	1,980	53,100	51,200
Longevity	3.60	4,750	163,000	158,000
Maturation	0.5	9,490	12,200	2,740

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 12,100$				
\hat{E}_{Adj-T}	128,000,000	10,200	13,900	3,690
<i>S larvae</i>	0.850	10,300	62,600	52,300
# Eggs/yr	8,060	2,330	62,600	60,200
Longevity	3.60	5,590	192,000	187,000
Maturation	0.5	11,200	14,400	3,220

Table 5.2.10-6. Estimated number of equivalent blackeye goby (*Coryphopterus nicholsi*) adults (\widehat{AEL}) equal to the adjusted number of larvae entrained per year (\hat{E}_{Adj-T}) at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{AEL})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{AEL}	$\widehat{SE}(\widehat{AEL})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	75,200	220,000	9,260,000	611
2) Oct 1, 1997–Sep 30, 1998	64,100	188,000	7,890,000	521
3) July 1, 1997–June 30, 1998	75,400	221,000	9,290,000	613

Table 5.2.10-7. Blackeye goby (*Coryphopterus nicholsi*): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 75,200$				
\hat{E}_{Adj-T}	128,000,000	87,900	62,600	25,300
$\hat{S}_{early\ larvae}$	0.00372	390,000	14,500	375,000
$\hat{S}_{early\ juvenile}$	0.158	390,000	14,500	375,000

Table 5.2.10-7 (continued). Blackeye goby (*Coryphopterus nicholsi*): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 64,100$				
\hat{E}_{Adj-T}	109,000,000	74,600	53,600	21,000
$\hat{S}_{early\ larvae}$	0.00372	332,000	12,400	320,000
$\hat{S}_{early\ juvenile}$	0.158	332,000	12,400	320,000

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 75,400$				
\hat{E}_{Adj-T}	128,000,000	87,000	63,900	23,100
$\hat{S}_{early\ larvae}$	0.00372	391,000	14,600	376,000
$\hat{S}_{early\ juvenile}$	0.158	391,000	14,600	376,000

Table 5.2.10-8. Blackeye goby (*Coryphopterus nicholsi*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.0141	0.00798	0.206	0.0187
Aug 25, 1997	0.0353	0.0130	0.219	0.0140
Sep 29, 1997	0.0398	0.0172	0.143	0.0127
Oct 20, 1997	0.452	0.288	0.0390	0.00500
Nov 17, 1997	0.291	0.185	0.0524	0.00554
Dec 10, 1997	0.0658	0.0332	0.0174	0.00160
Jan 22, 1998	0.0512	0.0270	0.0447	0.00556
Feb 26, 1998	0.859	0.543	0.0140	0.00150
Mar 18, 1998	0	0	0.00172	0.000310
Apr 15, 1998	0.859	0.361	0.0368	0.00285
May 18, 1998	0.291	0.130	0.0854	0.00667
Jun 8, 1998	0.202	0.111	0.140	0.0119

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.0377	0.0167	0.160	0.0115
Aug 26, 1998	0.0130	0.00539	0.182	0.0131
Sep 16, 1998	0.00747	0.00370	0.0687	0.0122
Oct 6, 1998	0.0186	0.00953	0.153	0.0236
Nov 11, 1998	0.167	0.148	0.0903	0.0118
Dec 9, 1998	0.0575	0.0514	0.00879	0.00118
Jan 12, 1999	0.0297	0.0413	0.00163	0.000310
Feb 3, 1999	0	0	0	0
Mar 17, 1999	0.859	0.504	0.0755	0.00730
Apr 14, 1999	0.395	0.217	0.0837	0.00785
May 24, 1999	0.0164	0.00620	0.0806	0.00555
June 23, 1999	0.0125	0.00555	0.0955	0.00862

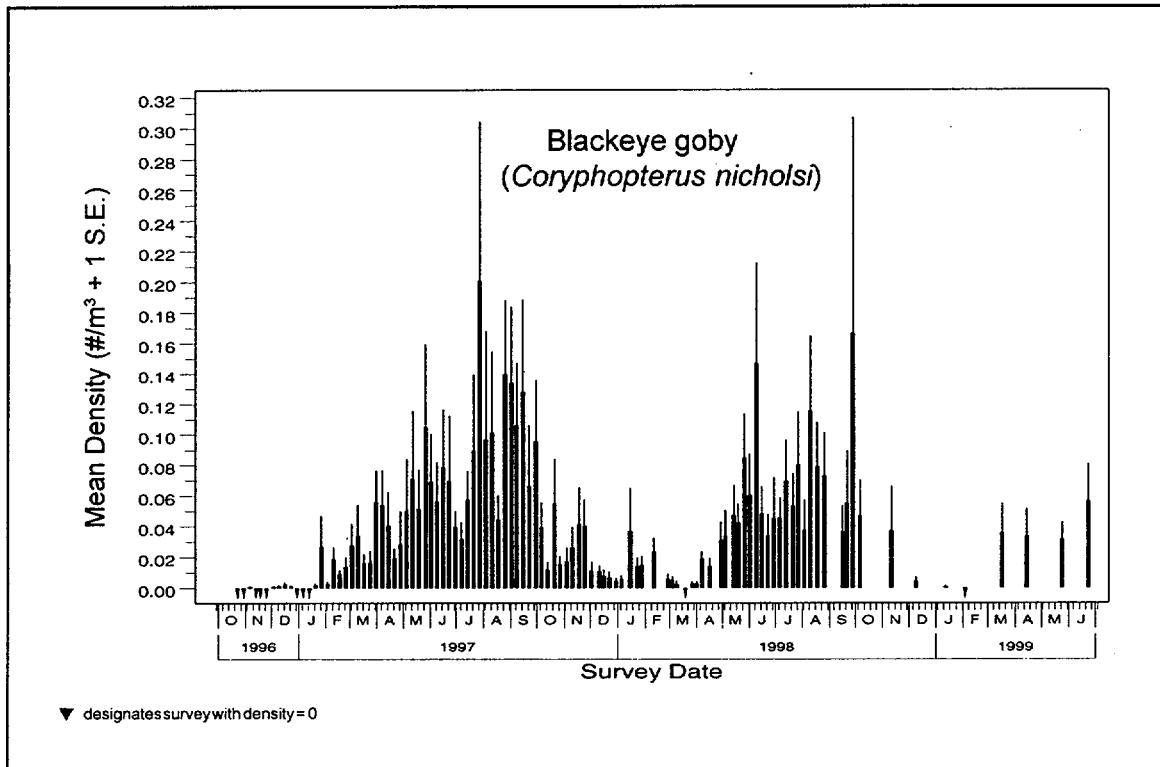


Figure 5.2.10-1. Weekly mean larval density ($\#/m^3 + 1$ S.E.) at the DCPD intake.

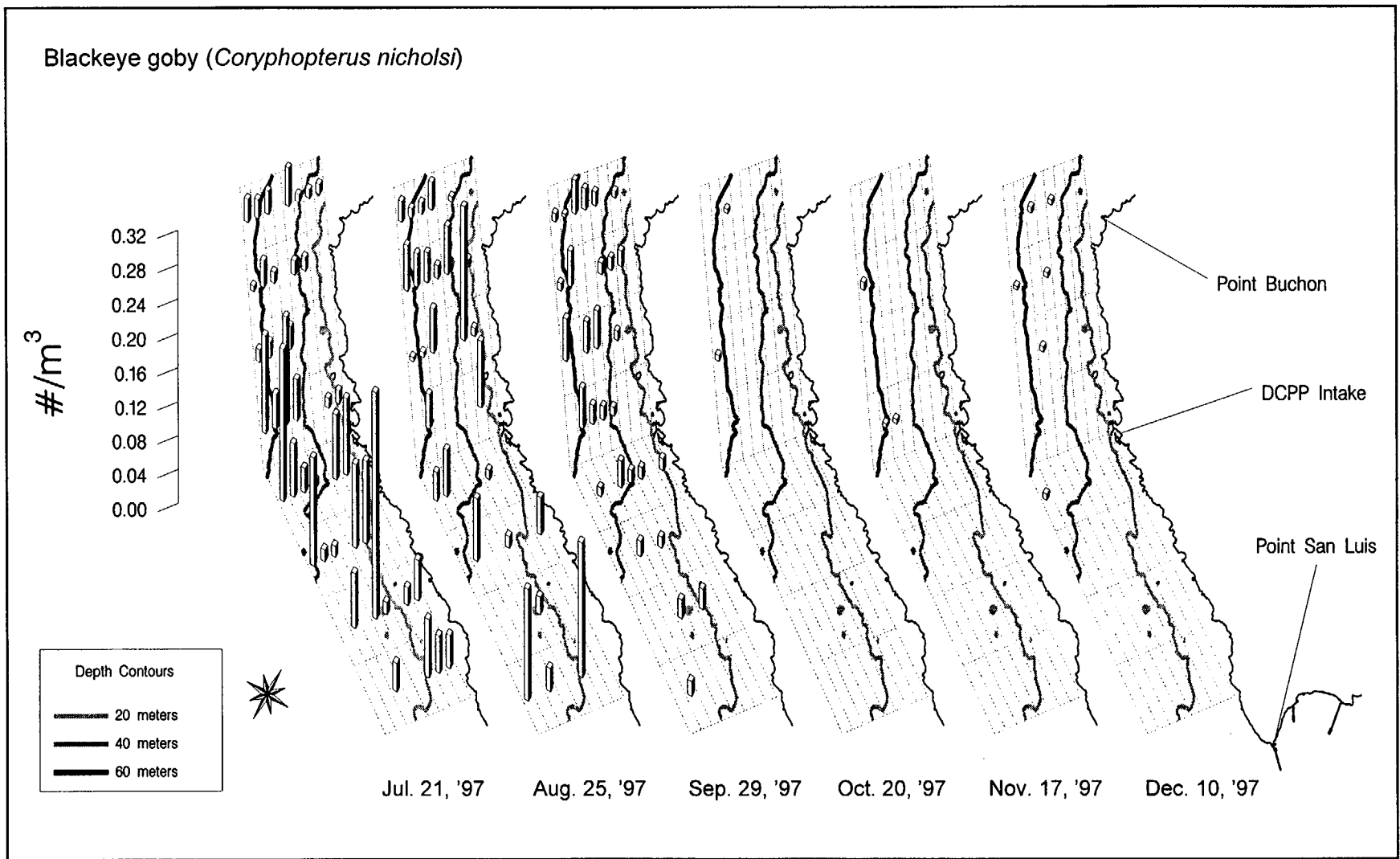


Figure 5.2.10-2a. Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

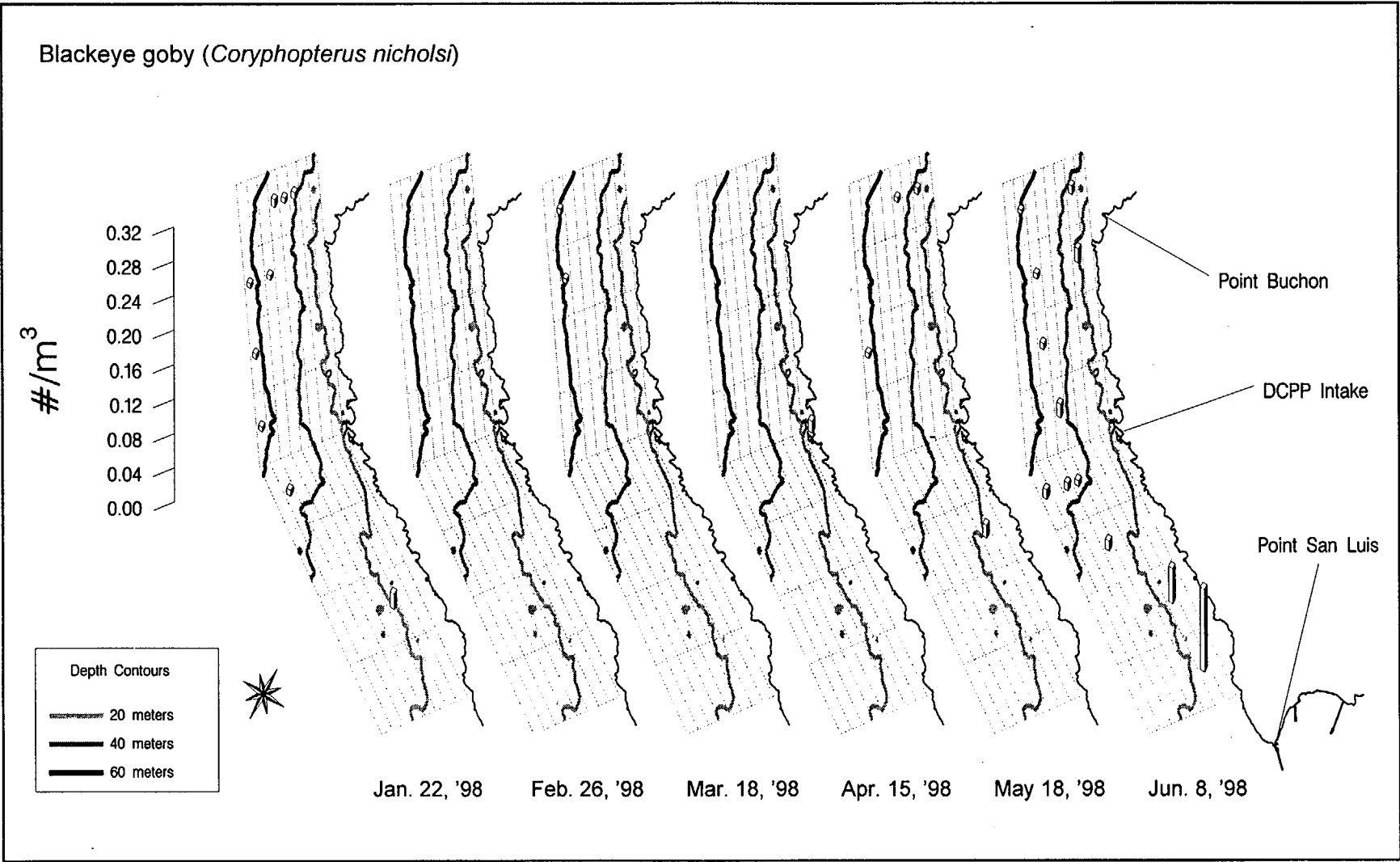


Figure 5.2.10-2b (continued). Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

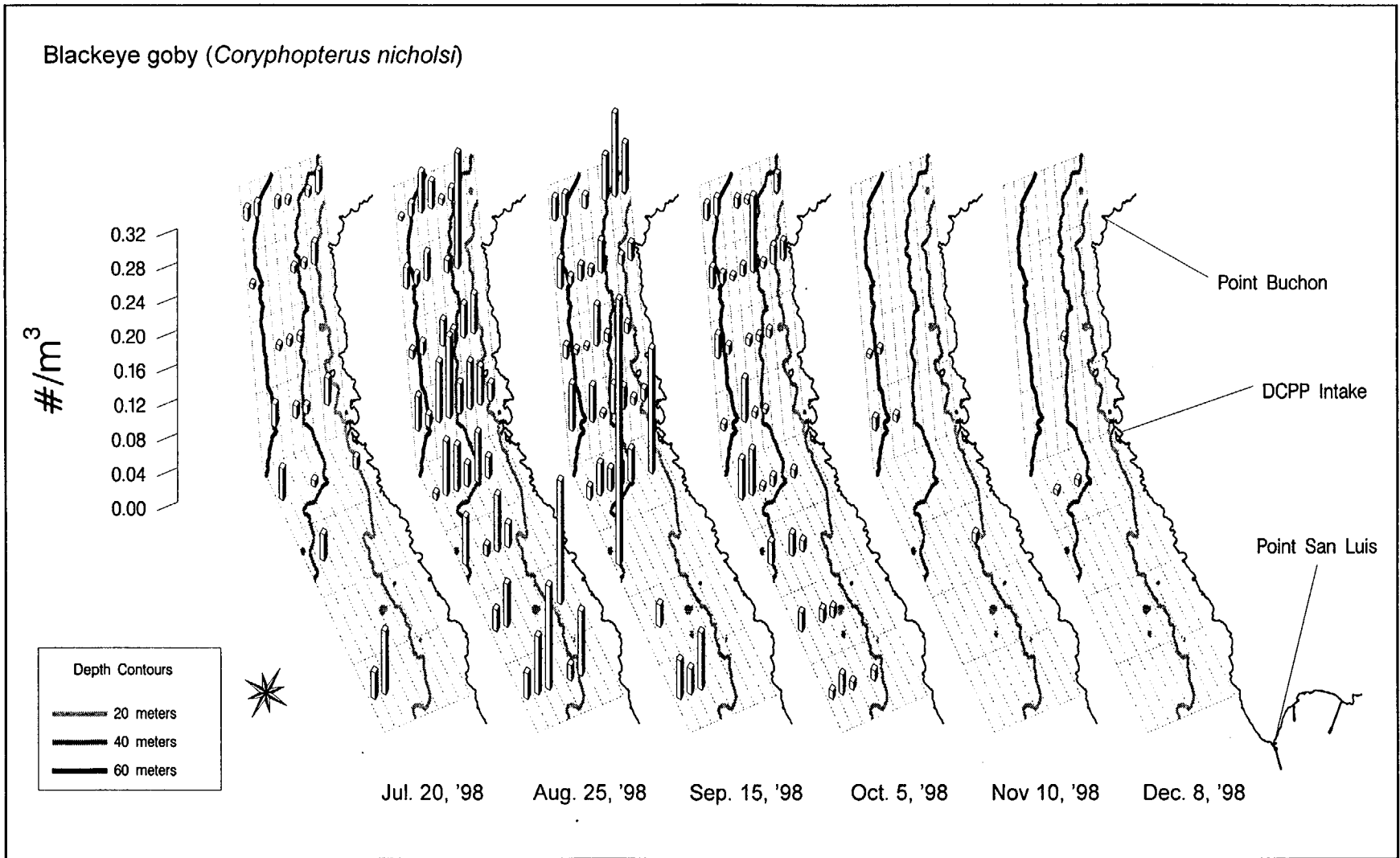


Figure 5.2.10-2c (continued). Mean larval density (#/m³) collected in the DCPP study grid cells and at the entrainment sampling location.

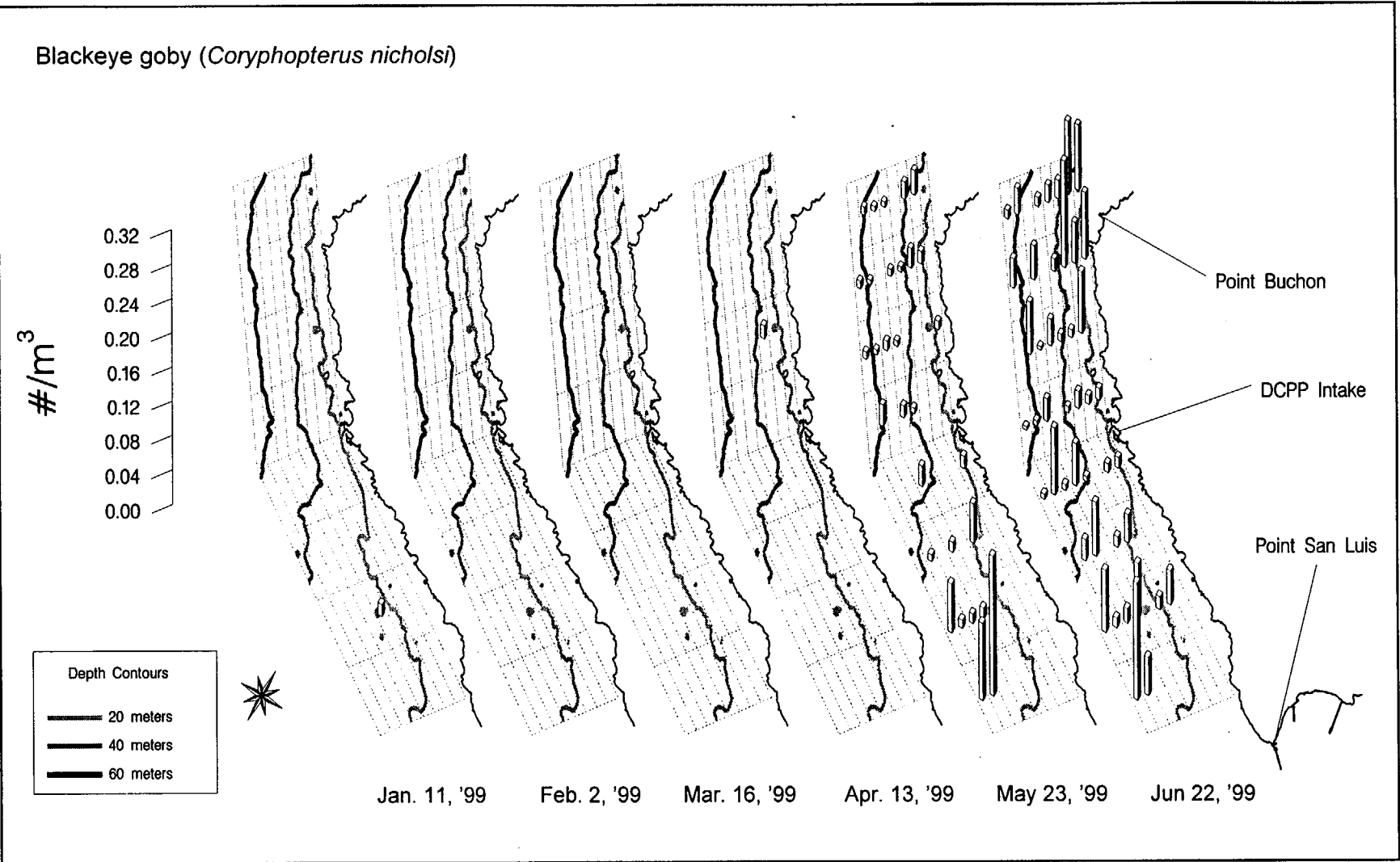


Figure 5.2.10-2d (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

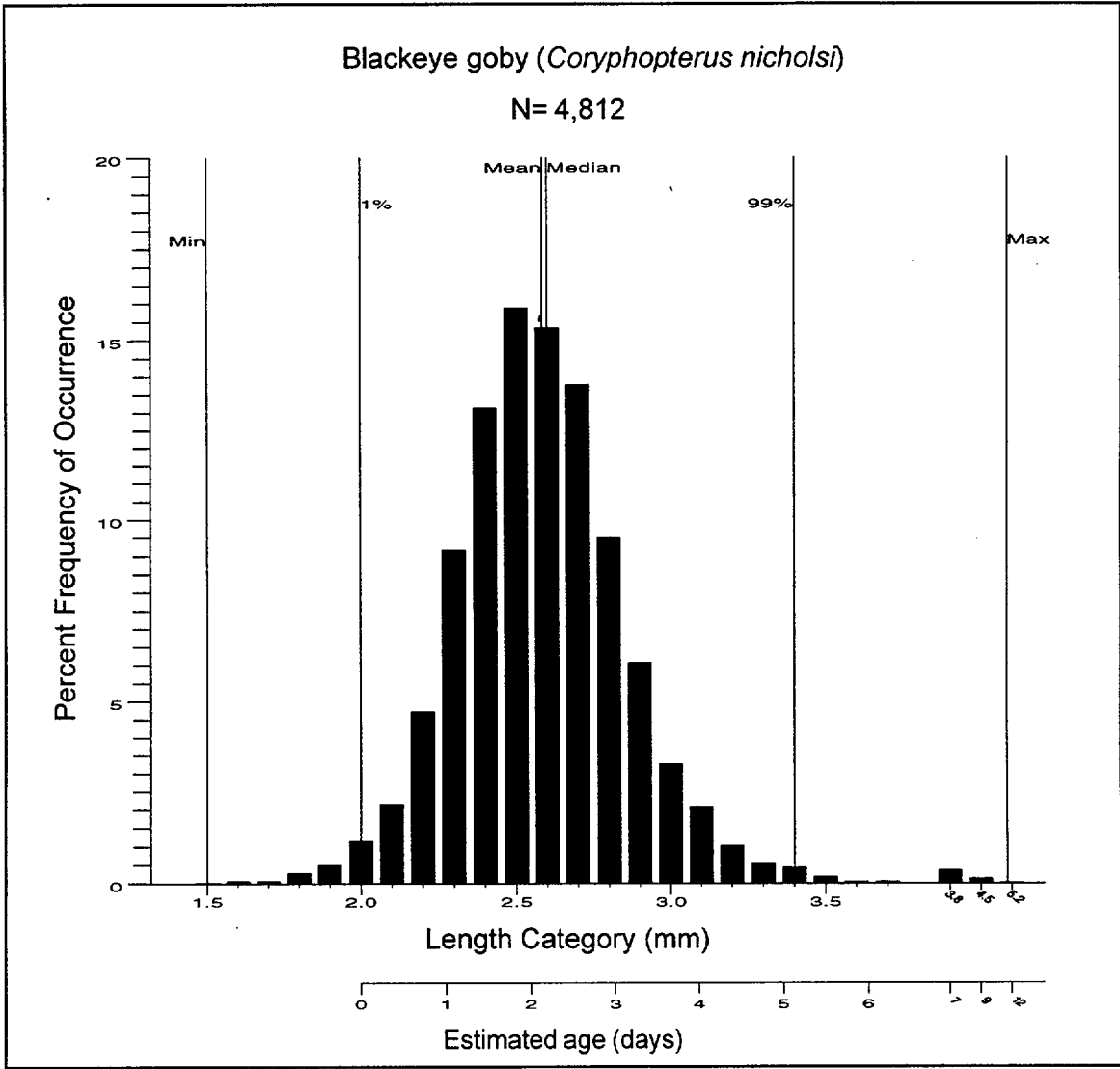


Figure 5.2.10-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

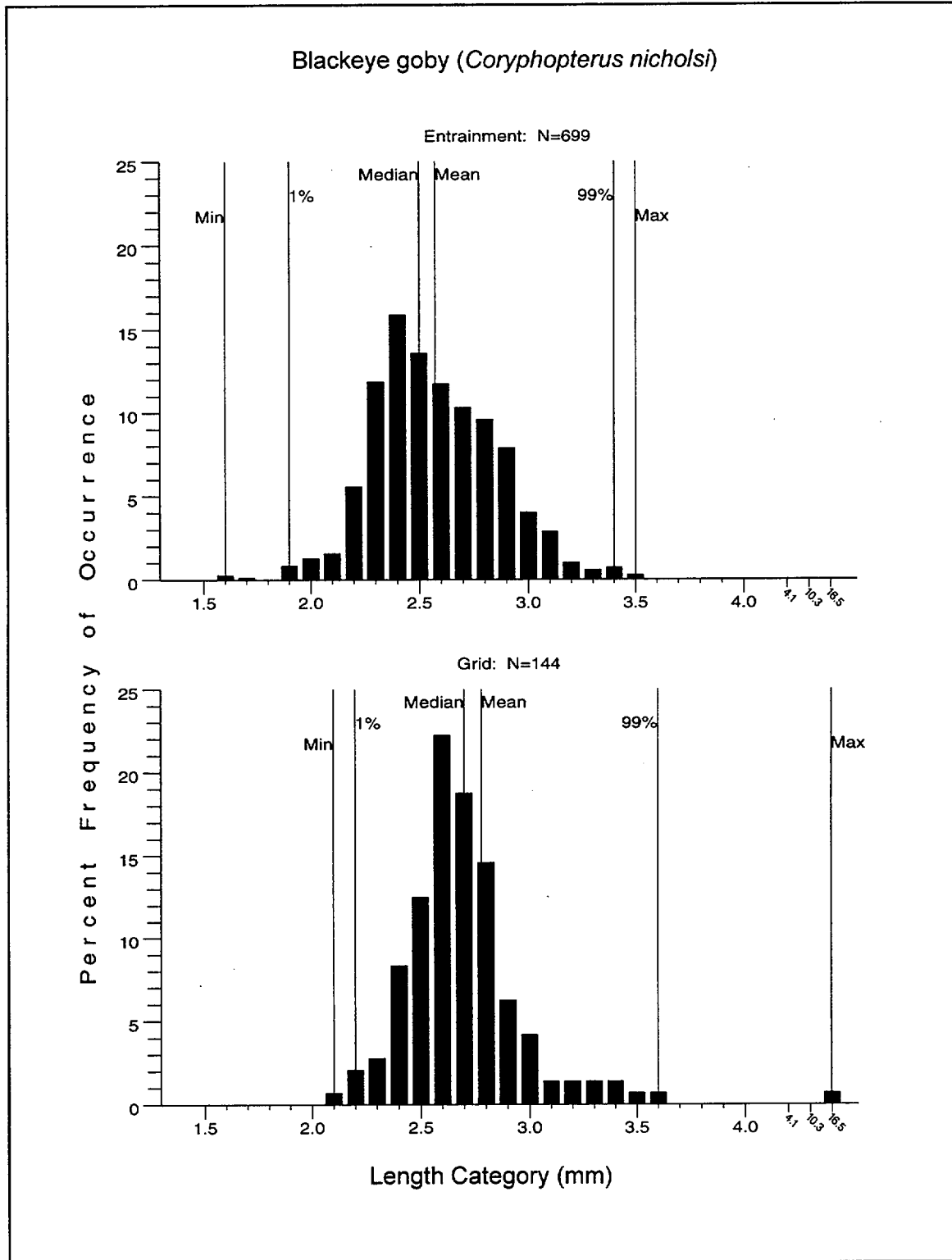


Figure 5.2.10-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

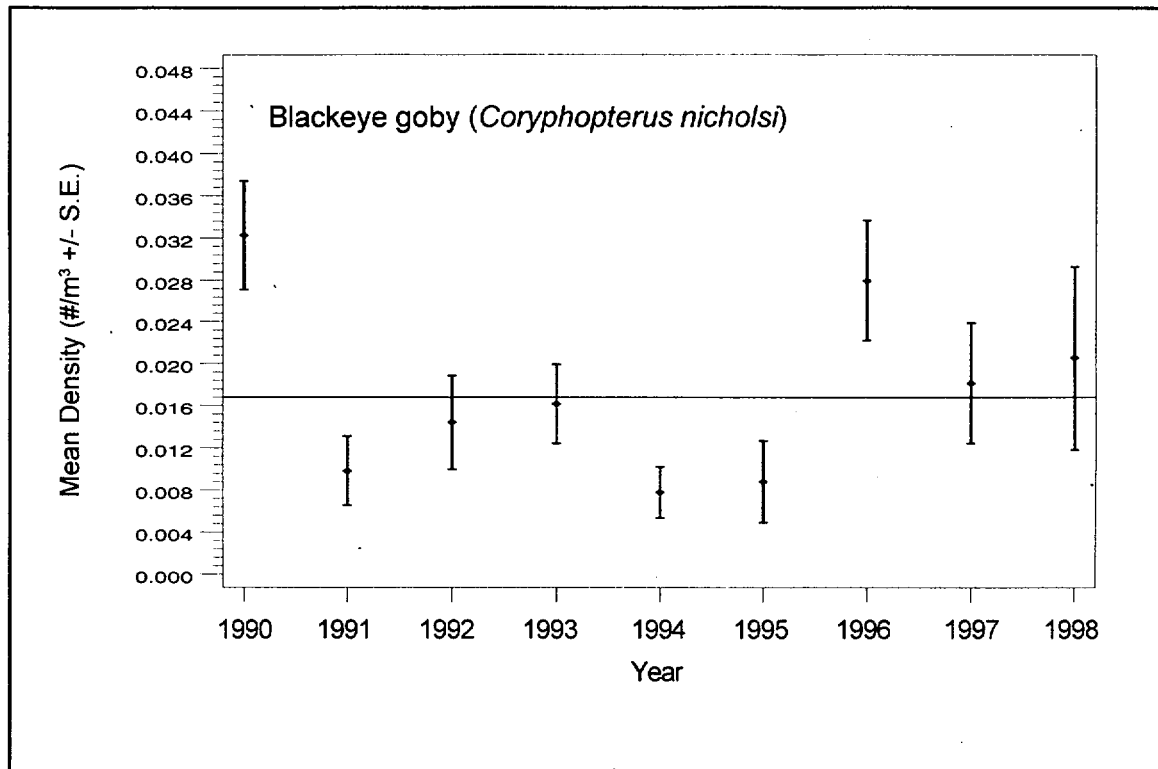


Figure 5.2.10-5. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

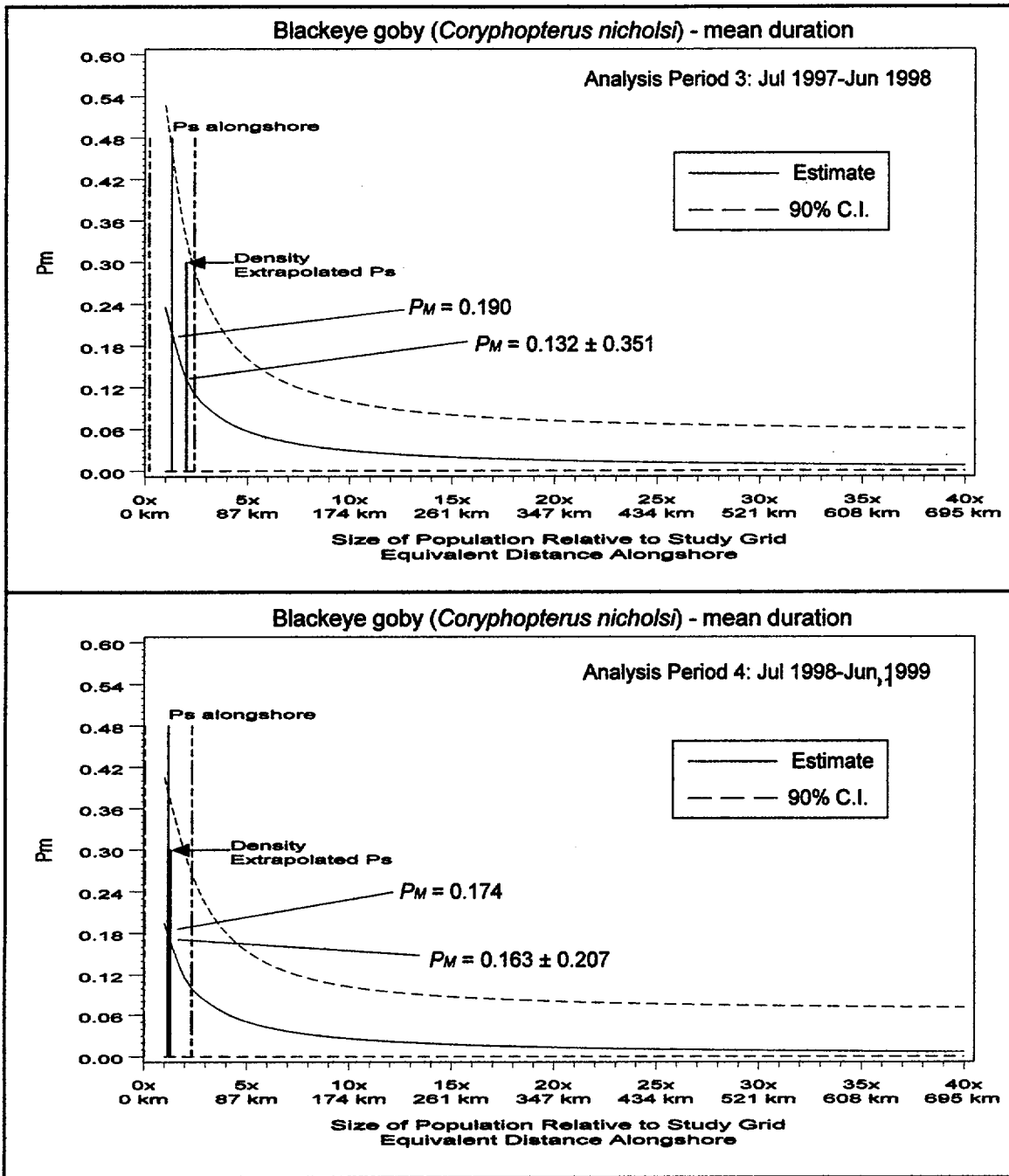


Figure 5.2.10-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

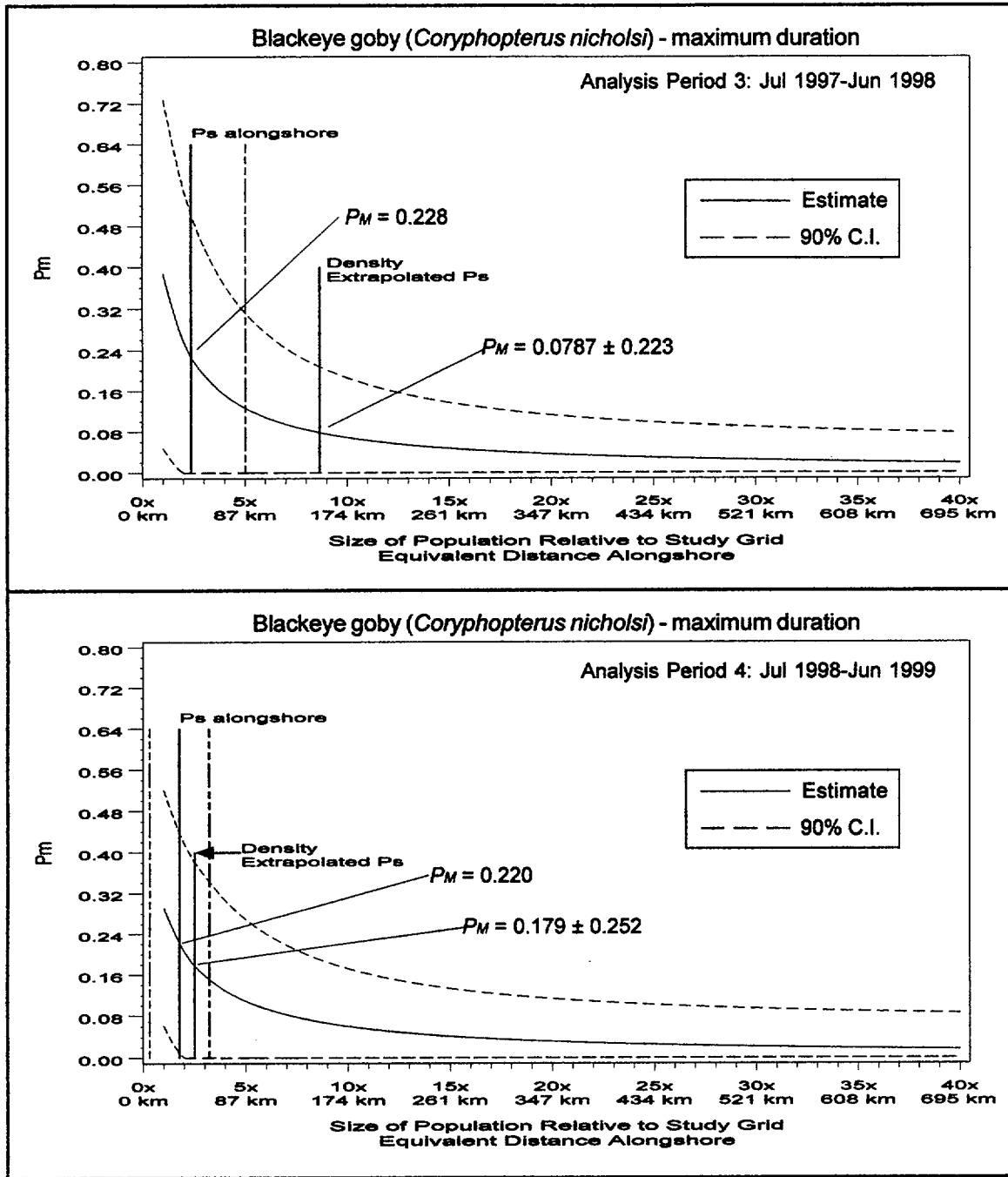


Figure 5.2.10-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

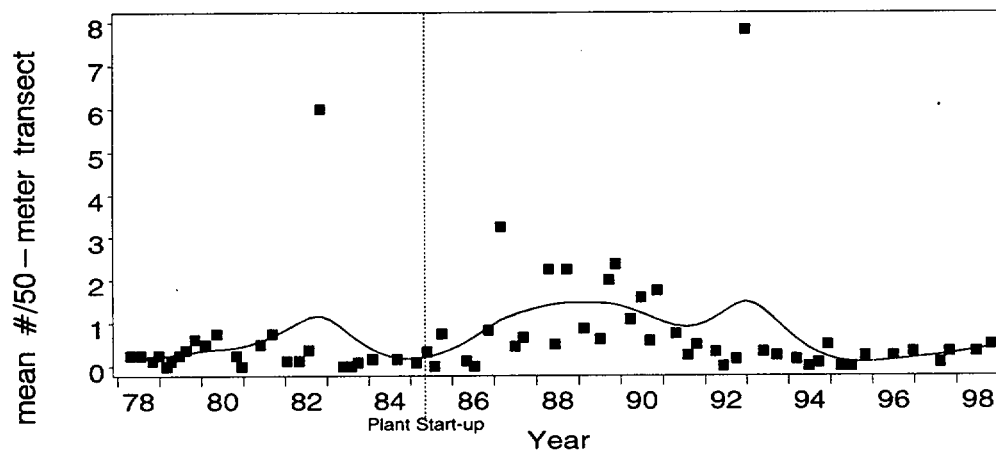


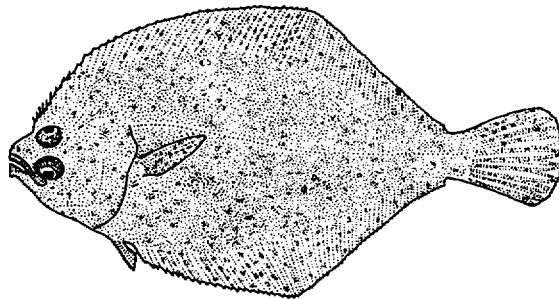
Figure 5.2.10-7. Mean number of blackeye gobies observed per 50-meter subtidal transect in the DCPW RWMP South Control area. Spline smoothing algorithm used to draw the curve through the points.

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5.2.11 Assessment of Flatfishes (Family Paralichthyidae)

Left-eyed flatfishes (Paralichthyidae) are represented in the California Current region by 8 genera and 19 species (Nelson 1994; Moser and Sumida 1996). The larvae of four sanddab species (genus *Citharichthys*) are abundant in CalCOFI tows up to 180 km offshore, while other paralichthyid flatfish such as the California halibut (*Paralichthys californicus*) are primarily found within 40 km of shore. Females in this family are oviparous with large batch sizes and multiple spawns. Spawning takes place throughout the year with seasonal peaks. DCPD entrainment effects on larvae were assessed for sanddabs (*Citharichthys* spp.) and for California halibut.

5.2.11.1 Sanddabs (*Citharichthys* spp.)



Citharichthys stigmaeus Jordan and Gilbert 1882; speckled sanddab; length to 17 cm; Prince William Sound, Alaska to Bahia Magdalena, southern Baja California; nearshore to 607 m; eyed side brown or tan with black speckles and spots; blind side white (Miller and Lea 1972; Eschmeyer et al. 1983).

Citharichthys sordidus (Girard 1854); Pacific sanddab; length to 41 cm; Sea of Japan to Bering Sea to Cabo San Lucas, southern Baja California; 0–549 m (Miller and Lea 1972; Eschmeyer et al. 1983); eyed side light brown, mottled with dark brown sometimes with yellow and orange spots; blind side whitish or light tan (Eschmeyer et al. 1983).

Citharichthys species, including the speckled and Pacific sanddabs, are commercially fished and generally found over sandy bottom, with the speckled sanddab generally found in shallow water bays and estuaries (Moser 1996; Rackowski and Pikitch 1989). Sanddab females are oviparous,

producing planktonic eggs and larvae (Moser 1996). According to Moser (1996), both species spawn year-round in the CalCOFI area with their highest abundance during the periods August–December for speckled sanddab, and January–February plus August–October for Pacific sanddab. In southern California, Goldberg and Pham (1987) found that speckled sanddab spawn March–October, while Ford (1965) reported that Pacific sanddabs spawn mainly from April–September.

Longevity and reproduction have been investigated in both species of sanddabs. Ford (1965) found that female speckled sanddabs begin to spawn in their second year and can produce up to three batches of eggs per year. They may produce 1,000–6,000 eggs per batch and may live over 4 yr (Ford 1965; **Table 5.2.11-1**). Some female Pacific sanddabs first mature at 2 yr (Smith 1936). Half of the older females are mature by 3 yr and all are mature by 4 yr (Arora 1951). Total lifespan may be over 11 yr (Love 1996). No estimates of annual egg production have been reported.

Both species of sanddabs can have extended planktonic durations. Sakuma and Larson's (1995) review reports that speckled sanddab (*Citharichthys stigmaeus*) larvae may be planktonic up to 324 d, while the Pacific sanddab (*Citharichthys sordidus*) may remain in the plankton for 271 d. Kendall (1992) found that speckled sanddabs probably settle after 113–324 d. Settlement sizes for speckled and Pacific sanddabs are 35 mm and 40 mm, respectively (Moser 1996). Larval growth rate of *Citharichthys* spp., mainly Pacific sanddab, for age-0 yr individuals was 0.19–0.30 mm/d, and the monthly instantaneous mortality rate was 0.437 in 1983 and 0.176 in 1984 (Rogers 1985). Speckled sanddab mortality during the egg and larval period is nearly 99.9% (Ford 1965; **Table 5.2.11-1**).

Summary of Field Collections

Sanddab larvae were collected at the DCCP intake structure during two periods: a minor pulse during December–March and a stronger pulse during July–September in all years 1996–1999 (**Appendix H**). Their highest density occurred in early August 1997 (**Figure 5.2.11-1**). The density during July–September 1998 was lower than during the same months in 1997, possibly

due to the El Niño event that occurred during the fall–winter seasons spanning 1997–98 (Lynn et al. 1998; NOAA 1999). There were 254 sanddabs identified from 170 bongo net subsamples representing 3.5% of the entrainment subsamples collected and processed from that location during this period. Of the total number identified from the entrainment subsamples, 113 were Pacific sanddabs, 71 were speckled sanddabs, and 70 were only identifiable to the generic level.

Sanddab larvae, notably *C. stigmaeus*, occurred year-round in the study grid (Appendix H), with their greatest density occurring during July 1997 and 1998 (Figure 5.2.11-2). The spatial distribution of sanddab larvae in the grid was inconsistent between surveys. Generally, they were collected farther from shore, except large numbers collected inshore in July 1997. There were 361 larval sanddabs identified from 43 bongo net subsamples representing 1% of the study grid subsamples collected and processed. Of the total number identified from the grid subsamples, 142 were Pacific sanddabs, 156 were speckled sanddabs, and 63 were identifiable to only the generic level.

Standard lengths of sanddab larvae in entrainment subsamples between October 1996 and June 1999 ranged from 1.3 mm to 32 mm (Figure 5.2.11-3). Only one larvae measuring 32 mm was collected; the next largest individual was 3.5 mm. The central 98% of the sanddab length-frequency distribution resulted in minimum and maximum lengths for the analyses of 1.3 mm and 3.5 mm, respectively. The growth rate of larval sanddabs (0.20 mm/d) reported by Kendall (1992) and Sakuma (1995) was used to estimate larval ages. The mean larval length in this distribution was 2.61 mm and approximately 6.5 d of age. The reported hatch length for *C. stigmaeus* is about 1.3 mm and less than 2.6 mm for *C. sordidus* (Moser 1996).

Lengths of sanddab larvae were collected for paired DCP intake and study grid subsamples (Figure 5.2.11-4). However, very few measurable larvae occurred in the coincident subsamples: 4 at the DCP intake and 52 in the study grid. These low sample sizes precluded statistical analyses and render difficult even qualitative comparisons between the two length distributions.

Estimating Total Annual Entrainment

The annual estimated mean entrainment and associated standard error for sanddab larvae show that few larval sanddabs were entrained (Table 5.2.11-2). Estimated entrainment was greater in 1996–97 Analysis Period 1 ($\widehat{E}_T = 7,160,000$; $\widehat{SE} = 702,000$) than in 1997–98 Analysis Period 2 ($\widehat{E}_T = 1,540,000$; $\widehat{SE} = 283,000$). The high larval abundance observed in summer 1997 produced the highest entrainment estimates. The apparent difference between the estimates for Analysis Period 2 (October 1997–September 1998) and Analysis Period 3 (July 1997–June 1998) illustrates the sensitivity of unadjusted annual entrainment estimates to the time period selected and to episodic oceanographic events. The estimates for these two periods were identical or very close in value for most target taxa. The estimated entrainment values for the analysis periods were not adjusted by the long-term weekly Intake Cove surface plankton tows (December–July), because sanddab spawning occurred mainly after the 7 mo surface tow period used for analysis (Figure 5.2.11-5).

Fecundity Hindcasting (FH)

Both *FH* and *AEL* methods required age-specific mortality, and *FH* required fecundity to assess entrainment effects. Egg and larval survival rates were estimated using Ford's (1965) estimate of 0.0015 survival through the first 90 d based on examination of fecundity, number of females, and transformed juveniles (Table 5.2.11-1). The calculated egg and larval daily survival was 0.930/d. An estimated age at entrainment of sanddab larvae was ca. 6.6 d, based on a growth rate of 0.2 mm/d and an average length at entrainment of 2.6 mm. Survival to entrainment was estimated as $0.93^{6.6} = 0.62$.

The *FH* approach combines larval entrainment losses and adult fecundity to hindcast the numbers of adult females effectively removed from the reproductively active population. An estimate of mean annual fecundity was 15,414 eggs/female based on a range of fecundity data for females measuring 85 to 148 mm in total length (Table 5.2.11-3; Ford 1965).

Age of maturation was assumed to be equal to 2.5 yr and longevity was assumed to be 6 yr from Ford (1965) and Arora (1951). The estimated total larval entrainment was used to estimate the

number of breeding females needed to produce the number of larvae entrained during the three analysis periods. A comparison of Analysis Periods 1 and 2 show that the value for 1996–97 ($\widehat{FH} = 426$; $\widehat{SE} = 996$) to be greater than the same time period for 1997–98 ($\widehat{FH} = 92$; $\widehat{SE} = 215$) (Table 5.2.11-4).

Sensitivity Analysis

Fecundity had the greatest effect on recalculated values of \widehat{FH} (Table 5.2.11-5). Varying this parameter in the model resulted in an \widehat{FH} range of ca. 18–2,210 adult females for Analysis Periods 1 and 2, compared to the original estimate of 92–426 adult females. Larval survivorship had the next greatest effect on recalculated \widehat{FH} .

Adult Equivalent Loss (AEL)

The *AEL* approach uses estimates of the abundance of entrained organisms to project the loss of equivalent numbers of adults based on mortality schedules and age at recruitment. Survival rates were estimated from entrainment of larval stage to recruitment into the fishery including juvenile to 2 yr adults (Table 5.2.11-1). Larval survival was estimated from the average age at entrainment through settlement as

$$S_{Larvae} = 0.930^{(90-6.6)} = 0.002.$$

Survivorship to recruitment was apportioned into several age stages from Ford (1965; Table 5.2.11-1), and \widehat{AEL} was calculated using the entrainment of a single age class having an average age of 6.6 d. Values of \widehat{AEL} for Analysis Periods 1 and 2 show that the value for 1996–97 ($\widehat{AEL} = 2,370$; $\widehat{SE} = 6,710$) to be greater than the same time period for 1997–98 ($\widehat{AEL} = 511$; $\widehat{SE} = 1,450$) (Table 5.2.11-6).

Sensitivity Analysis

Early larval survivorship had the greatest effect on recalculated values of \widehat{AEL} (Table 5.2.11-7). Varying this parameter in the model resulted in an \widehat{AEL} range of 99–12,300 adult equivalents among the three analysis periods, compared to the original estimate of 511–2,372 adult

equivalents. Late larval through pre-recruit survivorship had the next greatest effect on \widehat{AEL} . The range of entrainment estimates did not substantially change the calculated values of \widehat{AEL} .

Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) for sanddabs in the surveys from the two analysis periods ranged from a minimum of zero to a maximum of 0.859 ± 0.911 ($\pm 1SE(\widehat{PE}_i)$) in April 1998 (Table 5.2.11-8). When both \widehat{PE}_i and the annual proportion of larvae hatched in the i th survey period (\hat{f}_i) were equal to zero, no larvae were collected at either the DCP intake or from the study grid. When $\widehat{PE}_i = 0$ but $\hat{f}_i > 0$, larvae were collected at the DCP intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. For sanddabs, the relatively large \widehat{PE}_i for April 1998 resulted from the fact that no sanddab larvae were collected in the study grid. This \widehat{PE}_i was calculated using the larval density from the weekly entrainment sample (Appendix H) multiplied by the unsampled volume inshore of the two cells nearest the intake (D1 and E1) to approximate the number of larvae in this volume. This number was then added to the number of larvae found in cells D1 and E1, zero in this case as well as elsewhere in the grid, to approximate the number of larvae in the whole study grid. The accompanying low value of \hat{f}_i (0.00893) indicated that there were few sanddab larvae in the water column and, therefore, the high \widehat{PE}_i had relatively low weight in the annual estimate of entrainment mortality. July and August of the first study year and May and June of the second year had higher values of \hat{f}_i due to greater larval abundance in the subsamples from these months.

Estimates of \widehat{P}_M between years showed the greatest differences in point estimates (Figures 5.2.11-6a and b). Estimated mean and maximum larval durations (7 or 11 d, respectively) were relatively similar, causing minimal change in point estimates of \widehat{P}_M within-years. Since sanddab larvae were dispersed throughout the study grid, P_S was calculated using both onshore and alongshore current movements. Density was extrapolated offshore, with a common slope for all surveys of 0.0000342/m for Analysis Period 3 and 0.0000661/m for Analysis Period 4. The offshore extrapolation of study grid abundance, followed by an alongshore extension, yielded a

range of \widehat{P}_M from both analysis periods of 0.4–4.5% of the larvae contained in an estimated population of approximately 3 to 22 times that in the study grid. The area of extrapolation ranged between 3 to 20 times the 52 km² area study grid. The extrapolated area was slightly less than the population because of the slightly increasing trend in density. In comparison, using only alongshore extension of study grid abundance, \widehat{P}_M ranged from 1–7% of the larvae in an area two to four times the study grid alongshore or around 30–60 km of coastline distance.

Interpretation of Assessment Results

Estimates of adult equivalent loss, both *FH* and *AEL*, of sanddabs depend on estimated entrainment. Comparisons of the annual estimates of *FH* (92–426) and *AEL* (511–2,370) from Analysis Periods 1 and 2, that have comparable time periods, reflects the effects of the high entrainment estimates from summer 1997. The estimate of *AEL* assumes a recruitment age of 2.3 yr, while females in the fecundity hindcasting estimate range between 2.5 and 6 yr (3.7 yr assuming linear survival). The *FH* and *AEL* estimates are similar ($2 \cdot \widehat{FH} / 0.25 = 736\text{--}3,408$) when accounting for additional survival (**Table 5.2.11-1**) and equal number of males as females.

Sanddabs have both commercial and recreational fishery value. Catch data are available to compare harvest mortality rates to entrainment mortality rates. In 1998, an estimated 51,000 sanddabs were caught by recreational anglers in southern California waters (PSMFC RecFIN database). Commercial ex-vessel value in 1998 from ports between San Diego and Mendocino totaled \$420,100, representing 595.6 MT (PSMFC PacFIN database). Value of sanddab landings in the port area of Morro Bay, that includes Port San Luis, in 1998 totaled \$7,000, representing 12.7 MT (PSMFC PacFIN database).

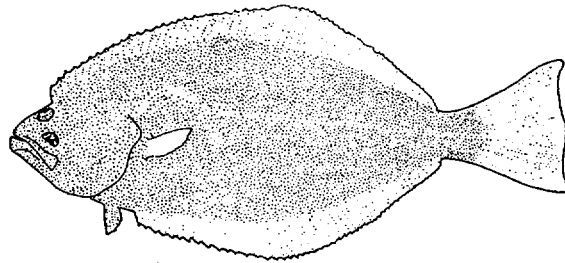
The estimated larval duration for sanddabs (7–11 d) produced a potential area of effects between 3–9 times the study area (for 7 d duration) and 9–20 times (for 11 d duration) that was used in computing an offshore extrapolation-based P_s (**Figure 5.2.11-6**). This indicates that only the commercial catch from the local ports of Morro Bay and Avila could potentially be affected by entrainment. An estimate of 60 g per average adult (Arora 1951) can be applied to the largest mortality predicted by the survival-weighted *FH* estimate. If we assume no compensatory

mortality and directly apply the *AEL*-based loss to the fishery catch, 3,400 fish represents 0.2 MT or \$110. However, *FH* and *AEL* models do not consider selectivity, catchability, and fishing effort when extrapolated to fishery losses, so this estimate of monetary value is likely an overestimate of the loss to the fishery because it assumes all equivalent adults were harvested.

Alternately, estimates of annual entrainment mortality (\widehat{P}_M) could be used to determine the effect of larval entrainment on Morro Bay area catches. Proportional entrainment mortality ranged from ~1–7% over areas ranging from 3–22 times the study grid area (larger area associated with smaller mortality). These proportional losses can be applied to the 1993–1999 annual average revenue for the Morro Bay area sanddab catch of ca. \$8,200/yr (PSMFC PacFIN Database) assuming no compensation. This results in an average dollar value impact on the Morro Bay area sanddab fishery of \$82/yr, by translating a 1% larval mortality to adult losses (using the larger extrapolated areas still conservatively less than the fishery area).

Long-term trends, shown by Intake Cove plankton tows (**Figure 5.2.11-5**), show wide variation of larval abundance from 1990–1998 with no apparent trend. Since the startup of power plant operations, sanddabs have increased in Diablo Cove compared to pre-operation observations (Figure 4-39 in PG&E 1997c). Fishery harvest information indicates that catches in the MBNMS have generally increased between 1980 and 1995 (Starr et al. 1998), but there may be a declining trend for catches in the Morro Bay area since 1994 (**Figure 5.2.11-7**). Declining catches in the Morro Bay area could be due to many factors, but without data describing fishing effort it is difficult to attribute this apparent decline to any feature of the fishery. Since larval abundance does not appear to be declining in the Intake Cove, it seems likely that entrainment mortality is not reducing larval production locally or that compensation in birth rates is occurring.

5.2.11.2 California halibut (*Paralichthys californicus*)



Paralichthys californicus (Ayres 1859); California halibut; length to 152 cm; Quillayute River, northern Washington to Bahia Magdalena, southern Baja California; nearshore to 183 m; eyed side mostly uniform dark brown to black, but often mottled with light and dark; blind side usually white (Miller and Lea 1972; Eschmeyer et al. 1983).

California halibut is an important part of California's commercial and recreational fisheries (Leet et al. 1992; Starr et al. 1998). It is generally found on sandy substrata near rocks, kelp holdfasts, or other bottom structures (Love 1996). One-year-old individuals can be greater than 80 cm SL (Allen et al. 1990). Halibut can live to 30 yr (Frey 1971), with 50% of females mature by 4 yr and 100% mature by 7 yr (Love and Brooks 1990). They are oviparous, producing planktonic eggs and larvae (Oda 1991; Moser 1996) with external fertilization (Allen 1990). Halibut can spawn year-round, with peak spawning taking place during the late winter to spring and usually in water shallower than 75 m (Lavenberg et al. 1986). Spawning for the fish under natural environmental conditions was investigated in the laboratory during three different spawning years (Caddell et al. 1990; **Table 5.2.11-9**). They found during their laboratory study that halibut spawned 57 million eggs per year in an artificial environmental setting.

Little information on the population dynamics of larval California halibut was found in the scientific literature. In southern California, halibut less than 10 cm SL are found in greater numbers in bays than in coastal waters (Plummer et al. 1983). Peak densities of California halibut larvae occurred during February in CalCOFI samples (Moser et al. 1993). Moser and Watson (1990) found that less than 1% of the halibut larvae within the CalCOFI study area were collected in the central California zone that extends from just north of Point Conception to just north of San Francisco Bay. Allen and Jensen (unpubl. data in Allen et al. 1990) stated that newly settled larvae are about 8–12 mm and about 30 d old. Kramer (1990) stated that halibut 6–10 mm larvae

grew <0.3 mm/d, while larger 70–120 mm halibut grew about 1.0 mm/d. In a laboratory study, halibut held at 16°C grew to a length of 11.1 mm ± 2.61 (SD) in 2 mo from an initial hatch length of 1.9 mm (Gadomski et al. 1990). Instantaneous mortality rates (Z_t) were greatest for the smallest length classes, followed by lower, relatively stable rates for subsequent length classes up to 70 mm (Table 5.2.11-10).

In the 1985–1988 commercial catch, 63% of the California halibut were 6–7 yr (Sunada et al. 1990). Fish over 8 yr averaged about 18% of the catch, while a few 3 yr fish were large enough to be included in the fishery. No stock assessment has yet been published for this species (Bob Leos, CDF&G, Monterey, pers. comm.).

Summary of Field Collections

California halibut larvae were collected seasonally in the DCPD intake entrainment surveys during the years 1996–1999 (Appendix H). Halibut larvae at the intake occurred in two periods: March–May and July–August (Figure 5.2.11-8). The greatest apparent densities occurred during late April 1998. There were 378 California halibut larvae identified from 157 bongo net subsamples collected at the DCPD intake structure between October 1996 and June 1999 representing 3% of the entrainment subsamples collected and processed.

Within the DCPD study grid, California halibut larvae occurred sporadically during the two years surveyed (Appendix H), with their highest densities occurring during April–May and July 1998 (Figure 5.2.11-9). No clear distribution pattern was observed in the grid. The density estimates from the study grid represented 251 larval California halibut identified from 164 bongo net subsamples: 5% of the study grid subsamples collected and processed.

Standard lengths of California halibut larvae collected at the DCPD intake structure ranged from 1.5 mm to 8.0 mm (Figure 5.2.11-10). The growth rate of larval California halibut (0.28 mm/d) reported by Allen et al. (1990) was used to estimate ages of entrained larvae. The central 98% of this larval length-frequency distribution resulted in minimum and maximum lengths for the analyses of 1.6 mm and 7.8 mm, respectively. The mean larval length in this distribution was

3.28 mm and approximately 6 d post-hatch. Reported hatching size for California halibut ranges 1.5–1.8 mm (Moser 1996,) and it is one of the smaller larvae entrained at DCP. The collection of just a few California halibut larvae from the paired entrainment and study grid surveys precluded statistical comparisons of larval length (Figure 5.2.11-11).

Estimating Total Annual Entrainment

Annual estimated entrainment of California halibut larvae was greater in 1997–98 Analysis Period 2 ($\widehat{E}_T = 14,300,000$; $\widehat{SE} = 2,130,000$) than in 1996–97 Analysis Period 1 ($\widehat{E}_T = 2,270,000$; $\widehat{SE} = 296,000$) (Table 5.2.11-11). These estimates represent a total of only 378 individual larval California halibut collected at the DCP intake structure. Although the number of larval California halibut entrained was low it was chosen for assessment because of its importance in sport and commercial fisheries.

Estimated annual entrainment of California halibut larvae was adjusted (Table 5.2.11-12) to the long-term average index (\bar{I}/I_i) estimated from Intake Cove surface plankton tows (Figure 5.2.11-12). The index was calculated as the ratio between the nine year average (\bar{I}) of Intake Cove sampling and the average annual index estimated from the plankton tows during the year being adjusted (I_i). The average indices for the years 1997 and 1998 (I_i) were 0.0005 and 0.0016 larvae/m³, respectively. The long-term average index (\bar{I}) was 0.0017 larvae/m³ for the years 1990–1998, yielding the ratio \bar{I}/I_i of 3.64 for 1997 and 1.10 for 1998 indicating that Intake Cove density in these years was lower than the long-term average. Annual adjusted entrainment of California halibut larvae was estimated to be 8,260,000 in 1996–97 Analysis Period 1 ($\widehat{SE} = 1,080,000$) and 15,700,000 in 1997–98 Analysis Period 2 ($\widehat{SE} = 2,340,000$) (Table 5.2.11-12).

NOTE: Annual entrainment estimates of California halibut larvae were not used to estimate *FH* or *AEL* because no larval survival data were available to parameterize these models. However, an approximate *FH* estimate is made in the interpretation section below.

Empirical Transport Model (ETM)

Monthly estimates of proportional entrainment (PE_i) for California halibut in each i th survey from the two years sampled ranged from a minimum of zero to a maximum of 0.859 ± 0.911 ($\pm 1 \widehat{SE}(\widehat{PE}_i)$) in April 1999 (Table 5.2.11-13). During periods when no larvae were collected at either the DCPPI intake or from the study grid, both the annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and \widehat{PE}_i were equal to zero. When $\widehat{PE}_i = 0$ but $\hat{f}_i > 0$, larvae were collected at the DCPPI intake during the survey period but not during the entrainment survey paired with the 72-hour study grid survey. The maximum \widehat{PE}_i , recorded in April 1999, was the result of using study grid estimates based only on inshore volumes as no larvae were found in study grid cells. That is, PE for this survey period was calculated using the larval density from the weekly entrainment sample (Appendix H) multiplied by the unsampled volume inshore of the two cells nearest the intake (D1 and E1) to approximate the number of larvae within this volume. The product was added to the abundance in cells D1 and E1, zero in this case as well as elsewhere in the grid, to approximate the number of larvae in the whole study grid. The low value of f_i during April 1999 indicated that California halibut were not as prevalent as they were during August 1998 or March 1999. In comparison with \widehat{PE}_i a month earlier, their distribution was more inshore during April 1999.

Estimates of \widehat{P}_M showed greater differences between years than between larval durations during the same year (Figures 5.2.11-13). Since halibut larvae were dispersed throughout the study grid, P_S was calculated using both onshore and alongshore current movements with a common slope used for offshore extrapolation of study grid abundance of 0.0000252/m for Analysis Period 3 and 0.0000127/m for Analysis Period 4. Using offshore extrapolation of study grid abundance pattern followed by alongshore extension yielded a range of \widehat{P}_M from both analysis periods of 0.07–0.08% (1997–1998) and 5–12% (1998–1999) of the larvae contained in a population area approximately 4 to 39 times the study grid area (and 4 to 35 times the grid's estimated larval population size). In comparison, \widehat{P}_M results using only alongshore extension of study grid abundance also reflected differences between the years' results, ranging from 0.3–25% of the

larvae in an area two to six times the study grid alongshore or around 41–105 km of coastline distance.

Interpretation of Assessment Results

California halibut have both commercial and recreational fishery value. Commercial vessel landing prices in 1998 from ports between San Diego and Mendocino totaled \$2,746,700 representing 532.1 MT (PSMFC PacFIN database). During the same year, landings in the Morro Bay area totaled about 10% of the catch from this larger area (54.8 MT and \$264,000; PSMFC PacFIN database). In 1998, recreational fishers in southern California caught 66,000 adult California halibut (PSMFC RecFIN database).

The estimated age of larval California halibut entrained at DCPD averaged six days with a maximum estimated age of 22 d. The average duration, combined with current meter data, produced an extrapolated reference population that ranged from 4–8 times the study area between sampling years, while the maximum duration produced a reference population contained in an area 23–39 times the study grid. The population contained within the study grid and extended alongshore using current meter data and both average and maximum larval age at entrainment ranged over shoreline distances of 10–170 km. Therefore, we assumed that the commercial catch likely affected by entrainment was limited to the local ports of Morro Bay and Port San Luis.

Estimates of stock size or adult density that could be used to convert \widehat{P}_M numbers of adult fishes were not available for this species. However, proportional losses predicted by *ETM* can be applied to the 1993–1999 average value of the local catch of \$161,000/yr (PSMFC PacFIN Database) assuming no compensation. Thus, the proportional dollar loss to this fishery in the Morro Bay area could range from ca. \$120–20,000 based on \widehat{P}_M ranging from 0.00076–0.123 from the combined offshore extrapolated and alongshore extension of the study grid abundance.

Between-year differences in larval California halibut density at DCPD could be the result of changes in nearshore, coastal transport processes or may reflect some other factors. Relatively higher abundance observed in the study grid during the 1997–98 El Niño event may have been

due to increased shoreward transport at DCP (out of the south) or could be related to suppressed upwelling during that period. However, the nine years of Intake Cove plankton tow data indicate that larval California halibut density does not vary greatly from the long-term average with the exception of a single strong year-class in 1992. Additionally, catches in the MBNMS appear to be relatively stable or only slightly decreasing between 1980 and 1995 (Starr et al. 1998); local Morro Bay area catches show a similarly stable catch between 1993 and 1999 (Figure 5.2.11-14). One explanation for the apparent between-year differences of entrainment effects is high interannual variability within the study period due to low sample size: only 378 California halibut larvae were collected over the course of the study. The large 1998–99 estimated larval mortality is based on a limited number of California halibut larvae.

Using the adjusted entrainment estimated over 1996–97, an estimate of FH can be made assuming a relatively small larval survival of 0.5/d during six days, average yearly fecundity of 4.9 million eggs (Table 5.2.11-9), and reproductive life of 11.5 yr as

$$\widehat{FH} = \frac{\hat{E}_{Adj-T}}{\hat{S} \times \hat{F}_T} = \frac{8.3 \times 10^6}{0.5^6 \times (4.9 \times 10^6) \times \left(\frac{30-7}{2}\right)} = 9 \text{ females}$$

An estimate similarly can be made for 1997–98 as 18 females. These small adult female losses indicate that while \hat{P}_M is large for 1998–99, the population impact is probably slight.

Table 5.2.11-1. Life table for speckled sanddab (*C. stigmaeus*) covering the probable lifespan, where x is the age in months, bx the number of eggs spawned per female within the interval and lx the number surviving at the start of the interval. Separate lx columns are given for the 1962–63 and 1963–64 survival data. Values of lx for age group 3 were estimated by assuming the same mortality rate for age 2 and 3 fish. Intrinsic rate of natural increase, intrinsic birth and mortality rate, and generation length, based on these data, are given for 1962–63 and 1963–64 (Table 25 in Ford 1965).

Life stage/Age (yrs)	Age (mo)	bx	1962–63 lx	1963–64 lx	Survival
Eggs and larvae	0–3	0	100,000	100,000	0.00150
0	3–6	0	150	150	0.563
	6–9	0	82	87	0.567
1	9–12	0	45	51	0.861
	12–15	3,500	44	38	0.859
	15–18	700	42	29	0.867
	18–21	0	41	22	0.851
2	21–24	0	40	16	0.788
	24–27	1,010	33	12	0.742
	27–30	2,000	27	8	0.782
	30–33	0	22	6	0.742
3	33–36	0	18	4	0.764
	36–39	1,860	14	3	0.762
	39–42	3,700	12	2	0.667
	42–45	0	10	1	

Table 5.2.11-2. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for sanddab (*Citharichthys* spp.) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	7,160,000	702,000
2) Oct. 1, 1997–Sep 30, 1998	1,540,000	283,000
3) Jul 1, 1997–Jun 30, 1998	6,610,000	704,000

Table 5.2.11-3. Estimated number of eggs spawned per season by speckled sanddabs (*Citharichthys stigmaeus*) collected during April and May 1963 (Ford 1965)

Total length	Total # mature and maturing eggs
85.0	4,300
90.5	4,100
109.5	15,200
110.5	9,000
129.0	20,900
130.0	23,600
148.0	30,800

Table 5.2.11-4. Estimated number of adult sanddab (*Citharichthys* spp.) females (\widehat{FH}) whose reproductive output was equivalent to the number of larvae entrained per year at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{FH})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{FH}	$\widehat{SE}(\widehat{FH})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	426	996	19,900	9
2) Oct. 1, 1997–Sep 30, 1998	92	215	4,320	2
3) Jul. 1, 1997–Jun 30, 1998	393	919	18,400	8

Table 5.2.11-5. Sanddabs (*Citharichthys* spp.): Sensitivity analysis for \widehat{FH} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 426$				
\hat{E}_{Adj-T}	7,160,000	357	495	137
\hat{S}_{larvae}	0.623	265	2,210	1,940
# Eggs/yr	15,400	82.3	2,210	2,130
Longevity	6	157	852	695
Maturation	2.5	314	1,490	1,180

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 92$				
\hat{E}_{Adj-T}	1,540,000	64.0	119	55.4
\hat{S}_{larvae}	0.623	57.1	475	418
# Eggs/yr	15,400	17.7	475	457
Longevity	6	33.8	183	150
Maturation	2.5	67.6	321	253

c) Analysis Period 3: July 1, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{FH}		
		Minimum	Maximum	Range
$\widehat{FH} = 393$				
\hat{E}_{Adj-T}	6,610,000	324	462	138
\hat{S}_{larvae}	0.623	245	2,040	1,790
# Eggs/yr	15,400	75.9	2,040	1,960
Longevity	6	145	787	642
Maturation	2.5	290	1,380	1,090

Table 5.2.11-6. Estimated number of equivalent sanddab (*Citharichthys* spp.) adults (\widehat{AEL}) equal to the number of larvae entrained per year at Diablo Canyon Power Plant including the standard error of the estimate ($\widehat{SE}(\widehat{AEL})$) and 90% confidence limits (C.L.).

Analysis Period	\widehat{AEL}	$\widehat{SE}(\widehat{AEL})$	Upper 90% C.L.	Lower 90% C.L.
1) Oct 23, 1996–Sep 30, 1997	2,370	6,710	249,000	23
2) Oct 1, 1997–Sep 30, 1998	511	1,450	54,000	5
3) Jul 1, 1997–Jun 30, 1998	2,190	6,200	18,400	8

Table 5.2.11-7. Sanddab (*Citharichthys* spp.): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

a) Analysis Period 1: October 1, 1996–September 30, 1997

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 2,372$				
\hat{E}_{Adj-T}	162,000	1,990	2,750	765
$\hat{S}_{early\ larvae}$	0.00241	458	12,300	11,800
$\hat{S}_{late\ larvae}$	0.563	458	4,210	3,750
$\hat{S}_{early\ juvenile}$	0.567	458	4,180	3,720
$\hat{S}_{juv. I}$	0.861	458	2,750	2,300
$\hat{S}_{juv. II}$	0.859	458	2,760	2,300
$\hat{S}_{juv. III}$	0.867	458	2,730	2,280
$\hat{S}_{juv. IV}$	0.851	458	2,790	2,330
$\hat{S}_{pre-recruit}$	0.788	458	3,010	2,550

Table 5.2.11-7 (continued). Sanddab (*Citharichthys* spp.): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

b) Analysis Period 2: October 1, 1997–September 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 511$				
\hat{E}_{Adj-T}	1,540,000	356	665	308
\hat{S} early larvae	0.00241	99	2,650	2,550
\hat{S} late larvae	0.563	99	906	808
\hat{S} early juvenile	0.567	99	900	801
\hat{S} juv. I	0.861	99	593	494
\hat{S} juv. II	0.859	99	594	496
\hat{S} juv. III	0.867	99	589	490
\hat{S} juv. IV	0.851	99	600	501
\hat{S} pre-recruit	0.788	99	648	550

Table 5.2.11-7 (continued). Sanddab (*Citharichthys* spp.): Sensitivity analysis for \widehat{AEL} from the three analysis periods recalculated for each model input parameter (θ): $\hat{E}_{Adj-T} \pm 1.645 \widehat{SE}(\hat{\theta})$; other parameters are $\theta \cdot e^{\pm 1.645 CV(\hat{\theta})}$ where $CV(\theta) = 1.0$ or 100%.

c) Analysis Period 3: July, 1997–June 30, 1998

Parameter	Estimate	Recalculated \widehat{AEL}		
		Minimum	Maximum	Range
$\widehat{AEL} = 2,190$				
\hat{E}_{Adj-T}	6,610,000	1,810	2,570	768
\hat{S} early larvae	0.00241	423	11,300	10,900
\hat{S} late larvae	0.563	423	3,890	3,460
\hat{S} early juvenile	0.567	423	3,860	3,440
\hat{S} juv. I	0.861	423	2,540	2,120
\hat{S} juv. II	0.859	423	2,550	2,130
\hat{S} juv. III	0.867	423	2,520	2,100
\hat{S} juv. IV	0.851	423	2,570	2,150
\hat{S} pre-recruit	0.788	423	2,580	2,360

Table 5.2.11-8. Sanddab (*Citharichthys spp.*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.00291	0.000750	0.645	0.0172
Aug 25, 1997	0.00101	0.00107	0.192	0.0127
Sep 29, 1997	0	0	0.0235	0.00452
Oct 20, 1997	0	0	0.00528	0.00200
Nov 17, 1997	0	0	0.000970	0.000970
Dec 10, 1997	0	0	0.0246	0.00516
Jan 22, 1998	0	0	0.0966	0.00966
Feb 26, 1998	0	0	0.00259	0.00116
Mar 18, 1998	0	0	0	0
Apr 15, 1998	0.859	0.911	0.00893	0.00269
May 18, 1998	0	0	0	0
Jun 8, 1998	0	0	0	0

b) Analysis Period 4: July 1, 1998–June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.00115	0.000840	0.126	0.0189
Aug 26, 1998	0.000740	0.000750	0.0467	0.0112
Sep 16, 1998	0.000540	0.000550	0.0453	0.0103
Oct 6, 1998	0.00271	0.00279	0.128	0.0167
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0	0	0	0
Jan 12, 1999	0	0	0	0
Feb 3, 1999	0	0	0	0
Mar 17, 1999	0	0	0	0
Apr 14, 1999	0	0	0	0
May 24, 1999	0.00855	0.00502	0.328	0.0277
Jun 23, 1999	0.0430	0.0416	0.327	0.0387

Table 5.2.11-9. Average spawn per female California halibut (*Paralichthys californicus*). Spawning frequency is average days between spawning events for each year. Data from Caddell et al. (1990).

Years	No. spawns	Average number eggs per spawn	Number of eggs spawned per year	Spawning frequency (d)
1985-86	12	455,000	5,460,000	7.0
1986-87	5	313,000	1,565,000	7.2
1987-88	13	589,000	7,657,000	14.0

Table 5.2.11-10. Mortality rates for juvenile California halibut (*Paralichthys californicus*) for the 1988 year-class up to 115 d. Data from Kramer (1990)

Length class (mm)	Age class (d)	(z(t _j))
<=10	30.3	
11-15	43.3	0.044
16-20	53.3	0.016
21-25	61.8	0.015
26-30	69.3	0.013
31-35	76.2	0.013
35-40	82.5	0.013
41-45	88.4	0.011
46-50	94.1	0.014
51-55	99.5	0.012
56-60	104.8	0.011
61-65	109.9	0.013
66-70	114.9	0.012

Table 5.2.11-11. Estimated total annual entrainment (\widehat{E}_T) and standard error ($\widehat{SE}(\widehat{E}_T)$) for California halibut (*Paralichthys californicus*) larvae from the three analysis periods.

Analysis Period	\widehat{E}_T	$\widehat{SE}(\widehat{E}_T)$
1) Oct 23, 1996–Sep 30, 1997	2,270,000	296,000
2) Oct 1, 1997–Sep 30, 1998	14,300,000	2,130,000
3) Jul 1, 1997–Jun 30, 1998	14,100,000	2,130,000

Table 5.2.11-12. Estimated total annual adjusted entrainment (\widehat{E}_{Adj-T}) and standard error ($\widehat{SE}(\widehat{E}_{Adj-T})$) for California halibut (*Paralichthys californicus*) larvae estimated for the three analysis periods.

Analysis Period	\widehat{E}_{Adj-T}	$\widehat{SE}(\widehat{E}_{Adj-T})$
1) Oct 23, 1996–Sep 30, 1997	8,260,000	1,080,000
2) Oct 1, 1997–Sep 30, 1998	15,700,000	2,340,000
3) Jul 1, 1997–Jun 30, 1998	15,500,000	2,330,000

Table 5.2.11-13. California halibut (*Paralichthys californicus*): Monthly estimates of proportional entrainment (\widehat{PE}_i) and annual proportion of larvae hatched in the i th survey period (\hat{f}_i) and associated standard errors (SE) used in estimating entrainment mortality for two analysis periods.

a) Analysis Period 3: July 1, 1997–June 30, 1998

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1997	0.000700	0.000530	0.0186	0.00284
Aug 25, 1997	0	0	0.0421	0.00582
Sep 29, 1997	0	0	0.00283	0.00107
Oct 20, 1997	0	0	0	0
Nov 17, 1997	0	0	0	0
Dec 10, 1997	0	0	0.00425	0.00127
Jan 22, 1998	0.0127	0.0155	0.0115	0.00240
Feb 26, 1998	0	0	0	0
Mar 18, 1998	0	0	0.000850	0.000600
Apr 15, 1998	0.00143	0.000650	0.761	0.0146
May 18, 1998	0	0	0.156	0.0109
Jun 8, 1998	0	0	0.00273	0.00104

b) Analysis Period 4: July 1, 1998– June 30, 1999

Survey Start Date	\widehat{PE}_i	$\widehat{SE}(\widehat{PE}_i)$	\hat{f}_i	$\widehat{SE}(\hat{f}_i)$
Jul 21, 1998	0.00136	0.000690	0.0910	0.00984
Aug 26, 1998	0	0	0.0249	0.00376
Sep 16, 1998	0	0	0	0
Oct 6, 1998	0	0	0	0
Nov 11, 1998	0	0	0	0
Dec 9, 1998	0	0	0	0
Jan 12, 1999	0	0	0	0
Feb 3, 1999	0	0	0	0
Mar 17, 1999	0.0751	0.0372	0.861	0.0112
Apr 14, 1999	0.859	0.911	0.0227	0.00392
May 24, 1999	0	0	0	0
Jun 23, 1999	0	0	0	0

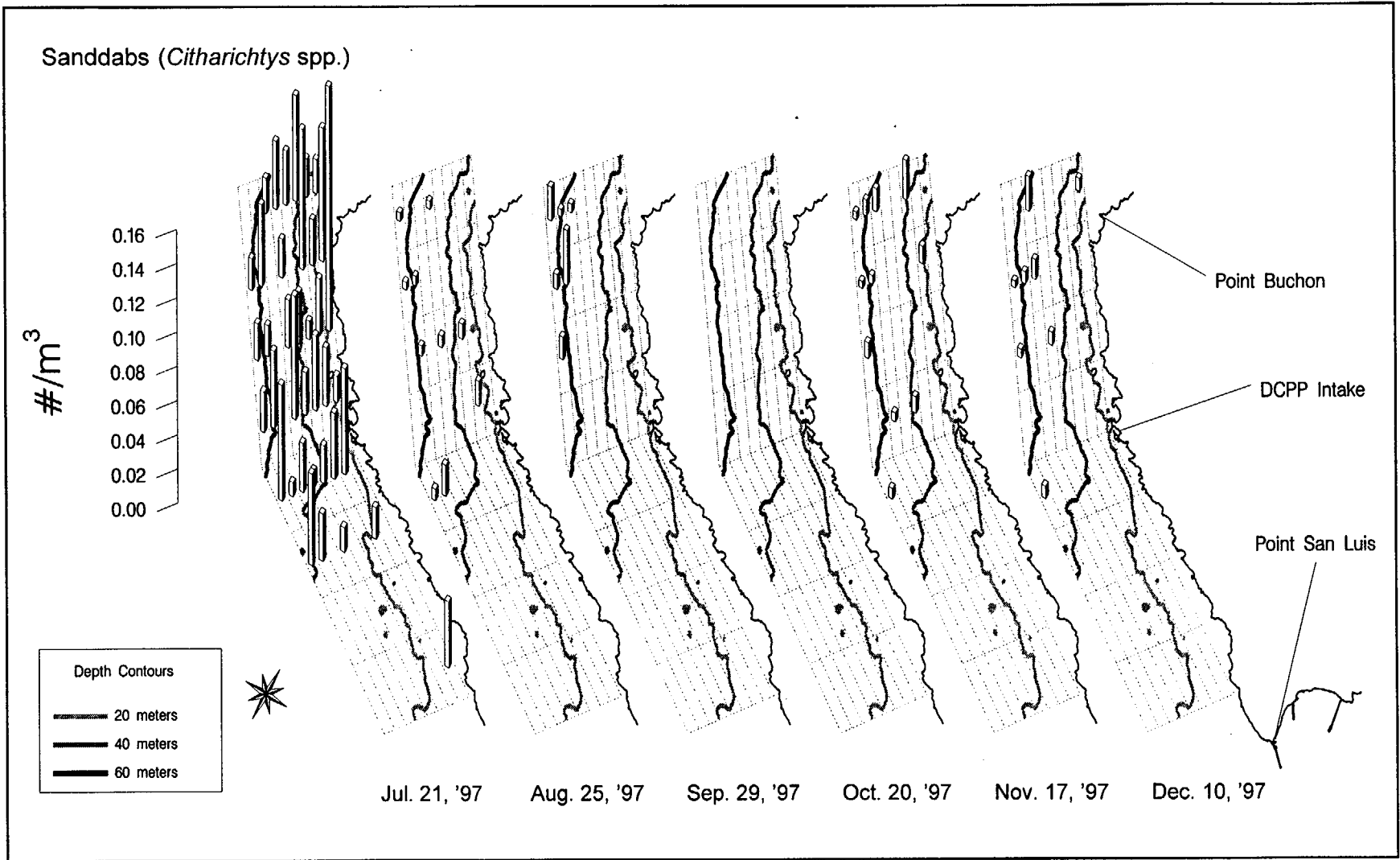


Figure 5.2.11-2a. Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

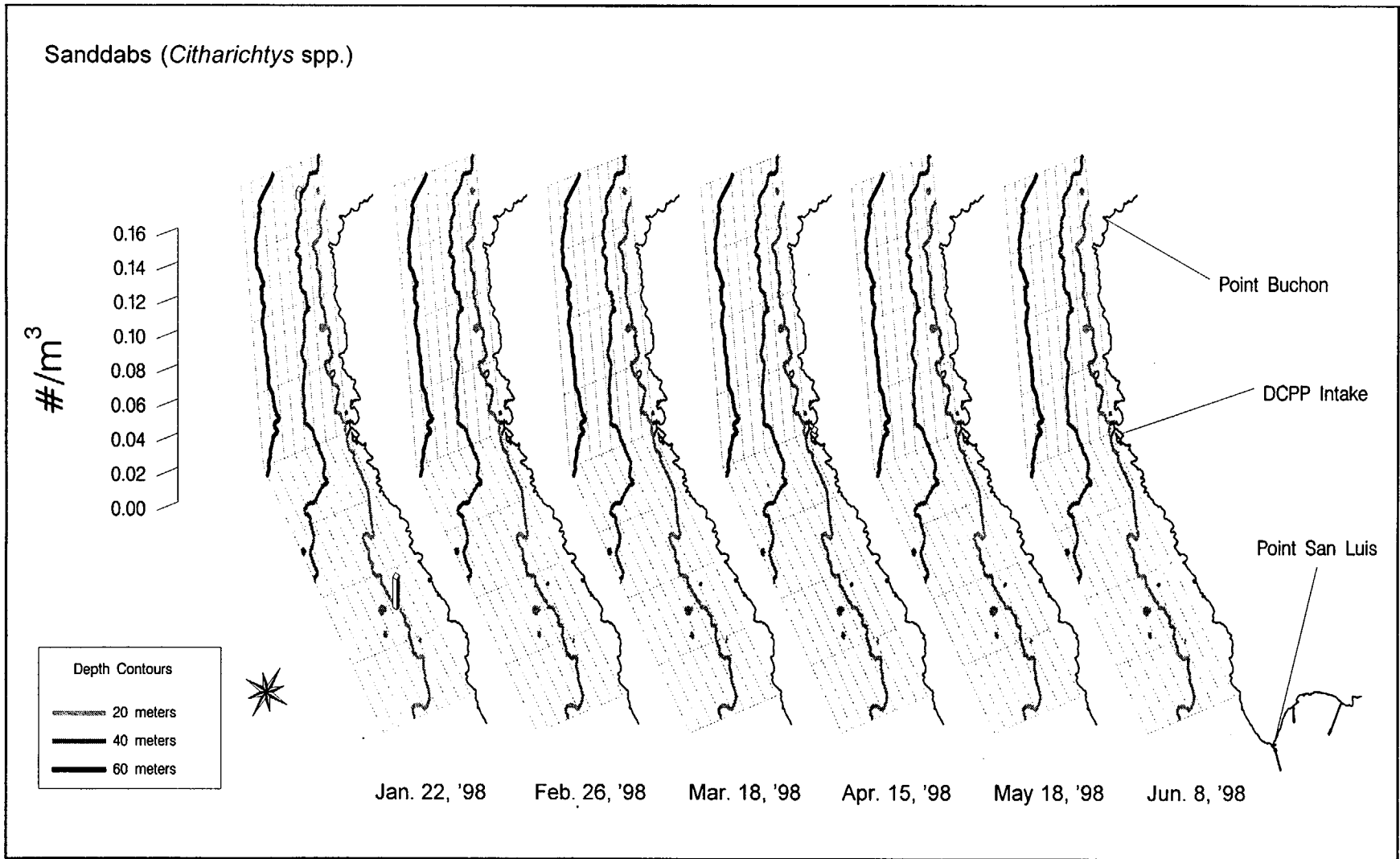


Figure 5.2.11-2b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

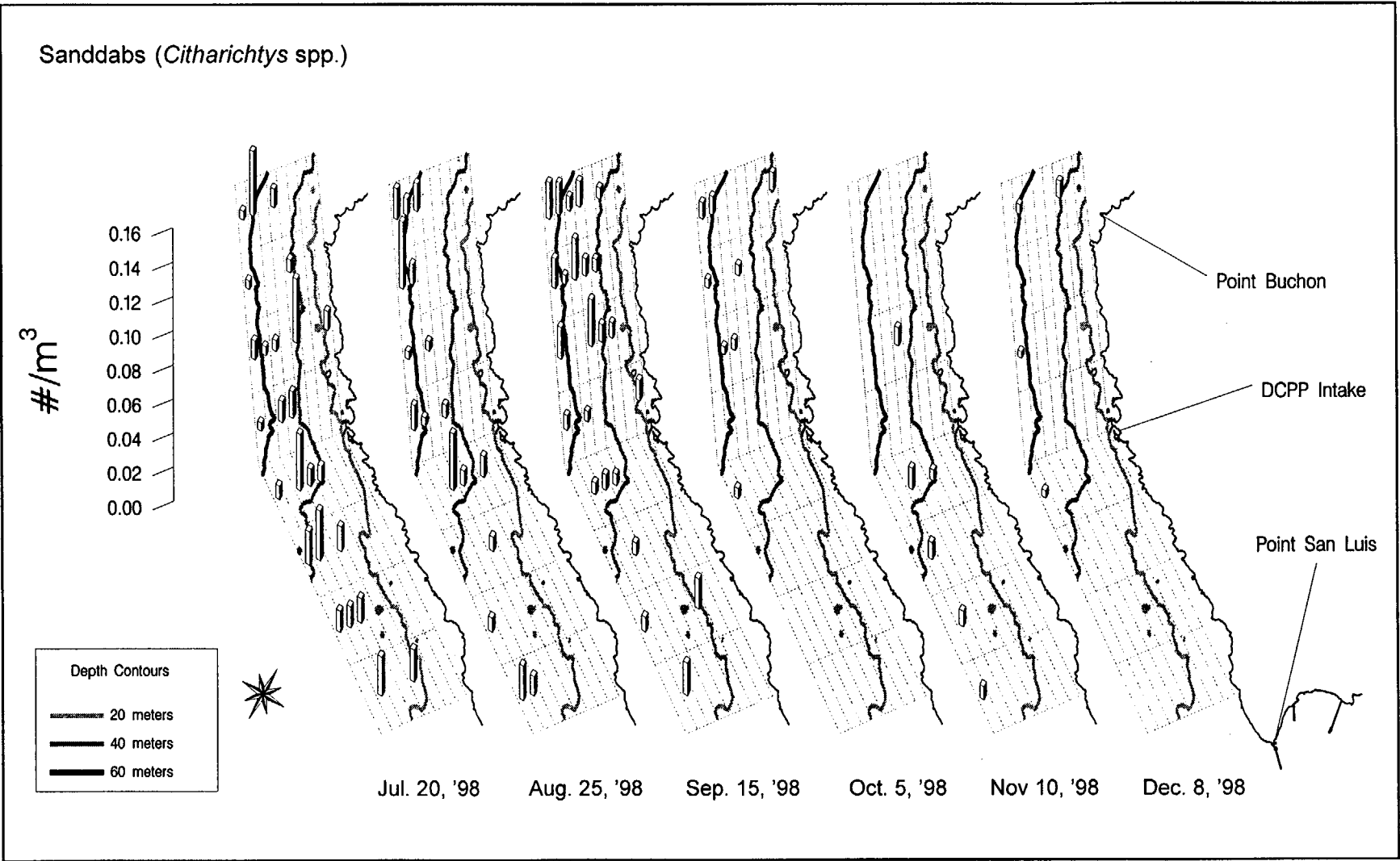


Figure 5.2.11-2c (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

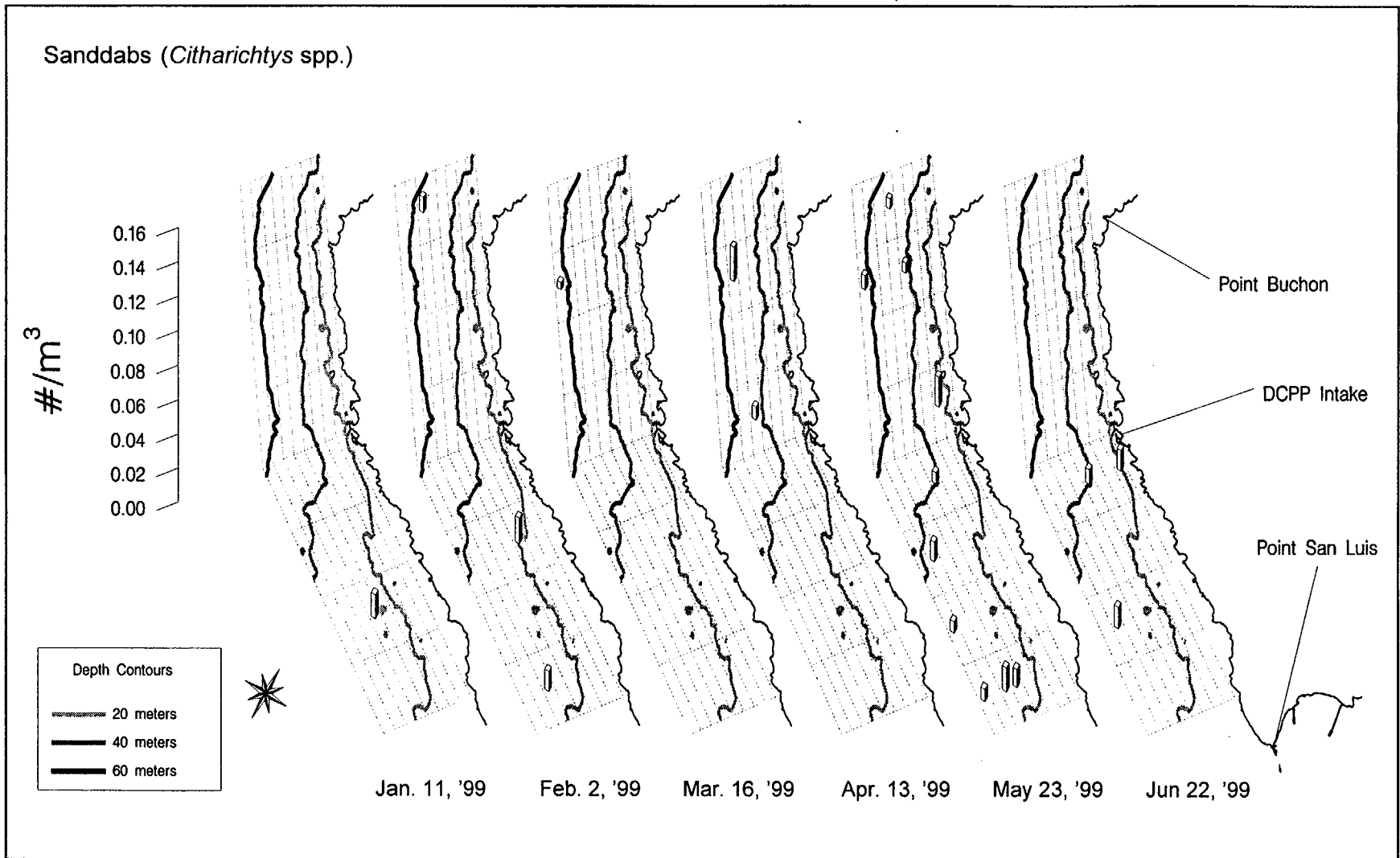


Figure 5.2.11-2d (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

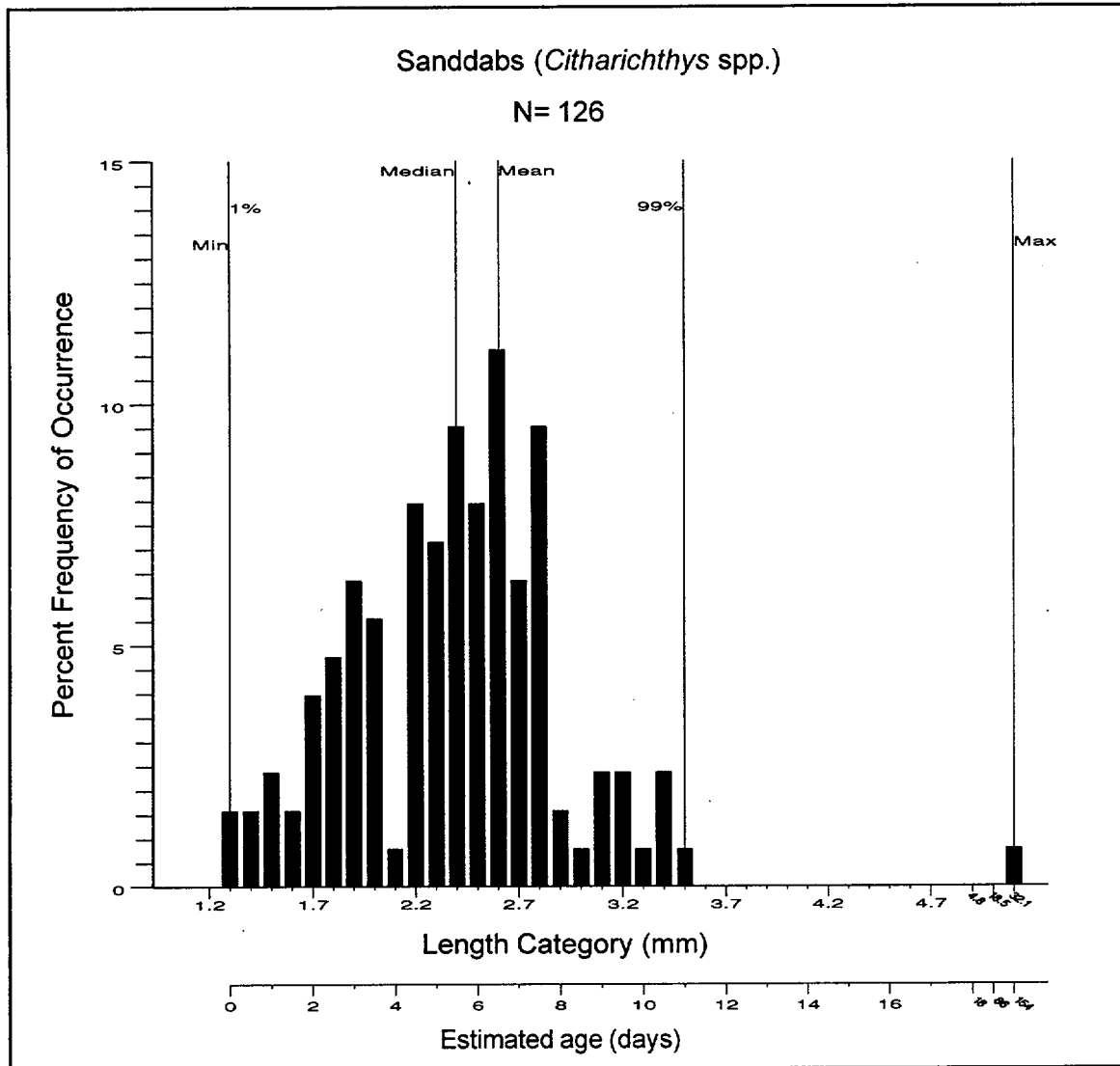


Figure 5.2.11-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

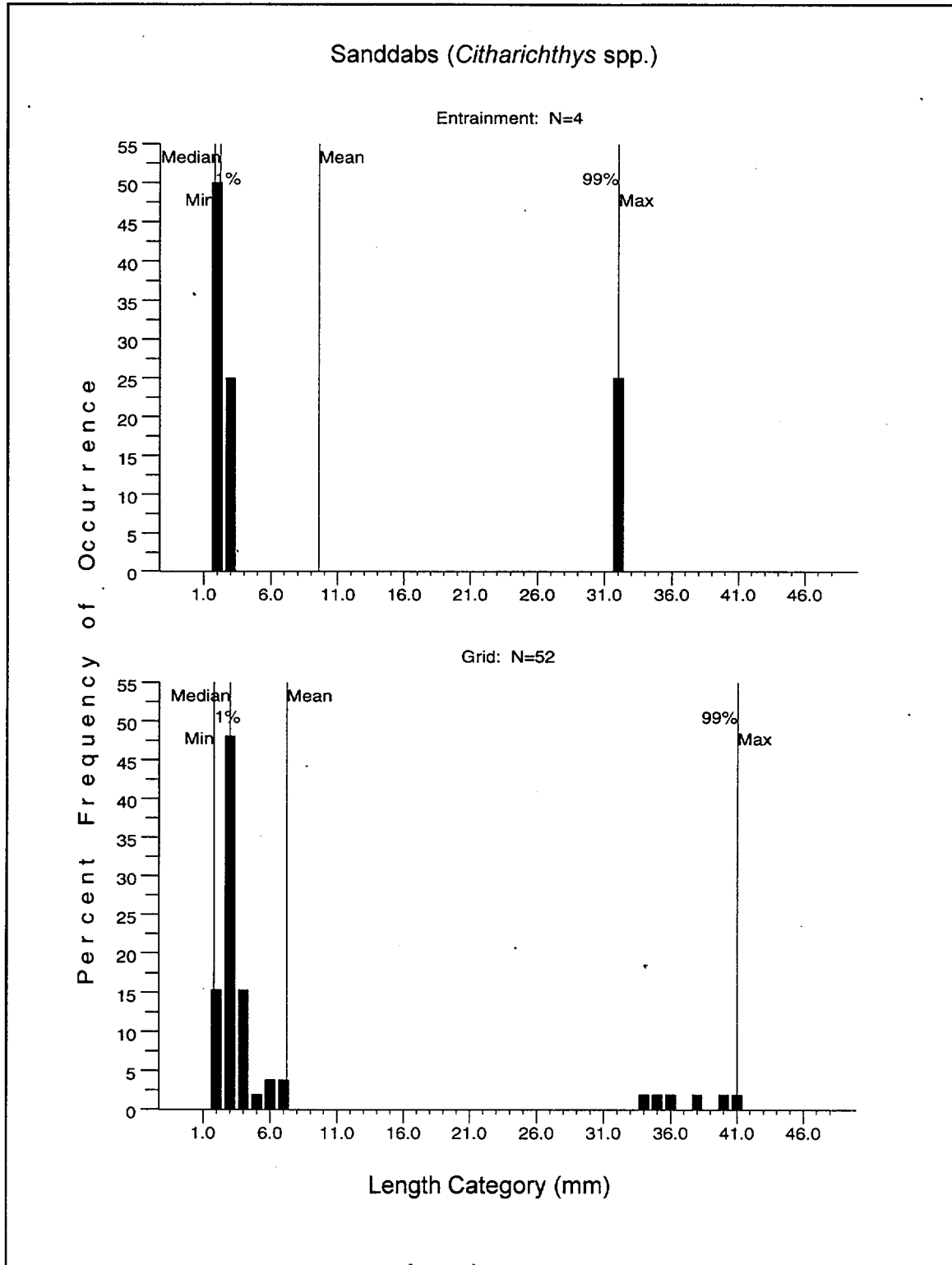


Figure 5.2.11-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

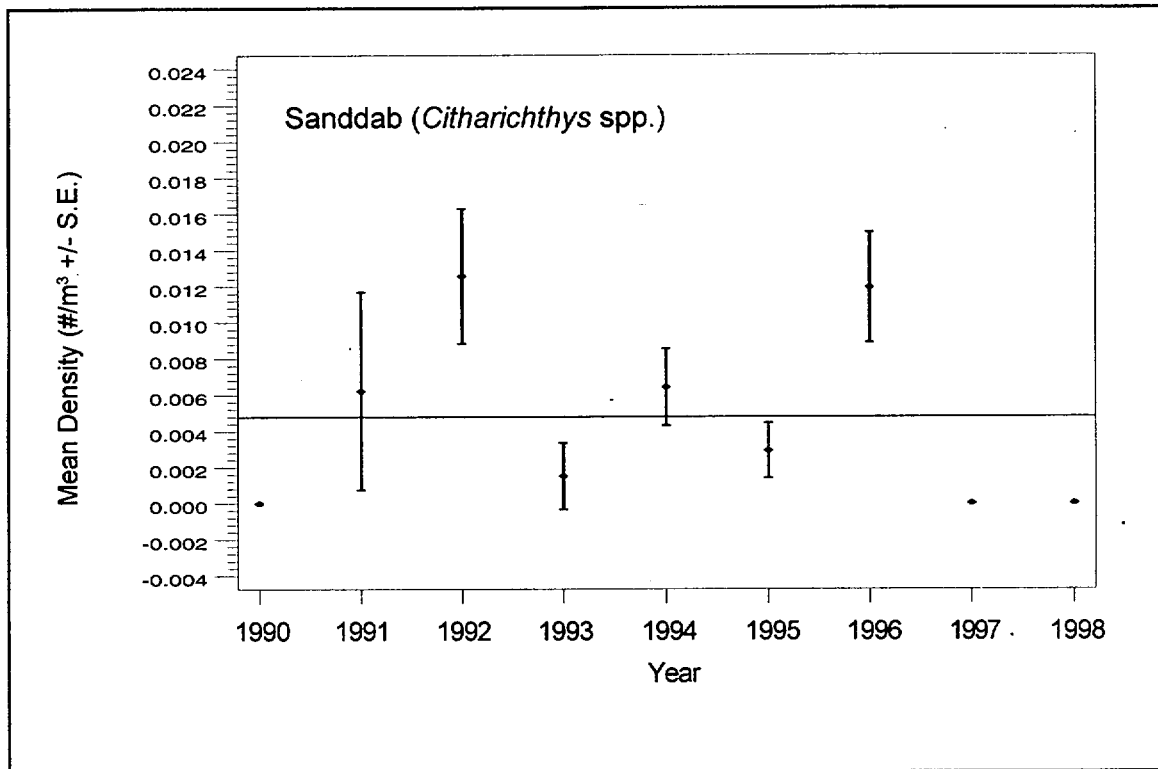


Figure 5.2.11-5. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

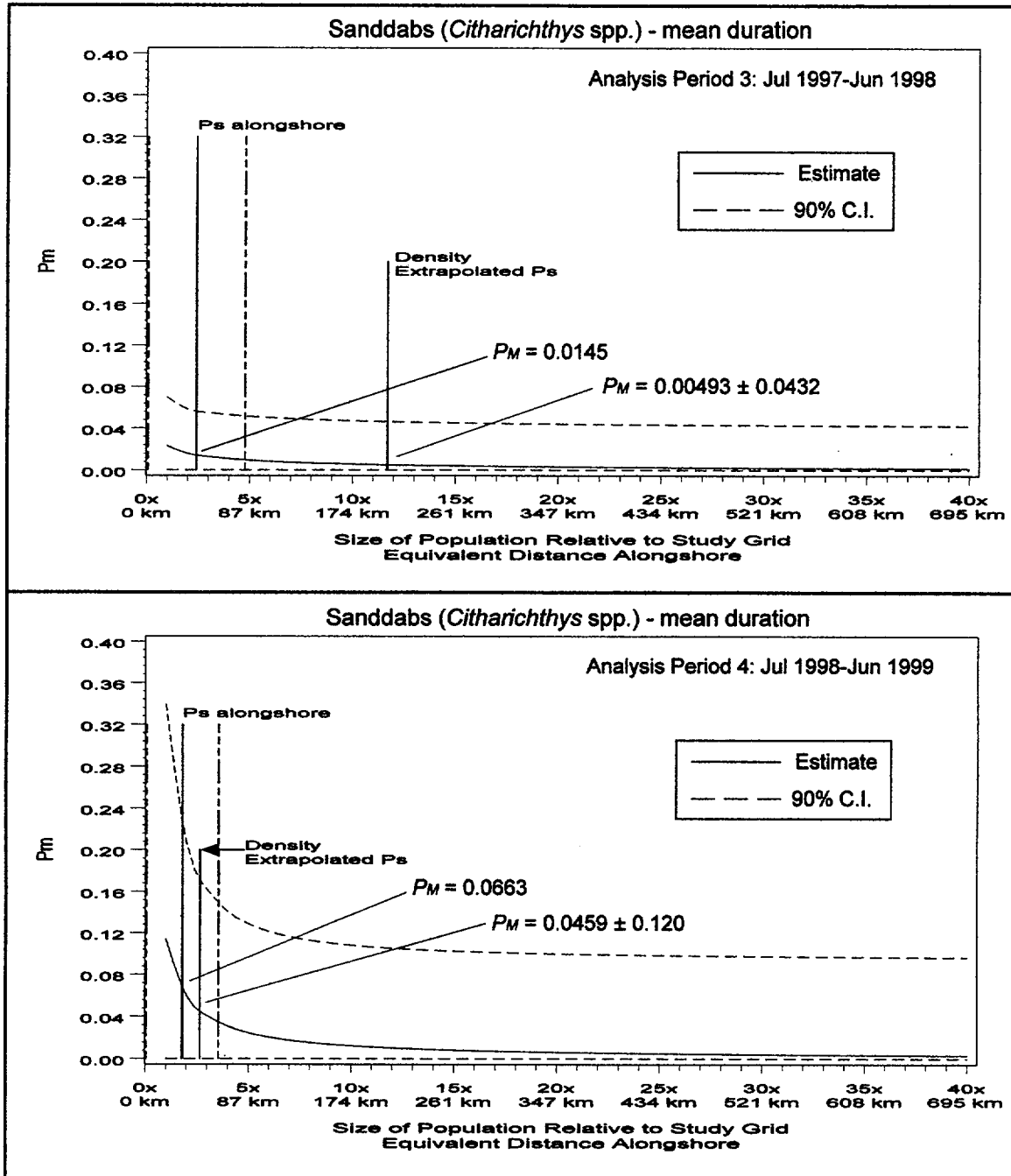


Figure 5.2.11-6a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

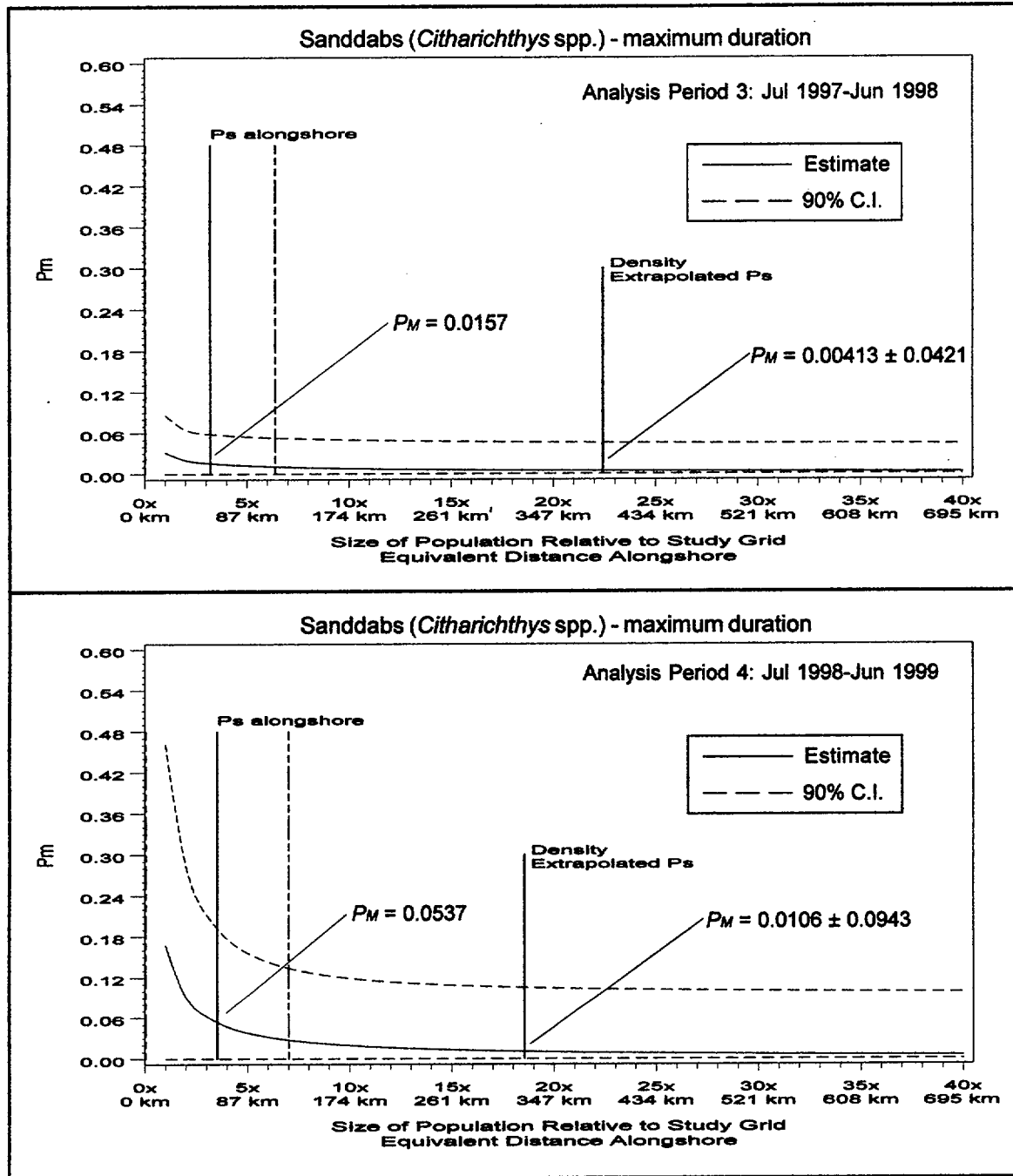


Figure 5.2.11-6b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

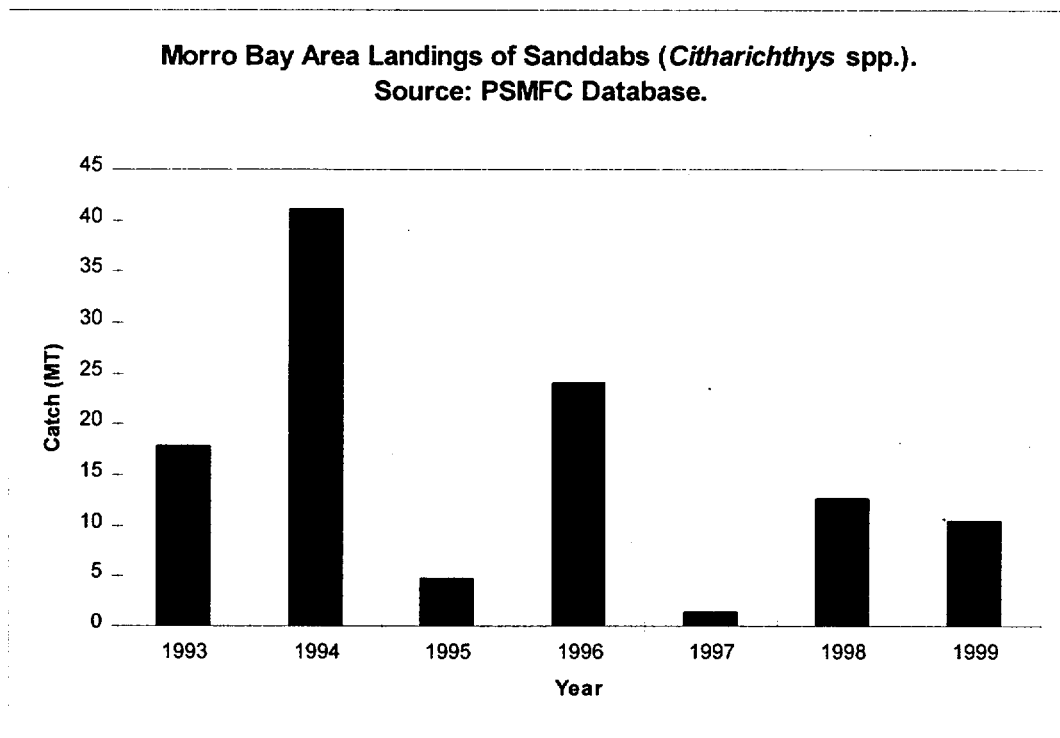


Figure 5.2.11-7. Commercial landings of sanddab species (*Citharichthys* spp.) in the Morro Bay area between 1993 and 1999 (Source: PSMFC Database).

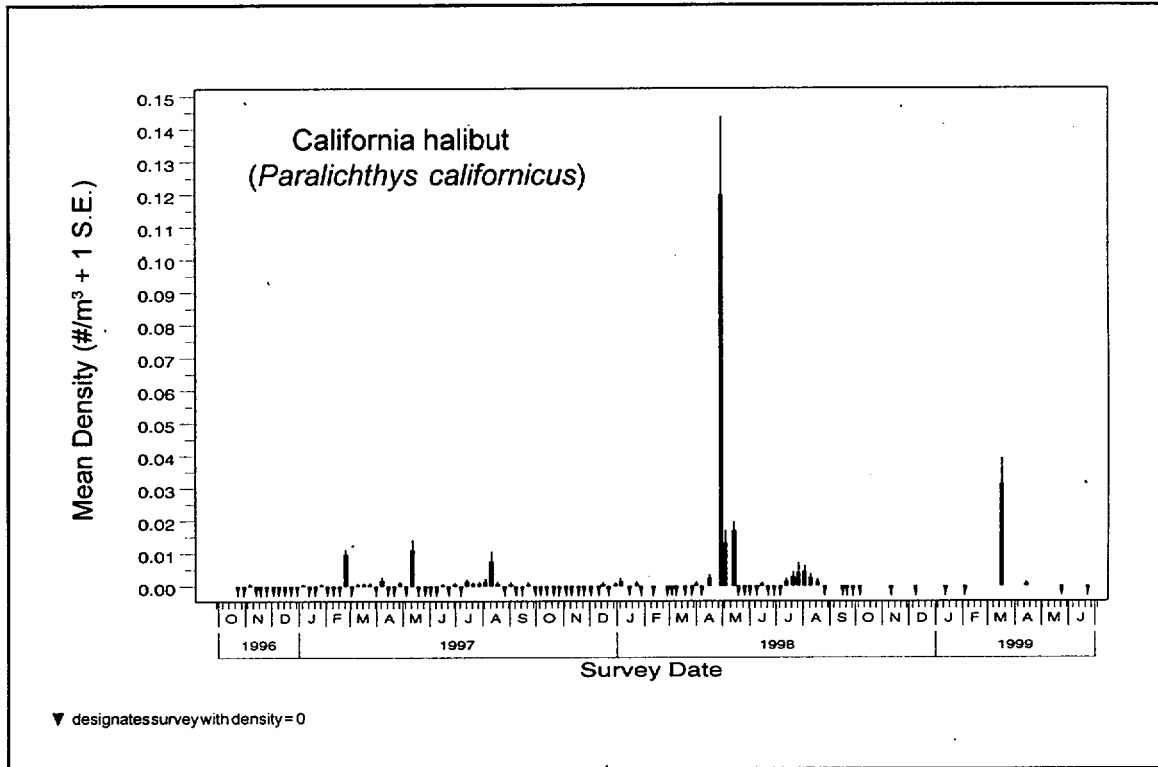


Figure 5.2.11-8. Weekly mean larval density (#/m³ + 1 S.E.) at the DCP intake.

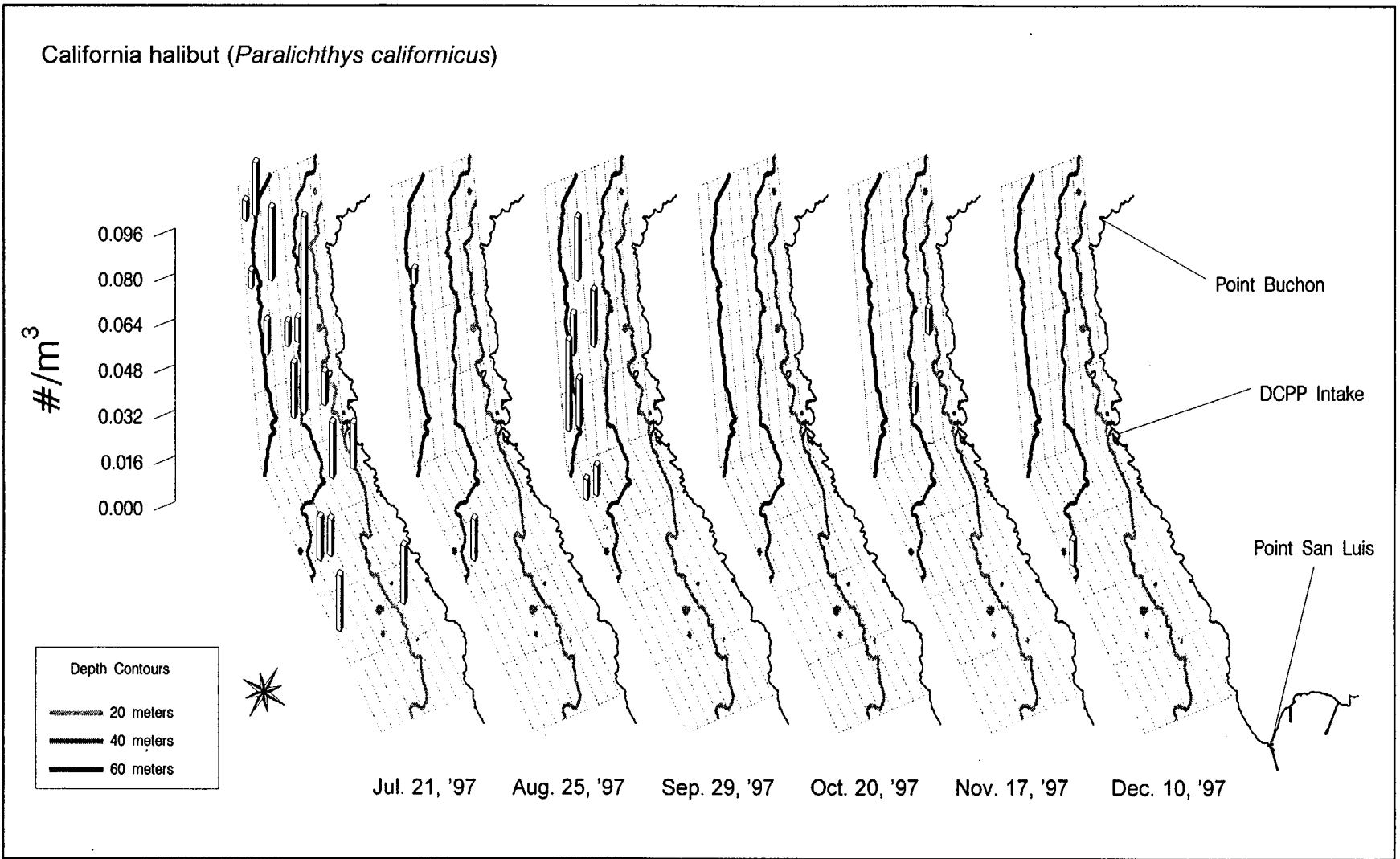


Figure 5.2.11-9a. Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

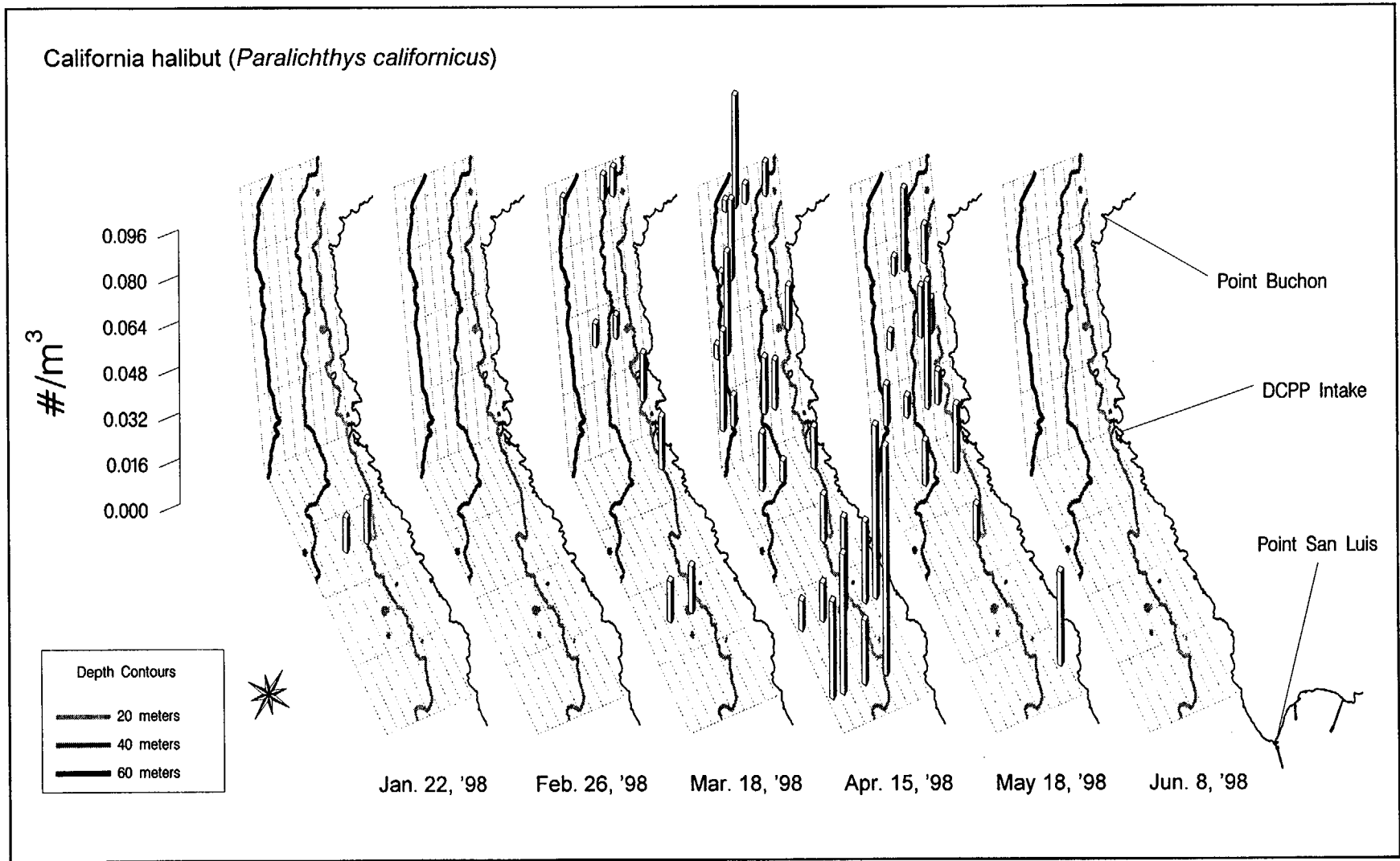


Figure 5.2.11-9b (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

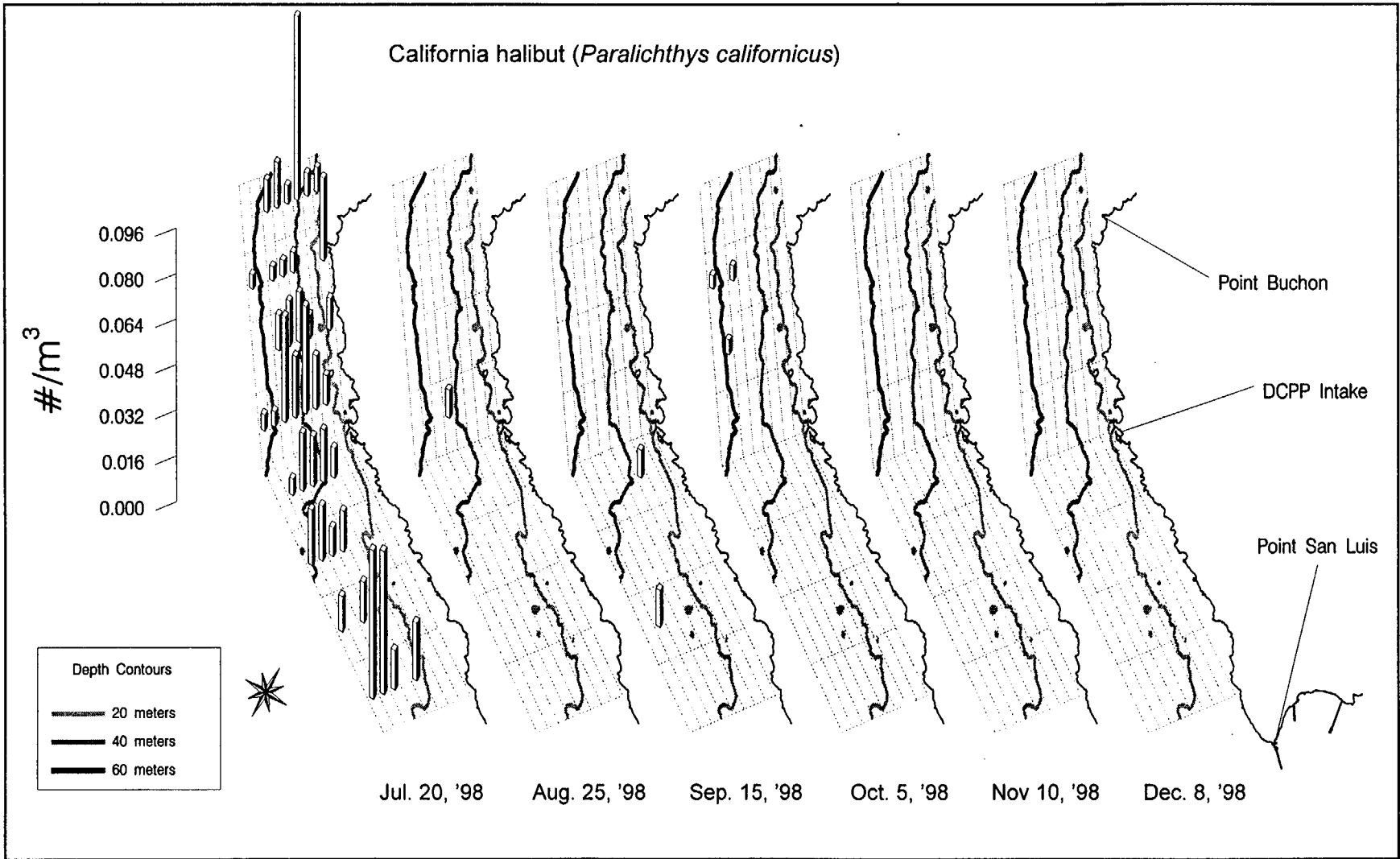


Figure 5.2.11-9c (continued). Mean larval density ($\#/m^3$) collected in the DCPD study grid cells and at the entrainment sampling location.

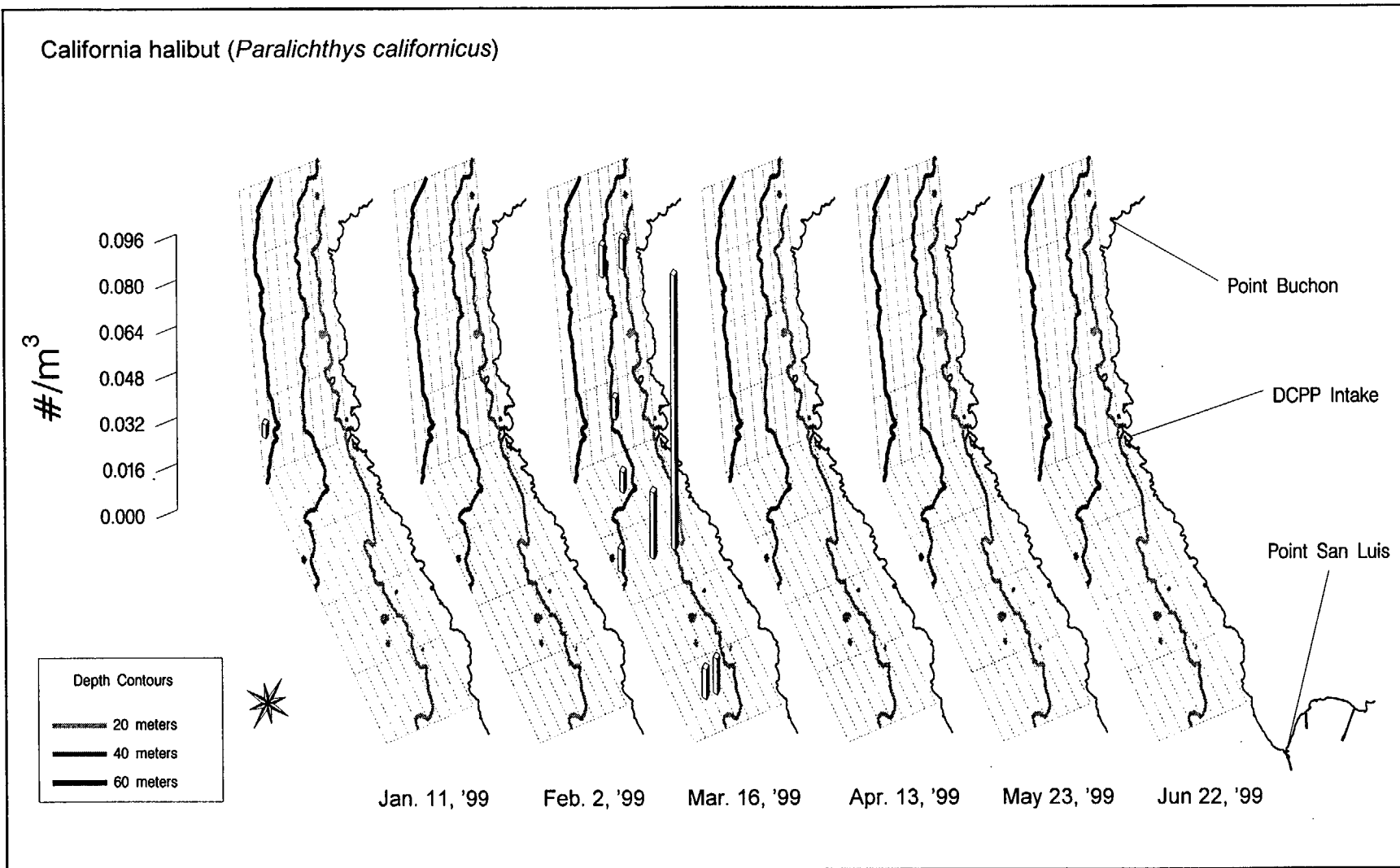


Figure 5.2.11-9d (continued). Mean larval density (#/m³) collected in the DCPD study grid cells and at the entrainment sampling location.

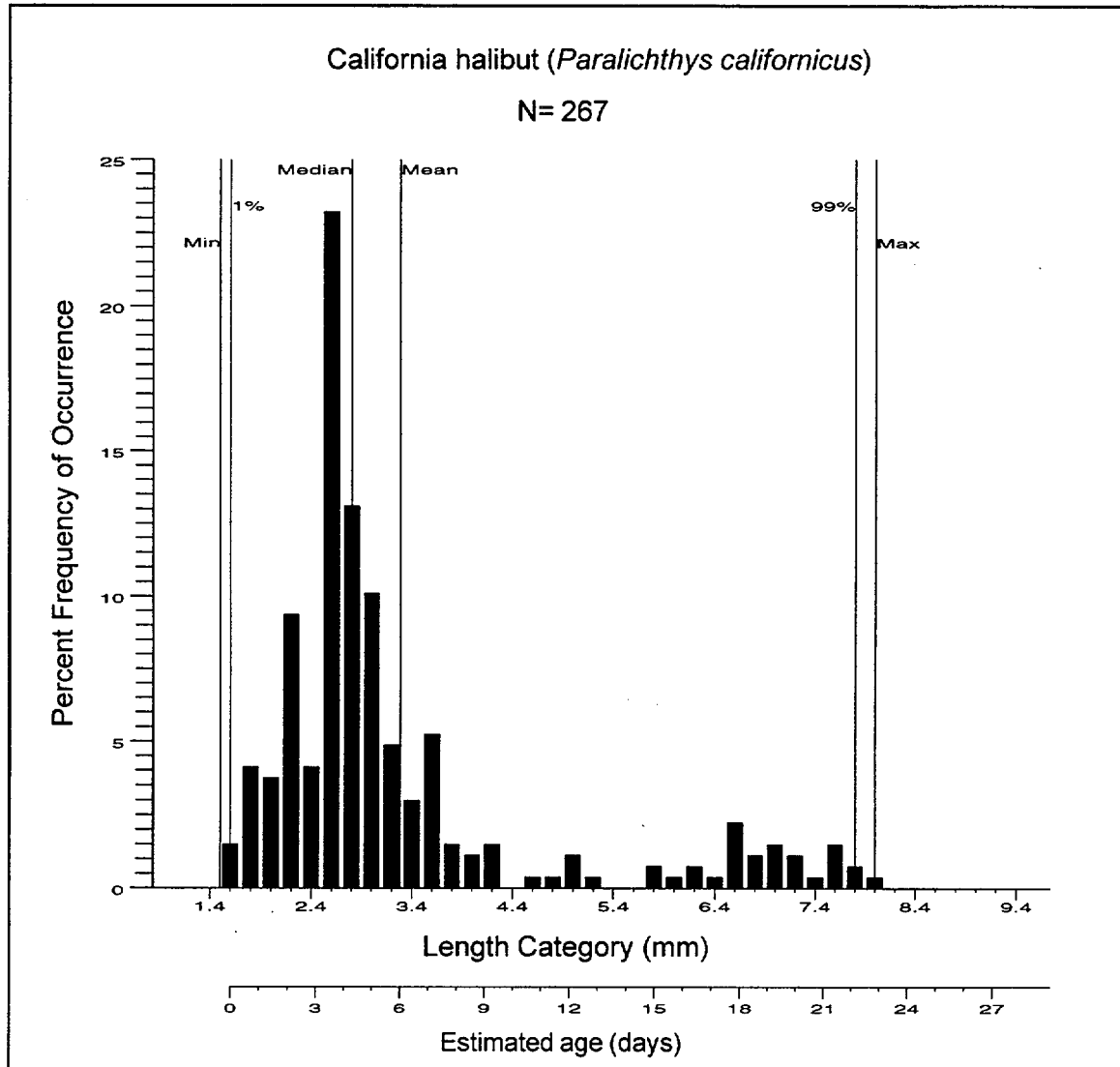


Figure 5.2.11-9. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

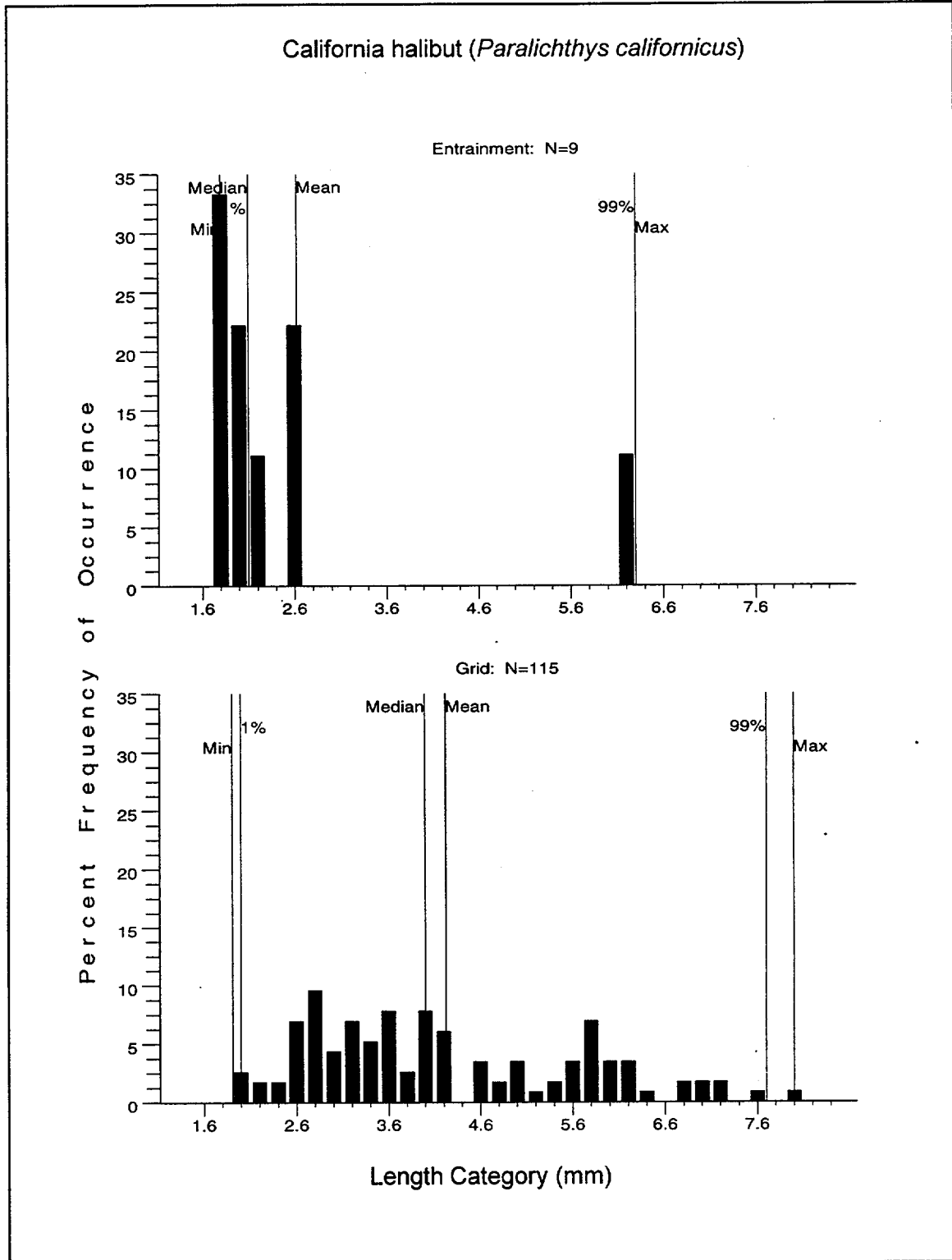


Figure 5.2.11-11. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

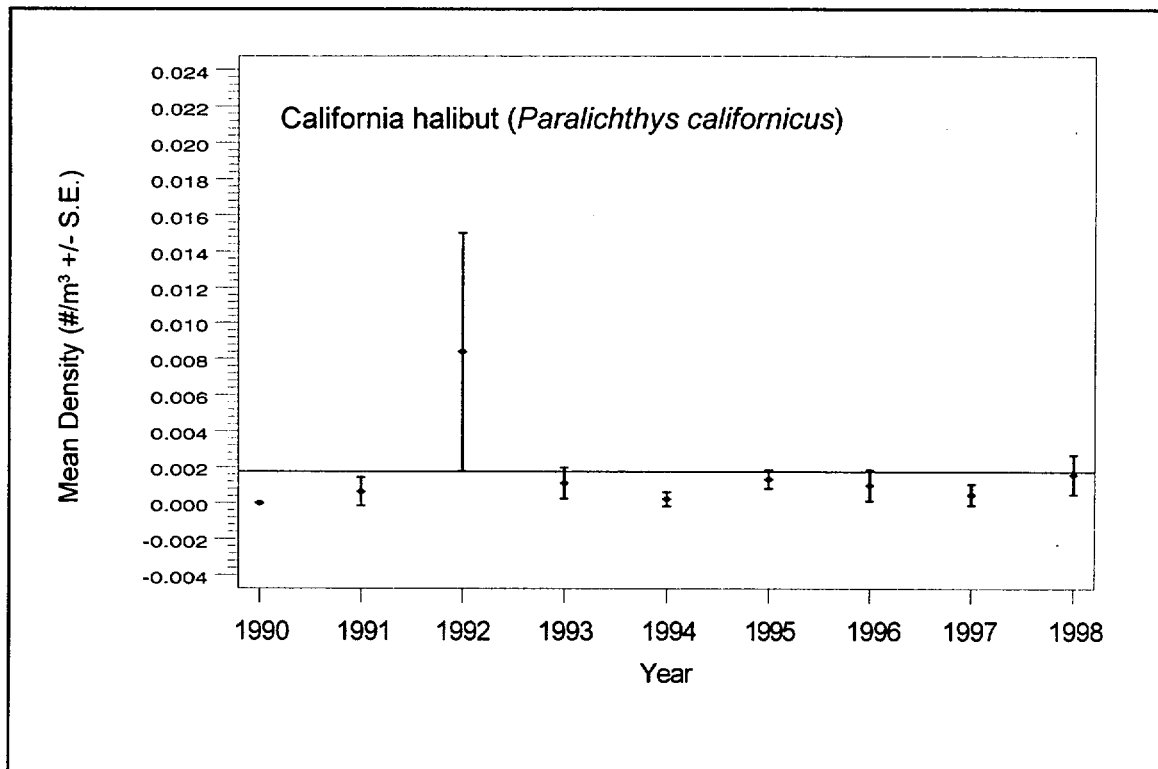


Figure 5.2.11-12. Annual mean density \pm 2 standard errors (vertical lines) and grand mean density for all years combined (horizontal line) for the Intake Cove surface plankton tows. The annual mean densities are based on seven consecutive months of data (December through June) except for 1990, which had only five months (February through June).

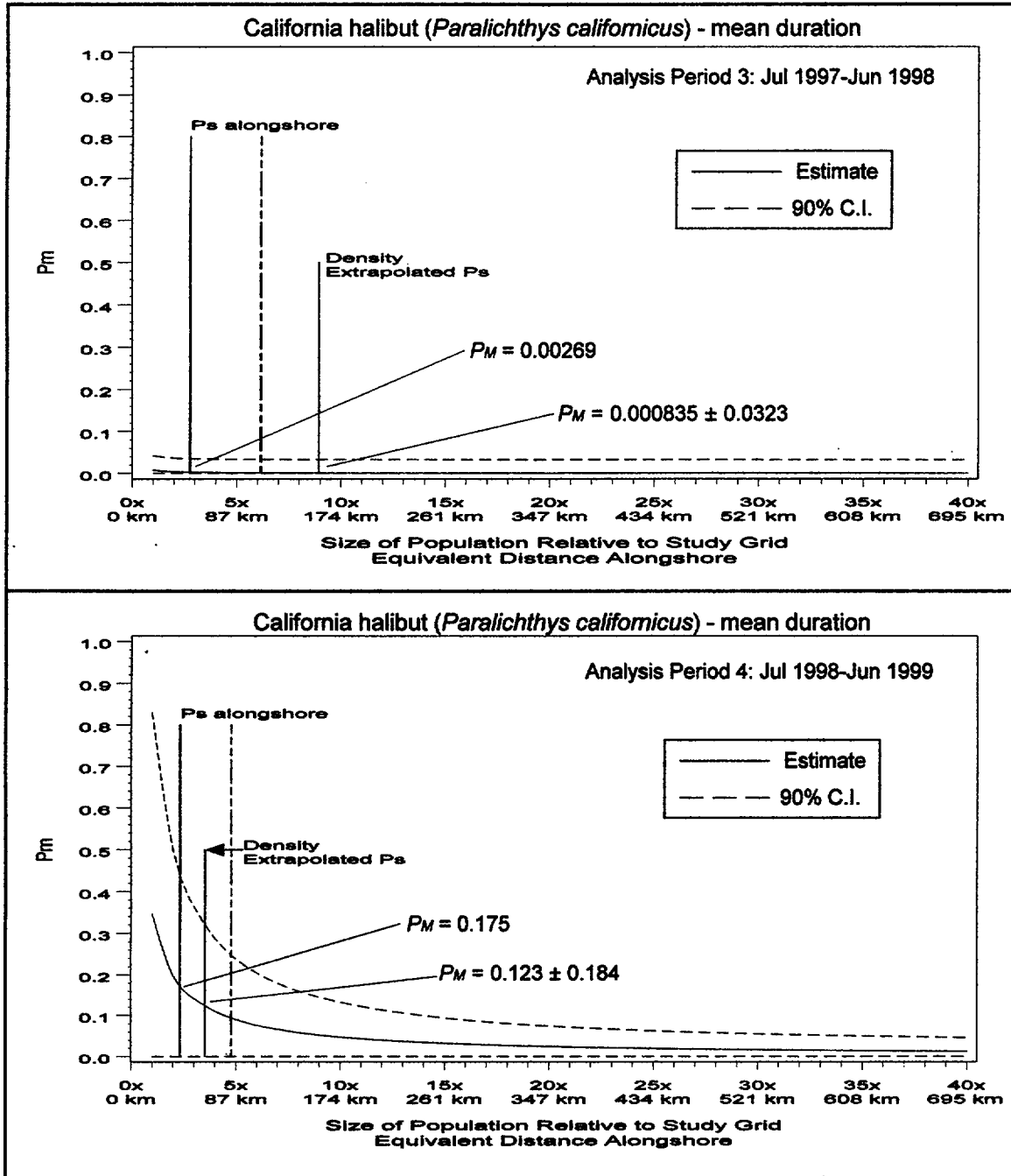


Figure 5.2.11-13a. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

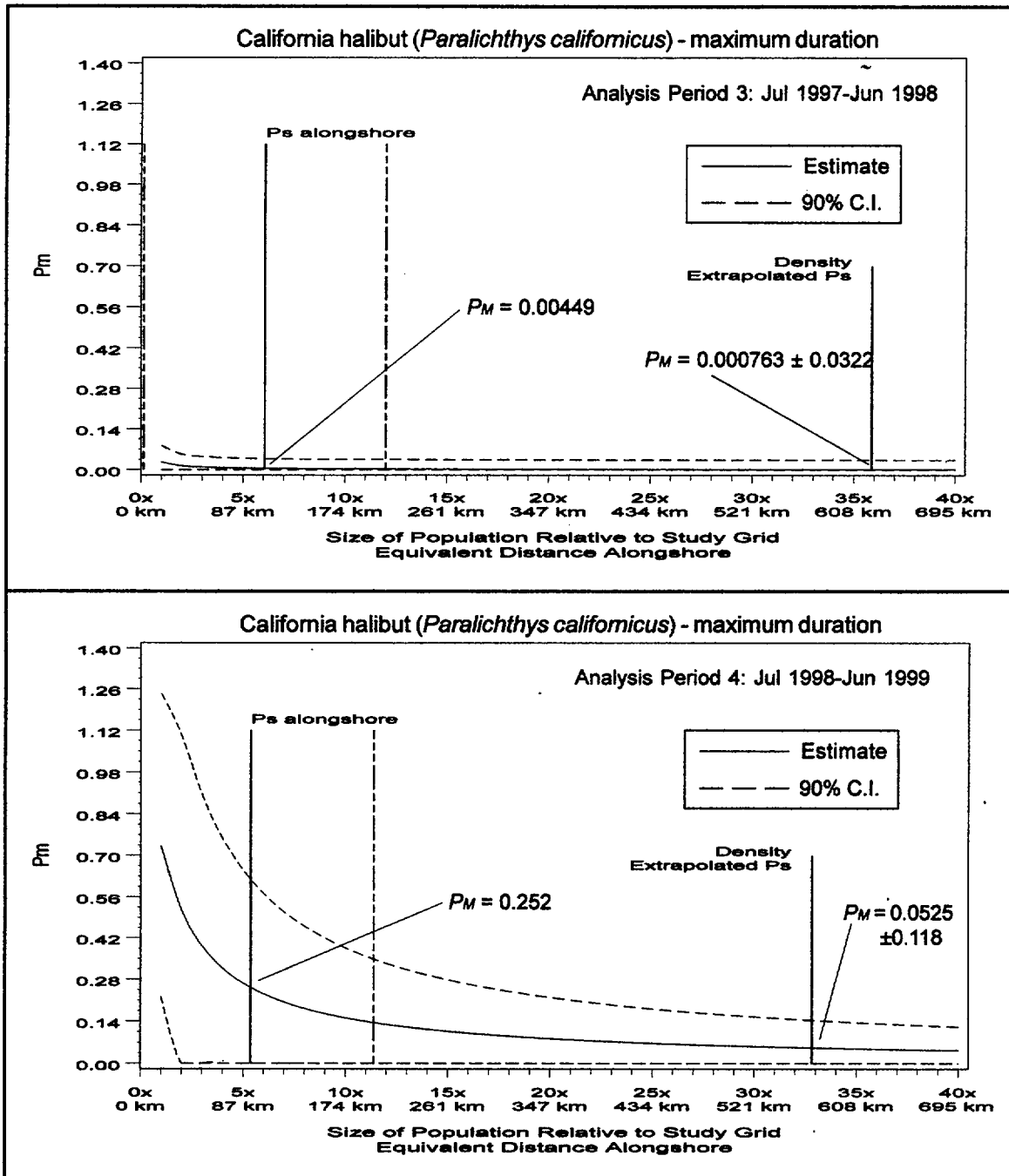


Figure 5.2.11-13b. Total annual entrainment mortality (\widehat{P}_M) and 90% confidence interval (C.I.) as a function of the reciprocal of the fraction of the population at risk and contained in the study grid (\widehat{P}_S) used to approximate the alongshore extent of the study grid population expanded on the basis of alongshore current movements and the offshore extrapolation of study grid abundance extended alongshore using both onshore and alongshore current movements with 90% C.I.'s indicated.

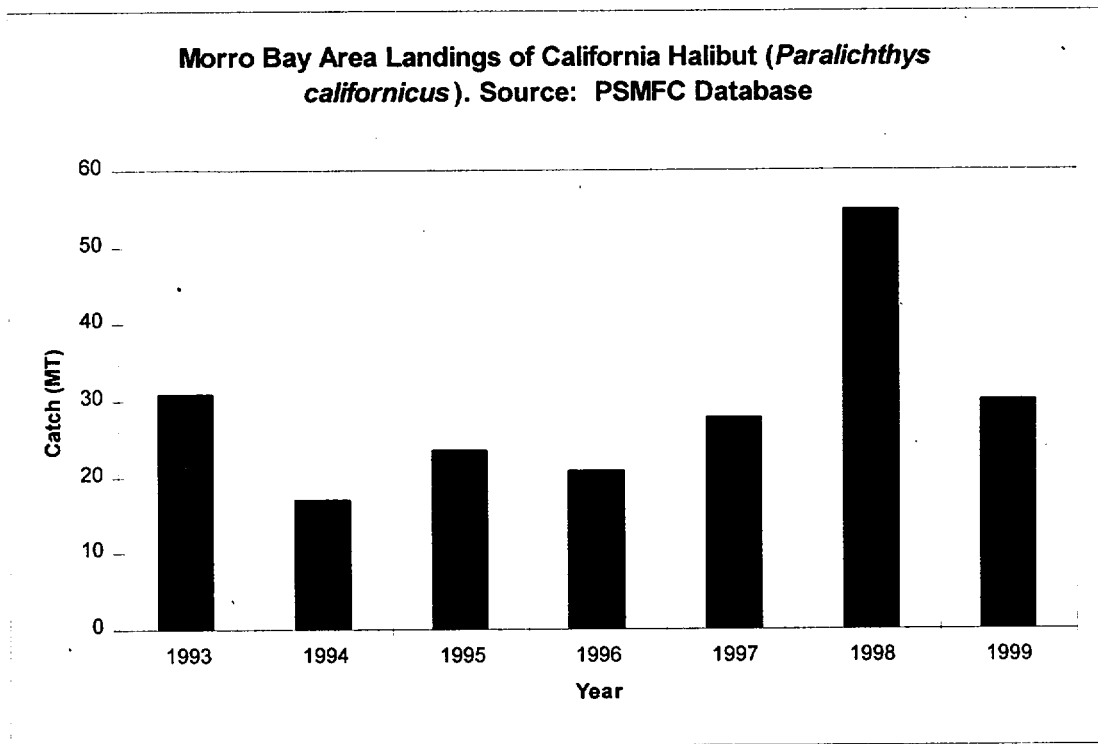


Figure 5.2.11-14. Commercial landings of California halibut (*Paralichthys californicus*) in the Morro Bay area between 1993 and 1999 (Source: PSMFC Database).

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6.0 EVALUATION OF ALTERNATIVE INTAKE TECHNOLOGIES

A number of cooling water technologies are explored which are currently in use elsewhere or proposed for use in power plant cooling water systems to minimize the loss of aquatic organisms due to entrainment and impingement. Section 316(b) of the Clean Water Act (CWA) states that "cooling water intake structures" are to "reflect the best technology available for minimizing adverse environmental impacts." As discussed in the Introduction (Section 2) of this report, USEPA has indicated that assessment of adverse environmental impacts (AEI) should be based on an evaluation of population-level effects. This report shows that Diablo Canyon Power Plant (DCPP) has not caused population-level effects and therefore, we concluded that DCPP has not caused AEI. However, we provide this section on alternative technologies in response to a requirement by the RWQCB. This section of the report includes a description of potential modifications to the present intake structure at DCPP. Additionally, for informational purposes, this section presents discussion of possible operational and technological alternatives to the current cooling water system that are not part of the intake structure although consideration of these alternatives is beyond the scope of the CWA.

This section evaluates the applicability of installing operational and technological alternatives for the existing DCPP cooling water system. For those applicable alternative technologies, we provide additional information relative to the potential cost of implementing the technology and the possible reduction of biological effects. These technologies include (1) cooling water system alternatives, (2) intake configuration alternatives, (3) behavioral and physical barriers, (4) fish collection and removal conveyance systems, and (5) intake maintenance and operational modifications.

6.1 Evaluation Criteria

A hierarchical evaluation system was used to assess which alternative intake technologies were initially evaluated on the basis of the following three criteria (Figure 6-1):

1. The alternative technology is available and proven (i.e., demonstrated operability and reliability at a cooling water intake similar in size and environment to the DCPD site).
2. Implementation of the alternative technology might result in a reduction in the loss of aquatic organisms compared to the present operating conditions.
3. Implementation of the alternative technology is applicable at the DCPD site, based on site-specific considerations of engineering, operations, and reliability.

For those alternatives that meet the three criteria, a detailed evaluation of applicability and general cost estimate is described in **Section 6-2**. All technologies considered and the application of the evaluation criteria are shown in **Table 6-1**.

A brief description and justification for the alternatives that do not meet Criteria 1, 2, and 3 are presented in the attached Appendices.

Appendix L—alternatives not meeting Criterion 1.

Appendix M—alternatives not meeting Criterion 2.

Appendix N—alternatives not meeting Criterion 3.

6.2 Applicability Analysis and Cost Estimates

This section discusses the applicability of each alternative intake technology that has met all three evaluation criteria. It is divided into two subsections: alternatives that reduce impingement and alternatives that reduce entrainment.

For those alternatives presented in previous reports, the cost figures presented here represent those original estimates (TERA 1982 and PG&E 1988a) in present day dollars as of December 1999. The annual cost and the life-of-plant cost figures presented in these earlier reports each consisted of two components: 1) capital, operation, and maintenance costs and 2) lost revenues. Other than considering the changing value of labor and material, the capital, operation, and maintenance costs of any of the alternatives was assumed not to have changed from previous estimates. To translate original cost estimates to present day values, we used representative indices from the Bureau of Labor Statistics for labor and material.

Due to significant changes in the price of electricity since the original estimates, the lost revenue component was re-forecast using the same assumed lost generation (MWe) resulting from load reduction (deratings) and lost production, but valued using a realistic plant capacity factor and the California Energy Commission's forecast of Power Exchange (PX) pricing for the price of electricity for the next 25 yr.

For comparative purposes, the cost of alternatives is expressed in net present value (NPV), which includes the total capital cost, the cost of the cumulative lost revenue, and increased maintenance costs over the life of the plant. Additionally, for the alternatives that reduce impingement, the cost per kg of fish is derived by dividing the total NPV by the cumulative weight (kg) of fish impinged for each option over the remaining licensed plant life, assumed to be 25 yr.

The cost estimations are considered to be accurate within an order of magnitude only. More accurate estimates would require detailed and plant-specific design of the various technologies. For example, neither TERA (1982) nor PG&E (1988a) considered the following costs, which would substantially add to the current estimates:

- Demolition and relocation of existing utilities, system components, plant facilities, buildings, etc.
- Security during construction and effect on permanent security boundary.
- Nuclear licensing (License Amendment Request to the NRC).
- Permitting (i.e. California Coastal Commission, RWQCB, etc.).
- Seismic design considerations.

Additionally, for cooling tower cost estimations, the following additional costs were not considered by TERA (1982):

- Tie-in with existing circulating water conduits.
- Change in pumping plant location, design, and configuration.
- New circulating water pumps (CWP) and system components.
- Changes in the turbine and condensate systems to accommodate higher cooling water temperatures.
- Salt water drift damage to existing plant facilities or structures and to electrical or mechanical equipment.

- Salt water drift damage to surrounding lands, terrestrial habitat and ecology, and agricultural productivity.

Therefore, the cost estimates provided in this report are considered approximate, likely to be conservative (low) and adequate as order of magnitude estimates.

6.2.1 Alternatives That Reduce Impingement Losses Only

The impingement rate at DCPD is low, based on 1985–86 impingement data and ongoing field observations (Section 5.1.2). In the 1985–86 study (Tenera 1998a) impingement rates were estimated at about 0.32 to 0.73 kg/day/unit. Divers observe fishes and invertebrates freely moving within the intake structure forebays and directly in front of the traveling screens (Tenera 1997a). Therefore, modifications to the intake structure can provide little improvement in reducing the number of impinged fish. The following discussion, however, provides information on possible alternative technologies to reduce impingement at DCPD, their estimated costs, and the comparison of costs to potential impingement reductions.

6.2.1.1 Increased Area Intake Structure

A detailed review of the intake velocities at DCPD (Wyman 1988), the literature on laboratory swimming performance of juvenile fish (reviewed in Tenera 1998a), and diver observations of impingement avoidance at the DCPD intake (Behrens and Larsson 1979) showed that fish impingement should be virtually independent of intake approach velocities of less than about 0.8 to 1.0 fps (present velocity at DCPD). Based on studies at Contra Costa Steam Plant (Kerr 1953) impingement is predicted to increase at intake approach velocities greater than 1.5 fps, particularly among juvenile fish that are less than approximately 80 mm in length. A reduction in approach velocities is not expected to substantially reduce fish impingement rates at DCPD. However, one approach to possibly reduce impingement would be to reduce the intake approach velocity. The approach velocity is inversely proportional to the cross-sectional area through which the water passes. Therefore, velocities entering the intake structure can be reduced by increasing the cross-sectional area exposed to the flow. Reduction in the intake approach velocity would require expansion of the intake structure including additional traveling screens to

increase the intake's cross sectional area. A design that halves the existing approach velocity was considered.

This design change assumes that reduced flow velocity translates to reduced impingement. A level of uncertainty exists around the use of a single parameter such as flow rate or velocity to accurately predict the potential for reducing impingement. Taft (1999) compares several sites with similar intake designs and flow characteristics that experience large differences in impingement. Higher rates of flow and intake velocity (through the traveling screens) are usually associated with higher impingement losses. Taft (1999) illustrates from the available data that neither velocity nor flow appear to be closely correlated to impingement rates. He concludes that impingement should be viewed as a site-specific event that is influenced by many parameters. It is the combinations of environmental conditions and species life stages that interact to influence impingement.

Plan and section views of the proposed modification to the intake structure are presented in **Figures 6-2 and 6-3**. As indicated in these figures, the modification would involve expanding the intake structure towards the ocean side with approximately 45° flare and deepening the existing intake invert slab elevation to (-) 46.0 feet.

Construction of the expanded intake structure would result in a major construction effort and require installing a cofferdam and dewatering the existing intake structure. Disruption associated with construction and dredging activities would contribute to localized impacts on kelp and benthic organisms inhabiting the Intake Cove.

During intake construction, the circulating water flow required for the operation of Units 1 and 2 would be disrupted, resulting in a complete loss of generating capability from both units for a period of approximately one year. Operating one unit while modifying the other unit would not change the cumulative revenue loss appreciably, because the construction duration for each unit would not change substantially. A major challenge to any construction project in front of the existing intake structure would be the potential for storm conditions interfering with work in the intake bays.

While the units are shut down, the auxiliary saltwater (ASW) system would have to remain operable to preserve the function of those systems necessary to maintain the plant in a safe shutdown mode and protect the nuclear fuel. Therefore, an extension of the ASW system would be required to provide continuous flow to the ASW pumps. Since the ASW system is a nuclear safety-related system, necessary safety-related design considerations such as seismic safety, control of heavy loads, and interaction between safety and non-safety related items would have to be evaluated as part of intake structure design and modification.

Prior to finalizing the design of the expanded intake structure, a detailed engineering evaluation would be necessary to ensure compatibility between hydraulic flow patterns, cooling water volumes, and pressure regimes associated with the expanded intake structure and the existing Units 1 and 2 condenser system. License amendments required to accommodate a modification such as this have not been reviewed. Additionally, other environmental and safety design considerations such as the effects of earthquakes, tsunamis, and probable maximum loads would require evaluation. These would result in additional costs that have not been factored into the following cost estimates.

The estimated capital cost for this project would be on the order of \$51,000,000. In addition, the cumulative lost revenue and increased maintenance would be approximately \$590,000,000 over the life of the plant. The implementation of this technology has a net present value (NPV) of (-) \$275,000,000. This results in a cost of \$61,700 to save each kilogram of impinged fish, assuming a 100% reduction in impingement over the remaining life of the plant.

6.2.1.2 Angled Screen Intake Structure

Angled traveling screen intakes are designed with conventional screens set at an angle to the incoming flow. A fish diversion system is installed at the downstream end of the intake such that incoming fish are directed along the face of the screens to the fish diversion path. Fish diversion systems include various designs of pivoting, fixed, or traveling screens, louvers, associated with traditional bar racks.

These intake designs have been utilized in both hydroelectric and thermal power station intakes to minimize impingement. At Brayton Point Station Unit 4 in Massachusetts, an 18 mo (October 1984 to March 1986) biological evaluation was conducted to determine the species, number, and initial and extended survival of fish diverted from the angled screen intake (Davis et al. 1988). The angled screen intake system had a high diversion capability and demonstrated effectiveness for mitigating fish impingement. Initial and extended survival varied by species; however, a certain group of numerically dominant taxa was classified by the authors as "fragile" (primarily, bay anchovy and Atlantic silverside). The fragile group had a calculated survival below 25 percent and a "hardy" group, dominated by winter flounder and northern pipefish, had survival values greater than 65 percent. The diversion efficiency for all species combined was 76 percent. Nine of the top 12 taxa collected had diversion efficiencies greater than 83 percent. The diversion flow collections resulted in an initial survival rate of 58 percent for all taxa (n= 28,186) combined. The initial survival rate ranged from 6 percent for bay anchovy to nearly 100 percent for American eel. Initial survival with the exclusion of bay anchovy was 83 percent. Extended survival for all fish (n=9,209) collected at the diversion flow was 63 percent. Extended survival trends were similar for the major species involved. Survival ranged from a low (bay anchovy) of 0 percent to a high over 99 percent (tautog wrasse).

Oswego Steam Station Unit 6 utilizes an angled screen diversion system similar to the system at Brayton Point Station (LMS 1992). Biological studies were conducted to investigate the effectiveness of the screens as systems. Alewife (herring) and rainbow smelt made up 90 percent of the collected species (from April 1981–March 1983). Diversion efficiency was 79 percent and 74 percent for alewife and rainbow smelt, respectively. The combined diversion efficiency for all the species collected was 78 percent, ranging from 53 percent for mottled sculpin to 95 percent for gizzard shad. Initial survival ranged from a low of 45 percent for rainbow smelt to a high of 87 percent for emerald shiner. A total of 34,294 individuals from the seven most frequently collected species were examined for initial survival, and 7,534 fish were observed for latent survival. The lowest latent survival rate was exhibited by alewife (22 percent) while the highest was mottled sculpin (94 percent). Overall, the angled screen system was effective in diverting

fish from the primary screenwell through the secondary screenwell back into the lake. The degree of effectiveness varied widely by species; size class or age, and condition of the population.

A full-scale angled screen test facility was constructed at the Danskammer Point Generating Station on the Hudson River in 1981 (LMS 1985). The angled screen facility was located in the cooling water intake canal and consisted of two 3 m (10 ft) wide vertical traveling screens set at a 25 degree angle to the approach flow. The effectiveness of the system was evaluated over a three year test period (LMS 1985). Diversion efficiency ranged from 95 to 100 percent, with a mean of 99 percent. Species included bay anchovy, blueback herring, white perch, spottail shiner, alewife, Atlantic tomcod, pumpkinseed (sunfish) and American shad. Overall, system efficiency (diversion efficiency times initial survival times latent [96 h] survival) ranged from 68 percent (alewife) to 99 percent (spottail shiner) with a mean of 84 percent (LMS 1985).

Angled traveling screen intake structures have been used in a marine environment and are well suited for reducing impingement. Wave energy and debris loading events that occur at DCPD were probably not experienced at facilities that have installed these screens. Angled screen intakes do not prevent entrainment of larval organisms.

One feature of angled screen intakes is that the velocities normal to the screens is quite low, on the order of 0.03 m/s (0.1 ft/sec) to 0.15 m/s (0.5 ft/sec) (EPRI 1999). Implementation of an angled screen intake at DCPD would require a major reconstruction of the intake to accommodate additional (at least twice the number currently installed) screens in the angled configuration. Although a specific design and cost estimate has not been prepared for this configuration, it is judged that the costs would be similar to the costs associated with the expanded area intake described in **Section 6.2.1.1**. Since this alternative addresses only impingement, the costs compared to the reported impingement rate would not make this option cost effective for implementation at DCPD.

6.2.1.3 Traveling Screen Operating Cycle Modifications and Fish Conveyance Systems

Operational modifications to the vertical traveling screens, such as the use of continuous screen rotation, screen baskets with “fish buckets”, low-pressure spraywash, and fish return sluiceways, are alternatives that have been proposed by the industry to increase the biological effectiveness of conventional vertical traveling screens. Typically, all of these elements must be used together to effectively reduce impingement mortality. Costs for the combination of modifications are presented in the section on *Combinations of Vertical Traveling Screen Modifications* (below).

Continuous Traveling Screen Rotation

Several studies have been performed to determine the effectiveness of continuous screen rotation on impingement survival. Studies conducted at the Pittsburg Power Plant (PG&E 1992) show that increasing the screen rotation frequency from 3 h intervals to continuous rotation did not result in consistently improved impingement survival for invertebrates such as California bay shrimp, brackish-water crabs, and oriental shrimp.

In contrast, more (26–56% after 96 h) young-of-the-year (YOY) white perch (*Morone americana*) survived impingement on continuously operating traveling screens compared to those operated 2–4 h intermittently (19–32% survival after 96 h). Likewise, striped bass (*Morone saxatilis*) latent survival improved (32–62%) after impingement on continuously operating screens compared to bass impinged on intermittently operated screens (26% after 96 h; King et al. 1978). King et al. (1978) concluded continuous traveling screen operation allowed maximum initial and latent survival for white perch and striped bass YOY.

Continuous screen rotation did not consistently result in improved impingement survival of the marine organisms examined at the Moss Landing Power Plant (PG&E 1988a, Section 4.2). Among impinged fish, hardy species such as plainfin midshipman and crabs had a high rate of survival regardless of screen rotation frequency. Increasing screen rotation frequency at the Moss Landing Units 6 and 7 intake did, however, contribute to a substantial increase in impingement survival for both surfperch and rockfish, which together constitute about 11 percent (by weight) of the fish impinged at DCP (PG&E 1988a, Section 4.2).

The studies referenced above show that impingement survival varies from site to site and is species specific. Testing of continuous screen rotation at DCPD would be required to determine if a reduction in impingement is achievable.

The current debris removal system at DCPD is designed to handle large quantities of kelp and other debris. The material washed from the screens is washed to a sluiceway and directed to a large sump. This material and wash water is pumped to a location approximately 244 m north of the intake structure at the shore end of the west breakwater. Grinders are installed at the entrance to the refuse sump to reduce the size of the kelp and algal debris to prevent clogging of the debris removal system. No impingement survival is expected with this system. This system is needed to support plant operation with the high debris loads. Increasing intake screen rotation offers the possibility of increasing survival of some impinged organisms only if this method is used in conjunction with other modifications (such as a gravity sluiceway and fish baskets to increase survival). These configurations are described in the next two sections.

Gravity Sluiceway Fish Return and Low Pressure Spraywash

There are two basic types of sluiceways for the return of impinged organisms and debris to the waterbody: one uses a pump to transport collected material away from the intake and one uses gravity flow. Based on the existing DCPD intake design, a gravity return sluiceway directing flow to the south end of the intake would be the least complex and least expensive option.

As described in the previous section, the current DCPD screenwash system is not designed to return impinged organisms to the receiving waterbody intact. The high debris loading experienced at DCPD requires that this system function in a way that makes impingement survival unlikely, and hence no survival of impinged organisms is expected.

To increase impingement survival at DCPD, a separate fish return trough, low pressure spray wash, and fish collection baskets as described in the next section would be required. Based on construction estimates, the implementation of a low pressure spray wash and fish return system would cost about of \$12,000,000. NPV analysis for this modification in conjunction with replacing screen baskets is included in the next section.

Combinations of Vertical Traveling Screen Modifications

Several modifications to conventional vertical traveling screens have been studied in recent years in an attempt to reduce the mortality of impinged organisms by incorporating new design features that improve the survival of impinged organisms. Such state-of-the-art modifications act to enhance fish and invertebrate survival related to screen impingement and spraywash removal. Screens modified in this manner are commonly called "Ristoph Screens". These modifications include the following features:

1. Hydrodynamically improved, watertight fish collection buckets along the base of each screen panel to provide a holding area for organisms during screen rotation;
2. Smooth woven mesh (e.g. 1.6 mm by 12.7 mm rectangular mesh) installed on the screen baskets to minimize abrasion;
3. Lighter composite screen baskets which allow for increased rotational speed;
4. A second sluiceway/fish return system with combined low pressure spray wash to transport organisms removed from the screen by the low-pressure spraywash back to the receiving waterbody;
5. Improved screen-to-collection trough flap seal design; and
6. Modifications to traveling screen bearings and motors to permit continuous rotation and cleaning, minimizing the time an organism is impinged on the screen.

Studies of the biological effectiveness using these modified Ristoph screens was conducted at the Salem Generating Station on Delaware Bay in New Jersey (Ronafalvy et al. 1999; Heimbuch 1999). An initial evaluation was performed after six of the 12 existing traveling water screens at the cooling water intake structure had been replaced with the new, improved screens, allowing a side-by-side comparison of the effectiveness of the old and new screens. Tests were conducted on 19 separate dates between June 20 and August 24, 1996. Fish collected from the old and new screens were held separately for observation of 48 h survival. The only species occurring in sufficient numbers to provide a statistically valid data analysis was juvenile weakfish (*Cynoscion regalis*; n = 1082 for the old screens, n = 1559 for the new screens). Overall, statistical analyses demonstrated a 48 h survival rate (uncorrected for control mortality) of 57.8 percent with the old screens and 79.3 percent with the new screens.

A second series of impingement survival studies was conducted in 1997 and 1998 to provide estimates of impingement survival rates with all 12 of the modified screens installed on Salem Units 1 and 2 (EPRI 1999). White perch (*Morone americana*) impingement survival rate estimates ranged from 98 percent in December to 93 percent in April. Estimates for weakfish ranged from 88 percent in September to 18 percent in July. For bay anchovy (*Anchoa mitchilli*), survival estimates ranged from 72 percent in November to 20 percent in July. Atlantic croaker (*Micropogonias undulatus*) survival estimates ranged from 98 percent in November to 58 percent in April. The estimated survival for spot (*Leiostomus xanthurus*) was 93 percent in November (November was the only month in which a significant number of spot were collected). *Alosa* species (herrings) combined produced survival estimates that ranged from 82 percent in April to 78 percent in November.

Impingement mortality rates for the modified screens (1997 and 1998 studies) were compared to mortality rates for the original screens from the 1978 to 1982 studies. Based on the comparisons, intake modifications were effective in improving the rates of fish survival. Estimates of impingement mortality rates were lower for the modified screens than for corresponding estimates from the original screens for white perch, bay anchovy, Atlantic croaker, spot, and the *Alosa* species.

Based on impingement survival data collected at the Diablo Canyon and Moss Landing power plants and at other facilities, it was concluded that operation of modified intake screens in combination with fish return sluiceways could enhance impingement survival of many of the fish and macroinvertebrates impinged at DCP, including skates and rays, rockfish, sculpin, plainfin midshipman, tubenouts, rock crabs, and sea urchin (PG&E 1988a). On the basis of data collected in the impingement survival studies (PG&E 1988a), it was estimated that losses of impinged fish and selected macroinvertebrates may potentially be reduced by approximately 75 percent under conditions of intermittent rotation, assuming no incremental mortality associated with passage through the fish return system. Rotating intake screens continuously could reduce impingement losses of fish and selected macroinvertebrates, assuming no incremental mortality resulting from passage through the fish return system. In light of DCP's low impingement rate,

however, this percentage reduction will not result in an appreciable biological benefit. The screen improvements are not expected to provide any reduction in entrainment.

Traveling screen modifications to reduce impingement mortality must be accompanied by a sluiceway designed to return organisms to the receiving waterbody. Most installations of modified traveling screens use a dual sluiceway return system: 1) a gravity sluiceway return system for impinged organisms removed from the screens by the low pressure spraywash and 2) another sluiceway for debris removed by the high-pressure spraywash. This type of system was selected for this evaluation.

The estimated capital cost for this project would be on the order of \$13,000,000. In addition, the cumulative lost revenue and increased maintenance would be approximately \$11,000,000 over the life of the plant. The implementation of this technology has a net present value (NPV) of (-) \$11,000,000. This results in a cost of at least \$2,200 to save each kilogram of impinged fish assuming a 100% reduction in impingement over the life of the power plant. The scope of implementing this alternative is expected to extend the duration of routine refueling outages, adding additional costs that have not been factored in to the estimates.

6.2.2 Alternatives That Reduce Entrainment Losses

The major focus of this study concerns losses to fish and invertebrate populations caused by withdrawal of larval stages. A majority of the young larvae are weak swimmers and cannot escape even very low entrainment velocities. In order to reduce entrainment, alternatives that use less cooling water are considered. The following discussion provides information on possible alternative technologies to reduce entrainment at DCPD and the estimated costs to install them.

6.2.2.1 Closed-Cycle Cooling Towers With Saltwater Makeup

Both mechanical and natural draft (hyperbolic) cooling towers using saltwater makeup were evaluated for applicability at DCPD (TERA 1982). Operational problems and environmental considerations (including air quality impacts from cooling tower drift and effects on vegetation from salt deposition) have limited the application of closed-cycle cooling where brackish water

or saltwater is used as a make-up source. The report concluded that no operating or proposed electric generating facilities in the United States use seawater in closed-cycle cooling systems. Since that report was written, natural draft cooling towers with saltwater makeup have been installed and operated at Crystal River units 4 and 5. Two cooling towers provide cooling for the two 750 MW coal-fired units. The towers are operated with a high blowdown rate (10%), such that the total saltwater demand from the ocean is reduced approximately 80 percent compared to a once-through system. Therefore, saltwater cooling towers, either with mechanical or natural draft, have been demonstrated on the scale required for a closed-loop system at DCP. Based on the Crystal River experience, the use of closed-loop cooling towers with saltwater makeup at DCP would reduce the cooling water flow rate by 80 percent (from 1.6 Mgal to 0.32 Mgal per unit), reducing entrainment by a similar percentage.

Conceptual designs and design parameters for both mechanical draft (**Figure 6-4**) and natural draft cooling towers (**Figure 6-5**) have adverse environmental impacts on air and water quality, land use, and aesthetics (TERA 1982).

- Air Quality — Would produce 37 h/yr of ground level fog, visible vapor plume and emit ca. 6,080–9,070 kg/d of salt drift.
- Water Quality — Would increase salinity of cooling water discharge by 1.5 times, worst case; effluent limitations could be exceeded if a treatment system is not installed.
- Land Use — Would require an additional 12 to 22 ha for cooling towers. Additionally, the terrestrial impact of salt drift would be significant downwind of the plant site, as well as to the plant facilities.
- Aesthetics — For a hyperbolic (natural draft) system with two 142 m diameter x 170 m high cooling towers, the vapor plumes could reach 1,000–2,000 m high. For a mechanical draft system with six 94 m diameter x 22 m high cooling towers, the vapor plumes could reach 100–200 m high.

The estimated capital cost for the hyperbolic system alternative is on the order of \$658,000,000. In addition, the cumulative lost revenue and increased maintenance would be approximately (-) \$454,000,000 over the life of the plant. The NPV of this alternative's costs is (-) \$503,000,000.

Actual project costs would be higher than the estimate as the use of a closed-loop cooling system would require major design changes to the DCPD turbine plant. The present circulating water pumps (CWP) are too large to supply a cooling tower system, so new cooling tower makeup pumps would be required. A new set of cooling tower supply pumps of similar capacity to the existing circulating water pumps would have to be installed in a new pumping facility. Supply and return water conduits would also have to be constructed. Since the DCPD main condenser and turbine cycle are designed to operate with cooling water temperatures between 11 and 14°C, extensive redesign and retrofitting of the condenser and other turbine systems would be required to allow reliable plant operation with closed-loop cooling with a supply temperature of 26 to 31°C. The costs of these modifications are not included in this estimate and would add substantially to the overall cost.

6.2.2.2 Closed-Cycle Cooling Towers with Freshwater Makeup

A closed-cycle cooling system using freshwater makeup is a well proven technology used at many different nuclear and fossil power plants on a scale similar to that required at DCPD. A conceptual design is outlined in this report.

A freshwater cooling tower system would require approximately a 132,500 m³/d (92 m³/min) makeup water supply. This corresponds to 43–49 million m³ of freshwater per year. There is no supply of fresh water (including sanitary treatment plant effluent) within 40 km of DCPD available to supply cooling tower makeup (TERA 1982). A multistage flash distillation plant could supply the needed fresh water, as could a reverse osmosis system of similar capacity. Both flash distillation and reverse osmosis systems have been constructed on a scale needed to support fresh water cooling towers at DCPD.

Environmental impacts are similar to those described for the closed-loop cooling tower with saltwater makeup except that the use of fresh water would reduce the emission of particulates to approximately 1,540 kg/d.

The use of freshwater cooling towers would reduce the required saltwater flow for condenser cooling from ca. 9.5 million m³/d (101 m³/sec) to ca. 0.4 million m³/d (5 m³/sec). This would reduce intake flow by 95 percent, reducing entrainment by a similar amount.

The construction effort involved would be similar in cost to the saltwater systems described previously, except for the additional costs for a desalination plant of sufficient capacity to supply cooling tower makeup.

The estimated capital cost for this alternative is on the order of \$1,174,000,000. In addition, the cumulative lost revenue and increased maintenance would be approximately \$1,367,000,000 over the life of the plant. The net present value of this alternative's costs is (-) \$1,072,000,000.

The use of saltwater or freshwater closed-loop cooling tower systems would reduce saltwater flow by 80 to 95%, reducing entrainment and impingement by a similar amount. Cooling tower technology is proven at many power plants, saltwater cooling tower operation has been demonstrated, and desalination plants of a size needed for freshwater cooling towers have been constructed. The implementation of a closed-loop system at DCPD would require a substantial design and construction effort. The costs of retrofitting a closed-loop system at DCPD (which range in net present value from (-) \$503,000,000 to (-) \$1,072,000,000 not including permitting challenges and extensive plant modifications to ensure reliable plant operation with cooling towers installed) would be difficult to justify, especially considering the uncertain value of the plant's electrical output as California deregulates electric generation. Although it would be possible to install a closed-loop cooling tower system, it is doubtful that an investment of the type described above would be viable in the current or future electrical generation market.

6.2.2.3 Fine Mesh Screens

Fine-mesh screening, frequently used in centerflow screens, has been investigated in laboratory studies to determine its potential to minimize entrainment at power plant intakes (Magliente et al. 1978). Application-specific studies are necessary to evaluate the survival of fish eggs and larvae impinged on fine-mesh screens.

Information from laboratory tests (Tomljanovich et al. 1978) shows that traveling screens equipped with 1.0 mm (0.04 in) screen mesh would substantially reduce entrainment of fish eggs and larvae at DCP, and that entrainment of larval fish and macroinvertebrates could be virtually eliminated by use of 0.5 mm (0.02 in) intake screen mesh. Impingement survival for fish larvae, however, is species-specific: under laboratory conditions, the survival rates for larvae at 48 h after a 16 minute impingement on fine-mesh screens ranged from less than one percent for striped bass to 96 percent for bluegill and smallmouth bass (PG&E 1988a, Appendix D; Tomljanovich et al. 1978). The smaller intake screen mesh would increase impingement of larval and juvenile fish and invertebrates presently entrained at DCP. The finer mesh screen would convert normally entrained organisms into impinged organisms.

In 1980, Tampa Electric Company (TECO) performed a pilot scale evaluation of a fine-mesh Ristroph screen in the intake canal to its Big Bend Station on Tampa Bay, Florida (Taft et al. 1981; Brueggemeyer et al. 1988). TECO agreed to evaluate the potential effectiveness of fine-mesh screens to reduce losses of the selected Representative Important Species: bay anchovy, black drum, silver perch, spotted seatrout, scaled sardine, tidewater silverside, stone crab, pink shrimp, American oyster, and blue crab. The screen was of the No-well design, a duo-flow screen design with the screen attached directly to the pump. Based on the positive results of the prototype testing, the regulatory agencies determined that Unit 4 could be constructed with a once-through condenser cooling system provided that fine-mesh screens were incorporated into the intake structures of both Units 3 and 4. Accordingly, six, 0.5 mm mesh No-well screens were installed at the station and studies of their biological effectiveness were conducted in 1985 (Brueggemeyer et al. 1988).

Initial and latent mortality varied by species and life stage. Collected invertebrates had mortality rates ranging from 10 to 35 percent. Engraulidae (primarily bay anchovy) had initial mortality rates ranging from 42 to 84 percent and latent mortality rates ranging from 32 to 35 percent. Bay anchovy, Atlantic tomcod, and Atlantic silverside eggs showed a total mortality of 72.4 percent (unadjusted for control). Yolk-sac larvae of mummichog, Atlantic silverside, Atlantic tomcod, white perch and winter flounder mortality ranged from 62 to 100 percent with the exception of

winter flounder, which had a projected mortality 11 to 62 percent. Assumed mortality for post-yolk-sac larvae ranged from 36 to 100 percent for all species in this life stage. The conclusion of the study was that survival rates were comparable to, and in some cases exceeded, those obtained during the prototype study. There was no significant difference in survival rates between the two sample locations.

At Brayton Point Station Unit 4, biological evaluations were conducted to determine the number, species, and initial and extended survival of fish impinged on the modified intake screens (Davis et al. 1988; LMS 1987). These fine-mesh, angled screens were installed at a new Unit 4 intake to divert larger, motile life stages and gently collect and recover early life stages. The lowest survival was calculated for bay anchovy and the highest was for tautog. Initial and extended survival varied by species; however, a certain group of numerically dominant taxa was classified by the authors as “fragile” (primarily, bay anchovy and Atlantic silverside). The fragile group had a calculated survival below 25 percent while a “hardy” group, dominated by winter flounder and northern pipefish, had survival values greater than 65 percent.

Retrofitting the existing DCPP through-flow screens with a fine mesh would be difficult due to the increased flow resistance increasing the potential for screen failure under high debris loading. The size of the existing DCPP circulating water pumps and the intake configuration would preclude the retrofitting of No-well screens. No-well screens would require a new, open intake structure, with new circulating water pumps.

As part of an evaluation of screening technologies for DCPP (PG&E 1996), retrofitting the DCPP intake with center flow screens with curved baskets and a fine mesh (2mm) was considered as a way to improve debris filtration. The curved baskets of the centerflow design would increase flow area and offset the flow restriction caused by the finer mesh. These screens could be equipped with finer mesh screens (1 mm) that would potentially allow screening of larval organisms. These screens could reduce entrainment but would require a site-specific evaluation to determine the following parameters:

1. The survivability of larval organisms washed from the screens.

2. The potential increase in impingement due to the screen basket shape and the flows associated with a centerflow design.
3. The ability of a fine mesh screen to function under high debris loading conditions experienced at DCPD.
4. The ability of the refuse handling system to process debris with minimal impact to screened organisms.

The estimated cost for these screens is estimated \$7,000,000 (PG&E 1996). This does not include any modifications to the debris handling system or potential modifications to the intake structure to accommodate the new screens. The total cost would be approximately \$10,000,000. The net present value of this modification is (-) \$7,906,000.

Center flow screens have a much more complex distribution of flow velocities, especially when installed in a screen well type intake like that used at DCPD. The entrance area to the center flow screen is roughly 60% as wide as the existing traveling screens, so the velocity at the screen entrance would be about 67% greater (1.3 to 1.7 ft/sec). The velocities at the screens are about 70% compared to the current screen approach velocity. In between, the flow turns 90 degrees, resulting in a complicated flow pattern. These flow patterns could increase impingement of juveniles and adults. In addition, the baskets for the proposed center flow screen are convex in cross section, which could increase retention of any fish impinged. With the mixed survivability data for larval organisms impinged on fine mesh screens, any biological benefit (or cost if there is an increase in impingement) would have to be evaluated prior to determining the effectiveness of this alternative.

6.2.2.4 Single Circulating Water Pump Operation

A reduction in the number of operating CWP would reduce cooling water flows, proportionately reducing the number of organisms entrained at DCPD.

The Diablo Canyon Power Plant is designed and operated as a base-loaded plant with relatively constant electrical generation for extended periods of time. The operational characteristics of Units 1 and 2 limit the potential effectiveness of single pump operation as an alternative for reducing entrainment and impingement losses. This would require extended operation at 50%

power, which lowers plant efficiency, reduces revenue, and degrades critical plant equipment. An option to running both units at 50% power levels would be to run only one unit at 100% power.

The use of a single pump per unit at DCCP with the units operating at reduced load would also present certain technical operating difficulties. The motors that operate the CWP are large (13,000 hp) and undergo substantial stress and wear during the startup. In order to achieve appropriate performance of the unit at reduced load (e.g. at 50% power or less) or to increase load above 50% in response to increased demand, the second circulating water pump would be needed from time to time. Intermittent re-starts of the second pump would greatly increase the wear, reduce pump motor reliability, and increase the frequency of maintenance.

A second difficulty arises directly from single pump operations. With one circulating water pump operating, there is no backup on-line. Thus, if the operating pump were to fail, the unit would undergo a forced shutdown. Ordinarily, with two circulating pumps running, failure of one requires a curtailment to only 50% power. Although there is no increased risk of an accident affecting the health and safety of the public by operating with one circulating water pump, plant operational transients that force a unit shutdown are regarded as a negative indicator by the Nuclear Regulatory Commission.

Because of the loss of reliability, potential equipment degradation, and operational inefficiency of generating units that would accompany operating each unit with one circulating water pump in service, a more likely strategy would be to take the option of shutting down one unit and both of its pumps, if operation in this mode was expected to be for a long period.

The NPV of this option is extremely negative, based on loss of generation. The lost revenue and NPV for this option are, however, considered proprietary information.

This option has a negative contribution to the environment as a result of the need for the ISO to purchase replacement power for the 1,100 MW reduction in power production. It is assumed that the replacement power will be generated by gas-fired power plants constrained to the state of

California emission standards. The increased amount of emissions from a natural gas-fired power plant generating 1,100 MW would be as follows (tons/yr):

NO _x	CO	CO ₂
5,500	3,700	5,900,000

NO_x and CO are EPA criteria pollutants regulated under Title V of the Clean Air Act. CO₂ is a "green house" gas and is of concern for global warming. Additional air toxics such as 1,3 butadiene, acrolein, and formaldehyde are generated in smaller quantities, but can represent a greater risk to the population and environment. These calculations are based upon emissions from a 750 MWe gas-fired power plant with moderate amounts of emissions controls. Emissions used were 95 ppm NO_x, 100 ppm CO, and 9.6% CO₂. Mass emissions were based upon operation of 24 h/d, 365 d/yr.

Because of the loss of generation that would accompany reduced circulating water pump operation, single circulating water pump operation or single unit operation is not considered an alternative that could reduce entrainment at DCPD in a cost effective manner.

6.2.2.5 Variable Speed Circulating Water Pumps

Installation of variable-speed motors on the circulating water pumps represents one approach to reducing cooling water flows to the minimum level necessary to maintain efficient operation of the unit at a specific generating load. For this analysis, the assumption is that circulating water flow would be reduced to that required for 100% power operation. The basis for this is that DCPD is designed to operate as a base loaded plant at 100% power and does not change power output on a daily or other scheduled basis.

The pumps currently in use are limited to no-flow or full-flow operation. Variable-frequency drives could be installed to allow these pumps to operate at lower speeds (and hence lower flows), thereby reducing the numbers of organisms entrained. Thus, the circulating water flow rate could be adjusted to provide only the flow needed for condenser cooling within operating limits imposed by ΔT and back pressure operating criteria. The magnitude of the resultant

reductions in entrainment losses would depend on the reduction in cooling water flow and the abundance of organisms at the times when the circulating water pumps were operated at reduced flow rates.

The intent of variable speed pumps is to reduce intake flow without impacting plant power operation (by adjusting circulating water flow to that needed to just allow operation within thermal limits) then the biological benefits of such a modification would be limited and based on the amount of flow reduction. DCPD was not designed for large extremes in cooling water ambient temperature, so there is little margin for reducing circulating flow. Based on calculations (VR Foster, PG&E, pers. comm. 1999), the maximum expected flow reduction would be 2–10% when ocean water temperatures are below the average (14.4° C). These calculations allowed for a temperature differential rise of 11.1° C (to allow for margin to the temperature limit) and did not consider the impact of condenser fouling. Further decreases in cooling flow would cause additional heating of the discharged circulating water.

Operation of the existing circulating water pumps is also limited by the pumps' ability to operate at reduced flows without cavitating. Hydraulic model test results for the existing circulating water pumps revealed that the available suction head in the present installation restricts operation at reduced speeds without subjecting the pumps to serious cavitation. There is data for cavitation performance of the circulating water pumps at 80%, 90%, and 100% of rated speed. The data demonstrates that the pumps will be more susceptible to cavitation as speed is reduced. Based on existing data, it is estimated that the greatest flow reduction would be on the order of 20 to 30% (corresponding to a speed reduction of 10%; PG&E Drawing DC663021-Sht. 29). The present circulating water pumps are not capable of reliable service at a significantly reduced speed. Since the circulating water pumps are embedded in the concrete intake structure, replacement of the circulating water pumps with pumps designed for variable speed operation would require the construction of a new intake structure similar in size to the existing structure. Variable speed circulating water pumps can allow substantial reductions in cases where power plants load follow (change power over the course of a day or week) and where plants are designed for large variations in heat sink temperatures. Since DCPD is a base loaded plant designed for a relatively

constant heat sink temperature, there is little flow reduction that can be expected (up to 10%). This limits the biological benefit of installing variable speed drives on the existing pumps. Since variable speed drives of a size needed are not normally produced, the costs for this modification are difficult to estimate. Based on input from one experienced vendor, the net present value of installing variable frequency power units would be approximately (-) \$7,652,000.

Due to the low reduction in flow and relatively high (and uncertain) costs to install these drives, the minimal reduction in entrainment is not considered to provide a substantial biological benefit.

6.2.2.6 Refueling Outage Scheduling

Diablo Canyon Power Plant Units 1 and 2 are periodically removed from service for refueling and maintenance. The unit outages occur at an interval of approximately 18 mo. Future outages are expected to last approximately 30 d. The seasonal planned reduction alternative would involve the selective scheduling of unit outages to coincide with the peak periods of abundance for key larval taxa in the area. Ideally, refueling outages would be scheduled for specific times of the year when densities of entrained organisms are greatest.

Over the past 15 years the majority of the 18 refueling outages have occurred during the months of March–April (7 outages) and September–October (5 to 8 outages). Fall outages have occurred regularly during these months, but in recent years winter outages started earlier, running from February–March. Of the 14 target taxa including subgroups, the majority reproduce during the spring months of March–June (**Table 6-2**). Few of these taxa are vulnerable as larvae during fall. A shift in outage scheduling to the spring would lessen the susceptibility of these larvae to entrainment. Having both units refuel each spring is highly uneconomical. Extending each unit to a 24 mo cycle would allow for spring outages, but is not possible with current fuel design. During the normal operational cycle about one-third of the fuel is consumed over an 18–21 mo period before refueling is required. This limits the possibility of modifying outage schedules to a shorter duration. Without the ability to lengthen fuel cycles, outages could not be scheduled only

during the spring. Without this flexibility, shortening outage schedules to occur on 12 month intervals would become inefficient.

A second scenario of reduced operation could involve curtailments during periods of greater larval density. Monthly densities of fish larvae peak during the spring months from March through June, as depicted for 1997 and 1998 in (Figure 6-6). During the months March –May approximately 55% of the fish larvae for the nine months ending in September are at risk to entrainment. This nine month period was used because plankton data after September 1998 were analyzed only once-per-month with paired study grid surveys. During both years, larval densities peak in May each year when 23 and 31 percent of larvae were collected. These strategies would be protective of many species including KGB rockfish (*Sebastes* spp. V_De), northern anchovy, monkeyface eel, Pacific sardine, northern lampfish, smoothhead sculpin, white croaker, and California halibut. Spring time curtailments, however, would not be protective of other fishes including clinid kelpfish, blackeye goby, blue rockfish (*Sebastes* spp. V), snubnose sculpin, and some KGB rockfish (*Sebastes* spp. V_D).

A dual unit curtailment for a three month period each spring would have a significantly negative financial impact on PG&E. The NPV of this option is extremely negative, based on loss of generation. The lost revenue and NPV for this option are, however, considered proprietary information. Replacement power obtained from gas-fired facilities would generate about one-half the EPA criteria pollutants and "green house" gas emissions calculated in Section 6.2.2.4 each year under this scenario.

6.2.3 Conclusion

A hierarchical evaluation was used to assess which alternative intake technologies were technically feasible and could reduce impingement and entrainment at DCPD.

A reassessment of the 1985–86 316(b) Demonstration Study (Tenera 1998a) confirmed that estimated impingement at DCPD is very low (0.32 to 0.73 kg/d/unit). The current report found that, for any type of modification, very little improvement can be made to the present DCPD

intake configuration to reduce the number of impinged fish, without incurring substantial costs relative to the benefit achieved. Regardless, **Section 6-2** of this report studied the feasibility of three alternative technologies: an increased area intake, angled screen intake, and modified traveling screens with enhanced fish handling equipment.

Increasing the cross-sectional area of the intake structure would decrease the water flow rate. But, apparently healthy juvenile and adult fish have been observed living and swimming inside the intake structure at DCPD without being impinged. Also, implementing this alternative would require very substantial disruption of the intake cove as a cofferdam would be required to de-water the cove while dredging and associated modifications took place. The angled screen intake design is judged to have similar costs and benefits as the increased area intake, with the potential for increase fish recovery.

The cost of implementing either the increased area intake or the angled screen intake alternatives is estimated to have a net present value of approximately (-)\$275,000,000. This equates to approximately \$61,700 per kilogram of fish saved, assuming the modification could completely eliminate impingement.

Due to the high cost as well as the high impact to the Intake Cove during construction and negligible reduction in impingement, these alternative intake technologies are not considered cost effective for DCPD.

Applicability of the most current intake screen and fish conveyance technologies were evaluated. Proposed modifications to the existing configuration include the addition of angled intake screens, watertight fish collection buckets, low pressure spray wash, a gravity sluiceway to convey fish back to the ocean, and modifications to the screens to allow continuous rotation.

None of the organisms impinged on the screens at DCPD are assumed to survive because of the current debris removal configuration. Installation of a gravity sluiceway and low pressure spray wash could reduce the mortality rate of impinged organisms.

Although there is insufficient data to perform a thorough site-specific analysis, modified angled traveling screens with continuous rotation, low pressure spray wash, and watertight fish

collection buckets have the potential to reduce the mortality of impinged organisms at DCP. Implementation of this modification has associated capital and maintenance costs resulting in a net present value (NPV) of (-)\$11,000,000. The cost of saving impinged fish with this modification, assuming 100% survival, is on the order of \$2,200 per kg of impinged fish assuming a 100% reduction in impingement. Site-specific testing of this proposed modification would be required to determine the actual biological benefit.

Because impingement at DCP is already low, modification of the current traveling screens to further reduce impingement is not considered cost effective for DCP.

For entrainment, five alternative technologies have been identified as technically feasible at DCP. The alternatives are closed-cycle cooling towers, fine mesh screens, single circulating water pump operation, variable speed circulating water pumps, and changes to refueling outage scheduling.

Two types of closed-cycle cooling towers were evaluated. Both would reduce the cooling water requirement, possibly as much as 80–95%, and result in entrainment reductions. However, installation and operation of closed-cycle cooling towers have negative environmental impacts on air quality (salt drift), increased salinity of the cooling water discharge, terrestrial impacts of salt drift, and poor aesthetics as a consequence of high cooling towers and vapor plumes.

Additionally, closed-cycle cooling towers have high capital and maintenance costs. Both units would be de-rated to accommodate the new cooling medium. Order of magnitude estimated net present values (NPV) range from (-) \$503,000,000 to (-) \$1,072,000,000, plus costs for design, licensing, demolition of existing facilities, and environmental damage to the land. Because of the adverse terrestrial environmental impacts and high implementation costs associated with closed-cycle cooling towers, they are not considered feasible at DCP.

Center flow screens with fine mesh (1 mm) baskets could be retrofitted to the existing DCP intake structure to allow screening of larvae. Studies have shown wide ranging mortality rates for impinged larvae, ranging from 5% to near 100%, depending on species. A site-specific investigation would be needed to determine the mortality for larval organisms at DCP. In addition, there is a potential that the center flow screens, with their higher inlet velocities,

complex flow patterns and curved baskets could increase impingement of juvenile and adult fishes. Both survivability of larvae and any changes to impingement would have to be evaluated prior to assessing a biological benefit for fine mesh baskets on center flow screens. The net present value of this modification is (-) \$7,906,000, with an uncertain benefit.

Single circulating water pump operation was also evaluated as a method to reduce entrainment. Operating only one of the two CWP running per unit would reduce the cooling water requirement by about half, reducing entrainment by the same amount. Single circulating water pump operation would require that both units at DCPD be operated at 50% power or less or that one unit be shutdown. The loss of revenue associated with single circulating water pump operation does not make this a feasible alternative.

Variable speed drives for the circulating water pumps offer the possibility of reducing flow to the minimum required flowrate (optimizing generation and condensate depression) needed to support operation at a specific level of plant output. Since DCPD is a base loaded plant operating at 100% power most of the time, the potential flow reduction is limited to 2 to 10% of rated flow, depending on ocean temperatures. Additional flow reductions are limited by the capabilities of the pumps themselves, such that significant flow reductions (even with a reduction in power are limited to flow reduction of approximately 20 to 30%). The costs and limited potential flow reduction with this alternative does not make this a cost effective alternative.

The feasibility of scheduling refueling outages to coincide with periods of high larval densities of certain organisms was also evaluated. During refueling outages, the amount of cooling water required is reduced and strategic scheduling could reduce the amount of entrainment. It is possible that at least some of the refueling outages could be scheduled to coincide with periods of high density of certain larval fish or invertebrate taxa. Many fishes produce larvae to benefit from the increase productivity associated with spring and summer months. Conducting outages during the spring could reduce the impact on nearshore taxa 7–10% assuming two cooling water pumps are out of service for 30 d.

Longer curtailments of cooling water pump operation, exclusive of refueling outages were also evaluated. Water flow conditions would be severely reduced for one to three months under this

scenario. Some or all cooling water pumps would be shut down when a majority of the fish larvae are present in the plankton. The current data indicate a large percentage of the larval fishes are vulnerable to entrainment through the spring months March–June. Suspending pumping operations, except for vital ASW flows, for three months would protect about half of the fish larval density from risk of entrainment. The costs of these measures are extreme and many fishes that reproduce at other times or have long-lived larval stages would remain vulnerable to entrainment during the 9–11 months of operation.

6.0 Alternative Intake Technologies

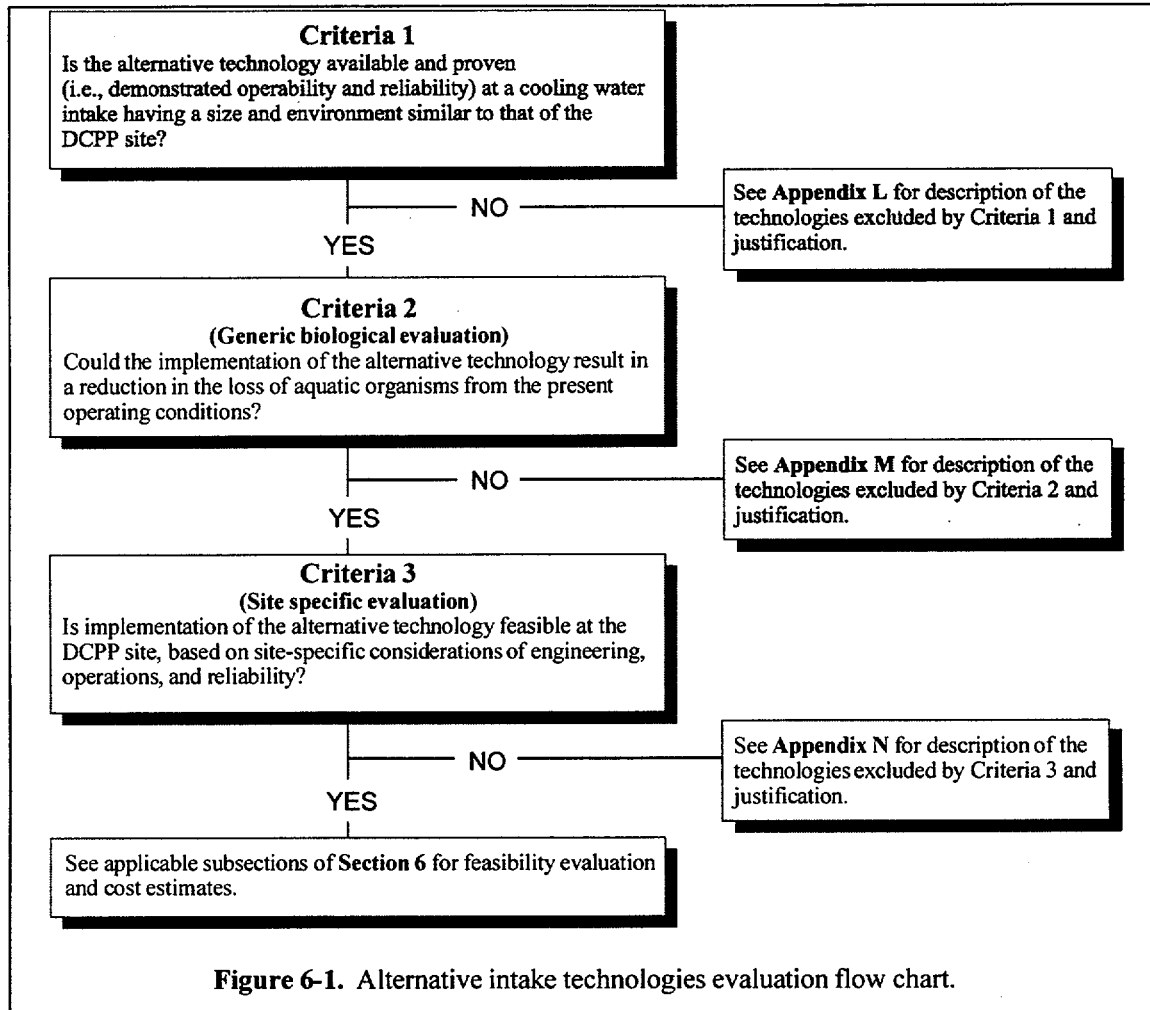
Table 6-1. Listing of the alternative technologies evaluated and location of the evaluation in this report.

Category	Intake Technology	Meets Criteria 1	Meets Criteria 2	Meets Criteria 3	Evaluated in noted Section or Appendix
Cooling Water System	Once Through	N/A	N/A	N/A	in use at DCPD
	Closed-cycle cooling tower (saltwater)	•	•	•	Section 6.2.2.1
	Closed-cycle cooling tower (fresh water)	•	•	•	Section 6.2.2.2
	Closed-cycle Cooling Pond or Canal	•	•		App. N
	Cooling system component modification				App. L
Intake Configuration	Offshore Intake Location / Velocity Cap	•			App. M
	Alternate Onshore Intake Location	•			App. M
	Shoreline	N/A	N/A	N/A	in use at DCPD
	Recessed	•			App. M
	Increased Area Intake Structure	•	•	•	Section 6.2.1.1
	Angled Screen Intake Structure	•	•	•	Section 6.2.1.2
Behavioral Barriers	Light	•			App. M
	Sound	•			App. M
	Bubble screen	•			App. M
	Velocity gradient (water jet or other turbulence)				App. L
	Electrical barrier				App. L
	Louvers				App. L
	Chemicals barriers				App. L
	Magnetic field (barrier)				App. L
	Chain and cable barriers				App. L
Physical Barriers	Vertical traveling screen	N/A	N/A	N/A	in use at DCPD
	Drum screen	•			App. M
	Centerflow traveling screen	•			App. M
	Fine Mesh Screen	•	•	•	Section 6.2.2.3
	Media filter				App. L
	Stationary screen				App. L
	Horizontal traveling screen				App. L
	Inclined Plane screens				App. L
Fish Collection, Removal and Conveyance Systems	Combinations of vertical traveling screen modifications	•	•	•	Section 6.2.1.3
	Gravity sluiceway	•	•	•	Sections 6.2.1.2 and 6.2.1.3
Maintenance and Operational Modifications	Maintenance Dredging	•			App. M
	Single circulating water pump operation	•	•	•	Section 6.2.2.4
	Variable Speed Circulating Water Pumps	•	•	•	Section 6.2.2.5
	Continuous screen rotation	•	•	•	Section 6.2.1.3
	Refueling outage scheduling	•	•	•	Section 6.2.2.6

N/A: Not applicable

Table 6-2. Estimated equivalent adults, months of peak density, and evaluation of susceptibility to entrainment for target crab and fish taxa collected in DCPD entrainment and study grid plankton samples.

Common Name	Months of peak density		Estimated Equivalent Adults (<i>FH</i> and <i>AEL</i>)	Reduced Entrainment Feb-Mar & Sep-Oct
	Entrainment	Study Grid		
<i>Cancer</i> crabs				
Brown rock crab	Spring	May-Jun	9,100-23,400	maybe
Slender crab	Winter-Spring	May-Jun	895-5,460	maybe
Pacific sardine	Mar-May	Mar-May	3,170-8,460	Yes
Northern anchovy	Dec-May	Mar-May	16,100-120,000	Yes
Rockfishes				
KGB complex	Mar-Jul	May	497-1,120	Yes
Blue complex	Jan-Mar	Jan-Feb	18-353	Yes
Painted greenling	all year, esp. Mar-May	May-Jun	nd	Yes
Sculpins	Apr-Jul	Apr-Jul	nd	No
White croaker	Dec-Mar	Dec-May	5,110-15,000	Yes
Monkeyface prickleback	Mar-Jun	Apr-May	nd	Yes
Kelpfishes	Jan; Jun-Aug	Dec-Feb	nd	No
Blackeye goby	Mar-Nov	July-Sept	10,300-75,400	Yes
Flatfishes				
Sanddabs	Jul-Sept	July-Sept	92-2,370	Yes
California halibut	April-May	Apr-May; Jul	nd	No



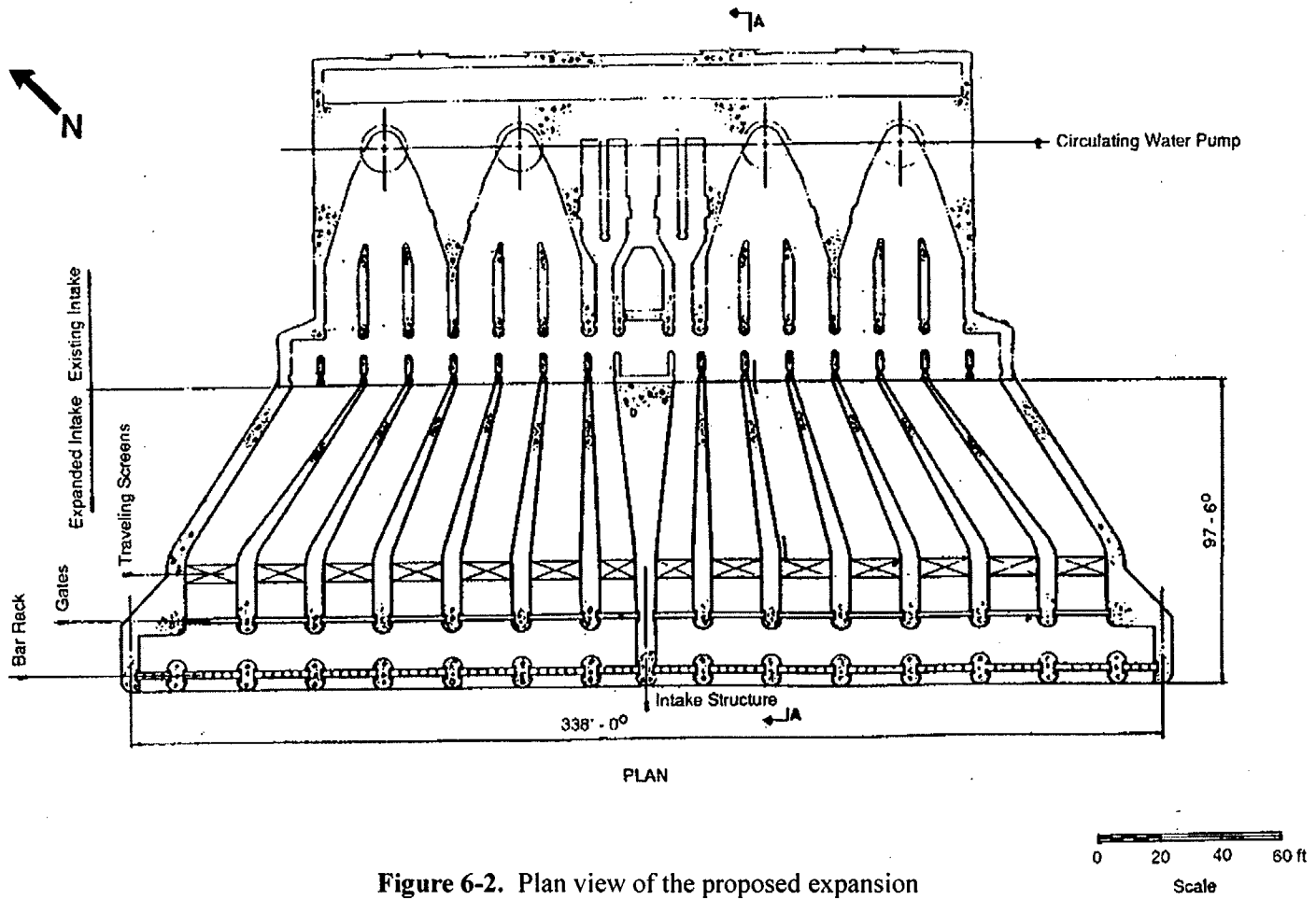


Figure 6-2. Plan view of the proposed expansion of the intakes at the Diablo Canyon Power Plant.

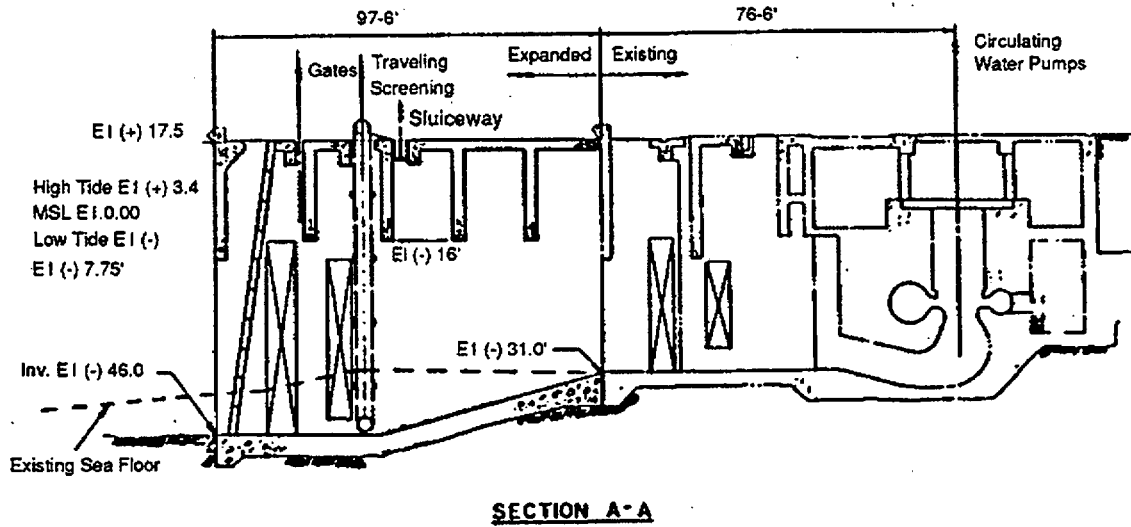


Figure 6-3. Sectional view of the proposed expansion of the intake at the Diablo Canyon Power Plant.

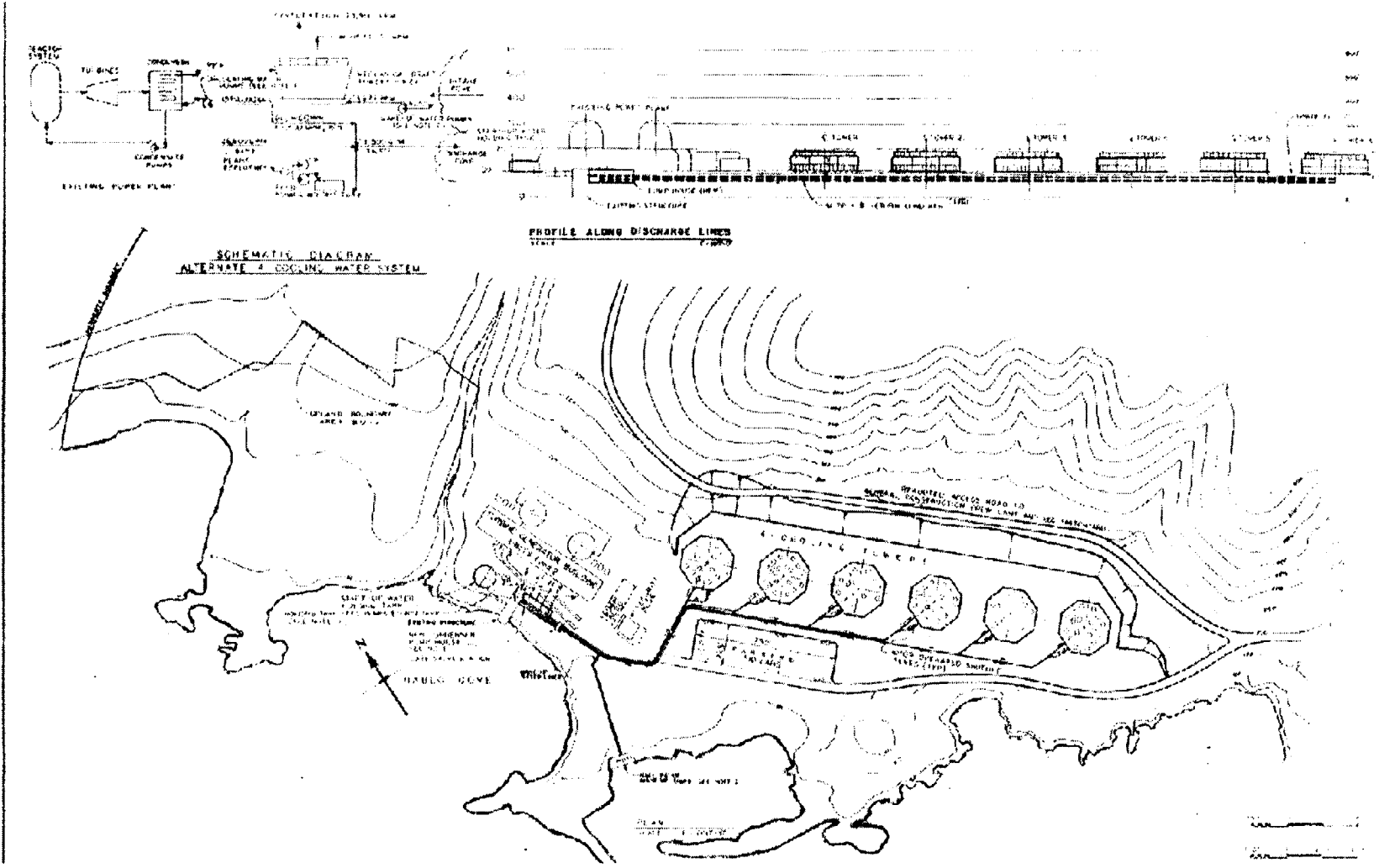


Figure 6-4. Schematic drawing of potential siting of mechanical draft cooling towers at the Diablo Canyon Power Plant site.

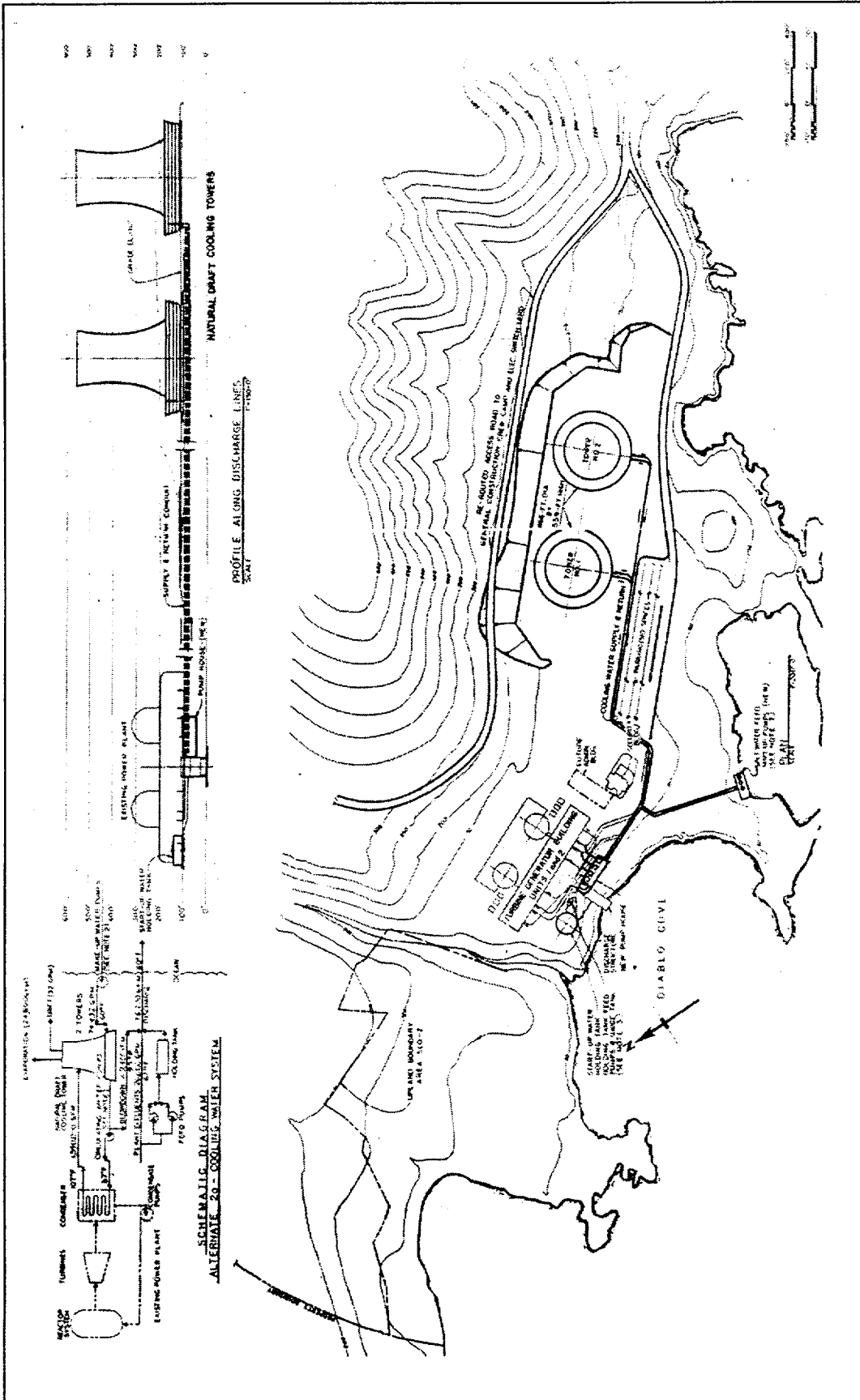


Figure 6-5. Schematic drawing of potential siting of natural draft cooling towers at the Diablo Canyon Power Plant site.

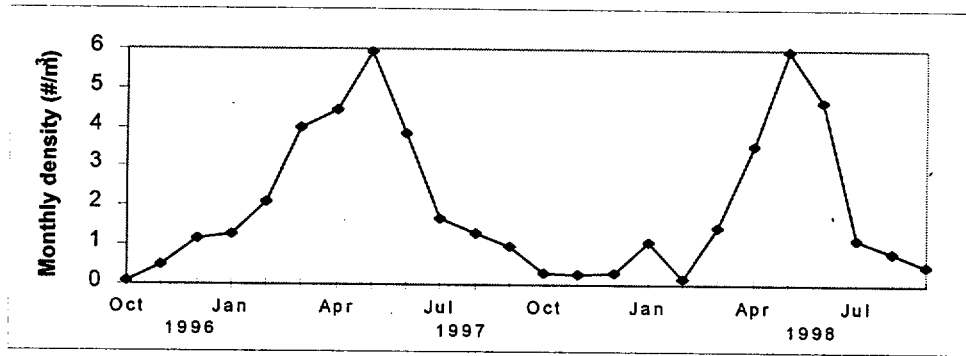


Figure 6-6. Monthly density of all fish larvae collected in weekly entrainment surveys conducted from Oct 1996 to Sep 1998.

7.0 DISCUSSION

The purpose of this study was to assess the effects of the Diablo Canyon Power Plant (DCPP) cooling water intake structure on populations of fishes and invertebrates. Effects from the plant's cooling water intake structure can result from impingement of organisms on the intake traveling screens or entrainment into the plant's cooling water intake structure. This study focused on entrainment effects, because an evaluation by the Regional Board's Entrainment Technical Workgroup (ETWG) determined that impingement effects were not significant (Tenera 1998b). Although many marine organisms have planktonic forms that could be entrained by the power plant, the ETWG focused on the larvae of fishes, crabs, and sea urchins. Although hundreds of different taxa were entrained, the ETWG chose 16 target taxa for this assessment that included 14 fishes and two species of crabs. Their decision was based on criteria that included the abundance of a taxon, the availability of suitable life-history information to meet assessment model requirements, and criteria outlined in USEPA Draft Guidelines (USEPA 1977) and modified by the ETWG (Tenera 1997b). The ETWG determined that several assessment approaches would be applied to the data for each taxon where possible. Where we were able to complete two or more approaches, we compared results to provide a basis for determining the accuracy of our assessment for an individual taxon.

7.1 Assessment Approaches

Three assessment approaches developed by PG&E, its consultants, and other members of the ETWG were used to estimate entrainment effects at DCPP. Estimates of entrainment loss, and the demographic data reported in the scientific literature, were used to parameterize two demographic approaches for estimating entrainment effects: Fecundity Hindcasting (*FH*) and Adult Equivalent Loss (*AEL*). These methods are similar except that *FH* uses the number of larvae entrained to hindcast the number of eggs, and the number of eggs is then used to estimate the number of female adults that would have produced them. The *AEL* method forecasts the number of adults that would have survived from the estimated number of entrained larvae, as if they had survived entrainment, using knowledge of natural mortality rates. It has been assumed throughout this

study that 100% mortality occurs for all entrained larvae. A third method, the Empirical Transport Model (*ETM*), estimates an average annual larval mortality due to entrainment \widehat{P}_M per individual taxon, using estimates of proportional entrainment (*PE*) that compare the number of larvae entrained in one day to the number of available larvae in the source water body. Larval mortality is calculated after *PE* is weighted by the estimated fraction of the total population affected and compounded by the time larvae are susceptible to entrainment.

The three approaches combine demographic information with environmental setting to model entrainment effects and then, where possible, compares these results to corollary data. The corollary data used in this report included fisheries information, data from Intake Cove plankton tows, and subtidal observations of juvenile and adult fishes. The integration of growth, reproduction, and mortality parameters in the three models are used in obtaining estimates of adult losses and entrainment mortality. These estimates help us better understand population measures such as length-frequency distributions and indices of year-class strength. Much of the effort in compiling these models is similar to the process undertaken by fishery scientists to conduct stock assessments used to gauge the health of fished populations.

Stock assessments are tools fishery scientists use to determine the health of a fish population. These assessments combine available biological and demographic data with information on fishing effort and landings to assess trends of fish abundance. These trends can be assessed from sources such as long running observational data sets (e.g., subtidal fish observations, Tenera 1997c), annual fishery catch statistics, and data on fishing effort. Fishery scientists divide the amount of catch by the amount of time spent fishing to create an index of abundance called 'catch-per-unit-effort.'

Catch data alone are an imperfect estimator of abundance since they are an indirect measure of the available fish population and may also reflect biases toward larger, more easily harvested, or more valuable fishes. Therefore, fishery scientists must combine biological data describing the population under study with catch data to understand the trends they observe. The types of biological data that are useful to have are: the age structure of the population, age at first entry into the fishery (recruitment), age at first reproduction, estimates of longevity, and perhaps most

importantly, estimates of total mortality. Total mortality is the combination of mortality due to both natural and anthropogenic causes like fishing. Understanding the effects of entrainment on larval fish populations requires similar steps as those taken to assess the health of adult populations.

Similar to the process fishery scientists use for assessing fish populations, the assessment models for DCPD required several decisions regarding the assumptions, level of complexity, data inputs, and application. Issues considered included the following:

- compensation;
- entrained eggs;
- calculation of larval duration; and
- application of model results in an assessment of habitat damage.

In addition, all assessments were based on the assumption of 100% mortality of all entrained organisms.

7.1.1 Compensation

Saila et al. (1987) define compensation as “the ability of a fish population to offset, in whole or part, reduction in numbers caused by impacts from natural and/or man-induced stresses, which includes fishing.” Postulated compensatory mechanisms include growth, competition, predation, cannibalism, size at maturity, fecundity, disease, and reproduction. Ricker (1975) reports that compensatory mortality, as a function of population size, reduces the intrinsic rate of population increase. Nisbet et al. (1996) say that compensation fails to prevent declines in adult stocks in response to added mortality of larvae by power plants, except when compensation occurs in the late immature stages, after entrainment but before maturation. Density-dependence is not confined to acting through mortality; growth and fecundity may also be density-dependent. Therefore, the processes that regulate populations are complex. Some entrainment studies have assumed that compensation is not acting between entrainment and the time when adult recruitment would have taken place, and further, that this specific assumption resulted in conservative estimates of projected adult losses (Saila et al. 1997). Others, such as Parker and DeMartini (1989), did not include compensatory mortality in estimates of equivalent adult losses

because of a lack of consensus on how to include it in the models and, more importantly, uncertainty about how compensation would operate on the populations under study. The uncertainty arises because the effect of compensation on the ultimate number of adults is directly related to the vital processes (fecundity, somatic growth, mortality) and affected life stages. In particular, Nisbet et al. (1996) showed that neglecting compensation does not always lead to conservative long-term estimates of equivalent adult losses. Density-dependent recruitment compensation is also hard to distinguish from competing climatic effects. Confounding of environmental and density-dependent effects is a major problem that can result in spurious environmental effects being mistaken as density-dependent effects (Clark et al. 1999). The sampling plan and modeling evaluation for these entrainment studies at DCP (Tenera 1998a) considered that population regulation could include both positive and negative compensatory mechanisms. We also concluded that it would be beyond the scope of the current study to include population regulation in the models used to predict adult losses.

Compensation (density-dependence) is also an important component of the fishery management concept of surplus production (Ricker 1975; **Figure 7-1**). This theoretical relationship describes the relationship between adult abundance and the number of progeny they produce. In this construct, there is an equilibrium population level at which there are just sufficient adults in the population to replace themselves. Production above and beyond this level is termed “surplus production” that can be harvested without depleting the population. Entrainment mortality is analogous to harvesting mortality, except that it removes younger animals from the population. It appears that for many of the target taxa examined at DCP, the additional mortality on early life stages added by entrainment in the cooling water intake system could be attributed to surplus production since there are no concurrent decreases in adult or larval abundance measured at other locations.

7.1.2 Eggs

Planktonic eggs are entrained along with larvae at DCP. Early in the process of developing the present study, the ETWG decided not to enumerate fish eggs in the plankton samples collected. The reasons for this decision were that, while there are some descriptions of marine fish eggs,

their classification is both difficult and time consuming, and ultimately, the initial list of possible target taxa did not include many fishes with pelagic eggs that would be subject to entrainment. Egg losses have been quantified in other 316(b) entrainment studies (e.g., Murdoch et al. 1989; Bailey et al. 1998; Cherry and Currie 1998; Jacobson et al. 1998; Richkus 1998). Lacking the egg entrainment data, one might assume that the numbers of adult equivalent losses resulting from egg entrainment would be equal to those estimated from larvae. However, the actual situation may be more complex; for example, there are differences in dispersion patterns between eggs and larvae, larval behavior may affect entrainment, etc. (Lasker 1981).

Populations of the five target taxa with pelagic eggs (Pacific sardine, northern anchovy, white croaker, sanddabs, and California halibut) are not adversely affected by the DCPD intake indicated by generally low to moderate estimates of annual entrainment mortality (\widehat{P}_M), \widehat{FH} , or \widehat{AEL} . Furthermore, these taxa are protected against localized effects by having widespread populations or spawning centers distant from DCPD. In the case of California halibut, with a relatively high \widehat{P}_M , but low approximated \widehat{FH} , very few individuals are entrained at DCPD so there is no adverse impact on their population. All other target taxa either brood their eggs attached to their bodies (*Cancer* spp. crabs), extrude live larvae (rockfishes), or have demersal adhesive eggs (greenlings, sculpins, pricklebacks, clinid kelpfishes, and gobies). Therefore, egg losses are not assumed to be an important factor in estimating entrainment effects.

7.1.3 Larval Duration

Larval lengths at entrainment were used to estimate age at entrainment from growth rates reported or derived from current scientific literature. This method has many assumptions with implications for the results of the present study. Primary among these is the assumption that the point estimates reported in the literature, often from areas geographically removed from the central coast of California, are representative of growth rates for larvae in the area around DCPD. Dividing all larval lengths by the same growth rate to obtain estimated ages assumes that growth is constant over the durations estimated. Variation in growth rates, more probable for larger individuals, could lead to miscalculations of larval age. Examination of length-frequency histograms for the various taxa treated in this study and comparison of these with reported hatch

lengths leads to the conclusion that there is much wider variation in hatch lengths of these fishes than is presently reflected in the literature. This follows from the observation that many of the larvae collected and measured in this study were smaller than the reported hatch lengths. In many cases, the average lengths of larvae entrained were less than reported hatch lengths. This may be due in part to larval shrinkage resulting from preservation (Theilacker 1980). The approximately-normal distributions observed for very small length larvae could also result from natural random variation in hatch lengths and could explain the lengths being less than those reported for hatching (Matarese et al. 1989; Moser 1996). If the actual larval ages at entrainment were younger than our estimates the areas containing the affected population would be smaller than those estimated using the present methods. If the affected populations are actually smaller than those used in the *ETM*, then \widehat{P}_M could be underestimated.

7.1.4 Application to Habitat

The conservation of fish habitat has been recognized by scientists and managers as an essential issue in fisheries management as a result of measures included in the reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act (Benaka 1999). These measures emphasize the need to preserve essential fish habitat and integrate ecosystem-based concepts into fisheries management. The ability to quantify the success of management practices for preserving essential habitat is potentially easier than quantifying fish populations that are mobile and difficult to sample. It is recognized that effective management of essential fish habitat requires knowledge of species-specific habitat requirements, descriptions of the physical environment and available habitats, and estimates of fish populations in the different habitats (Cobb et al. 1999). The type of information required to convert \widehat{P}_M into something more tangible that is representative of the effective area or habitat affected is not available for our nearshore target taxa. In addition, while loss of habitat may be logically converted into fish population losses, the conversion of entrainment losses into habitat is less reasonable because there is no specific shoreline area associated with, or degraded by, entrainment. The conversion of entrainment losses into habitat losses also ignores the fact that entrainment only affects one life stage, and recruitment and migration from unaffected portions of the population will continue to fill

available habitat niches. Continuing long-term shifts in oceanographic conditions affecting fish habitat quality and productivity also confounds attempts to convert entrainment losses into habitat.

7.2 Assessment of Entrainment Effects

The following criteria were developed by PG&E, its consultants, and other members of the ETWG for evaluating adverse environmental impacts (AEI) at DCP. These criteria are specific to the marine environment around Diablo Canyon, in most cases are unique to marine aquatic organisms, and are directly applicable to the present 316(b) entrainment study:

- environmental trends (climatological or oceanographic);
- abundance trends (e.g., Intake Cove plankton tows, subtidal fish observations, fishery catch data);
- life history strategies (e.g., longevity and fecundity);
- population distribution; and
- magnitude of effects.

These criteria are discussed in the sections that follow. The criteria were considered on a taxon-specific basis when trying to determine the extent of entrainment effects on the local environment and on the population at large. This provides a basis for our conclusions in **Section 7.3** for assessing AEI using USEPA guidelines to determine the “*relative biological value of the source water body zone of influence for selected species and determining the potential for damage by the intake structure*” (USEPA 1977). The USEPA (1977) also stated that the biological value of a given area to a particular species be based on “*principal spawning (breeding) ground, migratory pathways, nursery or feeding areas, numbers of individuals present, and other functions critical during the life history.*”

7.2.1 Environmental Trends

Changes in recruitment and adult abundance appear to be periodically accentuated by El Niño events observed in the DCP receiving water monitoring program (RWMP) long-term subtidal juvenile and adult fish observation data. A decline in abundance in the subtidal fish observation data following the 1991–1993 El Niño event is common to many of the target taxa. In 1992–

1993, nearly all taxa experienced a sharp decline in abundance followed by relatively constant but lowered abundance to the present time. The extended El Niño event between 1991 and 1993 had important implications for many of the fish taxa found here (Yoklavich et al. 1996). Warm water events can have very large detrimental effects on rockfish year-class strength since these are typically species with cold water affinities (Karpov et al. 1995; Lenarz et al. 1995; Ralston and Howard 1995; Lea et al. 1999; Love et al. 1999). Abnormally high water temperatures and suppression of annual upwelling along the California coast have been linked to large-scale reductions in the primary prey of juvenile and adult rockfishes (Mullin and Conversi 1989). Reductions in food sources can negatively affect the somatic and reproductive condition of these life stages (Lenarz and Wyllie-Echeverria 1986; VenTresca et al. 1995).

Another strong El Niño event occurred along the central California coast and eastern Pacific Coast during the fall, winter, and spring seasons of 1997–98 (Lynn et al. 1998). This may explain the differences in entrainment estimates between the years 1996–97 and 1997–98 for some of the taxa (Table 7-1). Changes in distribution and dispersal patterns of pelagic larvae are expected during anomalous warm oceanographic events (Bailey and Incze 1985; Brodeur et al. 1985). For example, estimates of entrainment, FH and AEL for both Pacific sardine and northern anchovy increased markedly between the first and second year of the study. The spawning biomass for both of these species is typically centered south of Point Conception (Hart 1973; Butler et al. 1987; PFMC 1998; Hill et al. in press), and it was likely displaced northward with the north-flowing El Niño currents present in the second year. White croaker \widehat{FH} and \widehat{AEL} also appeared to increase slightly, which may also be due to additional transport northward during the El Niño year. Other species appeared to be somewhat less affected by El Niño-related transport since \widehat{FH} and \widehat{AEL} remained relatively constant or decreased only slightly between years (e.g., KGB rockfishes, blue rockfish complex, blackeye goby, and sanddabs). These fishes probably have more localized spawning populations that were less affected by the El Niño event.

Coastal marine ecosystems in the Southern California Bight have experienced reduced productivity associated with a climate regime shift towards warmer water conditions that began during the 1976–77 El Niño (Holbrook et al. 1997). These changes have led to large impacts on

population abundances and trophic structure in nearshore benthic communities within the Bight. In general, they showed that the diversity and abundance of fishes with more northern biogeographic distributions have declined in the Southern California Bight since the advent of this warmer water regime. Furthermore, these assemblages have shown a shift in the dominant species away from more northern distributed taxa and toward more southerly distributed species that are presumably more tolerant of warm water. Similar trends were also observed further north at Santa Cruz Island where populations of surfperches, the standing stock of their crustacean prey, and the biomass of understory macroalgae all declined by ca. 80%. Holbrook et al. (1997) hypothesize that fish abundance declined as a result of declining recruitment that became insufficient to compensate for losses of older age classes. This can be termed "recruitment overfishing" defined by Gulland (1983) as limiting the amount of larvae a population produces by taking primarily older, more fecund adults and leaving young, less fecund individuals. These recruitment levels fell more than one order of magnitude over two decades and were correlated among years with broad indicators of Bight-wide productivity of the coastal marine ecosystem; namely the biomass of zooplankton in the California Current (Holbrook et al. 1997).

7.2.2 Abundance Trends

Data collected for this 316(b) study can be compared with other corollary and long-term data sets to give broader temporal context to the 2–3 year study at DCP. Several of the target taxa are nearshore species that are not taken by commercial or recreational fisheries. For these taxa, data from long-term studies at DCP on larval, juvenile, and adult fish abundance were used to examine changes in abundance that may be correlated with entrainment effects.

Declines in adult abundances of clinid kelpfishes and snubnose sculpin over the last several years were detected in DCP subtidal fish observation data in the control area (Tenera 1997c). This decrease in adult abundance also appears to be correlated with a decline in their larval abundance apparent from Intake Cove plankton tows. These taxa also had some of the highest estimates of total annual entrainment among the target taxa. Smoothhead sculpin, while having relatively high total annual entrainment, did not show similar declines in adult or larval abundance. These and

other nearshore taxa appear to demonstrate similar variation to that observed in previous years from subtidal fish observations and Intake Cove plankton tows.

Intake Cove plankton tows were collected at DCPD starting in 1990. Although sampling occurred throughout the year, larval density estimates were calculated from only the seven months of the year when larval fishes were most abundant (December–June). These data were used to adjust entrainment estimates to a long-term average density in the Cove. This procedure could introduce a bias in the adjusted estimate for fishes whose larvae are only abundant in the water column during the other five months of the year (e.g., sanddabs), and for some taxa an adjustment was not calculated. Two taxa, blackeye goby and clinid kelpfishes, were very abundant during the five months of Intake Cove samples that were not processed. They were adjusted to the long-term average because larvae for these taxa were present in the sorted samples.

Trends in adult abundance of the commercially important blue rockfish complex and cabezon also showed declines in our long-term fish observation data. The early and mid-1990's saw the advent of live-fish fishing along the central coast of California (Bloeser 1999) that could be related to these declines. Live-fish fishing has been identified as a cause of "growth overfishing" (Gulland 1983) and sharp declines in adult abundance (Starr et al. 1998). Landings at Morro Bay area ports do not indicate long-term declines in the catch of adult cabezon, although a 26% reduction in landings in 1999 compared to 1998 suggests that the 'live-fish' fishery cannot be sustained at high exploitation rates for long. Fishery harvest data do not indicate any long-term declining trends for other commercially or recreationally important species also entrained at DCPD. Any potential effects of power plant larval entrainment on catches of harvested species may be masked by changes in exploitation rates and the lack of credible catch-per-unit-effort data needed to examine long-term trends. Clearly, other longer-term declines associated with a climate regime shift that began in the late 1970's (Holbrook et al. 1997) must also be considered.

7.2.3 Life History Strategies

Life history strategies played an important role in the three assessment approaches we used to assess the magnitude of entrainment effects. Fecundity hindcasting (*FH*) estimates of adult losses relied on the number of eggs and fish or crab larvae produced during their life. Pelagic taxa like

northern anchovy typically produce numerous eggs that hatch relatively under-developed larvae. This strategy hedges against high egg and larval mortalities by reducing the amount of energy placed into any one progeny and assures that at least a few will survive to adulthood. Another common strategy found among the target fish taxa is producing relatively fewer, demersal, adhesive eggs. More energy is expended into fewer eggs that hatch more developed larvae than the taxa with pelagic eggs. This strategy is advantageous when combined with the demersal eggs since this latter adaptation reduces otherwise high egg mortalities. Thus, egg and larval survival rates up to the point of entrainment are directly linked to the reproductive strategy of the particular species being assessed and have marked effects on the demographic approaches used for estimating entrainment effects. The *AEL* approach depends on survival estimates from the time of entrainment to recruitment of adults into the fishery. Estimates of survivorship are undocumented for many of the taxa considered in this report and therefore they had to be estimated or substituted from other related taxa. The level of uncertainty associated with these survivorship estimates is typically unknown and can contribute to overall uncertainty in the estimates from these approaches. This also shows the importance of larval duration in the formulation of the approaches. Differences in life histories and adult distributions were accounted for in the formulation of the *ETM* among taxa. For example, pelagic species that released planktonic eggs are treated differently from nearshore species with demersal egg masses by estimating the population of inference using offshore extrapolation and alongshore extension of study grid abundance.

The availability of life history information allowed multiple assessment approaches to be used on several of the target taxa, but in the absence of independent population estimates for these taxa, our ability to assess effects was limited. For example, demographic data on egg and larval mortality for blackeye goby allowed the application of multiple assessment approaches, but in the absence of a population assessment or any fishery data for this species we could not provide any context for the estimates. The utility of any modeling technique to yield relative assessments of population-level effects depends on data describing the size of the adult fish populations and the ability to convert *FH*, *AEL*, and *ETM* estimates into comparable units of fishes in the wild.

For taxa where all three assessment approaches were completed, comparison among the results illustrate the usefulness of the multiple assessment approach. While the range and variance of life history parameters and population estimates are sources of uncertainty in our estimates, we can determine our areas of uncertainty through model comparison. Where both *FH* and *AEL* estimates exist, assuming a 50:50 sex ratio and aligning the ages of recruitment and maturation, the models can be compared directly using the relationship $AEL \equiv 2FH$ presented in previous assessment reports (Tenera 1999a, b). This conversion requires that ages of *AEL* and *FH* individuals are aligned and equal. The results from the demographic approaches are in similar units of either adult females (*FH*) or adults (*AEL*).

The *FH* and *AEL* model estimates for some of the target taxa were not in particularly close agreement (Table 7-1b). The age-aligned estimate for $2FH$ was over 4 times greater than the initial *AEL* estimate for Pacific sardine. In contrast, the *FH* estimates for sanddabs were low relative to *AEL*. When *FH* estimates are aligned for age the estimates remain low, relative to *AEL*. Sensitivity analyses were conducted to help determine the parameter estimates contributing the greatest influence on the *FH* and *AEL* estimates. The uncertainty associated with many of the parameters resulted in the use of a coefficient of variation of 100% to estimate their variance, in accordance with ETWG recommendations. This reduced the usefulness of the sensitivity analyses in interpreting model results.

Results for target taxa that were in close agreement with the relationship $2FH \equiv AEL$ (subject to age alignment) provide some assurance that the parameters used in the models were representative for the central California populations we sampled. They also increase confidence that the assessments of effects on these populations are reasonably accurate. Two examples were northern anchovy and the blue rockfish complex. In the blue rockfish complex, *FH* and *AEL* estimates were used to extrapolate population level effects using local fishery landings (Section 5.2.4). Using an estimate of the weight per adult blue rockfish in the fishery of 0.5 kg, an estimated *AEL* of 343 adults represented 172 kg of 3 yr old recruits, ca. 1% of the catch landed in the Morro Bay area in 1999, and valued at approximately \$740. Blue rockfish P_M ranged from 0.004–0.02, bracketing the *AEL*-based percentage of catch. It was also relatively linear over an

extrapolated area of 220–1,100 km² (smaller mortality associated with larger areas). Despite the limitations and assumptions of the models, the results of the assessment for the blue rockfish complex provide assurance that the effects on this taxon are low.

Model assumptions also need to be considered when interpreting the large *FH* estimate for brown rock crabs (Table 7-1a). The estimated number of reproductive adults using the *FH* model was extrapolated to known fishery-sized animals using estimates of adult mortality because females are reproductive before they enter the fishery. This reduced the *FH* estimate by an order of magnitude. Therefore, because of the additional assumptions required for the *FH* estimate, the estimate of P_M was used in extrapolating fishery effects. If all larval stages in the population are equally entrainable, then the estimate of P_M that was based on megalops would be representative of all larval stages. This assumption was made when \widehat{P}_M was applied to the catch.

For target taxa without available life history information, measurements of larvae from the entrainment and study grid provided some insight into their larval life history and ecology. The length ranges for most of the entrained target larval fish taxa indicate that their exposure to entrainment occurs over a relatively short time period during their development. The length-frequencies for several of the target taxa, including KGB and blue rockfish complex larvae, larval painted greenling, cabezon, and blackeye goby, appeared normally distributed. Average lengths were small demonstrating that they were exposed to entrainment for a brief period during their larval development. This supposition is supported by another characteristic common to these taxa; very few flexion or post-flexion larvae were entrained. Flexion and post-flexion stage larvae have more developed swimming abilities than younger individuals and could be avoiding the nets and potentially entrainment. The lack of these later developmental stages in our samples may also indicate that these taxa demonstrate larval behavior that removes them from risk of entrainment as they develop (e.g., settlement to benthic habitats or migration into deeper areas away from the intake). In contrast, the length-frequency distributions for the two target taxa with evidence of localized entrainment effects, clinid kelpfishes and snubnose sculpin, were skewed and included larger individuals than other taxa. Thus, it appears that these two taxa are exposed to entrainment over longer periods of development that include flexion and post-flexion stage larvae. An

extended duration of exposure to entrainment may partially explain the apparent declines in adult and larval abundance for these two taxa. Paradoxically, the extended exposure to entrainment that apparently results in localized effects on these taxa may also insure that localized effects do not become greater population-level effects. Extended planktonic duration will allow for larval transport and dispersal to occur over a much larger area.

7.2.4 Population Distribution

The assessment considered taxa that occurred in the entrainment samples at DCP. Their abundance depended on temporal and spatial distribution of adults as well as larval life stages. The taxa can be described as pelagic (*Cancer* crabs, Pacific sardine, and northern anchovy), subtidal (rockfishes, painted greenling, snubnose sculpin, cabezon, white croaker, blackeye goby, sanddabs, and California halibut), and nearshore subtidal and intertidal (smoothhead sculpin, monkeyface prickleback, and clinid kelpfishes). These different spatial distributions contributed to the ETWG's decision to use two strategies in applying the *ETM*. Nearshore species population size was assessed by alongshore extension of study grid abundance only; otherwise, an offshore extrapolation of study grid abundance was conducted and then extended alongshore. These expansions of the study grid abundance were based on measures of current speed and direction at the DCP current meter station and constrained by larval ages at entrainment.

The *ETM* approach applied to all target taxa required an estimate of a population that was defined by extrapolating larval density over an area delimited by estimated larval duration combined with current speed and direction in the study period. Estimates of total annual entrainment mortality (\widehat{P}_M) rely on the estimates of P_S (# of larvae at risk in the study grid/# of larvae in the population of inference). The results for target fish taxa in this 316(b) study indicate that while some entrainment effects remain localized, other effects can be spread over wide areas of inference (Table 7-2).

When estimated larval durations were relatively short and the subsequent area containing the population of inference remained relatively small, the extent of extrapolation was also small, based on the current meter data. Under these conditions, \widehat{P}_S was likely a more precise estimate, potentially less susceptible to model bias, resulting in a more accurate estimate of entrainment

effects, \widehat{P}_M . There is less confidence in our estimates of \widehat{P}_S where the extrapolated areas were substantially larger than the study grid. The variance component, resulting from density estimates projected offshore well beyond the zone that the measurements represented, was not included in our variance estimates of \widehat{P}_M (Appendix F). Thus, the estimated reference population of fishes with short larval duration of exposure (e.g., cabezon and blackeye gobies) are potentially more precise than those with a long time of susceptibility to entrainment (e.g., crabs and Pacific sardine). However, the situation for nearshore species is more complex. For example, those with longer times of susceptibility to entrainment (durations) may disperse into the study grid area, becoming more available to plankton sampling gear, resulting in better estimates of \widehat{P}_M .

It is unlikely that areas on the order of hundreds to thousands of times greater than the study grid are representative of the actual area affected by entrainment. Therefore, when \widehat{P}_M was applied to a stock assessment or fishery (e.g., for northern anchovy), it was based on a proportion of areas (area of extrapolation / stock assessment area). In some cases, this proportion was more approximate and, for brown rock crab, relied upon an estimate of the fishery grounds.

Target taxa that are not commercially or recreationally harvested are primarily small, nearshore fishes. As might be expected due to the shallow water, shoreline location of the DCP intake structure, several of these taxa are entrained in relatively high numbers, resulting in large P_M estimates (Table 7-2). For example, adult kelpfish occur in rocky, nearshore habitat and also had one of the highest P_M estimates (ca. 30–40%). If we use only the alongshore estimate of P_S for calculating \widehat{P}_M to compare results, those taxa with nearshore distributions, including smoothhead sculpin, snubnose sculpin, and monkeyface prickleback, had relatively large P_M estimates. Their greatest larval abundance occurred in the study grid cells closest to shore. This distribution is consistent with their adult distributions. Confidence in estimates of entrainment mortality for nearshore and intertidal fishes is supported when noting that \widehat{P}_M for these taxa does not vary between extremes of larval ages at entrainment when extrapolating larval abundance alongshore. Although entrainment sampling occurred at the shoreline intake where these nearshore taxa are in greatest abundance, the study grid sampling did not adequately sample other nearshore areas. Therefore, modifications were made to the calculations of PE to account for nearshore volumes

that were not sampled. While the addition of these inshore volumes may have overestimated \widehat{P}_M for some of these taxa, estimates for blackeye goby and California halibut, species that had broader adult distributions, were also high (July 1998–June 1999 period only: **Table 7-2**). Blackeye goby larvae ($\widehat{P}_M \approx 20\%$) were distributed throughout the study grid and occur as adults from the intertidal out to recorded depths of over 100 m (Eschmeyer et al. 1983). The relatively high \widehat{P}_M for blackeye goby may be due, in part, to the high density of adults directly in front of the intake structure. Entrainment of larvae hatched from demersal eggs within Intake Cove may explain our estimate of larval duration (6 d) that is considerably shorter than literature values (75 d). Therefore, while it is likely that some bias is introduced into the estimates of P_M due to the nearshore areas not sampled by the study grid surveys, the bias is probably species dependent and may not be related solely to adult distributions.

In contrast to species with nearshore distributions, estimates of P_M for species with more widespread, pelagic larvae (e.g., Pacific sardine and northern anchovy) were low, as expected by their long larval durations and large areas estimated by alongshore and offshore extrapolation. An assumption of the *ETM* is that larval distributions in the nearshore study grid are representative of densities in the area used for calculating P_S . While this assumption may be reasonable for values of P_S that represent relatively small areas of coastline, density in the grid is probably not representative of offshore areas used in calculating P_S for pelagic and subtidal species. As a result, applying \widehat{P}_M to stock assessments or fisheries data may not accurately represent entrainment effects because density in the nearshore study grid is probably not representative of average density in the areas used for estimating standing stock biomass. However, the extrapolation of the larval density trends observed in the study grid out to waters further offshore was an attempt to account for this inaccuracy. When \widehat{P}_M was applied to the fishery stock assessment by proportional area, in the case of northern anchovy, the biomass was similar to that determined using the two other methods of estimating adult losses, *AEL* and *FH*. The close correspondence in results for the different models suggests that the methodology was appropriate, and gives us confidence in the accuracy of the results.

7.2.5 Magnitude of Effects

Results from the present study indicate that effects on commercially and recreationally harvested species with subtidal or pelagic distributions are minimal. For cases where we were able to apply all three assessment approaches, the effects detected were relatively small, appeared to be localized, and thus could not affect the overall adult populations. These conclusions are supported by results for taxa such as KGB rockfishes where the estimated low levels of entrainment effects were corroborated by the corollary data that showed no consequent adult abundance or larval production decreases. While the alignment of results among assessment methods for other commercially or recreationally important taxa was less compelling, it nevertheless did not indicate the potential for any significant long-term population-level effects.

There was very little available information describing the demography of target taxa that were not commercially or recreationally important and this limited the applicable assessment approaches to the *ETM*. These were typically taxa distributed nearshore as adults, rendering their larvae highly susceptible to entrainment. In fact, these taxa were included in the targeted list by the ETWG because of their high abundance in entrainment samples. The *ETM* approach showed that entrainment could remove 10–40% of the annual larval production of several of these nearshore and intertidal taxa. In some of these cases, corollary data indicate that entrainment is probably only removing surplus production since there are no apparent long-term declines in local adult populations. For those nearshore taxa that do not display decreasing adult abundance, it is apparent from their length-frequency distributions that they were exposed to entrainment mortality for a brief portion of their early development. In contrast, for kelpfishes and snubnose sculpin, whose adult abundance do appear to be decreasing (with corresponding declines in long-term plankton tow index), the length-frequency distributions indicate a longer duration of exposure to entrainment. The combination of length-frequency analyses with the *ETM* estimates offer support to the conclusion that some nearshore taxa are affected differentially by entrainment. The increased duration of exposure to entrainment for kelpfishes and snubnose sculpin may also insure that these effects remain localized since extended planktonic duration provides additional opportunity for larval transport and dispersal.

7.2 Summary Assessment

In summary, populations of fishes and crabs do not appear to be adversely affected by the DCPD cooling water intake structure. Some are commercially important taxa with pelagic eggs and widespread populations (e.g., northern anchovy, Pacific sardine, white croaker, sanddabs, and California halibut). Their assessments resulted in either low estimated larval mortalities or small numbers of adult losses to their populations. Other widespread species also had low numbers of estimated adult equivalent losses to their populations and low estimated larval mortality, with populations that are distributed well beyond the zone of influence of DCPD. These included commercial species (rockfishes, crab, and cabezon). Five taxa (smoothhead sculpin, snubnose sculpin, monkeyface prickleback, clinid kelpfishes, and blackeye goby) had larval mortalities that exceeded 10% in reference to that part of the population living in an area 2–8 times the study grid area. For most of these (except kelpfishes and snubnose sculpin), subtidal observations of adults and long-term plankton sampling of larvae showed no decline in numbers over recent years in the vicinity of DCPD. Effects on kelpfishes and snubnose sculpin appear to be localized and the area affected is a small part of their total geographic distribution.

The models used for entrainment assessment considered functions critical to the life history of the 16 target taxa. These models were applied both at the point of entrainment for estimating the numbers of individuals entrained and also in the adjacent offshore areas for estimating the population of inference. We also considered migratory, pelagic species and other widespread taxa differently than nearshore taxa in estimating the population of inference. The area around DCPD encompasses nursery and feeding areas for many species including the 16 target taxa. These areas also extend well outside the DCPD zone of influence and in the cases of northern anchovy and Pacific sardine the center of the spawning biomass is located south of Point Conception. Measurements of larvae indicate that most of the target taxa are exposed to entrainment for a relatively short period of time during their larval development and thus were produced locally. These results indicate that entrainment effects appear to be limited to localized effects on nearshore species. Therefore, the potential for damage due to entrainment on the biological value of the source water body is low.

7.3 Best Technology Available

Although no adverse environmental impact was determined, a generic review of alternative cooling water technologies applicable to DCPD was evaluated in **Section 6**. A hierarchical set of three criteria were applied to the alternatives that were considered:

A review of alternative cooling water technologies applicable to DCPD was evaluated in **Section 6**, as required by the RWQCB. A hierarchical set of three criteria were applied to the alternatives and considered:

- available technology with demonstrated operability and reliability at intakes similar to DCPD;
- a reduction in the loss of aquatic organisms; and
- applicability at DCPD, based on engineering, operations, and reliability considerations.

The technology assessments examined modifications that may affect impingement and entrainment although impingement rates are very low at DCPD. Site-specific studies determined impingement rates were low ranging between 0.3 and 0.7 kg per day per unit, which is equivalent to 360 kg/yr for both units. Compared to other west coast generating stations (Tenera 1998a) that impinge between 2,800 to 24,100 kg/yr, impingement at DCPD does not represent an adverse environmental impact. Consultation with industry authorities and published engineering evaluations of demonstrated technologies applicable to reducing entrainment, revealed few intake modifications that might reduce the density of fish larvae at risk to entrainment in a cost effective manner. Although several facilities have reduced entrainment by modifying intake screen systems, the harsh coastal environment at DCPD precludes application of these strategies without extensive site-specific testing. Reduction of operation to periods when fish densities are lower was considered not viable in the current power exchange pricing environment. Replacement of the heat exchange processes from open-cycle seawater cooling systems to closed-cycle cooling tower strategies was determined to be economically unfeasible and added substantial environmental risk to terrestrial communities.

As discussed in the other sections of this report, DCPD is not causing an adverse environmental impact (AEI) and therefore no consideration of alternative cooling water intake structure

technologies for minimizing AEI is necessary. However, this assessment of alternative technologies is included in response to a requirement by the RWQCB. The conclusion based on this assessment is that the existing cooling water intake structure is the best technology available for DCP.

Table 7-1a. Estimates of fecundity hindcast adult females (\widehat{FH}) and projected equivalent adults (\widehat{AEL}) in numbers of individuals for Analysis Periods 1 (December 1996–November 1997) and 3 (July 1997–June 1998) for the two target crab taxa collected and analyzed at DCPD with their potential relative value.

Taxon	Analysis Period	\widehat{FH}	\widehat{AEL}	Interpreted Annual Value (applied modeling approach)		
Brown rock crab	1.	117,000	234,000	\$1,090 ^c	\$2,170 ^c	\$1.760
		(11,700) ^a	(23,400) ^b	(\widehat{FH})	(\widehat{AEL})	(<i>ETM</i>)
	3.	91,000	182,000	\$845 ^c	\$1,690 ^c	\$2.040
		(9,100) ^a	(18,200) ^b	(\widehat{FH})	(\widehat{AEL})	(<i>ETM</i>)
Slender crab	1.	27,300	54,600	no fishery value		
		(2,730) ^a	(5,460) ^b			
	3.	8,950	17,900	no fishery value		
		(895) ^a	(1,790) ^b			

^a Estimate extrapolated to fishery-sized female crabs.

^b Estimate extrapolated to fishery-sized crabs, both male and female.

^c Value based on assumption of 10% vulnerability to fishery (from mark-recapture experiments and fishery recapture data: see Section 5.2.1.1).

Table 7-1b. Estimates of adjusted annual entrainment (\hat{E}_{Adj-T}), fecundity hindcast adult females (\widehat{FH}), and projected equivalent adults (\widehat{AEL}) in numbers of individuals for Analysis Periods 1 (October 1996–September 1997), 2 (October 1997–September 1998), and 3 (July 1997–June 1998) for the 14 target fish taxa collected and analyzed at DCPD with their potential relative value. When more than one valuation procedure was used, the largest value is listed. The total number of target taxa impinged during April 1985–March 1986 are included for comparison.

Taxon	Analysis Period	\hat{E}_{Adj-T}	\widehat{FH}	\widehat{AEL}	Total Impinged 1985-86	Interpreted Annual Value (applicable valuation method)
Pacific sardine	1.	8,470,000	3,170	2,630	0	\$710 (ETM modeling applied to reduction and live bait fisheries)
	2.	22,600,000	8,460	7,000		
	3.	22,600,000	8,460	7,000		
Northern anchovy	1.	136,000,000	16,100	43,200	1	\$576 (AEL and ETM modeling applied to non-reduction wetfish fishery)
	2.	376,000,000	44,700	120,000		
	3.	377,000,000	44,700	120,000		
KGB rockfish complex	1.	275,000,000	617	1,120	12	\$20,000 (ETM modeling applied to commercial live-fish fishery)
	2.	222,000,000	497	905		
	3.	222,000,000	497	906		
Blue rockfish complex	1.	84,040,000	43	353	8	\$1,230 (ETM modeling applied to commercial fishery)
	2.	33,800,000	18	164		
	3.	33,900,000	20	142		
Painted greenling	1.	24,200,000	—	—	1	forage species (no economic valuation)
	2.	9,610,000	—	—		
	3.	12,100,000	—	—		
Smoothhead sculpin	1.	57,700,000	—	—	10	forage species (no economic valuation)
	2.	115,000,000	—	—		
	3.	129,000,000	—	—		
Snubnose sculpin	1.	110,000,000	—	—	9	forage species (no economic valuation)
	2.	83,500,000	—	—		
	3.	105,000,000	—	—		
Cabezon	1.	51,900,000	—	—	1	\$9,000 (ETM modeling applied to commercial live-fish fishery)
	2.	36,300,000	—	—		
	3.	36,300,000	—	—		
White croaker	1.	305,000,000	5,110	14,700†	0	\$872 (AEL modeling applied to commercial fishery;)
	2.	440,000,000	7,380	21,300†		
	3.	447,000,000	7,500	21,600†		
Monkeyface prickleback	1.	83,100,000	—	—	0	no demographic or economic data were available for this species to estimate adult losses or fishery valuation
	2.	61,500,000	—	—		
	3.	60,200,000	—	—		
Clinid kelpfishes	1.	181,000,000	—	—	17	forage species (no economic valuation)
	2.	308,000,000	—	—		
	3.	458,000,000	—	—		
Blackeye goby	1.	128,000,000	12,000	75,200	0	forage species (no economic valuation)
	2.	109,000,000	10,300	64,100		
	3.	128,000,000	12,100	75,400		
Sanddabs*	1.	7,160,000	426	2,370	4	\$82 (ETM modeling applied to commercial fishery)
	2.	1,540,000	92	511		
	3.	6,610,000	393	2,190		
California halibut*	1.	8,260,000	—	—	0	\$10,060 (ETM modeling applied to commercial fishery)
	2.	15,700,000	—	—		
	3.	15,500,000	—	—		

— = not estimated

* = entrainment estimates were not adjusted to the long-term (1990–98) Intake Cove plankton tow mean

† = 2FH aligned to fishery-age adult equivalents

Table 7-2a. Total annual entrainment mortality (\widehat{P}_M) and zone of extrapolation ($1/\widehat{P}_S$) as a multiple of study grid areas (using alongshore currents) or of study grid population (using alongshore and offshore extrapolation) for larvae of the two target crab taxa from Analysis Periods 3 (July 1997–June 1998) and 4 (July 1998–June 1999) estimated by using 2 methods of calculating \widehat{P}_S using maximum larval duration estimates through the megalops stage at DCPD and water current measurements.

Taxon	Analysis Period	\widehat{P}_S calculated using alongshore currents		\widehat{P}_S calculated using alongshore currents and extrapolating densities offshore	
		\widehat{P}_M	$1/\widehat{P}_S$	\widehat{P}_M	$1/\widehat{P}_S$
brown rock crab	3.	0.00563	8.3	0.0000186	2,590.7
	4.	0.00652	9.3	0.000146	417.6
slender crab	3.	0.0844	8.1	0.0107	236.9
	4.	0.0113	7.9	0.000784	114.2

Table 7-2b. Total annual entrainment mortality (\widehat{P}_M) and zone of extrapolation ($1/\widehat{P}_S$) as a multiple of study grid areas (using alongshore currents) or of study grid population (using alongshore and offshore extrapolation) for larvae of the 14 target fish taxa from Analysis Periods 3 (July 1997–June 1998) and 4 (July 1998–June 1999) estimated by using 2 methods of calculating \widehat{P}_S using both mean and maximum larval duration estimates derived from lengths of entrained larvae at DCP and water current measurements.

Taxon	Analysis Period	\widehat{P}_S calculated using alongshore currents				\widehat{P}_S calculated using alongshore currents and extrapolating densities offshore			
		based on mean duration		based on max. duration		based on mean duration		based on max. duration	
		\widehat{P}_M	$1/\widehat{P}_S$	\widehat{P}_M	$1/\widehat{P}_S$	\widehat{P}_M	$1/\widehat{P}_S$	\widehat{P}_M	$1/\widehat{P}_S$
Pacific sardine	3.	–	–	–	–	0.000284	47.3	0.0000669	1,078.1
	4.	–	–	–	–	*		*	
northern anchovy	3.	–	–	–	–	0.000575	16.5	0.0000786	683.8
	4.	–	–	–	–	0.00205	7.9	0.000201	454.5
KGB rockfishes	3.	0.0365	2.8	0.0532	5.1	0.0146	7.2	0.00962	29.5
	4.	0.0380	2.5	0.0376	6.7	0.0218	4.4	0.00476	53.9
blue rockfish complex	3.	0.00338	2.6	0.00468	4.1	0.000955	9.3	0.000456	42.1
	4.	0.0471	2.0	0.0411	5.0	0.0211	4.6	0.00356	60.0
painted greenling	3.	0.0490	3.6	0.0671	6.2	0.00877	20.7	0.00910	47.7
	4.	0.0319	3.6	0.0381	7.3	0.0114	10.3	0.00444	63.9
smoothhead sculpin	3.	0.105	2.8	0.153	7.3	–	–	–	–
	4.	0.146	3.0	0.198	8.2	–	–	–	–
snubnose sculpin	3.	0.102	2.0	0.144	4.3	0.0361	7.0	0.0231	39.3
	4.	0.202	1.5	0.239	4.2	0.1206	2.6	0.0210	55.8
cabezon	3.	0.0243	2.5	0.0337	3.5	0.00683	9.1	0.00569	21.8
	4.	0.0140	1.4	0.0161	2.5	0.00835	2.4	0.00919	4.4
white croaker	3.	0.0190	2.8	0.0297	5.5	0.00255	21.2	0.00133	127.5
	4.	0.0366	1.9	0.0550	3.9	0.0211	3.4	0.00704	32.3
monkeyface prickleback	3.	0.162	3.0	0.232	6.9	–	–	–	–
	4.	0.108	2.4	0.113	8.0	–	–	–	–
clinid kelpfishes	3.	0.318	3.1	0.410	7.3	–	–	–	–
	4.	0.294	2.7	0.395	6.2	–	–	–	–
blackeye goby	3.	0.190	1.3	0.228	2.4	0.131	2.0	0.0787	8.6
	4.	0.174	1.2	0.220	1.8	0.163	1.3	0.179	2.5
sanddabs	3.	0.0145	2.4	0.0157	3.2	0.00493	11.7	0.00413	22.4
	4.	0.0663	1.8	0.0537	3.5	0.0459	2.7	0.0106	18.5
California halibut	3.	0.00269	2.8	0.00449	6.1	0.000835	8.9	0.000763	35.9
	4.	0.175	2.3	0.252	5.4	0.123	3.5	0.0525	32.8

– no calculations of this class made for this taxon

* No Pacific sardine larvae were collected in paired entrainment and study grid samples for this period.

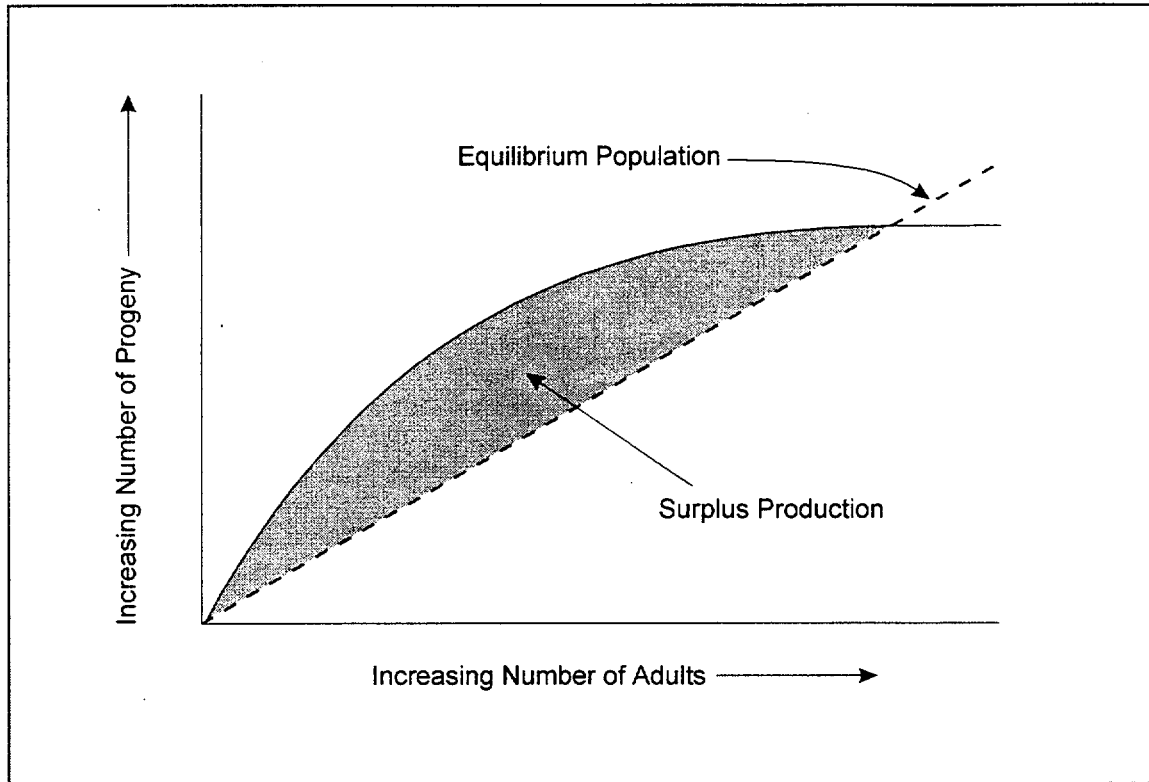


Figure 7-1. Surplus production model.

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8.0 Conclusion

Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act) requires that the Diablo Canyon Power Plant (DCPP) cooling water intake structure represents the best technology available (BTA) to minimize adverse environmental impacts (AEI). As discussed in the Introduction of this report, the United States Environmental Protection Agency (USEPA) has indicated that assessment of AEI should be based on an evaluation of population-level effects. The results of the assessments on the 16 target taxa selected for this DCPP 316(b) study by the Entrainment Technical Work Group (ETWG) show no population level effects due to entrainment and impingement. Consequently, we conclude that the DCPP intake structure is not causing AEI.

Since DCPP is not causing population-level effects, no consideration of alternative cooling water intake structure technologies for minimizing AEI is necessary. However, this report does include an assessment of alternative technologies in response to a requirement by the Central Coast RWQCB. The conclusion of this alternative technologies assessment is that the existing cooling water intake structure is the best technology available for DCPP.

Summary of Effects

- Populations of the five target taxa with pelagic eggs (Pacific sardine, northern anchovy, white croaker, sanddabs, and California halibut) are not adversely impacted by the DCPP intake indicated by generally low to moderate estimates of \widehat{P}_M , \widehat{FH} , or \widehat{AEL} . Furthermore, these taxa are protected against localized effects by having widespread populations or spawning centers distant from DCPP. In the case of California halibut, with a relatively high \widehat{P}_M , but low approximated \widehat{FH} , very few individuals are entrained at DCPP so there is no adverse impact on their population.
- Both groups of rockfishes (KGB and blue rockfish complexes) had low numbers of estimated adult equivalent losses to their populations. Cabezon had low estimated larval mortality (<1%), based on extrapolations using the alongshore and onshore currents. This study also estimated that the larval mortality of painted greenling was generally below 1%, using similar extrapolations. In addition, brown rock crab and

slender crab had low estimated larval mortality. All of these species have populations that are distributed well beyond the zone of influence of DCP.

- The remaining taxa (smoothhead sculpin, snubnose sculpin, monkeyface prickleback, clinid kelpfishes, and blackeye goby) had larval mortalities that exceeded 10% in reference to that part of the population living in an area 2–8 times the study grid area. However, the area affected is only part of these species' geographic range. Therefore, these effects appear to be localized and do not constitute population-level effects.
- Of the five taxa with relatively high estimated larval mortalities, only two had corroborating evidence that local adult and juvenile abundance could be affected by the DCP cooling water intake system: clinid kelpfishes and snubnose sculpin. Both subtidal observations of adults and long term plankton sampling of larvae showed declining numbers over recent years in the vicinity of DCP.

It is important to note that the corroborating evidence noted above for clinid kelpfishes and snubnose sculpin is based on limited sampling at one local subtidal sampling transect four times per year (as visibility permits) and weekly plankton tows at the mouth of the Intake Cove. Additionally, there is some evidence in southern California (Holbrook et al. 1996) that the effects of a regime shift in the California Current towards warmer water temperatures combined with successive El Niño events have continued to cause general population declines in more northerly distributed species (e.g., rockfishes). It should also be noted that the *ETM* methodology was originally developed and adapted for species with larvae dispersed throughout the study grid area and not for nearshore species. Clinid kelpfishes and snubnose sculpin are nearshore fishes and thus were undersampled by the study grid methodology. Both kelpfishes and snubnose sculpin (as well as the other nearshore species) are found in these inshore areas, and thus their larval mortality estimates could be overestimated.

The effects of the cooling water intake structure estimated by the *AEL* and *FH* models did not include the very small losses due to impingement. When added to the *AEL* and *FH* estimates, these losses do not change the overall conclusion that entrainment effects of the plant's cooling water intake system do not constitute AEI for populations of the 16 target taxa for which assessments were made.

Using criteria supplied by the USEPA (1977) for determining the extent of AEI and supplemented by criteria specific to the present 316(b) study at DCP, estimates of entrainment effects on the populations of the 16 target taxa presented in this report do not constitute AEI. For two of the nearshore taxa assessed (clinid kelpfishes and snubnose sculpin) there is some evidence of local decreases in both larval and adult abundance which may be attributable to entrainment of early life stages in the DCP cooling water intake system. However, climatological and oceanographic conditions (e.g., regime shifts, El Niño events) may have contributed to these local declines to an unknown extent and should be considered.

Alternative Technologies

Alternatives to the current cooling water system evaluated for DCP included seasonal refueling outages; reduction in annual operation; modifications to the traveling screens; sluiceways and their operation; expansion of the existing shoreline intake structure and installation of modified screening; and reductions in cooling water flow rates. In addition, consideration was given to transferring the ocean heat sink, open-cycle cooling process to land-based closed-cycle cooling towers. Each alternative is expected to offer some potential for reducing the losses of organisms resulting from entrainment or impingement.

The judgment of the best technology available for the Diablo Canyon Power Plant is based on a consideration of the level of impact caused by entrainment and impingement on the marine community, demonstrated operation and reliability of various alternative technologies, and the biological effectiveness of these technologies for further reducing entrainment and impingement, engineering and operational feasibility, and cost effectiveness of the alternative technologies.

Based on the evaluation of alternative intake technologies for DCP it was concluded that:

- There is no reasonable alternative intake location that would reduce entrainment and impingement losses.
- Behavioral barriers would not reduce the numbers of fish exposed to impingement or entrainment.
- Media filters, barrier nets, and Gunderboom were determined to be not applicable at the DCP site due to the large flow volumes, high debris loading, and potential for rough ocean conditions.

- Inclined screens, drum screens, and centerflow screens with fine mesh, would not significantly reduce impingement losses and have not been proven to substantially reduce entrainment losses.
- Modifications to the intake screens and the addition of a fish return system could reduce the losses due to impingement. Because of the low numbers of fish impinged on existing intake screens and the relatively high costs involved, installation of modified intake screens is disproportionate to the benefit.
- Expansion of the intake structure to achieve a lower approach velocity or to provide an angled screen intake could reduce impingement. The cost of modification, however, is disproportionate to the benefits of reduced impingement.
- Variable speed pump drives could be provided to allow reductions in circulating water flow to minimums required for plant operation. The design margins of the condenser system at DCPD could allow a 2 to 10 % reduction in circulating flow when ambient seawater temperatures are below 14.4 °C without exceeding discharge temperature limits. The high cost, uncertain reliability, and low biological benefit make this option impractical.
- Seasonal patterns were detected for entrained larval fishes and some benefit has occurred when cooling water pumps are shut down for refueling and maintenance outages in spring and fall. Fewer larval fishes would be susceptible to entrainment if all outages were scheduled for the spring. However, scheduling outages to coincide with the seasonal distribution in abundance of a particular fish or group of fishes is not economically feasible, due to the characteristics of the nuclear fuel.
- Consideration was given to curtailing power plant operation during spring months when density of fish larvae was highest. In the current pricing structure practice for electrical production, the losses associated with nine month operation windows make this scenario not economically feasible. Replacement power from gas-fired facilities would also have a negative contribution to air quality because of the release of emissions that are not generated by nuclear facilities.
- Closed-cycle cooling towers were evaluated to reduce entrainment and impingement losses. Cooling towers using saltwater would impact the land and biota with their

large “foot-print,” corrosive fogs, vapor plumes, and salt drift. There is no resource large enough to provide freshwater makeup for cooling towers, and the addition of a seawater desalination plant of sufficient capacity would add considerably to project costs. The costs to retrofit closed-loop cooling towers to DCP, which would require substantial construction, refitting, and redesign of the plant, would not be viable in the current or future power generation market.

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Appendix A

DCPP 316(b) Demonstration Study: Phase 1-
Entrainment Study Design, I. Sampling Location.

Diablo Canyon Power Plant
316(b) Demonstration Study
Phase 1 — Entrainment Study Design
I. Sampling Location

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FOREWORD

Section 316(b) of the Clean Water Act requires that "...the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." This project is designed to determine whether Diablo Canyon Power Plant's (DCPP) cooling water intake design complies with Section 316(b) of the Clean Water Act. The determination of compliance with Section 316(b) involves an evaluation of whether the operation of the DCPP intake system results in an adverse environmental impact and if so, what technologies are both available and cost effective in reducing any adverse impacts.

In June 1996, the DCPP Entrainment Technical Working Group reviewed and concurred with the Diablo Canyon Power Plant 316(b) Entrainment Sampling Study Plan Proposal. The proposal was organized into four phases which encompassed the development and verification of sampling methodology and resource assessment. The study plan proposal only presented the entrainment component of a 316(b) Demonstration study. It did not include plans for the re-evaluation of the previous impingement study or the review and update of the impact assessment and intake technology assessments. The 316(b) Demonstration study would also consist of completion and submittal of a final report (316(b) Demonstration) which will be used in making recommendations on further actions to the Central Coast Regional Water Quality Control Board (CCRWQCB).

A summary of anticipated 316(b) Demonstration studies and documents includes:

Information Gathering/Activities	Documents/Reports
Entrainment	Chapter in 316(b) Demonstration Report
Phase 1 Entrainment Sampling Verification Studies	Entrainment Study Design Report I. Sampling Location II. Sampling Methods
Phase 2 Entrainment Larval Abundance Sampling	Entrainment Study Plan
Phase 3 Resource Comparison Model Evaluation — Sampling Verification Studies	Entrainment Source Water Study Design Report
Phase 4 Resource Comparison Sampling	Entrainment Source Water Study Plan
Impingement	Chapter in 316(b) Demonstration Report
Impact Assessment	Chapter in 316(b) Demonstration Report
Technology Assessment	Chapter in 316(b) Demonstration Report
316(b) Demonstration Study Plan	316(b) Demonstration Study Plan
316(b) Demonstration Report	316(b) Demonstration Report

The 316(b) Entrainment Sampling Study Plan Proposal described four phases and a timeline for development and verification of methodology, and actual sampling for both entrainment and resource assessment. The study plan proposal also included progress reports, and preparation and submittal of a final report at the completion of all sampling and sample processing. The proposed phases of the entrainment study are summarized as follows:

Phase 1 — Entrainment Sampling Verification Studies

Evaluate potential sampling sites and methods which provide sample results that best represent the composition and abundance of larvae entrained by the power plant cooling water system.

Results from Phase 1 studies to evaluate sampling methodology, location, sample size, number of samples, and length of sample collection per week will be used to determine the Phase 2 sampling design that will provide the most representative samples of entrained organisms.

Phase 2 — Entrainment Larval Abundance Sampling

Conduct sampling necessary to estimate the composition and abundance of organisms entrained by the power plant's intake.

Phase 3 — Resource Comparison Model Evaluation – Sampling Verification Studies

Evaluate conceptual models for assessing entrainment losses, and develop sampling methods, if necessary, to provide empirical data for the selected model. Some of the methods of assessing effects on the resource may involve source waterbody (SWB) sampling. If required, methods to accurately sample the SWB will be evaluated to ensure that samples are comparable to entrainment samples and can be used to compare the proportion of larval withdrawal from the SWB by the power plant.

Phase 4 — Resource Comparison Sampling

This phase will consist of collecting the data necessary to support the resource comparison model chosen in Phase 3.

The impingement, impact and technology assessment components of the 316(b) Demonstration may involve similar design and implementation phases. Study plan proposals for these other components will be developed after implementation of the entrainment study in coordination with the DCP Entrainment Technical Working Group.

SUMMARY

The purpose of the Diablo Canyon Power Plant (DCPP) entrainment study is to provide a reasonable estimate of organisms passing through the power plant's cooling water system. It is assumed that a following step will be an assessment of the potential impact due to the loss of entrained organisms from source water populations. The objective is to provide as accurate and precise an estimate of organisms entrained as reasonably achievable. The selection of both gear types and sampling locations for the Phase 1 — Entrainment Sampling Verification Studies are based on requirements for regulatory information, on-site trials of field methods and results of sampling gear evaluations. The proposed Phase 1 studies were described in the 316(b) Entrainment Sampling Study Plan Proposal.

A survey rationale was developed to evaluate eight potential entrainment sampling locations. Three of these sampling locations were recommended for evaluation in the Study Plan Proposal. The additional locations include sites that were potential candidates in early stages of the study design and discarded before or added after submittal of the Study Plan. A series of field inspections and trials was performed to evaluate the candidate locations based on a set of sampling design criteria. The initial acceptance criteria included the ability to safely and repeatedly collect samples over a 24-hour period, to estimate sampled flow volumes, and to avoid any loss of fish larvae due to cropping from biofouling organisms. The results of field trials and test samples were evaluated for the more preferred entrainment sampling locations and reviewed along with all of the candidate sites against acceptance criteria.

All sites located on the cooling water system conduits were eliminated due to potential cropping losses of entrained organisms by biofouling organisms living on the conduit walls. More detailed inspections and analyses were performed at a header pipe located just inside the main cooling water conduit as a test of the possibility of sampling other downstream locations in the cooling water system. The header pipe was selected for these tests, because of the lower potential for biofouling at this point inside the cooling water system.

The intake cove sampling location is an open water site located in front of the intake structure. After the site passed initial acceptance criteria, plankton samples of approximately 50 m³ were collected about 10 m in front of the intake structure at four fixed stations corresponding to the location of the maximum flow to the power plant's four main circulating pumps. These pumps are spaced equidistant from each other. A 0.7 m diameter bongo net made of 505 µm mesh and equipped with a flowmeter was continuously lowered and raised through the water column at each of the four sampling stations. The 505 µm mesh net was replaced with 335 µm mesh following two separate sampling occasions when larval cabezon (approximately 4–6 mm in length) were observed protruding through the net mesh. The horizontal intake flows at the intake cove sampling location tend to produce an oblique angle to the tow path of the vertically hauled net. The sampling was repeated at the four stations every 3 hours for a 24-hour period 1 day a week.

The bar rack sampling location, a second site that passed initial acceptance criteria had other problems due to the requirements that the bar rack openings be clear of drifting kelp and debris. The debris would interfere with towed plankton nets and sample collections. Occlusion of the bar

rack openings also significantly altered intake flow patterns such that the source and volume of intake flow from the bar rack locations to the individual pumps could not be reliably determined. These estimates of flow are necessary to weight the densities of entrained organisms. There is no promising solution to the problem within the foreseeable future.

The traveling screen sampling location, a third candidate site after initial screening, did not pass initial acceptance criteria due to a lack of feasible site access. Since there is no existing sampling access to the location, large diameter holes would have to be drilled in the concrete upper deck of the intake structure. The access ports would need to be large enough to accommodate high volume submersible pump samplers required to pump sample water as much 6 meters (20 ft).

The fourth alternative sampling site, at the header pipe did not pass acceptance criteria, because entrained organisms could be lost due to biofouling organisms that exist between the bar racks and the sampling location. In addition, the piping system made it very difficult to measure source water flows to the location. If conditions change so that long-term, reliable samples can be collected at this location, equipment has been installed which could be used to sample water drawn from the header pipe.

The remaining four alternative sampling sites, which are all downstream of the header pipe, did not pass initial screening based on the possibility that entrained organisms would be lost from cropping by biofouling organisms throughout the remaining length of the power plant's cooling water system. The intake cove was the only location that satisfied the acceptance criteria for a sampling site. Sampling methods and testing are presented in Phase 1, Entrainment Study Design, II. Sampling Methods. The intake cove location will serve as the primary sampling site for the duration of the study. Supplemental entrainment information may be gathered from either the bar racks or header pipe locations. The details are presented in the Phase 2 Entrainment Study Plan, including specific field methods and laboratory procedures. All samples will be sorted to the lowest possible taxa of larval fishes and *Cancer* crabs (rock crabs). A special study will be developed to evaluate larval abalone entrainment.

Entrainment sampling will continue at this primary sampling location for a period projected at this time to be 18 to 22 months. This sampling period is consistent with EPA Guidance which recommends that the biological survey be conducted over a period of one to three years. This will allow for the sampling of two consecutive annual peaks in larval fish abundance. At the end of each year, the sample results will be assessed by comparing larval abundance and species compositions with other data from the study area. This assessment will estimate the magnitude of entrainment through direct determination of the diel and seasonal variation of the entrained organisms. The intent is to meet the EPA requirement for a survey to provide a sufficient and valid data base for reasonable assessment of environmental impact related to the design, construction, location, and capacity of a cooling water intake structure.

The data assessment will be reviewed by the Entrainment Technical Working Group to determine the adequacy of the data for making a reasonable assessment of environmental impact as related to the cooling water intake structure relative to a Best Technology Available determination. Based on this review, the Entrainment Technical Working Group will make a recommendation as to the need to continue data collection. The recommendation will be provided to both the Multiagency Workgroup and the Regional Board. If it is recommended that the data collection phase extend beyond 22 months, the Board may give direction to the work group regarding the project's overall timeline. During the data assessment and the decision

process on the length of sampling, described above, data collection will continue so that there is no gap in data collection.

1.0 PHASE 1 STUDY PLAN DESIGN RATIONALES

The purpose of this report is to document the results of the Diablo Canyon Power Plant (DCPP) Phase 1, Entrainment Sampling Verification Studies, Part I, Sampling Location, and to provide recommendation for the Entrainment Larval Abundance Sampling locations as well as recommendations for specific sampling methodologies and parameters for the entrainment study. The entrainment study should provide a best estimate of organisms entrained by the cooling water system and minimize biases to the estimate caused by the cooling water system operation or passage through the plant's cooling water system. The results will be used to compute the annual entrainment losses in the impact assessment portion of the 316(b) Demonstration.

The four phases presented in the DCPP 316(b) Entrainment Sampling Study Plan Proposal (Appendix A) are as follows. Phase 1, Entrainment Sampling Verification Studies, evaluates the potential sampling sites and methods which best represent the composition and abundance of larvae entrained by the power plant cooling water system. Phase 2, Entrainment Larval Abundance Sampling, entails conducting the sampling necessary to determine the composition and abundance of the organisms entrained by the power plant's intake. Phase 3, Resource Comparison Model Evaluation, encompasses evaluation of resource comparison models for assessing entrainment losses and developing sampling methods to provide empirical data for the selected model. Phase 4, Resource Comparison Sampling, is the actual resource comparison sampling using methods developed in Phase 3.

Sampling locations of the power plant's cooling water system were identified as possible sites for entrainment sampling. The eight locations included for initial site screening were:

1. Intake Cove
2. Bar Rack
3. Traveling Screens
4. Header Pipe
5. Meteorological Tower
6. Condenser Outlet
7. Discharge Tunnel
8. Discharge Outfall

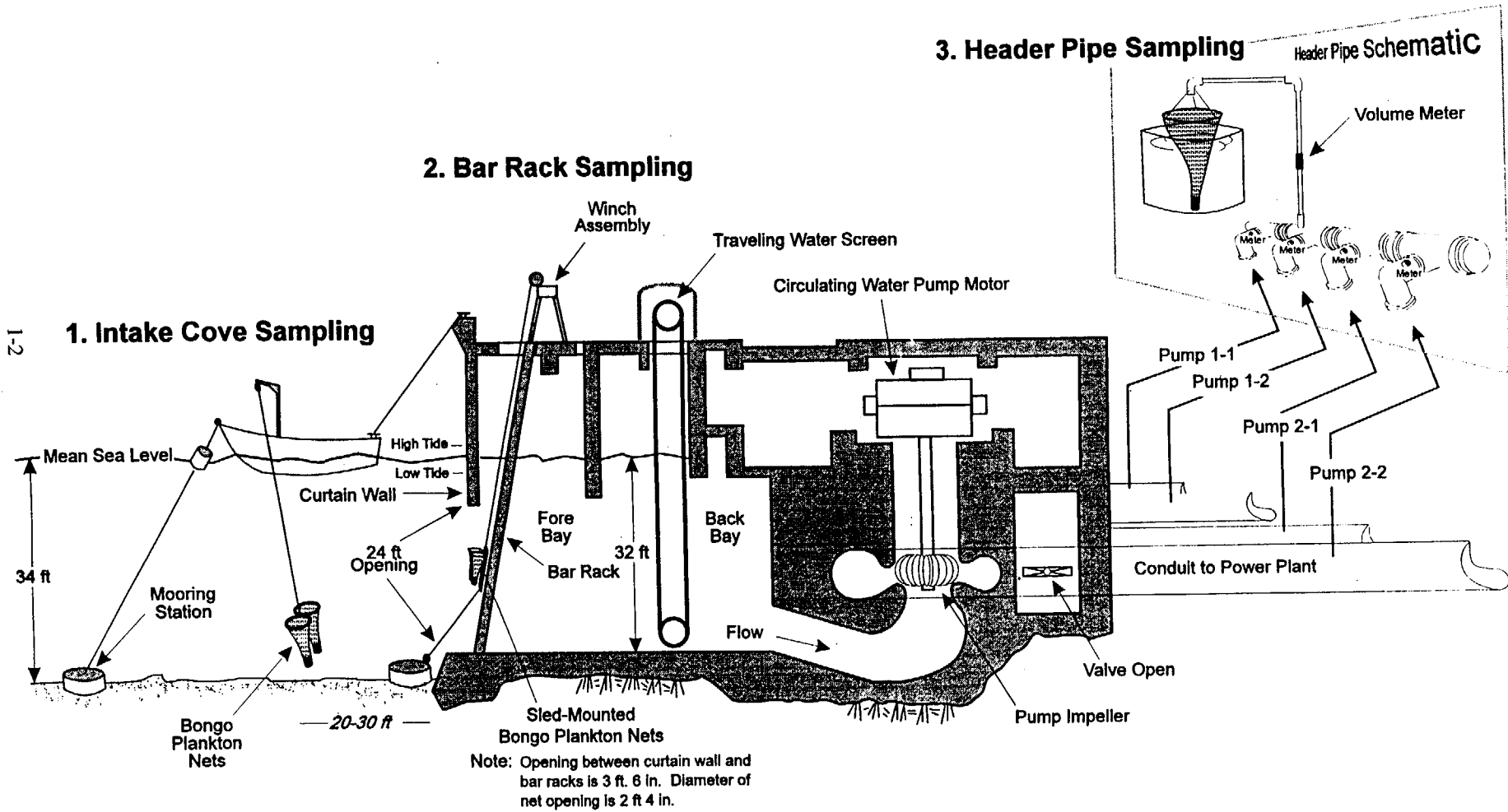
These sites are later described in Chapter 2 and discussed Chapter 3 along with their acceptance test results.

An initial screening eliminated four of the sites due to a potential cropping loss of entrained organisms by biofouling organisms living on the walls of the power plant's cooling water system. The sites that were eliminated are described in this report along with a discussion of their advantages and disadvantages. Two sampling sites accepted from the initial screening were recommended in the Study Plan Proposal for evaluation as potential entrainment sampling locations. The sites were (1) directly in front of the bar racks and (2) the header pipe system. Realizing several potential difficulties at the two sites proposed for design studies, a third location was added in the intake cove in front of the intake structure. This site was added to the list of potential sampling sites after submittal of the Study Plan Proposal. These three sites (Figure 1-1) were evaluated to determine which site(s) could be sampled reliably to provide accurate and precise estimates of entrainment loss. Other sampling parameters evaluated as part

Figure 1-1

Cross-Section View of the DCPD Intake Structure Illustrating the Location of Entrainment Sampling Sites

(not to scale)



1-2

of Phase 1 included determination of optimum volume of water to be filtered per sample, number of samples, length of sample collection time, and schedule of sample collection.

The target organisms for the entrainment study as defined by the DCCP Entrainment Technical Working Group are larval forms of fishes, *Cancer* spp. crabs (rock crabs), and abalone. This report summarizes the results of Phase 1 analyses and recommendations based on considerations of larval fish and *Cancer* spp. sampling locations, as well as preliminary sampling methods and equipment required to sample selected locations. Procedures for capture and analysis of abalone larvae are still under development.

1.1 Rationale for Entrainment Sampling

The DCCP cooling water intake volumes do not vary greatly, because the plant is operated normally as a base-loaded generating facility. However, the taxonomic composition and density of entrained organisms varies seasonally. Therefore, to provide the best reasonably obtainable estimate of the power plant's entrainment losses, using present technology, it is necessary to collect samples of entrained organisms for a minimum of one year. Additional sampling time may be necessary if unusual oceanographic conditions such as an El Niño, affect the normal distribution or survivorship of organisms in the source water body. The study design's goal is to produce conclusions that support confident regulatory decision-making.

Larval fish taxa expected to be captured in sampling design tests are those that were found in previous larval fish studies conducted in the area of Diablo Canyon. A peer-reviewed study performed from 1975 to 1977 provides information on seasonal patterns of plankton and ichthyoplankton taxa composition, abundance, and length frequencies.¹ Weekly samples were collected during an eighteen-month survey of nearshore and offshore locations. The sampling net had a larger opening (1 m²) than the opening of the bongo nets (0.7 m²) planned for Phase 1 study tests. The net was made of similar 505 µm mesh with a towing bridle harness immediately in front of the net opening rather than the single line used to tow bongo nets.

Ichthyoplankton in the intake cove and offshore area was recently surveyed again in 1986–87 and 1990–91. Sampling has continued to the present, but sample and data processing has not been completed for the 1992–96 surveys.² Samples were collected in surface tows, through the center of the intake cove, on a weekly basis, using a standard bridle on a 0.5 m diameter plankton net made of 335 µm mesh. Occasionally, the 335 µm mesh was severely plugged by phytoplankton during the 3-minute tows used in the survey. The fish larvae were sorted from the samples up to 1992 and identified to the lowest possible taxa; the more recent samples have been archived.

The percent composition of abundant larval fish taxa found in the intake cove and at an offshore station, based on past studies (1986–87)³ and preliminary results of more recent studies (1990–91), are summarized in Table 1-1. The table also includes a similar summary of results from the earlier PG&E (1975–77)⁴ offshore larval fish survey, described above. Using a percent similarity index to compare the percent composition of taxa among surveys showed that the highest degree of similarity (73.9) was between the intake cove results from 1986–87 and 1990–91. Results from the 1990–91 offshore survey were also similar (72.6) to the 1974–75 results from the same survey area. The lowest similarity score (55) was found between 1974–75 and 1986–87 offshore survey results; similarity scores below 60 indicate a lack of similarity. The relative composition of *Sebastes* spp. and *Cottidae* in 1986–87 was noticeably different from both 1974–75 and 1990–91 relative percent compositions of the two taxonomic groups. The relative percent composition

Table 1-1

Percent composition and density (mean number of fish per cubic meter) of the dominant larval fish species collected in the DCP study area summarized from ichthyoplankton studies in 1974-75⁵, 1986-87⁶, and 1990-91⁷. Values from surface plankton tows collected during the early morning hours on one day per week. Density of larvae per m³ are shown in parentheses; this data not available for 1974-75 results.

Intake Cove

TAXA	Common Name	1986-87	1990-91
Clinidae	Kelpfish	17.3 (0.07)	19.4 (0.14)
Cottidae (less <i>S. marmoratus</i>)	Sculpin	35.1 (0.15)	18.3 (0.14)
<i>Sebastes</i> spp.	Rockfish	7.7 (0.03)	17.9 (0.13)
Sciaenidae	White Croaker	5.5 (0.02)	13.2 (0.10)
Stichaeidae	Prickleback	9.3 (0.04)	7.3 (0.05)
Gobiidae	Goby	9.8 (0.04)	6.5 (0.05)
Myctophidae	Lampfish	1.0 (0.004)	4.1 (0.03)
<i>Engraulis mordax</i>	Northern Anchovy	2.0 (0.01)	3.3 (0.02)
Pleuronectidae/Bothidae	Flatfish	4.4 (0.02)	2.9 (0.02)
<i>Scorpaenichthys marmoratus</i>	Cabazon	0.5 (0.002)	2.0 (0.01)
Pholididae	Gunnel	1.1 (0.01)	1.3 (0.01)
Others/unknown	—	3.0	3.8
		1986-87 vs. 1990-91	
Percent Similarity Index		73.9	

Offshore

TAXA	Common Name	1974-75	1986-87	1990-91
<i>Sebastes</i> spp.	Rockfish	38.0	21.7 (0.06)	35.3 (0.17)
<i>Engraulis mordax</i>	Northern Anchovy	8.6	7.4 (0.02)	14.5 (0.07)
Sciaenidae	White Croaker	20.5	7.4 (0.02)	13.6 (0.07)
Pleuronectidae/Bothidae	Flatfish	2.2	13.8 (0.04)	10.6 (0.05)
<i>Scorpaenichthys marmoratus</i>	Cabazon	1.2	1.8 (0.01)	5.5 (0.03)
Clinidae	Kelpfish	**	3.1 (0.01)	5.2 (0.02)
Cottidae (less <i>S. marmoratus</i> and <i>Artedius</i> spp.)	Sculpin	6.1	22.0 (0.06)	4.9 (0.02)
Stichaeidae	—	**	3.4 (0.01)	1.8 (0.01)
Myctophidae (less <i>S. leucopsarus</i>)	Lampfish	0.3	1.1 (0.003)	1.6 (0.01)
Gobiidae	Goby	2.4	8.4 (0.02)	1.5 (0.01)
<i>Stenobranchius leucopsarus</i>	Northern Lampfish	3.2	1.1 (0.003)	1.5 (0.01)
<i>Artedius</i> spp.	Sculpin	3.5	2.2 (0.01)	0.5 (0.002)
Pholididae	—	**	0.3 (0.001)	>0.1 (.00)
Blennioidei	Blenny, Lampfish	11.0	**	**
Others/unknown	—	3.0	6.3	3.5
		1974-75 vs. 1986-87	1986-87 vs. 1990-91	1990-91 vs. 1974-75
Percent Similarity Index		55	66.4	72.6

** Not reported as this taxon in this study.

of *Sebastes spp.* in 1986–87 survey was roughly half of the 1974–75 and 1990–91 values in the offshore survey results and half of the 1991–91 value from the intake cove survey. The mean density of *Sebastes spp.* larvae in 1986–87 was approximately one-half of the density value from 1990–91 intake cove results and two-thirds of the corresponding offshore survey density. These declines in *Sebastes spp.* were nearly mirrored by an increase in the relative percent composition and density of cottid larvae during the 1986–87 and 1990–91 surveys of the offshore and intake areas; the relative increase being less in the intake cove results. The results of these three surveys will be used to identify seasonal patterns of taxa composition and abundance and to evaluate which larvae of the target organisms are at risk to entrainment loss. The findings also give some indication, based on a relatively small sample, of the degree of seasonal variation that could be expected in the taxonomic composition and abundance of larval fish populations in the DCPD study area.

Previous larval fish surveys (Figure 1-2 and Figure 1-3) indicate an increase in larval fish densities beginning in December and January, reaching peak abundance during the period of January to June. The findings also indicate that the peak occurs earlier offshore than onshore due to differences in taxonomic composition. The average seasonal densities of *Sebastes (rockfish)*, which constitute a significant numerical fraction of the DCPD site's larval taxa (see Table 1-1), show similar patterns of high larval densities in the period of January to April in CalCOFI (California Cooperative Oceanic Fisheries Investigations) surveys of central California summarized from 1951 to 1981 in a recent report.⁸

1.2 Sampling Location Rationale

The objective of Phase 1 of the entrainment sampling is to evaluate which potential sampling site best represents the composition and abundance of larvae entrained by the power plant cooling water system. Evaluations of alternative sampling sites involved examinations of site conditions (accessibility, safety, reliability, and representativeness) in combination with issues of sampling equipment design and deployment. Design rationale for location selection, described in this section, were used to evaluate site conditions followed by evaluations of sampling equipment at selected qualified sites. Final selection of a preferred site was based on a balance of expected site conditions and performance of various sampling gear.

The process used to select a preferred site is described for each location and based on the following sampling location design rationale.

The preferred entrainment sampling location(s) will provide samples that are representative of:

1. The densities of entrained organisms
2. The taxa of entrained organisms
3. The sizes of entrained organisms

The samples should be collected to minimize sampling biases due to:

1. Cropping (predation) by biofouling organisms (e.g., barnacles, mussels)
2. Specimen mutilation
3. Unreliable sampling gear performance due to site conditions

Figure 1-2
 1986-1987 Monthly mean densities of total larval fish and *Sebastes spp.* (rockfish) per cubic meter at two sampling locations onshore and offshore of Diablo Canyon Power Plant. LOLIM and UPLIM indicate lower and upper 95 % confidence limits, respectively. (ND = No data)

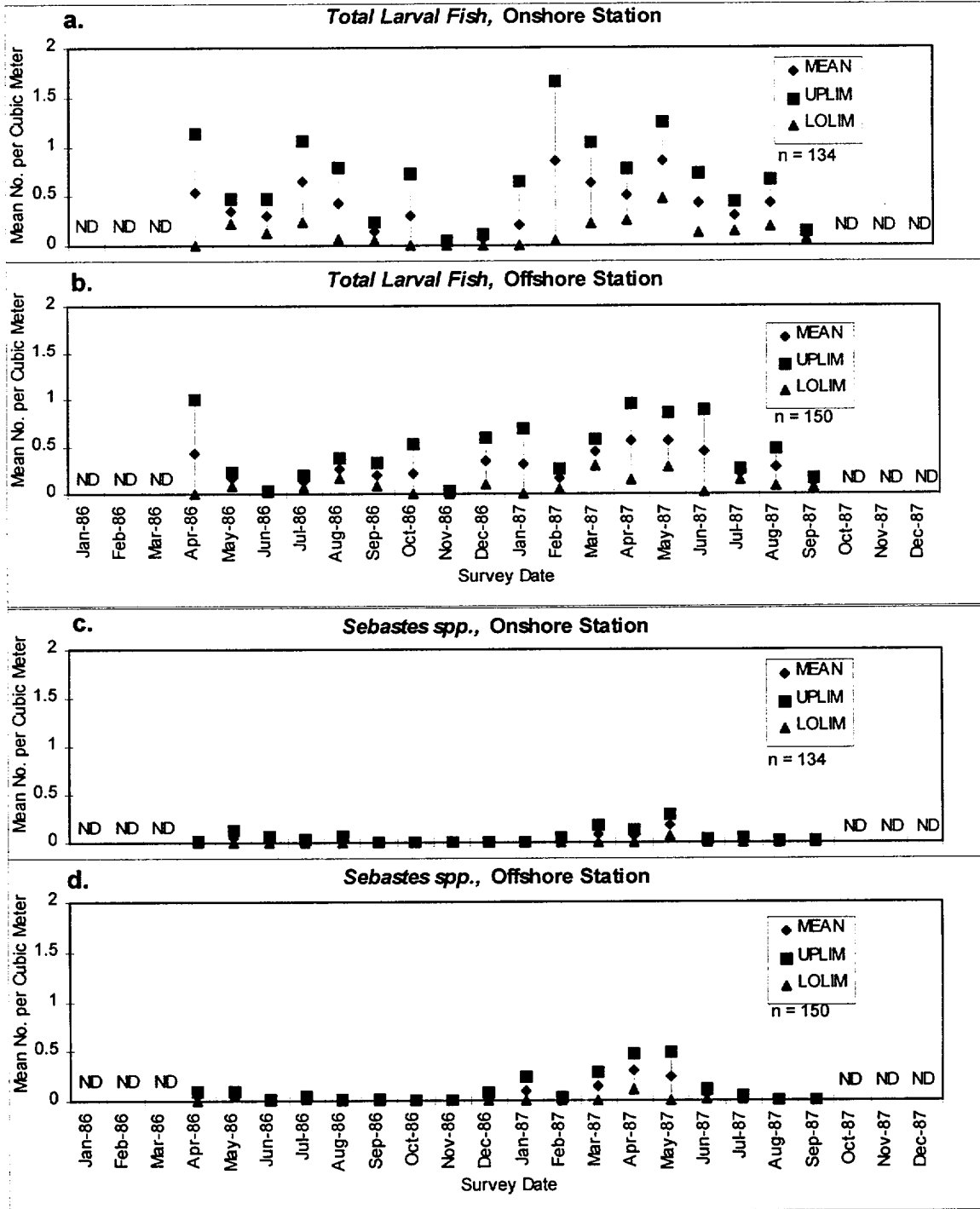
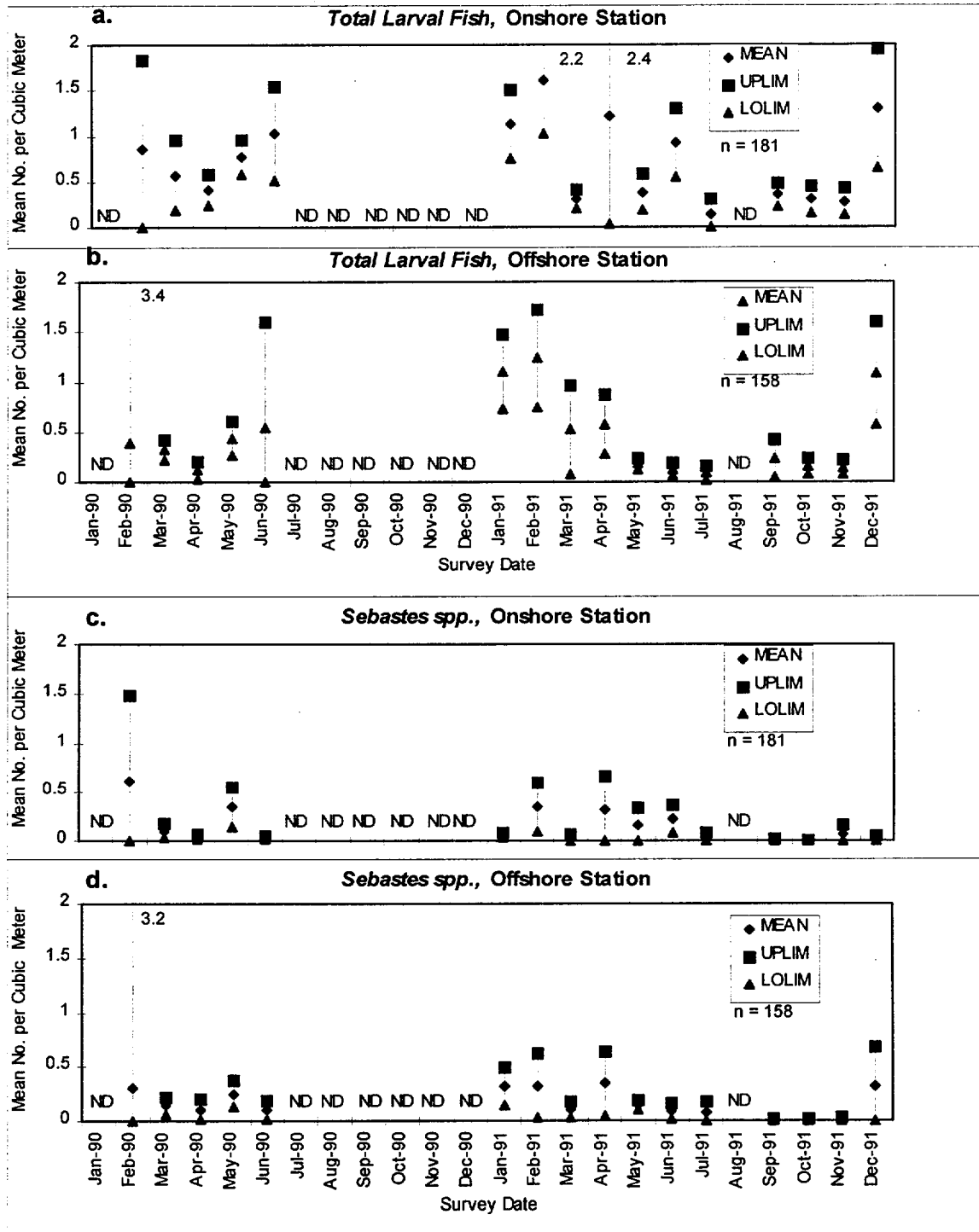


Figure 1-3
 1990-1991 Monthly mean densities of total larval fish and *Sebastes spp.* (rockfish) per cubic meter at two sampling locations onshore and offshore of Diablo Canyon Power Plant. LOLIM and UPLIM indicate lower and upper 95 % confidence limits, respectively. (ND = No data)



The evaluation and selection of the study's preferred entrainment sampling location will be based on an assessment of the above location-characteristics and practical considerations of safety and efficiency at each candidate sampling location. Safe, reliable and repeatable access to a sampling location is the primary factor in site selection. The preferred site will be the one which best minimizes the combination of the three potential sampling biases listed above. In case two sites are similar, a preferred site will be selected based on a closer examination of the site characteristics listed above, plus site hydraulics, and preliminary studies of entrainment sample taxa, size and abundance. If both sites still appear similar to each other based on sampling representativeness and bias listed above, a single, preferred site will be selected based on which one is the most convenient to sample.

The decision-making process for selecting a preferred sampling location is summarized graphically in the decision tree presented in Appendix B. A number of sites were screened out on the basis of high potential for biofouling cropping losses of entrainment organisms before further analysis of acceptance criteria for the site. The results of these preliminary screenings are discussed in Section 3.0 of this report. The results from field inspections of the selected candidate sites' conditions, preliminary gear tests, and test sampling results from Phase 1 are evaluated according to the order and criteria illustrated in the decision tree shown in Appendix B. Any candidate site that failed to adequately meet its acceptance tests was removed, with explanation, from the list of candidate sites. The decision-making process recognized that there is no one perfect site. The process was used to guide the selection of a preferred site.

2.0 SAMPLING LOCATIONS

This section describes the characteristics, advantages and disadvantages of eight potential entrainment sampling locations. Sampling parameters evaluated in this section also include sample frequency, field and laboratory processing, and quality assurance. These criteria and others were organized into a decision tree analysis illustrated in Appendix B. The advantages and disadvantages that lead to the selection of a final preferred site from the ones listed below are described in Section 3.0.

The following eight potential sites were evaluated during the Phase 1 entrainment sampling location studies. The location of each site is illustrated in previous Figure 1-2 and Figure 2-1:

1. **Intake Cove** — located in front of the curtain wall opening
2. **Bar Rack** — located on surface of the bar racks behind the curtain wall opening
3. **Traveling Screen** — located in stilling well between the bar rack and traveling screens (site not presently accessible)
4. **Header Pipe** — located on discharge side of the circulating water pump
5. **Meteorology Tower Outlet** — located midway between the intake and condenser, along the intake conduit
6. **Condenser Box Outlet** — located on condenser discharge conduit
7. **Discharge Tunnel** — located in the discharge canal upstream of flow control weir
8. **Discharge Outfall** — located in the discharge flow to the receiving water

The bar rack, traveling screen, and header pipe locations were recommended for evaluation in the June 1996 Study Plan Proposal. The intake cove location was added to the list of potential sampling sites after submittal of the Study Plan Proposal. The five additional sites included in the above list of potential sampling locations were considered in various stages of the early study design process, but were discarded before the study design proposal was written. All of the locations, as well as their advantages and disadvantages, are presented here to provide a complete description of information and decisions that were employed in selection of the final recommended sampling location.

Intake Cove

This location is illustrated as Point 1 in previous Figure 1-2 and Figure 2-1. Intake cove samples will be collected from a moored boat at each of four sampling stations arrayed to align with the flows to each of the power plant's four main circulating pumps. Each station will be equipped with a permanent buoyed-mooring and a stern line mooring to the intake structure. Results of both an underwater visible dye study and field trials of sampling equipment will be used to locate the boat in a position as close as possible to the curtain wall opening, without the risk of impinging the sampling equipment to the bar racks. The dye study will aid in determining where

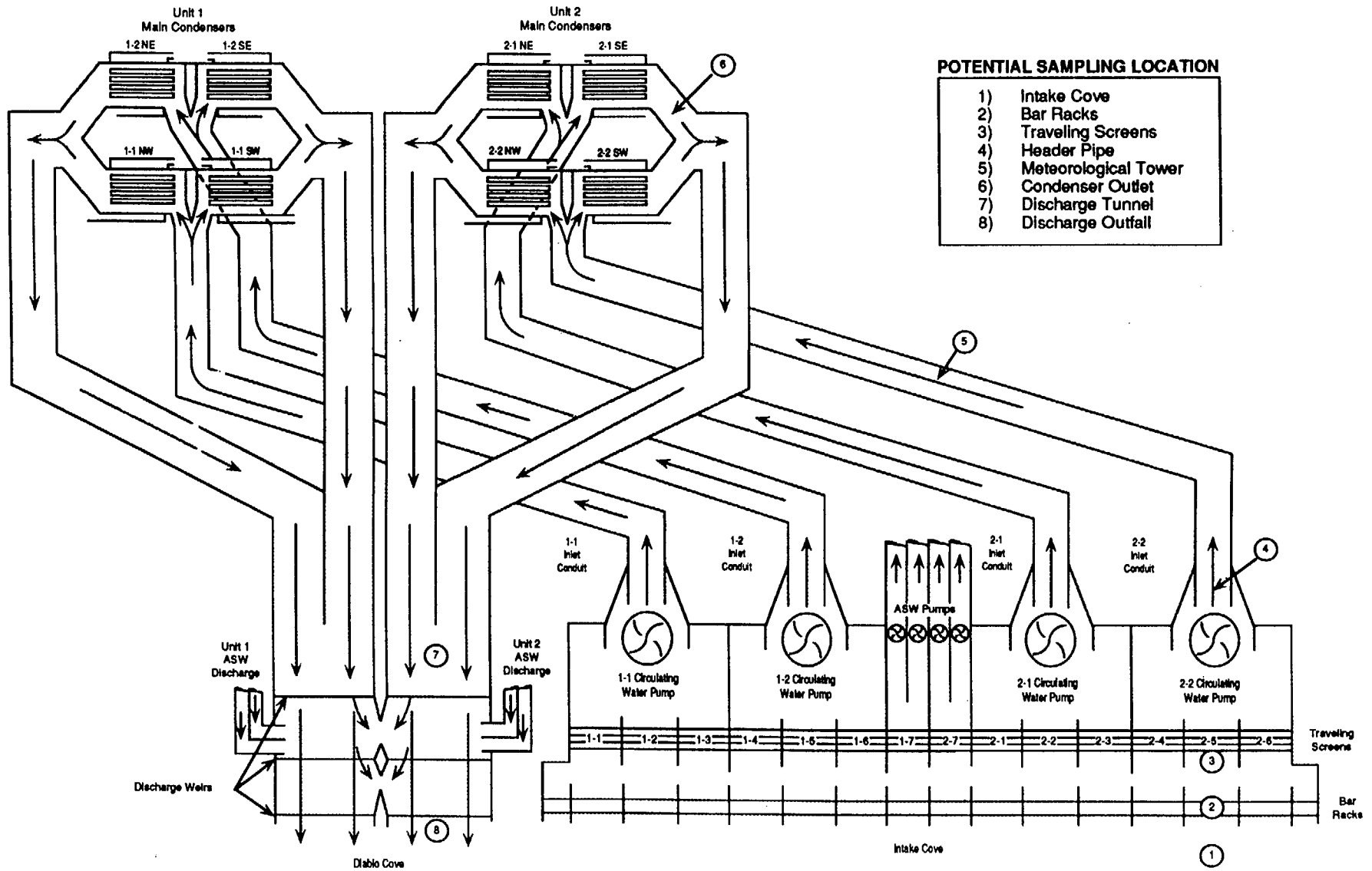


Figure 2-1
Schematic view of DCPD cooling water system and potential sampling locations

to collect samples to be in the area of central flow to each of the four circulating water pumps and as close to the bar racks as possible.

The dye study will be performed by divers who will release dye in front of each of the four circulators from positions approximately 8-10 m from the intake structure. Dye will be released at 4 feet off the bottom and 12 feet below the surface at each of the four test locations. The study will be undertaken during a period of full operation of all four circulating water pumps. Alignment of entrainment sampling locations with the center of each intake pump flow reduces the potential for sampling bias due to systematic differences in densities of organisms entrained among individual pumps.

It was reasoned that plankton nets towed up-and -down in front of the intake structure would provide a nearly complete water column sample of entrainable organisms. Bongo nets which are designed to reduce evasion effects were selected to perform preliminary entrainment sampling at the intake cove location. The bongo nets, which were deployed from a vessel moored to a sampling station buoy, were raised by a winch at speeds similar to those used by CalCOFI⁹, (1 fps). The horizontal water flow into the power plant in front of the intake produces an oblique, instead of vertical, tow as the nets are raised and lowered from the moored sampling vessel. The 505 μm mesh size for the bongo nets used in the design-phase location studies was also selected to match mesh used in the offshore CalCOFI investigations.¹⁰

Bar Rack

Entrainment samples could be collected from a point directly in front of the intake structure's bar racks approximately 0-1 meters (0-3 ft) behind the curtain wall opening. This location is illustrated as Point 2 in previous Figure 1-2 and in Figure 2-1. The intake structure is made up of devices to prevent debris from plugging the power plant's steam condenser. The first of the devices is a concrete curtain wall at the front of the intake structure that forms an inverted weir approximately 10 feet below mean sea level (MSL) to prevent floating debris from entering the submerged intake opening. On occasion, wave action and surge will carry floating kelp beneath the curtain wall. The second device to stop debris from entering the circulating water system is a series of vertical metal bar racks spaced on 3 inch centers extending from the water surface to the ocean bottom and across the entire intake structure. The advantage of collecting entrainment samples in front of the bar racks is that water sampled at this point has not been being subjected to biofouling cropping, but will very likely be entrained. During periods of large storm waves, surges are produced by hydraulic back pressure flows when waves swell into the intake faster than circulating pump rates. The disadvantage of sampling at the location is that debris occlusion of the bar racks makes sampling difficult and causes entrainment water flows to be irregular and unpredictable.

Each of the four main circulator pump forebays contain three sets of bar racks, as shown in previous Figure 1-2 and Figure 2-1. Entrainment samples would have to be collected from each of the four forebays. Samples collected from the center bar racks could be used to represent flow through the two other sets. A sampling system for the bar rack location is being evaluated. This method is contingent upon developing a procedure to remove all drift kelp and other debris from the bar racks. Since bar rack debris removal may adversely affect power plant operations, a removal procedure for entrainment sampling must be approved by PG&E engineering staff. This may provide an alternative location for routine entrainment sampling if the site's engineering and logistical problems can be solved.

Traveling Screen

Entrainment samples could be collected from a location in the forebay between the bar rack and traveling screen approximately 4 meters (13 ft) inside the intake structure bar racks. This location is illustrated as Point 2 in previous Figure 1-2 and Point 3 in Figure 2-1. Entrainment samples would be collected from each of four central forebays to represent the combined flow to the four main circulator pumps. Previously existing holes in the deck which provided instrumentation access to the area have been recently sealed to prevent structural corrosion. The traveling screen location is outside of the power plant's protected access area. Sampling would require drilling at least four-four inch diameter holes in the intake structure upper concrete decking. Due to the approximately 20-foot distance to the water surface at this point, a submersible pump would be needed to pump samples from the intake water flow up to the deck. Samples would be filtered through a plankton net submerged in a tank on the intake deck.

Header Pipe

Entrainment samples could be collected from a header pipe which is supplied from a point along the intake conduit, approximately 5 meters (16 ft) from the main circulating pump scroll case outlet. This location is illustrated as Point 3 in previous Figure 1-2 and Point 4 in Figure 2-1. At this point in the power plant's cooling water system, entrained seawater is available from a 4 inch pressurized line that is used for the power plant's cooling water chemical injection system. This header pipe system is fed by four separate 10 in. pipes from each of the main pump conduits (see Figure 1-1). A sample of entrained water at this location would be well mixed by the circulating pumps. A dye study was performed to determine patterns of flow through the intake cooling water system leading to the header pipe sampling location (Appendix C).

Meteorology Tower

Entrainment samples could be collected from a water outlet located on the intake conduit approximately 200 meters (656 ft) from the intake at a point that passes the DCPD site meteorological tower. This location is illustrated as Point 5 in Figure 2-1. The site had been considered as a potential entrainment sampling location in the previous DCPD entrainment studies, but was abandoned in favor of a discharge conduit sampling location. The Meteorology Tower site on the inlet conduit is provided with a blind flange which could be opened to draw samples. At this point in the conduit, the intake water is under approximately 30 PSIG pressure as it is being pumped uphill to the condensers. Sampling at this location, would be accomplished by piping metered water to an entrainment collection net suspended in a water bath. Entrainment equipment and methods would be similar to those that might be employed at the header pipe location. After filtering through the net, the sample water would have to be pumped back into the conduit.

Condenser Outlet

Entrainment samples could be collected from an outlet located on the discharge conduit approximately 4 meters (12 ft) from the condenser tube outlets (Point 6, Figure 2-1). At this point in the cooling water system, seawater exiting the condenser water box has passed through 1 inch diameter heat exchanger tubes at a velocity of approximately 2 m/s (7 fps). The cooling water temperature is raised approximately 11 C (20 F) after passing through the 17 meter (56 ft) length of condenser tube. Entrainment samples would have to be collected from four separate

conduits each of which carry the combined flow from two condenser halves (eight halves altogether).

Since the confined water flow from the condenser box creates siphon suction in its fall to the lower elevation discharge point, a pump will be required to collect entrainment samples. Several flanged openings in the outlet conduits could provide access points to discharge flow. Special space and support accommodations for sampling equipment would be necessary. The sampling pump would need to be redesigned with an electric motor to avoid additional facilities, in an already limited space, to vent combustion engine exhaust fumes. This sampling location and the discharge tunnel location are the only sites located inside the power plant protected area. The extra logistics involved in routine entrainment sampling operations inside the protected area would normally favor any similar site outside the protected area.

Discharge Tunnel

Entrainment samples could be collected from the discharge tunnel conduit approximately 100 meters (328 ft) from the outlet of the condensers boxes and 610 meters (2,000 ft) from the bar racks. This location is illustrated as Point 7 in Figure 2-1. The actual sampling location would be based on a specific site where flow from the eight condenser halves are combined in the cooling system into four channels of discharge flow. At this point the discharge flows are checked by a weir just before the flow cascades down the energy dissipaters to the discharge outfall, approximately 35 meters (115 ft) below. Flow rates in the channels, which are approximately 1.5 m/s (5 fps), vary with intake and condenser flows. This sampling location and the condenser outlet location are the only sites located inside the power plant protected area. Entrainment sampling equipment would be similar to equipment that might be used at either the traveling screen or condenser box outlet.

Discharge Outfall

Entrainment samples could be collected at the discharge structure from discharge flow to the receiving water. This location is illustrated as Point 8 in Figure 2-1. Samples could be collected either by pump or plankton net sampling equipment. Pump equipment could be placed on a parapet above the discharge or on a platform to the side of the discharge structure. Piping to the pump would have to be placed and secured in a position to collect samples from both left and right sides of the discharge structure to account for separate flows from the Unit 1 and Unit 2 discharge tunnels.

Samples would have to be pumped from the discharge flows and up to the height and location of the entrainment pump and net sampling equipment. Discharge outfall pump sampling equipment would be similar to equipment that might be used at the bar rack, traveling screen, condenser box outlet, and discharge tunnel. Towed plankton net sampling equipment could also be employed at the discharge outfall to collect samples from the discharge flow. The equipment might either be deployed by crane from the discharge structure or towed from a boat operating in the discharge zone. Several considerations would have to be given to the fast speed of the discharge water flow and the effects this might have on larval extrusion.

2.1 Sampling Frequency

The study design's proposed sampling frequency and study duration are based on a need to account for the various sources of temporal variance that might bias entrainment sampling results. These sources of variation and the aspects of the sampling design intended to address them are summarized in Table 2-1.

The sampling frequency is also limited by the number of samples that can be collected in any one day. The study design plan is to sample all qualified locations every three hours during a 24-hr survey period once a week for three months to evaluate sites and then continue to sample at the preferred sampling location. The temporal coverage and/or amount of sampling time should be maximized to a reasonable extent that it will produce a meaningful increase the precision of the samples. The proposed frequency is expected to provide samples that adequately represent short-term temporal/spatial and diurnal variation in entrainable organisms. The sampling frequency recognizes the practical limitations associated with routine field sampling. If only one site qualifies for testing or is identified clearly during Phase 1 as the preferred site for Phase 2 sampling, the three-month Phase 1 study will be terminated and findings reported to the DCP Entrainment Technical Working Group.

Sampling frequency for the study will be based on existing knowledge of target organisms. As a first approximation, entrainment samples will be collected weekly. Allowing for unfavorable sea state conditions, the survey will be conducted on the same weekday in order to maintain a uniform time span between each survey.

Entrainment sampling will continue at this primary sampling location for a period projected at this time to be 18 to 22 months. This sampling period is consistent with EPA Guidance which recommends that the biological survey be conducted over a period of one to three years. This will allow for the sampling of two consecutive annual peaks in larval fish abundance. At the end of each year, the sample results will be assessed by comparing larval abundance and species compositions with other data from the study area. This assessment will estimate the magnitude of entrainment through direct determination of the diel and seasonal variation of the entrained organisms. The intent is to meet the EPA requirement for a survey to provide a sufficient and valid data base for reasonable assessment of environmental impact related to the design, construction, location, and capacity of a cooling water intake structure.

The data assessment will be reviewed by the Entrainment Technical Working Group to determine the adequacy of the data for making a reasonable assessment of environmental impact as related to the cooling water intake structure relative to a Best Technology Available determination. Based on this review, the Entrainment Technical Working Group will make a recommendation as to the need to continue data collection. The recommendation will be provided to both the Multiagency Workgroup and the Regional Board. If it is recommended that the data collection phase extend beyond 22 months, the Board may give direction to the work group regarding the project's overall timeline. During the data assessment and the decision process on the length of sampling, described above, data collection will continue so that there is no gap in data collection.

2.2 Processing

Field and laboratory procedures will be approved by the entrainment study project manager and

laboratory supervisor. If modifications to the procedures are required based on either initial field conditions, sampling gear performances, or laboratory processing, the project manager and laboratory director and Entrainment Technical Working Group will approve and document all changes. Formal quality assurance/quality control (QA/QC) field audits of sampling procedures will be performed by the project's designated QA/QC manager with independent audit oversight by independent expert(s). The project manager will periodically requests such audits during the period of routine entrainment sampling. Results of all audits will be reviewed by the project manager and independent expert. Corrective actions, if any, and resolutions will be identified and reported to the Technical Working Group for review.

A portion of the weekly entrainment samples will be preserved in 80% alcohol only, in order to preserve a subsample of otoliths for possible future use in aging the larval fish. All other samples will be initially fixed in 5% formaldehyde and then transferred to 80% alcohol. A separate sampling effort may be developed and implemented for aging. Only fish larvae and *Cancer* crab (rock crabs) larvae will be identified to the lowest possible taxon and enumerated. Fish lengths will be measured as soon as possible after preservation to minimize measurement error caused by shrinkage effects of preservatives. Detailed laboratory procedure and quality control (QC) program have been developed and will be included with the Phase 2 Study Plan. The laboratory procedures and quality control program will implemented and maintained in effect throughout the period of the 316(b) studies. The rejection or voiding of any data, field or laboratory, will be retained in data format, and only process after thorough documentation and review by the study's field or laboratory manager and project manager.

Taxonomic identification will be done by onsite laboratory personnel. An onsite QC program for all levels of laboratory sorting and taxonomic identifications has been developed and will be systematically applied to all entrainment samples and other related sources of entrainment information. An offsite QC program will incorporate the use of outside taxonomic experts to review the study voucher collection, resolve taxonomic uncertainties, and randomly check individual identifications. The independent consultants for the RWQCB will also participate in the taxonomic QC process.

Table 2-1

Types and sources of temporal variance expected in entrainment sampling results and the design element planned to reduce sample bias due to temporal variance.

TEMPORAL VARIANCE		
Type	Sources	Sampling Design Plan
Short-range	Patchiness and diurnal vertical migration of plankton	Collect entrainment samples every three hours for twenty-four hours.
Medium-range	Oceanic and meteorological storm events, duration of larval stages, and other indirect biological phenomena (growth, starvation, predation).	Collect entrainment samples once per week for duration of study.
Long-range	Seasonal changes in sunlight, nutrients, temperature, and other features of the study area's oceanic seasons.	Collect entrainment samples for a period of 18–22 months that span major source water oceanic and biological seasons.

3.0 ENTRAINMENT SAMPLING LOCATION STUDY RESULTS

The results of field inspections and sampling tests to determine a preferred entrainment sampling location are summarized for each candidate location that was proposed in Section 2.0. During the location selection process, it was necessary to give preliminary consideration to sampling methods that were both feasible at a candidate location and appropriate to target species. The following section also provides preliminary information on target entrainment species and experiments to test sampling methods and equipment appropriate for the selected location. The results from these proposed sampling methods and equipment experiments will form the basis of the planned Part II. Sampling Methods of the Phase 1, Entrainment Study Design report.

3.1 Sampling Location

Eight entrainment sampling locations were investigated based on site inspections and in some cases field tests of sampling equipment. The various results from these studies were used to evaluate the candidate site using decision tree criteria and pathway analysis. Examples of decision tree criteria and analysis are presented in Appendix B. The location referred to as the intake cove is located approximately 10 meters in front of the intake structure. Samples collected from the site are assumed to represent the water and organisms that will be entrained, because of intake proximity and flow. The site's study focused on issues of intake flow direction and dynamics and sampling methods. A second alternative sampling site referred to as the bar rack is located on the seaward surface of the intake structure's bar racks ahead of the traveling screens. Samples from this location would contain organisms that have been entrained into the intake system. The studies of this site focused on kelp debris problems and complex water flows. The third alternative sampling site investigated was the header pipe which is located inside the intake structure and downstream from the main circulating water pumps. Studies at this alternative location addressed issues such as balancing flows from four main pumps and potential organism cropping by biofouling within the intake structure and piping leading to the sampling site.

Intake Cove

The intake cove location passed all initial acceptance criteria for providing representative samples of entrainment, therefore, further site studies and sampling methods for the location were developed. A preliminary selection of sampling equipment and methods were necessary to test the feasibility and use of the location for entrainment sampling. Brief descriptions of results from these preliminary equipment and methods field trials are included in the following location descriptions. Conclusions and recommendations for further studies of sampling equipment and methods tests are presented in Section 4.0 Recommendations. The selection of sampling equipment and methods to be employed at the sampling location recommended in this Part I. Sampling Location design report will be described in Part II. Sampling Methods.

From mid-October 1996 to the present, weekly entrainment samples were collected from the intake cove immediately in front of the curtain wall opening, concurrently with sampling at the header pipe entrainment location.

- Plankton samples were collected at four permanently buoyed sampling stations from a three-point, moored research vessel located approximately 10 m in front of the intake opening.

- The sequence of sampling stations was randomly selected for each collection cycle during the 24 hour survey period.
- Approximately 50–55 m³ of water was sampled by each of the bongo nets within every three-hour interval during a 24 hour sampling period at each of the four intake cove sampling locations.
- The sample contents of each bongo net were preserved separately by sampling station, sampling cycle and weekly survey period.
- The vertical lifting speed of the nets was measured with flow meters and held constant at approximately 0.3 m/s (1 fps). The downward speed will be determined primarily by gravity acting on the mass of the bongo net frame and the drag resistance of the nets.
- A standard 71 cm diameter CalCOFI style bongo frame was used to avoid the bridle effects (evasion bias) of single net designs.
- Each net opening was fitted with an flow meter.
- The nets were approximately 2 m in length and have a mesh size of either 505 μm or 335 μm. A shorter length net was adopted, based on the opinion of the CalCOFI net designer that net efficiency (505 μm mesh at 1 fps) over short tows would not be measurably altered and to facilitate ease of boat handling.¹¹

Site studies of the intake cove location included reviewing previous studies of the hydraulics and general circulation patterns in the intake cove, additional circulation studies using diver released-dye, and preliminary sampling for ichthyoplankton and crab larvae.

Hydraulics

Water velocities and flow patterns were investigated in an area immediately in front of the intake structure and in other areas of the intake cove. Studies were designed to test assumptions about the direction of flow related to location and alignment of permanent sampling locations and flow velocities as a function of distance from the intake inlet. Using information on flow patterns in front of the intake, sampling stations would be positioned in alignment with the maximum flow to the four main circulator pumps.

A 1 to 75 scale physical model of DCPD intake and discharge coves was used in 1981 to study intake current velocities and flow patterns.¹² The investigators mapped distribution patterns of syringe-injected dye releases under various conditions of tide, wave and intake flow. Results from these previous model studies showed general momentum flow towards the intake structure from an intake cove location in mid-channel to west of mid-channel. In a majority of model test cases, gyres associated with momentum flows were located between the inner end of the west breakwater and the intake structure, and also in the east end of the intake cove.

Information on flow patterns and velocity measurements were recently gathered underwater with the assistance of SCUBA divers. Hand-held flowmeters were positioned by divers at selected intake locations including approach areas, curtain openings and bar racks. Divers also performed underwater dye releases at several points of the intake cove entrance channel and along the west breakwater. Flow measurements made in October 1996, by divers using hand held flowmeters, showed velocities ranged from approximately 0.2–1.0 fps at a distance of 8 meters from the intake to as high as 4 fps on the surface of the bar racks in debris-free areas during periods of

widespread debris occlusions. These incidents of high occlusion which are typical during the months of September and October and can be exacerbated by heavy storm activity.

Results of entrainment dye studies (Appendix C) showed that velocities based on travel times were highest from release points at midwater depths, centerline approaches, and along forebay walls. Patterns of intake cove water currents were investigated by observing the distribution of fluorescein dye released by divers along the west breakwater, intake cove entrance, and intake approach area. Result of dye releases studies showed no detectable amounts of dye entrained from the west breakwater or entrance channel locations. Investigators conducting the dye tests noted that the visible dye patch moved quickly from the point of release directly towards the Unit 2 pumps. Since the fluorometer was set up to measure dye concentrations in pump 1-1 intake water, the dye release that entered the Unit 2 pumps was not detected. Any dye that was dispersed and entered the pumps was below the fluorometer's limits of detection. Dye releases in approach areas to the intake confirmed entrainment of water from this locations. Entrainment from these intake approach areas appeared to depend on internal cross-bay flows and the degree of bar rack occlusion. However, for the purposes of sampling station location, intake flows within the approach areas were predictably related to centerline flows to main circulating pumps. Underwater diver observations of intake approach flow velocities showed that plankton sampling gear could be operated safely at a distance of approximately 7–10 meters (23–33 ft) from the intake structure.

Preliminary Sampling

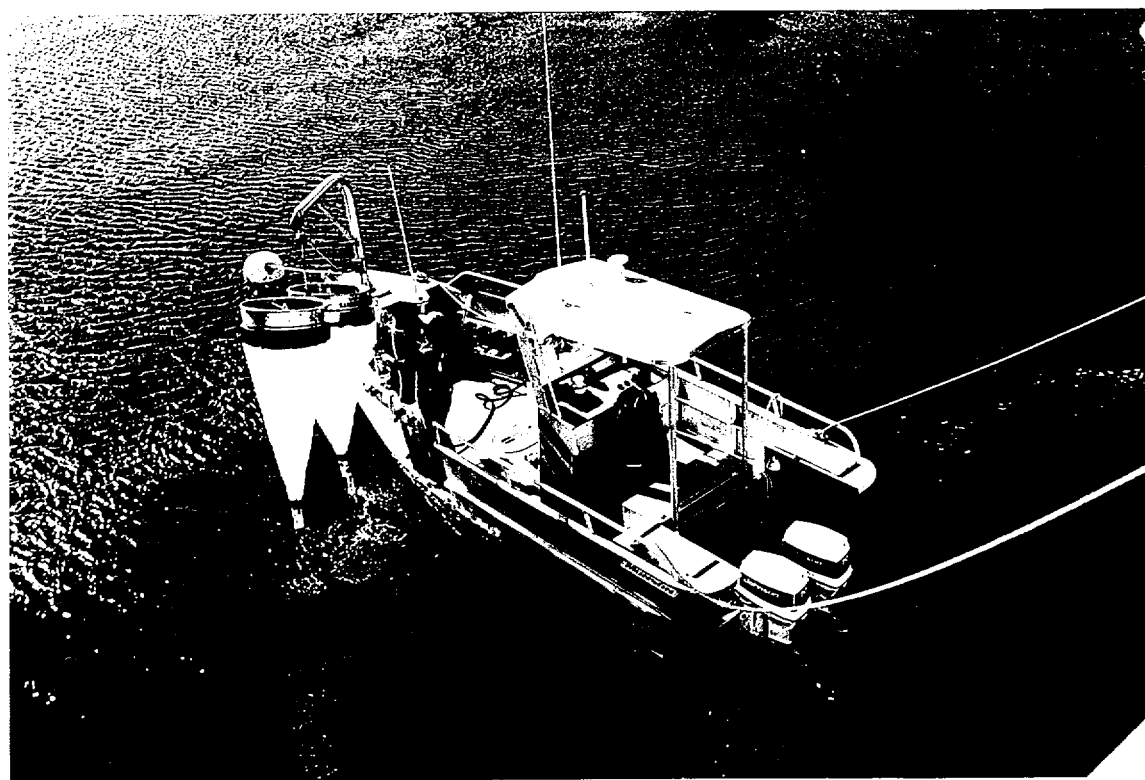
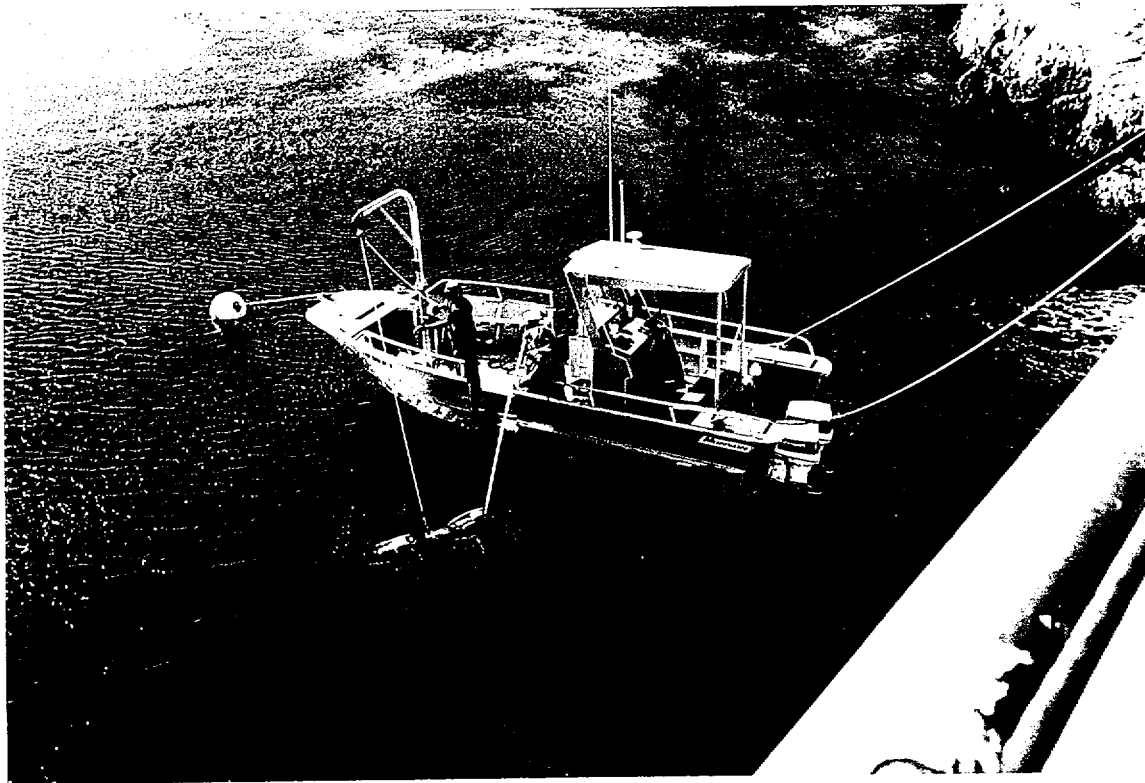
It was determined that oblique or vertical tows for collection of the samples at the intake cove location were preferable because this method integrates sample organisms throughout the water column. Due to the horizontal flow of intake water, a vertically towed net towed close to the intake structure will follow an oblique path. Any vertical stratification of ichthyoplankton would be uniformly combined using a vertically towed plankton net. The method assumes that the water mass sampled will be uniformly entrained. Although differences in vertical densities of organisms could be measured with horizontal tow samples, there is no practical method that would enable combining the samples to account for the differences in intake flows from the different depths. To representatively sample the potential horizontal variation in larval densities, four stations were sampled along the intake structure. See Figure 3-1.

Preliminary testing was conducted to further develop the sampling protocol described in Section 2.1.1. Initially the sampling was to be completed by lowering the net towards the bottom and only sampling as the net was raised towards the surface. This testing showed that the bongo frame could be modified to allow sampling both as the nets were lowered towards the bottom and raised towards the surface. This allowed for a larger sample of water to be filtered by each net. Diver observations of the sampling showed that the net was "fishing" within 20 cm of the bottom. This observation was verified by samples which contained 20–30 mm juvenile fishes that are normally found close to the bottom.

Agreement was reached with the members of the DCPD Entrainment Technical Working Group¹³ that 505 μm mesh would be an appropriate size to test in the design phase location studies. Representatives of CDF&G, concerned about the ability of 505 μm mesh to collect *Cancer* crab (rock crab) larvae, examined samples collected during August 1996, in the intake cove, and they concluded that 505 μm mesh would be acceptable.¹⁴ A recent study of the larval stages of five species of *Cancer* crabs was conducted using 500 μm mesh nets to collect samples.¹⁵ Expert

Figure 3-1

Photographs of intake cove location sampling vessel and bongo net equipment underwater (upper photograph) and lifted above water for sample collection (lower photograph).



opinion also held that a 505 µm mesh plankton net would be a good choice for capturing representative samples of *Cancer* crab larvae¹⁶.

Field tests of various gear and methods were performed from June to October 1996. Routine entrainment sampling began at the intake cove location on October 16, 1996. Sampling methods and equipment used in the initial 1996 stage of entrainment sampling will be tested during periods of peak larval fish abundance in 1997. In addition, continuous quality assurance tests of sampling methods and equipment will be systematically conducted throughout the entrainment study. If at any time, the results from preliminary tests or ongoing quality assurance and inspections of sampling methods or equipment, suggest that a sampling modification could achieve significant and worthwhile improvement, the change will be implemented; and, if it is reasonable and necessary, the routine entrainment sampling program re-initiated.

Bar Rack

Underwater visual inspection of the bar racks during September and October, 1996, showed large amounts of kelp debris and other materials occluding the bar rack openings. High occlusion is generally seen at least during the months of September and October and is also seen during periods of heavy storm activity. The observed occlusion was caused by the normal seasonal breakdown of annual algae. The degree of occlusion is illustrated in the underwater photographs of the bar racks in Figure 3-2. Currently the power plant does not have any methodology in place to remove the kelp debris on a regular basis. Diver observations showed that the debris occlusion caused areas of very low water flow, and also areas of extremely high flow. This would significantly affect estimates of power plant entrainment, based on samples collected at the bar racks. The practical difficulties of clearing kelp to enable reasonable sampling conditions at this location disqualified the location from further Phase 1 sampling. The disqualification of this location from further entrainment sampling design tests was discussed and approved by the DCPPE Entrainment Technical Working Group.

Traveling Screen

The traveling screen location did not pass its preliminary site screening due to a lack of existing access. The advantage of this location is its position at the entrance to the power plant's cooling system where sampled organisms have been entrained, and only limited biofouling is present. However the disadvantage is that the lack of sampling access at the site requires that four large diameter holes to be drilled into the intake structure's upper deck. Other similarly positioned sites where sampling access is presently available and the potential for cropping losses are low, such as the bar rack and header pipe locations would be favored over this location.

Header Pipe

The header pipe location at first passed all initial acceptance criteria for possibly providing representative samples of entrainment. Sampling methods for the location were developed and initial sampling implemented.

Figure 3-2
Underwater photographs of barnacles and kelp in bar rack openings (upper photograph) and distant view of occluded bar rack openings (lower photograph).



From October to November 1996, weekly entrainment samples of DCPD cooling water flow were collected at the header pipe location, concurrently with the collection of samples at the intake cove, the other sampling location that meet the initial acceptance criteria.

- Plankton samples were collected by filtering a flow-through source of cooling water from a header pipe which contained water flow from each of the plant's operating main circulators. The header pipe collected flow immediately downstream of the four pumps.
- Two to three, thirty-minute period samples of 20–25 m³ were collected during each three hour interval during a 24 hour sampling period.
- The volume of water sampled by the plankton net was measured by an in-line flow meter.
- Each thirty-minute header pipe sample was preserved separately.
- A 505 µm mesh net mounted inside a collection tank beneath the outlet pipe flow was used to collect the samples.
- The net length was approximately 1.3 m (4.3 ft).

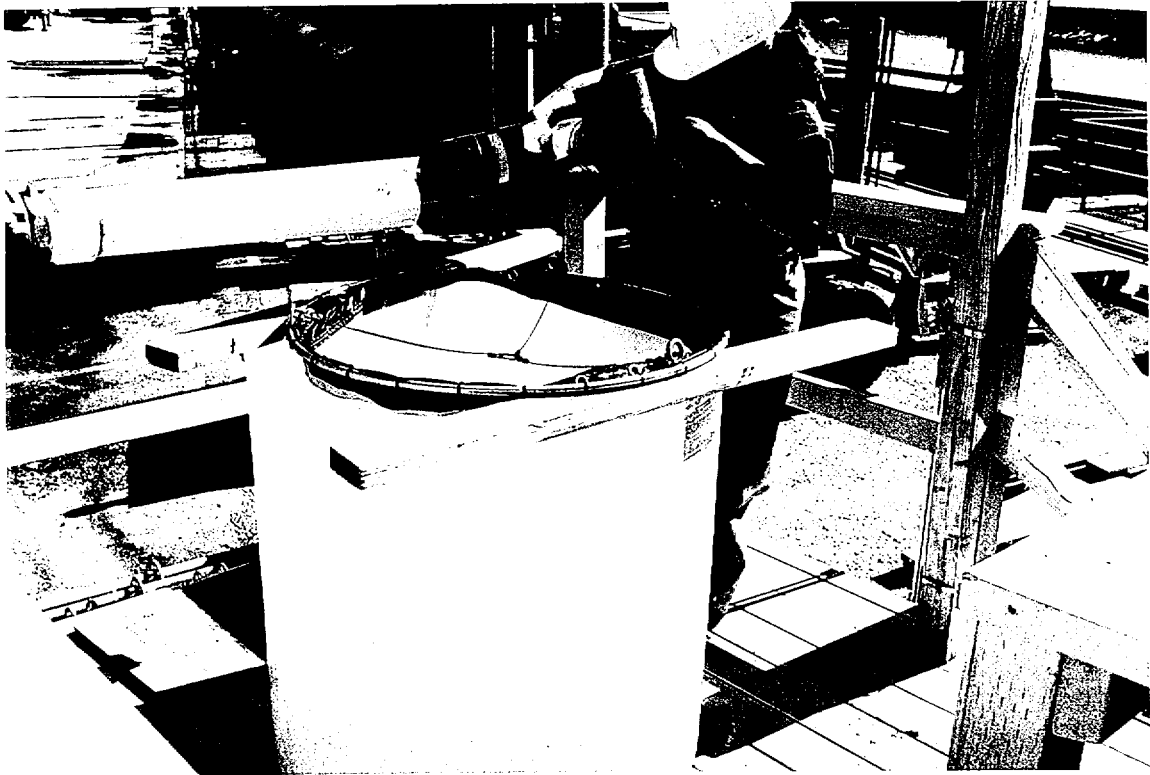
After sampling began, further observation of the inside of the piping between the main plant cooling water conduits and the header pipe sampling location showed that the piping was not totally free of biofouling organisms (See Figure 3-3). Although the fouling in the piping was minimal, this, along with the fouling on the bar racks and the forebays, raises the question that the abundance of target organisms sampled at the header pipe might have been altered by upstream biofouling.

Currently there is no way to measure the water flow contribution from each of the four circulating water pumps to the header pipe system. Tests of instruments to measure header pipe flows from the exterior of the header piping were completed. The results showed that, probably due to the plastic liner in the pipe, flow measurements could not be determined from the outside of the pipe. It is impractical at this time to change this piping for a new piece containing an internal flowmeter.

Hydraulics

PG&E studies of the intake velocities, performed in conjunction with the previous 316(b) studies, showed a moderate degree of variability in the velocity of flows passing through the curtain wall openings.¹⁷ The highest velocities were found at the inlet edges and along the walls of the curtain wall opening. Detailed studies of the current flows through the intake's traveling screens were recently completed using dye transport methods (Appendix C). The primary purpose of the study was to measure the hydraulic variability of flows to the header pipe, and by evaluating the results, assess the use of the header pipe flows as a possible source for entrainment sampling. Dye was released at uniformly spaced locations near the traveling screens for the 1-1 and 1-2 circulators and measured by an in-line fluorometer connected to a source of header pipe water flow. Divers injected a measured quantity and concentration of fluorescein dye using a long pipe inserted through the bar rack openings. The resulting times of travel and concentrations of dye were recorded by a downstream fluorometer. The results of the dye studies indicated that flow rates through the traveling screen varied among different locations on the screen's surface. While the variability of flow would be expected to be amplified by varying tidal stage, wave surge, and kelp-occlusion of the intake bar racks, the results of the dye studies

Figure 3-3
Photographs of the flow-through net sampler and inlet pipe at the
header pipe location (upper photograph) and barnacles fouling section of
line leading to sampling location (lower photograph).



suggested that there was a larger contribution of water from the lower sections of the forebay to the average intake flow.

Biofouling

Inspections of portions of the header pipe system indicate the presence of biofouling organisms. At present, PG&E is unable to ascertain the extent of biofouling in the system and does not foresee any changes in the immediate future to enable adequate system inspection or biofouling control to insure that the biofouling population is eliminated to the extent necessary to enable selection of this location as a suitable location for entrainment sampling.

Meteorology Tower Outlet

The meteorology tower location did not pass its preliminary site screening due to a significant potential for losses of entrained organisms to biofouling cropping. The advantages of this location is its position in the power plant's cooling system where entrained organisms have been well mixed; sampling pumps, that might damage collected specimens, are not required to collect sample; and access is conveniently outside of the power plant's protected area. However at this point in the cooling water system, the potential for loss of entrained organisms due to biofouling is significant.

Condenser Box Outlet

The condenser box location did not pass its preliminary site screening due to a significant potential for losses of entrained organisms to biofouling cropping. The advantage of this location is its position to the power plant's cooling system where entrained organisms have been well mixed. However at this point in the cooling water system, the potential for loss of entrained organisms due to biofouling cropping is significant. Another disadvantage of the location is that the location is inside the power plant's protected area.

Discharge Tunnel

The discharge tunnel location did not pass its preliminary site screening due to a significant potential for losses of entrained organisms to biofouling cropping. The advantages of this location is its position to the power plant's cooling system where entrained organisms have been mixed and access is conveniently outside of the power plant's protected area. However at this point in the cooling water system, the potential for loss of entrained organisms due to biofouling cropping is very significant as a result of uncontrolled biofouling in the discharge tunnels.

Discharge Outfall

The discharge outfall location did not pass its preliminary site screening due to a significant potential for losses of entrained organisms to biofouling cropping. The advantages of this location is its position in the cooling system where entrained organisms have been well mixed (theoretically units 1 and 2 discharge flows are combined in front of the outfall weir) and access is conveniently outside of the power plant's protected area. However at this point in the cooling water system, the potential for loss of entrained organisms due to biofouling cropping is very significant as a result of uncontrolled biofouling in the discharge tunnels. Other disadvantages at the site are that specimens may be damaged by the effects of high speed discharge flows on towed nets or by passage through sampling pumps required to collect samples; receiving water

flows and other organisms may be entrained with discharge flows; and debris and foam entrained from the receiving water may interfere with sample collection.

3.2 Entrainment Taxa

A preliminary list of fish taxa collected in the initial period of entrainment surveys (October–December 1996) is shown in Table 3-1. The list is based on samples taken during the time of year when the total density of larval fish typically begins to increase to annual springtime peaks. The abundance of individual species peak at various times during the winter-spring build-up period. Taxa listed in Table 3-1 include species such as cabezon that have appeared in large numbers early in the larval fish season. Other species that are commonly present in the study area's larval fish samples and are (see previous Table 1-1) missing from the list have early Spring peaks in abundance. Target organisms for the entrainment study, agreed upon by the DCPP Entrainment Technical Working Group, include larval forms of fishes, *Cancer* crabs (rock crabs), and abalone. Preliminary consideration and selection of target taxa was necessary for an initial selection of sampling methods and gear for collection of entrainment samples. Most eggs and some invertebrates, including abalone, produce larvae that are too small to be captured by mesh size that is efficient for larval fish and crabs. Special collection methods which could be employed to collect abalone larvae are still under development.

3.3 Sampling Gear

A number of decisions on sampling methods and equipment are required for the selection of the intake cove for entrainment sampling. The various methods and equipment choices will be evaluated and reported in the following Phase I, Entrainment Study Design, II. Sampling Methods. At this stage it is possible to report that there is no apparent advantage to using plankton pump samplers in open-water sampling situations. Except for specific applications, pumps are not appropriate sampling techniques in open water. Plankton pumps have been used to collect samples at DCPP during early environmental studies. Pump samplers are particularly useful for collecting samples from specific depth strata, at least to a depth where the required length of intake pipe is manageable on deck. Strong currents and wave action also make it difficult to handle the equipment and maintain its position. In general, even in situations where it is desirable to measure vertical stratification of plankton organisms, towed opening-and-closing or depressor plane nets are preferred over pumping equipment.

Three general sources of sample bias are involved in the use of towed nets. These include the ability of organisms to evade the approaching net, escape through the mesh and extrusion by force through the net mesh opening. The selection of equipment to collect entrainment samples in the intake cove will require a balancing of these three factors with respect to the target species and sampling conditions. Several preliminary decisions on equipment and methods were made in order to begin sampling this location. Initially, standard equipment and methods were adapted from CalCOFI research.

Initial trials of the CalCOFI equipment and methods in November lead to an important observations which caused an adjustment in sampling equipment and resulted in an inclusion of additional equipment testing in the entrainment sampling design program.

Table 3-1
Larval fish taxa identified from DCPD Intake Cove oblique tows, October–December 1996.

FAMILY/GENUS/SPECIES	COMMON NAME
ATHERINIDAE	
ATHERINOPS AFFINIS	TOPSMELT
ATHERINOPSIS CALIFORNIENSIS	JACKSMELT
AULORHYNCHIDAE	
AULORHYNCHUS FLAVIDUS	TUBESNOUT
BATHYLAGIDAE	
BATHYLAGUS SPP.	BLACKSMELT
CHAENOPSIDAE	
NEOCLINUS SPP.	FRINGEHEAD
CLINIDAE	
CLINIDAE UNID.	KELPFISH
GIBBONSIA SPP.	KELPFISH
HETEROSTICHUS ROSTRATUS	GIANT KELPFISH
COTTIDAE	
ARTEDIUS HARRINGTONI	SCALYHEAD SCULPIN
ARTEDIUS LATERALIS	SMOOTHHEAD SCULPIN
ARTEDIUS SPP.	SCULPIN
CLINOCOTTUS / OLIGOCOTTUS SPP.	SCULPIN
COTTIDAE UNID.	SCULPIN
LEPTOCOTTUS ARMATUS	STAGHORN SCULPIN
OLIGOCOTTUS SNYDERI	FLUFFY SCULPIN
OLIGOCOTTUS SPP.	SCULPIN
ORTHONOPIAS TRIACIS	SNUBNOSE SCULPIN
SCORPAENICHTHYS MARMORATUS	CABEZON
CYCLOPTERIDAE	
CYCLOPTERIDAE UNID.	SNAILFISH
LIPARIS SPP.	SNAILFISH
LIPARIS MUCOSUS	SLIMY SNAILFISH
ENGRAULIDAE	
ENGRAULIS MORDAX	NORTHERN ANCHOVY
GOBIESOCIDAE	
GOBIESOCIDAE UNID.	CLINGFISH
GOBIESOX MAEANDRICUS	NORTHERN CLINGFISH
RIMICOLA SPP.	KELP CLINGFISH
GOBIIDAE	
CLEVLANDIA IOS	ARROW GOBY
CORYPHOPTERUS NICHOLSII	BLACKEYE GOBY
GOBIIDAE UNID.	GOBY
LEPIDGOBIUS LEPIDUS	BAY GOBY
LETHOPS CONNECTENS	KELP GOBY
TYPHLOGOBIUS CALIFORNIENSIS	BLIND GOBY
HEXAGRAMMIDAE	
OXYLEBIUS PICTUS	PAINTED GREENLING
MERLUCCIDAE	
MERLUCCIIUS PRODUCTUS	PACIFIC HAKE
MYCTOPHIDAE	
NANNOBRACHIUM RITTERI	BROADFIN LAMPFISH
PROTOMYCTOPHUM CROCKERI	CALIFORNIA FLASHLIGHTFISH
STENOBRACHIUS LEUCOPSARUS	NORTHERN LAMPFISH
OPHIDIIDAE	
OPHIDION SCRIPPSAE	BASKETWEAVE CUSKEEL
PARALICHTHYIDAE	
CITHARICHTHYS SPP.	SANDDAB
CITHARICHTHYS SORDIDUS	PACIFIC SANDDAB
PARALICHTHYS CALIFORNICUS	CALIFORNIA HALIBUT
PLEURONECTIDAE	
PLATICHTHYS STELLATUS	STARRY FLOUNDER
PLEURONECTIDAE UNID.	FLATFISH
PLEURONICHTHYS COENOSUS	C-O TURBOT
SCIAENIDAE	
GENYONEMUS LINEATUS	WHITE CROAKER
SCORPAENIDAE	
SEBASTES MYSTINUS	BLUE ROCKFISH

The 505 μm mesh net was replaced with 335 μm mesh following two separate sampling occasions when larval cabezon (approximately 4–6 mm in length) were observed protruding through the net mesh. Samples of the escaping larvae were collected, identified and measured in the laboratory along with the same larval fish in the net sample. The size of the larvae were larger (800 μm average transverse section) than the mesh aperture. However, it remains possible that the body of cabezon larvae can compress to fit through much smaller mesh.

The second sampling design consideration to come from November's preliminary equipment tests was the importance of increasing larval fish abundances making it possible to effectively test sampling equipment and methods. A secondary issue in this consideration was the seasonality of species and the potential change in gear selectivity as species appear and grow. It was realized that a specific period of time was needed during a period of peak larval fish abundances to test proposed sampling methods and equipment. Because of the change to the smaller 335 μm mesh, a number of equipment performance parameters which had been investigated by CalCOFI researchers for the 505 μm mesh needed to be re-evaluated using 335 μm mesh nets. These include performance measures of sampling efficiency for the 335 μm at various lengths of net, towing speed, and methods of fishing the nets (vertical versus continuous oblique tow). Also, the modification of CalCOFI's simple oblique tow pattern to the present method of using an up-and-down oblique tow pattern may have resulted in changes in the assumptions of the net's sampling performance, based on CalCOFI oblique tow findings.

Field tests of methods and equipment proposed for entrainment sampling in the intake cove will be performed and reported on in Phase 1, Entrainment Study Design, II. Sampling Methods. These tests include net efficiency trials of paired 335 μm bongo nets towed horizontally, obliquely and up-and-down obliquely in the intake cove. Flow meter readings taken with meters mounted in each net opening will be compared to readings from a flow meter mounted on the bongo frame outside the nets. Towing speed will also be systematically varied during each method test, in order to evaluate the effect of speed on net efficiency. The nets have been constructed with a length of 2 meters which allows them to be fished close to the intake structure without impingement and easily handled on the boat deck in adverse wind and sea conditions. The length of the nets will be temporarily and systematically changed to investigate the effect of net lengths on net efficiency at various towing speeds and towing patterns.

4.0 RECOMMENDATIONS

The locations and methods which were tested were compared in a series of decision steps outlined in Appendix B. The decision tree format was developed to assist in the review and selection of recommended locations and sampling methods for the Phase 2 Entrainment Study Plan. Recommended sampling design and methods, based on general observations, sampling results, and a review of relevant literature during the Phase 1 Entrainment Sampling Verification studies, include the following:

- Collect entrainment samples in the intake cove as closely as practical to the bar racks.

It was determined that intake flow volumes could not be reliably estimated for samples collected at the bar rack and header pipe locations evaluated in the Phase 1 Entrainment Sampling Verification studies. Additional difficulties were discovered at each of these locations. At the bar rack, uniform collection of samples could be compromised by kelp and other debris on the racks interfering with the sampling equipment. At the header pipe location, cropping by biofouling organisms could remove entrained organisms before the sampling point. There is currently a lack of knowledge about the contribution of individual sources of intake flow.

- Collect entrainment samples at four locations in front of the intake structure in order to avoid sampling bias due to systematic differences in current flows approaching the intake structure.

A review of results from various studies of current flow and circulation patterns in the intake cove suggest that persistent patterns of water circulation such as gyres are commonly present in the area of the sampling location. The patterns appear to vary slightly with tide and wave conditions. The presence of these hydraulic characteristics in the sampling area pose the possibility of systematic sampling bias in the entrainment samples. This would be more of a problem if the samples were collected from a single location, rather than several locations spanning the entire front of the intake structure as proposed.

- Collect entrainment samples with standard sampling methods and equipment appropriate to the size of target organisms to enable easy comparison with other relevant and similar data sources.

It was determined that sampling methods and equipment similar to those used in CalCOFI ichthyoplankton surveys (vertical/oblique tows with bongo nets) could be used at the intake cove location to collect uniform and reliable entrainment samples. Pump samplers that were considered provided no advantages over towed nets in open water. Pump sampling can be an effective sampling method inside intake structures or cooling water systems where entrained organism densities are well mixed by turbulent flow, assuming no biofouling-cropping losses of entrained organisms

- Collect entrainment samples for a sufficient period of time to include at least two annual cycles of peak larval fish abundance.

Review of findings from previous ichthyoplankton studies in the area of the intake cove sampling location indicate large differences in annual densities of ichthyoplankton taxa. Such differences may be due in part to climatic changes in the area's ocean conditions

(El Niño, storms) which can affect larval survival rates as documented in the literature.

- Collect samples over a 24-hour period at a frequency of once per week.

Review of findings from previous ichthyoplankton studies in the area of the intake cove sampling location indicate noticeable day/night patterns in the density and composition of taxa. Given the relatively short duration of larval stages for many of the area's taxa, it is necessary to collect samples at a frequency appropriate to life history time scales.

- Validate sampling methods and equipment selections through site-specific studies conducted during the periods of peak larval fish abundance.

Such studies are described in detail in Phase 1, Entrainment Sampling Verification Studies, Part II, Sampling Methods, of the Entrainment Study Design Report.

Both the basis for the above recommendations and the implementing procedures for Phase 2 Entrainment Sampling will be continually reviewed during the course of Phase 2 Entrainment sampling. Recommended modifications will be quickly reviewed and implemented with approval of the DCP Entrainment Technical Working Group.

ENDNOTES

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- ¹ Icanberry, J., J. W. Warrick, and D.W. Rice 1978. Seasonal larval fish abundance in water off Diablo Canyon, California. *Trans.Am.Fish.Soc.* 107:225-233.
- ² TENERA. 1996. Unpublished field observations.
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Appendix A

**Diablo Canyon Power Plant
316(b) Entrainment Sampling Study Plan Proposal**

Diablo Canyon Power Plant 316(b) Entrainment Sampling Study Plan Proposal

Project Description

This project is designed to determine whether Diablo Canyon Power Plant's (DCPP) cooling water intake design complies with Section 316(b) of the Clean Water Act. The determination of compliance with Section 316(b) involves an evaluation of whether the operation of the DCPP intake system results in an adverse environmental impact and if so, what technologies are both available and cost effective in reducing any adverse impacts.

Project Objective

The Central Coast Regional Water Quality Control Board ("the Board") Diablo Canyon Power Plant Multiagency Workgroup has developed goals for the group and the work that will be conducted with input from the Workgroup and its Technical Subgroups. The goals for the Workgroup and objectives of the project are to determine appropriate designs for 316(b) entrainment studies, develop criteria for evaluating impacts and determine the ecological significance of the impacts on marine life, and to make final recommendations to the Board, including mechanisms for implementation and follow-up.

Project Setting

Section 316(b) of the Clean Water Act requires that "...the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." The potential for a cooling water intake to cause environmental effects arises primarily from the movement of aquatic organisms within the cooling water flow, and the ultimate fate of those organisms. Historically, environmental studies designed to achieve compliance with Section 316(b) have focused on entrainment (passage of smaller individuals through the cooling water system), and impingement (entrapment of larger individuals on the plant's screening systems).

Impact Analysis

The impact analysis for the project will involve the design and successful completion of a study to quantify losses of organisms due to entrainment and the impact of those losses on the affected resources. The impact analysis will also consist of completion and submittal of a final report which will be used in making recommendations on further actions to the Board.

The plan is organized into four phases which encompass the development and verification of methodology, and actual sampling for both entrainment and resource assessment. The plan would also include progress reports, and preparation and submittal of a final report at the completion of all sampling and sample processing. The proposed study phases with anticipated durations (including sample processing and analysis) are summarized as follows:

Phase 1 - Entrainment Sampling Verification Studies; 5/96 - 10/96

Evaluate potential sampling sites and methods which best represent the composition and abundance of larvae entrained by the power plant cooling water system. Determinations from

Phase 1 on selection of the most representative sampling methodology, location, sample size, number of samples, and length of sample collection per week will be used in designing Phase 2 sampling.

Phase 2 - Entrainment Larval Abundance Sampling; 11/96 - 11/98

Conduct and complete sampling necessary to determine the composition and abundance of organisms entrained by the power plant's intake.

Phase 3 - Resource Comparison Model Evaluation - Sampling Verification Studies; 9/96 - 4/97

Evaluate conceptual models for assessing entrainment losses, and develop sampling methods to provide empirical data for the selected model. Some of the methods of assessing effects on the resource may involve source waterbody (SWB) sampling. Methods to accurately sample the SWB will be tested so that samples are comparable to entrainment samples and if necessary, can be used to compare the percent of larval withdrawal from the SWB by the power plant.

Phase 4 - Resource Comparison Sampling; 5/97 - 11/98

This phase will consist of collecting the data necessary to support the resource comparison model chosen in Phase 3.

Because subsequent steps depend on the outcome of preliminary studies, only Phase 1 is detailed in the present plan. As experimental data become available concerning the effectiveness and representative nature of the proposed sampling in Phase 1, methods to be used in later project phases will be formulated. Figure 1 is a proposed timeline for submittal of the study plans and completion of each phase of the project.

Phase 1: Entrainment Sampling Verification Studies

The objective of Phase 1 of the entrainment sampling is to evaluate which potential sampling site best represents the composition and abundance of larvae entrained by the power plant cooling water system (CWS). There are three sample locations within the intake field that could logistically be used as sample collection sites. These are: 1) directly in front of the bar racks, 2) directly in front of the traveling screens, and 3) the intake header piping system. Figure 2 shows these three locations in relation to the CWS and Table 1 lists the strengths and limitations of each of these sites. Access points within the CWS which were beyond the intake header were not considered for sampling locations because of potential larval losses due to predation by biofouling organisms. In addition to sample location, other sampling parameters will be determined during Phase 1 such as optimum volume of water to be filtered per sample, number of samples, length of sample collection time, and the schedule of sample collection.

In Figure 2, the bar rack location (#1) is external to the intake structure and could be sampled by either towed plankton nets or pumps. The area adjacent to the traveling screens (#2) is accessible through a three-inch opening in the concrete intake deck and would require pump sampling. The intake header pipe (#3) is a four-inch pressurized pipe that interconnects to a piping system that withdraws water from the conduits just behind the plant's circulating water pumps. Due to the relatively small volume of water that could be practically collected through a three-inch pump line, location #2 in front of the traveling screens was eliminated from further

consideration because of potentially insufficient sample volumes. Phase 1 of this study will determine which of the other two locations better represents the abundance and species composition of entrained organisms.

Measuring Intake Flow Characteristics

Initially, a dye-dilution study will be performed to determine the nature of flows from the header pipe in relation to the total entrained water mass. The basic procedure will be to inject a measured stream of fluorescent dye through a diver-held pipe positioned inside the forebay area of the intake. It is proposed that nine positions in each of the six forebays be tested per unit. The nine positions include left, middle and right sides at the top, middle and bottom inside of each set of bar racks. A known concentration of the dye will be injected for a period of from 5-10 min. at each of the noted locations. A fluorometer connected to the intake header pipe at the proposed entrainment sampling location will detect and record any dye entering the intake header. By comparing the amount of fluorescence detected under differing experimental conditions, a relationship between dye concentrations at the injection locations and at the header pipe can be determined. If the dye study shows that the intake header pipe is not a representative location for the collection of a homogeneous water sample, then no further sampling will be completed there and sampling in front of the intakes will be the preferred alternative (Location 1).

Besides assessing if the intake header pipe is a representative sampling location, the dye testing procedure will also accurately verify existing data on circulating water pump capacity. These values will be used as part of the equation to calculate the estimated total number of larvae entrained by the operation of the power plant.

Comparing plankton samples between header pipe and bar rack sampling locations

If dye studies confirm that water flows at the header is collecting a homogenous water sample representing the total entrained water mass, the next step is to determine if actual samples of larval fishes and crabs (*Cancer* spp.) drawn from the header are representative and proportional to the total mass of entrained plankton. This is necessary because particles in suspension (plankton) may behave differently than the fluid medium itself (cooling water).

During earlier special entrainment studies conducted during 1985-1987, plankton samples were collected with pumps from three depths in front of the intakes (PG&E 1988). Overall it was determined that there were significantly less larval fish in samples from near-bottom locations than from either midwater or surface locations, which were approximately equal in fish densities. This vertical stratification must be accounted for by sampling within the near-bottom and surface strata during Phase 1 verification studies and then using an average larval densities to estimate the total number of entrained organisms. Significant diurnal differences in larval abundance were also noted during the earlier studies and must be accounted for in the experimental design by collecting samples throughout several 24-hr periods.

Plankton sampling can be accomplished by either filtering pumped seawater through a plankton net or towing the net through the water in front of the bar racks. The main limitation of pump sampling is that a fixed and relatively small-diameter inlet point is sampled, potentially under-sampling the spatial variation in plankton distributions. However, an advantage of pump sampling is that the collected sample is temporally integrated over the duration

of the pumping cycle which can reduce temporal variability caused by plankton patchiness. Larval damage caused by pump impeller forces can also make identifications difficult and result in loss of data.

Net sampling has the advantage of providing a much greater volume of filtered water than pump sampling over a given time period. This can be an important factor because average fish densities are typically quite low, and larger sample volumes can better assess temporal variation in abundance and species composition. Also, towing a plankton net across a known area can integrate some of the spatial patchiness as well, whereas pump sampling is typically restricted to a few fixed locations as previously noted. Net sampling has been widely used as a standard protocol for marine plankton sampling (e.g. CalCOFI Program). For these reasons, net sampling is the preferred alternative for collection of samples near the bar rack location.

Some sampling methodology questions must first be addressed before extensive net sampling is initiated. Although a net mesh size of 333 μ is a well-established standard for zooplankton collection, typical net opening diameters can be either 0.5m or 1.0m. The larger net may have a significantly greater capture efficiency and therefore yield better estimates of true larval density. It is proposed that side-by-side comparisons of the two net opening be tested, initially in 10 paired sub-surface tows in front of the intake structure. An analysis of abundance and composition data from the two sample sets will test the effects of net diameter and sample volume. Results will determine if a 0.5m net will be sufficient for mass balance comparisons with intake header samples.

Proposed Phase 1 sampling protocol

- Samples will be collected from water flows extracted from the header pipe. For Phase 1 verification studies, samples of approximately 15m³ will be filtered through 333 μ mesh at continuous 15 min. intervals over three 24-hr periods. This will yield samples of approximately 60m³ per hour during each special entrainment study. Larval fishes and *Cancer* spp. will be sorted and identified as per standard procedures. QA/QC programs will be in place for all phases of sampling, sorting, identification, and reporting.
- For comparison, 0.5m or 1.0m diameter plankton nets will be towed in front of the intake bar racks to collect samples which represent the water being entrained into the CWS. Because of potential vertical stratification differences, a net will be towed at a depth of approximately 3m below the surface (depth to lower edge of curtain wall) and also 1-2m above the sea floor in front of the intake structure (level across bottom of intake opening). Samples will be taken twice per hour over the same three 24-hr periods during which sampling is taking place at the intake header pipe. A 333 μ 0.5m diameter net towed the length of the intake structure (ca. 80m) at each depth will yield a total sample volume of approximately 60m³ per hour of sampling. This approximates the same volume of water filtered from concurrent sampling at the header pipe.

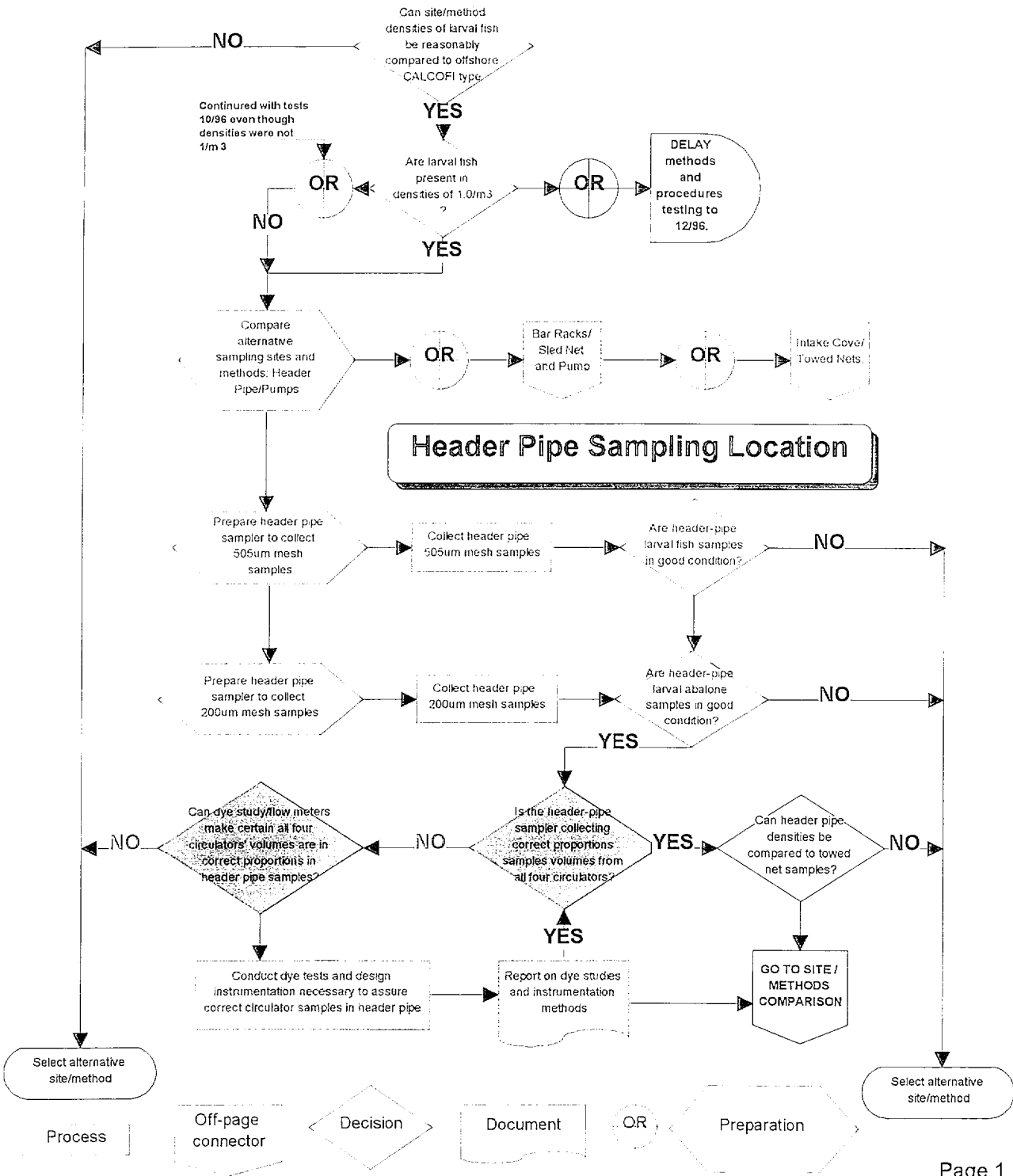
In both cases, data from towed-net samples and header pipe samples would be used to hindcast daily entrainment abundances for each sampled taxa. If abundance and composition do not vary significantly between the two methods, the header pipe will be selected as the preferred alternative for further entrainment sampling,

based on logistical and safety considerations. If net sampling density and composition estimates are significantly greater than estimates obtained from header pipe samples, a net sampling program will be designed to estimate entrainment abundances during Phase 2. If the highest larval density and composition is found in the header pipe samples, then that location will be the preferred alternative for entrainment sampling. A simplified summary of the Phase 1 decision process is presented in Figure 3.

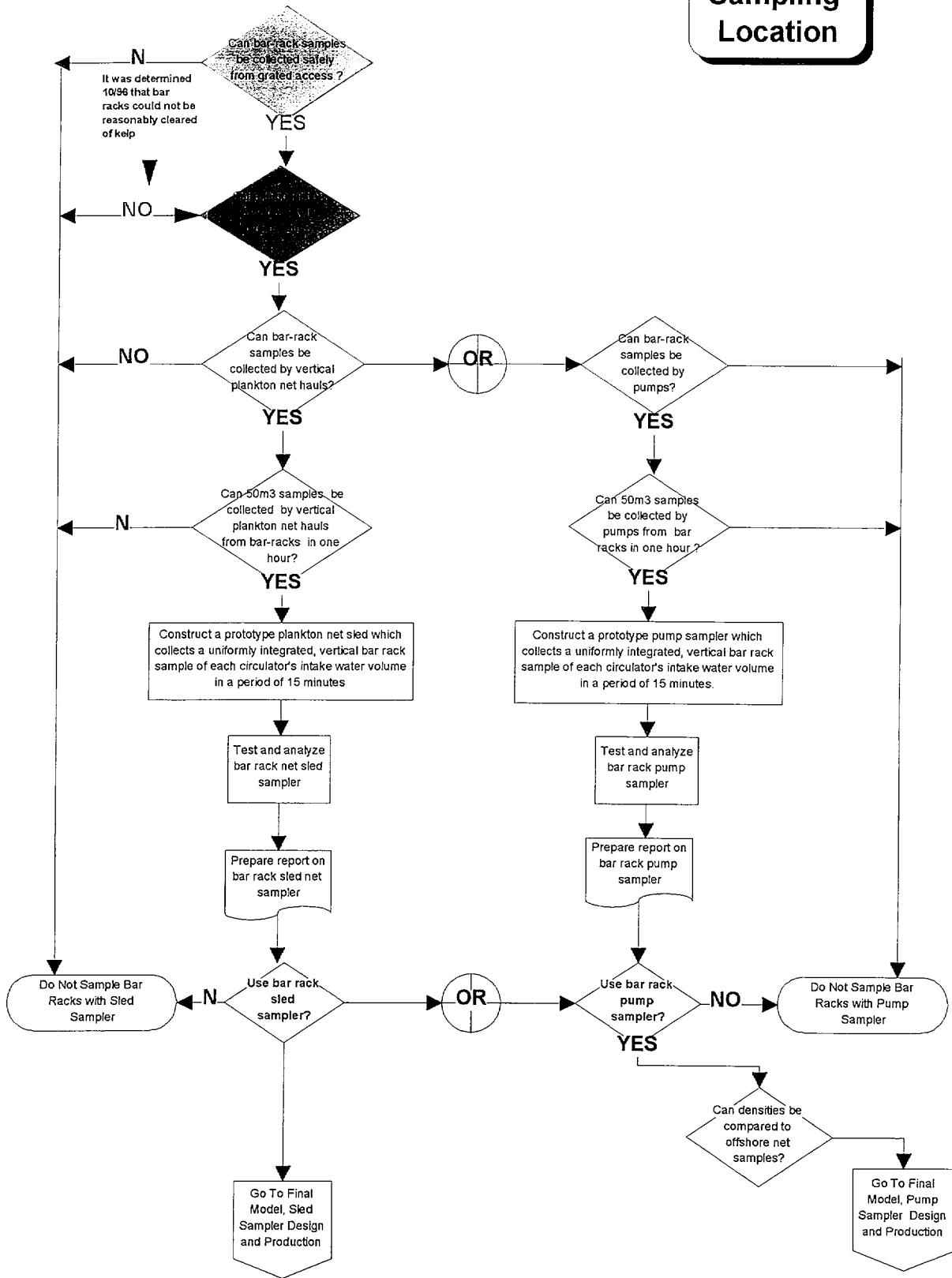
Appendix B

Sampling Design Decision Tree

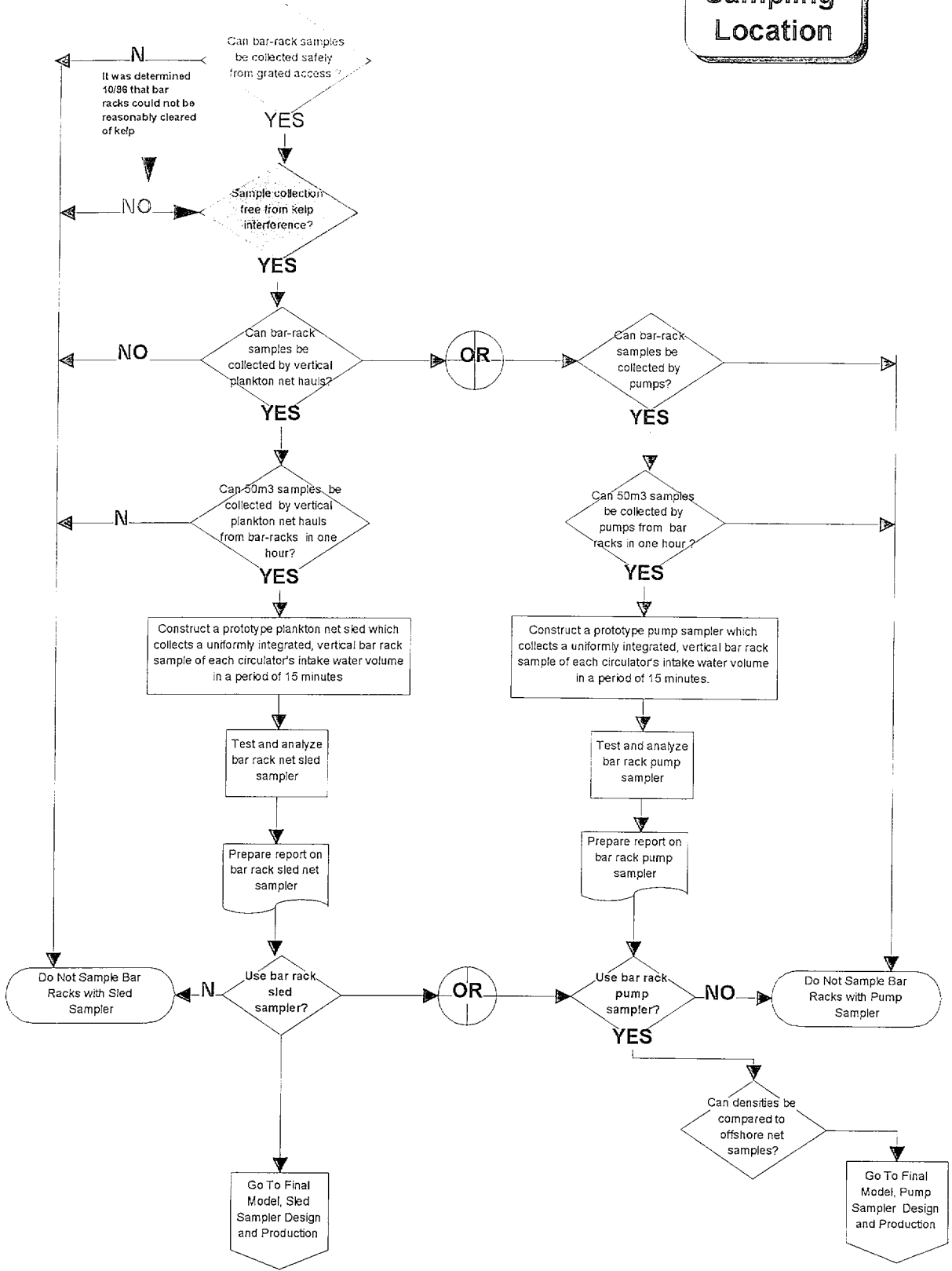
Select alternative sampling sites and methods: header pipe, bar racks, and intake cove.



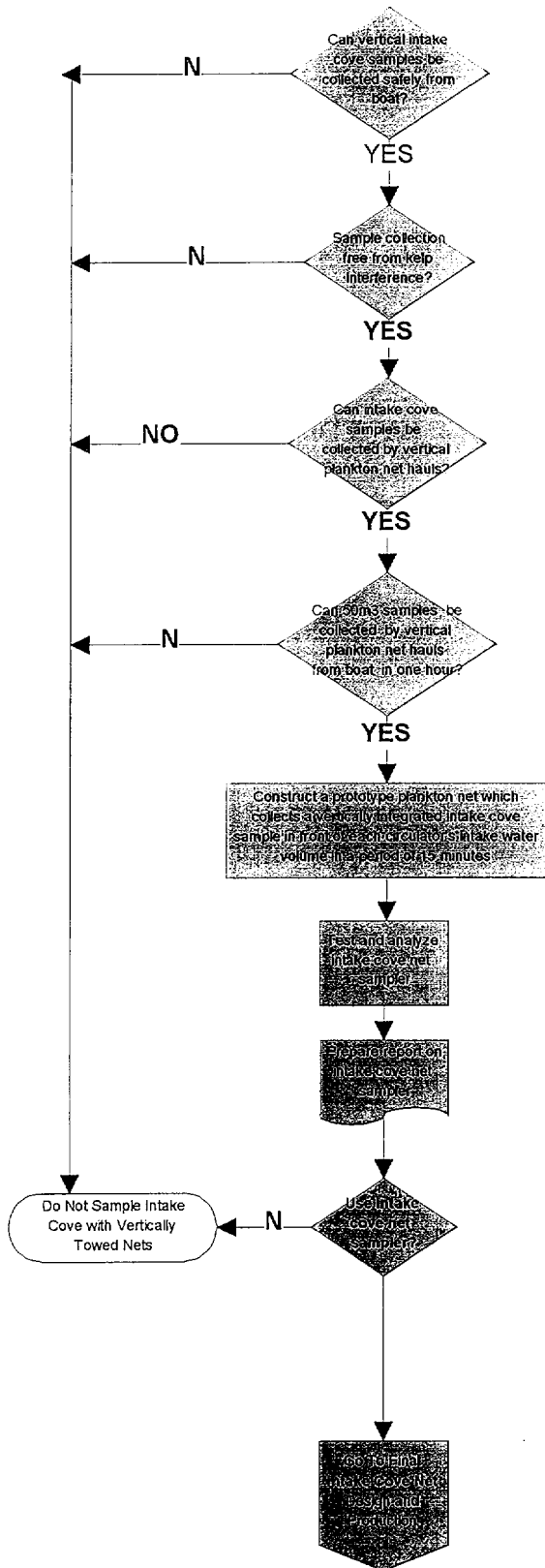
Bar Rack Sampling Location



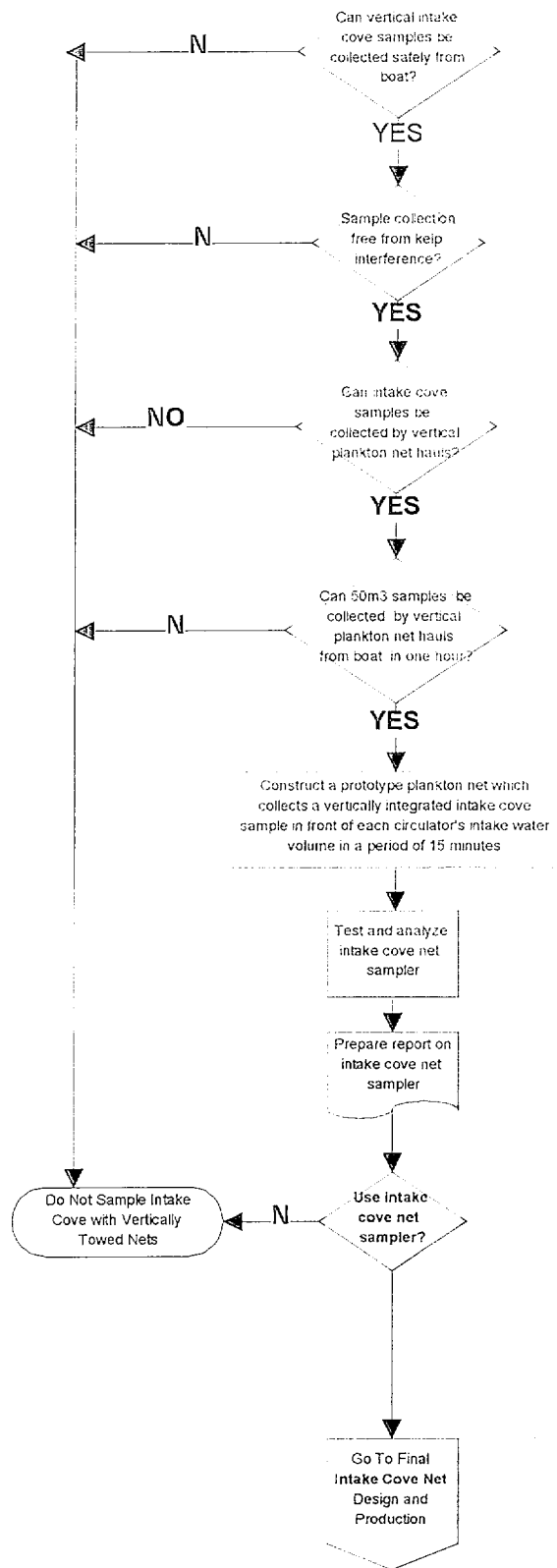
Bar Rack Sampling Location

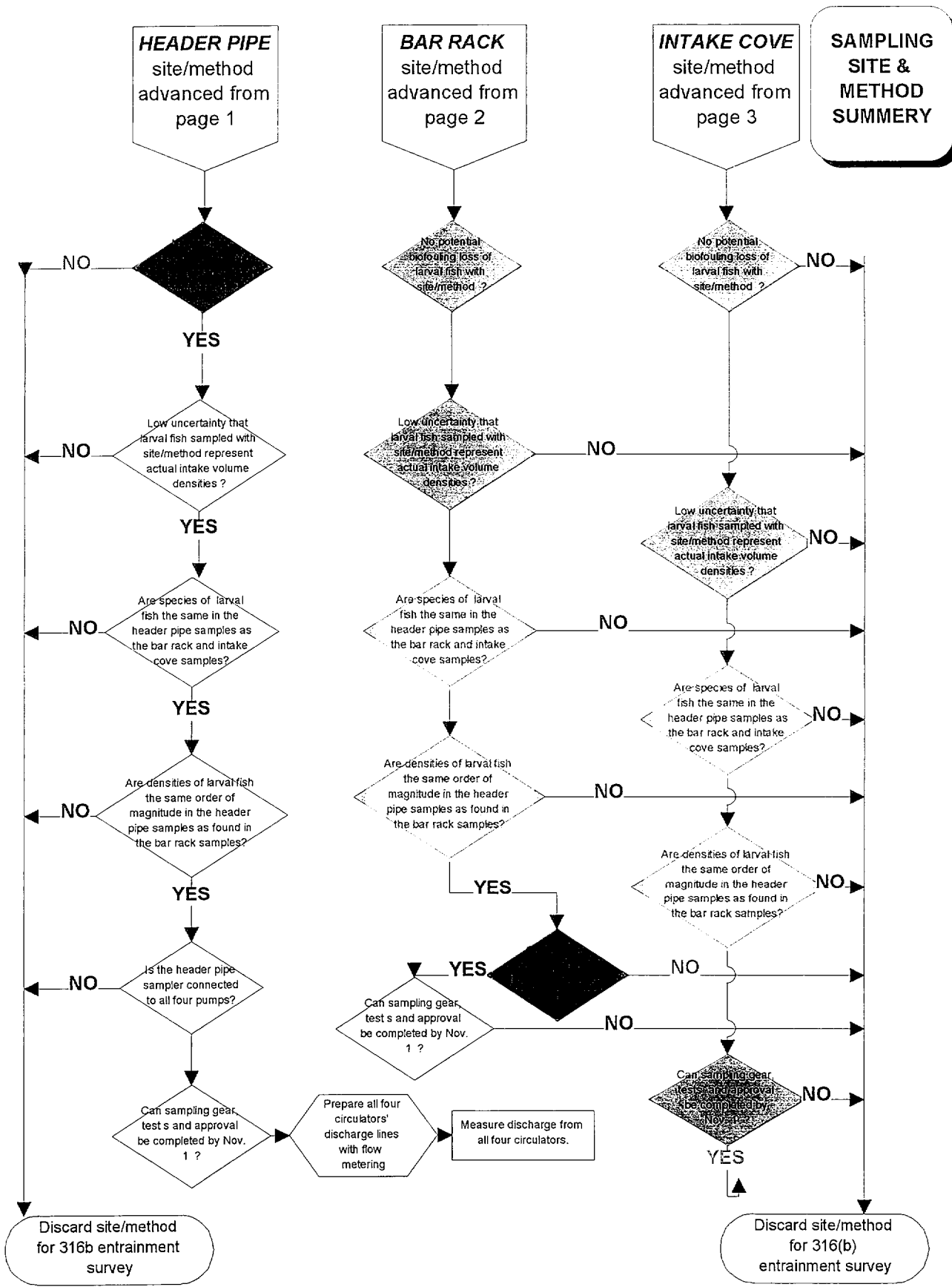


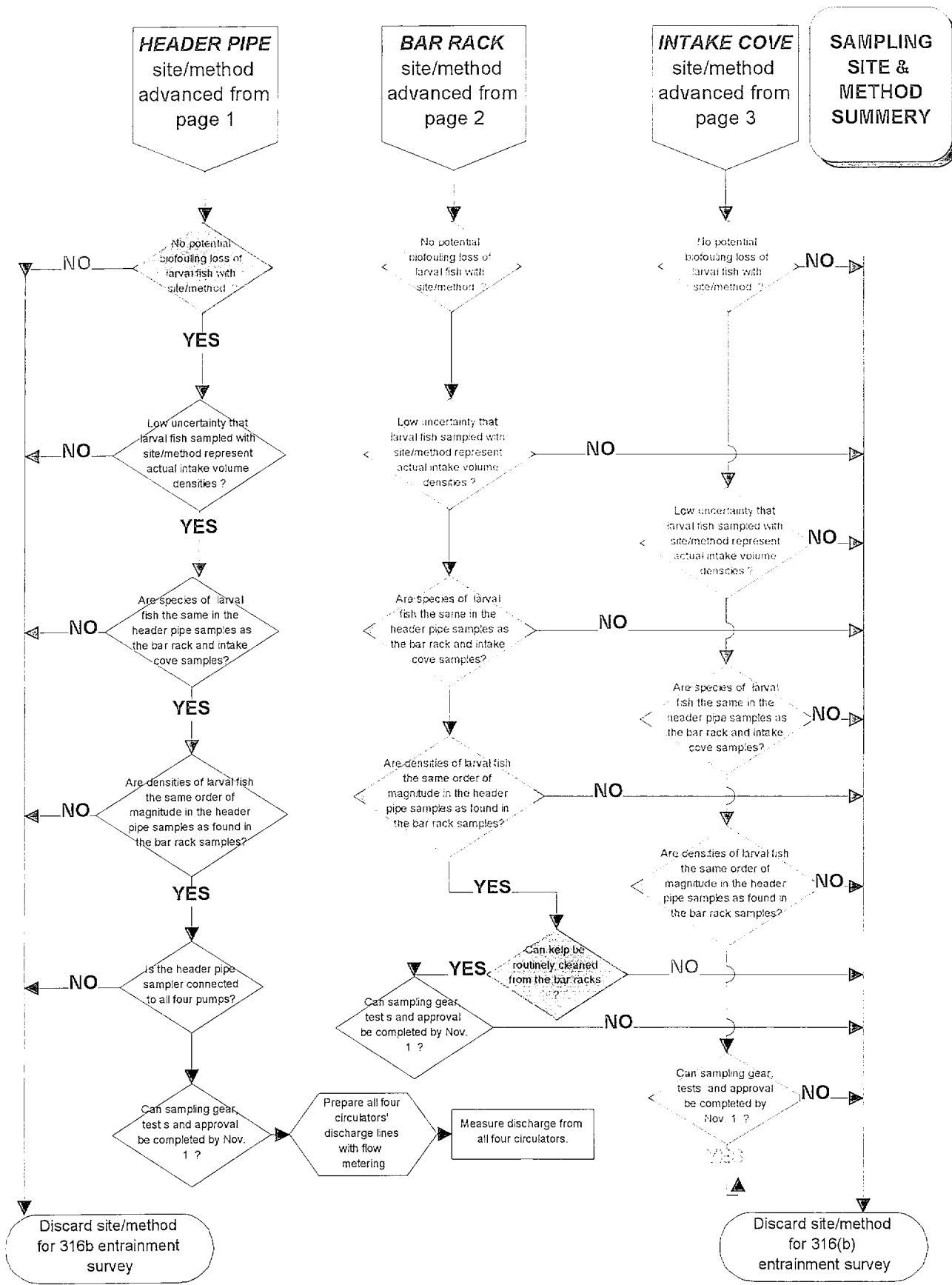
Intake Cove Sampling Location



Intake Cove Sampling Location







Appendix C

Results of DCPD Dye Flow Studies Conducted on 17-21 June 1996

**Results of DCPD Dye Flow Studies
Conducted on 17-21 June 1996**

Prepared for Tenera

by

John Graham

22 July 1996

**Dye Flow Technologies a Division of
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**RESULTS OF DCPD DYE FLOW
STUDIES CONDUCTED ON
17-21 JUNE 1996**

INTRODUCTION

A new water supply from the header of the intake coolers at the Diablo Canyon Power Plant was established to provide a source of seawater for various biofouling related studies. This water source has been proposed as a possible sampling point for plankton studies. A dye study was conducted to determine the suitability of using the intake cooler source as a seawater sampling point for these plankton studies as mandated by state and federal regulatory agencies.

44 Dye injections and two bulk dye releases were conducted in this study.

27 Dye injections were conducted on the 1-2 pump and screen assemblies, covering most of the area in front of the travelling screens.

17 Dye injections were conducted on the 1-1 pump and screen assemblies, examining areas thought to be critical in light of the 1-2 pump data.

BACKGROUND

Only a limited number of preexisting seawater openings exist between the main circulating water pumps and the condensers, none of which were designed for obtaining a uniform representative sample of water necessary for biological sampling. The intention was to use a fluorescent dye injection technique to determine the suitability of one of these openings as a sampling source. For this purpose, these tests must demonstrate that the water sampled is obtained from the entire profile of the intake, ideally yielding a uniform sample across the entire extent of the three sets of travelling screens.

PROCEDURE

A 410 gpm flow of water was established between one selected pump and the sample point. A fluorescent dye sensing unit was connected to the sample point and a 5 gpm water flow was established through the unit. A separate 2.2 gpm carrier injection stream driven by a piston driven high pressure injection pump was established through a flexible diver held hose in front of the bar racks with a 20 foot long extension pipe capable of reaching into the traveling screens. At intervals, precise quantities of dye were injected into the carrier stream. The dye was recognized by the sensing unit and a time-of-travel and a dilution factor obtained. By moving the carrier stream to 27 positions in front of the travelling screens and using precisely measured injection rates and times, the suitability of the sampling point was analyzed. This procedure was done on 18-19 June 1996 in front of the 1-2 pump and involved three dye injections at three depths in front of each of the three sets of travelling screens comprising a pump intake. The following nomenclature was used to identify the positioning of each test:

1-1, and 1-2 Identifies the specific plant unit and pump associated with each test.

BR Identifies tests where dye releases were made in front of the bar racks

A, B, and C Identify the specific location of the three travelling screens associated with each pump intake. Facing the intake, A represents the leftmost travelling screen, B the centerline screen, and C the rightmost travelling screen.

numeric designations 0 to 9 represent locations of dye injections in front of the travelling screens in the following pattern:

	0	
1	2	3
4	5	6
7	8	9

These locations represent the following layout horizontally and vertically:

Location 0. Center of inlet, and approximately six inches below water surface behind curtain wall (used only in bar rack BR tests)

Location 1. Approximately one foot to the right of the left concrete wall, and one foot below the level of the curtain wall.

Location 2. Center of inlet, and one foot below the level of the curtain wall.

Location 3. Approximately one foot to the left of the right concrete wall, and one foot below the level of the curtain wall.

Location 4. Approximately one foot to the right of the left concrete wall, and centered between the curtain wall and the floor of the intake.

Location 5. Center of inlet, and centered between the curtain wall and the floor of the intake.

Location 6. Approximately one foot to the left of the right concrete wall, and centered between the curtain wall and the floor of the intake.

Location 7. Approximately one foot to the right of the left concrete wall, and one foot above the floor of the intake.

Location 8. Center of inlet, and one foot above the floor of the intake.

Location 9. Approximately one foot to the left of the right concrete wall, and one foot above the floor of the intake.

In practice, water movement and turbulence made these locations difficult to hold, and most side wall and floor locations were stabilized by pushing or laying the 20 foot long wand against the support structure. Midwater locations were affected by turbulence and may be regarded as approximate locations within a 3 to 6 foot circle.

As time permitted, on 20-21 June, 17 additional dye injections on the 1-1 pump and in front of the bar racks were undertaken to compare data with the 1-2 pump and establish water movement patterns within the intake. Additionally, two bulk dye releases were made. In these tests, emphasis was placed on times of travel between the injection site and the sample site to determine velocities of water movement and the porosity of the breakwater.

RESULTS

Table 1 summarizes test conditions and processed data associated with each test sequence.

Figures 1 through 5 display the fluorometer readings associated with each test and are identically scaled and grouped to represent the spatial layout of the tests within each pump or individual traveling screen bay.

Table 1. m. data file

place	date	duration of dye injection (seconds)	dye injection weight (gm)	dye injection rate (gm/min)	time of the dye injection	time that measurement of dye began	time that measurement of dye ended	duration of dye measurement (seconds)	time of travel from dye injection to dye measurement	time of travel in seconds	sum of fluorometer readings during time of dye measurement	number of measurements	average of fluorometer measurements during test
1-1A1	6/20/96	299.94	105.20	21.044	9:37:00	9:40:11	9:45:39	327.97	0:03:11	190.99	442.60326	165	2.68244
1-1A4	6/20/96	299.92	104.98	21.002	9:25:00	9:28:11	9:33:37	325.99	0:03:11	191.02	541.11084	184	3.29946
1-1A7	6/20/96	300.04	130.67	26.131	9:11:00	9:14:27	9:20:27	359.94	0:03:27	207.02	832.93974	181	4.60188
1-1B2	6/20/96	299.99	105.60	21.125	9:50:00	9:52:55	9:58:17	322.01	0:02:55	175.03	785.00124	162	4.84569
1-1B8	6/20/96	300.13	106.20	21.231	10:03:00	10:05:57	10:11:25	327.97	0:02:57	177.03	706.04116	184	4.30513
1-1C3	6/20/96	300.11	106.24	21.240	10:28:00	10:31:07	10:37:18	371.00	0:03:07	186.96	619.20088	166	3.73013
1-1C6	6/20/96	300.19	106.12	21.215	10:41:00	10:43:58	10:49:20	322.01	0:02:58	177.99	705.38809	162	4.35425
1-1C9	6/20/96	300.06	106.06	21.208	10:16:00	10:19:06	10:25:36	369.92	0:03:06	186.04	736.98211	165	4.48656
A1	6/18/96	300.00	40.96	8.192	12:10:00	12:12:54	12:18:54	360.03	0:02:54	173.97	149.49823	181	0.82596
A2	6/18/96	300.03	62.25	12.449	10:42:00	10:45:03	10:50:17	314.06	0:03:03	182.97	305.40091	158	1.93292
A3	6/18/96	300.04	45.08	9.015	14:09:00	14:11:43	14:17:27	343.96	0:02:43	163.01	236.95761	173	1.38126
A4	6/18/96	299.99	45.66	9.132	12:23:00	12:25:46	12:30:28	281.92	0:02:46	166.04	166.69640	142	1.17392
A5	6/19/96	300.02	36.91	7.382	10:25:00	10:27:54	10:33:12	317.95	0:02:54	174.03	186.28149	160	1.18426
A6	6/18/96	300.10	50.40	10.077	13:55:00	13:57:40	14:03:42	362.02	0:02:40	160.00	248.30838	184	1.34950
A7	6/18/96	300.24	58.80	11.950	9:51:00	9:53:54	9:59:34	339.98	0:02:54	174.04	405.42586	171	2.37091
A8	6/19/96	299.99	38.72	7.744	10:12:00	10:15:02	10:20:38	336.01	0:03:02	181.96	222.73293	169	1.31795
A9	6/18/96	300.12	48.78	9.752	10:09:00	10:11:41	10:17:01	320.03	0:02:41	160.99	325.91055	161	2.02429
B1	6/18/96	300.09	46.10	9.217	14:22:00	14:24:42	14:30:12	330.05	0:02:42	161.99	263.32593	166	1.58630
B2	6/19/96	299.90	68.05	13.615	10:54:00	10:58:58	11:02:10	311.99	0:02:58	178.01	468.41066	157	2.98351
B3	6/18/96	300.14	38.13	7.622	15:28:00	15:30:49	15:36:25	336.01	0:02:49	168.96	192.97684	169	1.14187
B4	6/18/96	299.99	47.17	9.434	14:36:00	14:38:43	14:43:57	313.98	0:02:43	163.01	278.90709	158	1.78523
B5	6/19/96	299.79	72.29	14.468	11:06:00	11:08:54	11:14:12	317.95	0:02:54	174.01	611.30517	160	3.82066
B6	6/18/96	300.07	44.66	8.930	15:15:00	15:17:35	15:23:05	329.96	0:02:35	155.03	298.06216	166	1.79556
B7	6/18/96	300.11	54.32	10.860	14:48:00	14:50:41	14:56:13	332.04	0:02:41	160.99	397.75484	167	2.38177
B8	6/19/96	300.19	63.83	12.758	11:21:00	11:24:05	11:29:39	334.02	0:03:05	185.01	488.97299	168	2.91055
B9	6/18/96	300.19	63.88	12.770	15:02:00	15:05:07	15:11:21	374.03	0:03:07	186.98	455.99798	188	2.42552
C1	6/18/96	300.03	44.30	8.859	11:16:00	11:18:49	11:24:05	316.05	0:02:49	168.96	260.26672	159	1.63702
C2	6/18/96	300.06	28.47	5.693	11:59:00	12:02:01	12:06:29	268.01	0:03:01	180.96	113.41017	135	0.84008
C3	6/18/96	300.14	47.51	9.498	10:54:00	10:56:39	11:02:01	322.01	0:02:39	159.00	240.59057	162	1.48513
C4	6/18/96	299.95	44.28	8.857	11:32:00	11:34:39	11:39:56	317.00	0:02:39	159.01	341.35433	160	2.13346
C5	6/19/96	300.07	38.12	7.622	11:47:00	11:49:55	11:55:05	310.00	0:02:55	175.03	208.33053	156	1.33545
C6	6/18/96	300.08	42.38	8.474	11:57:00	11:59:37	12:04:47	310.00	0:02:37	157.02	217.22548	156	1.39247
C7	6/18/96	300.05	42.69	8.537	11:45:00	11:47:51	11:53:17	325.99	0:02:51	171.04	288.26557	164	1.75772
C8	6/19/96	290.26	62.14	12.645	11:35:00	11:38:04	11:43:26	321.75	0:03:04	184.04	413.99051	163	2.53982
C9	6/18/96	300.04	49.81	9.961	10:28:00	10:30:43	10:36:05	322.01	0:02:43	163.03	290.49965	162	1.79321
BR-A0	6/20/96	300.15	104.60	20.910	14:40:00	14:43:24	14:52:10	526.00	0:03:24	203.98	363.19411	191	1.90154
BR-A1	6/20/96	299.98	105.97	21.195	15:08:00	15:10:56	15:18:38	341.97	0:02:56	176.04	314.54122	115	2.73514
BR-A4	6/20/96	299.97	108.10	21.222	15:29:00	15:32:02	15:37:32	330.05	0:03:02	181.97	317.41736	111	2.85962
BR-B0	6/21/96	299.90	104.63	20.933	9:11:00	9:14:32	9:21:08	395.97	0:03:32	212.04	370.84067	133	2.78828
BR-B2	6/21/96	300.08	104.14	20.824	9:27:00	9:30:08	9:35:32	324.00	0:03:08	188.01	420.91764	109	3.86163
BR-C0	6/21/96	299.93	104.32	20.869	9:50:00	9:53:05	9:59:35	390.01	0:03:05	184.96	390.20981	131	2.97870
BR-COM2	6/21/96	300.00	104.43	20.866	10:06:00	10:09:06	10:16:03	417.05	0:03:06	185.99	388.52823	140	2.77520
BR-C3	6/21/96	300.11	104.63	20.918	10:19:00	10:22:01	10:29:16	435.02	0:03:01	181.00	428.80683	120	3.57339
BR-C6	6/21/96	300.03	104.85	20.968	10:33:00	10:36:14	10:42:24	369.96	0:03:14	194.03	454.33528	109	4.16821
bulk#1	6/20/96	0	1000	immediate	11:55:00								
bulk#2bkwtr	6/21/96	0	250	immediate	12:39:00								
A7 test1 not used	6/18/96	300.22	56.41	11.274	9:39:00								

Table 1. master data file

place	water temperature at start(°F)	water temperature at end(°F)	pre-test average fluorometer background reading	rise in fluorometer units during test	pump flow (gpm)	tide level (ft)	intake area (sq ft)	cross-sectional water velocity (fps)	observed dye concentration (µg/Kg) (ppb)	expected dye concentration (µg/Kg) (ppb)	obs-exp (µg/Kg) (ppb)	%dev conc	corrected pump flow (gpm)
1-1A1	51.4	51.4	-0.46825	3.15070	410434	0.82	885.6	1.033	8.031	11.678	-3.647	-31%	424434
1-1A4	51.4	51.4	-0.46775	3.76720	410434	0.49	881.7	1.037	9.602	11.725	-2.122	-18%	424434
1-1A7	51.4	51.3	-0.46926	5.07114	411248	0.37	878.1	1.043	12.926	13.192	-0.266	-2%	425248
1-1B2	51.5	51.6	-0.47235	5.31803	410478	0.77	890.1	1.027	13.555	11.938	1.617	14%	424478
1-1B8	51.6	51.5	-0.46503	4.77016	411914	0.84	895.2	1.025	12.159	11.748	0.411	3%	425914
1-1C3	51.4	51.3	-0.46255	4.19268	412510	1.11	900.3	1.021	10.887	10.375	0.512	3%	426510
1-1C6	51.3	51.3	-0.46675	4.82100	413251	1.30	908.0	1.016	12.288	11.919	0.369	3%	427251
1-1C9	51.5	51.4	-0.47017	4.93673	412613	1.88	923.4	0.996	12.583	9.852	2.731	28%	426613
												0%	
A1	49.6	49.5	-0.43220	1.25816	380412	3.30	986.0	0.877	3.207	4.237	-1.030	-24%	414912
A2	49.3	49.3	-0.42536	2.35827	374719	1.84	922.2	0.905	6.011	7.485	-1.474	-20%	409219
A3	49.3	49.3	-0.42188	1.80313	380882	3.51	972.3	0.873	4.596	4.876	-0.280	-6%	415382
A4	49.5	49.5	-0.42927	1.60319	380633	3.41	969.3	0.875	4.086	6.029	-1.942	-32%	415133
A5	49.3	49.3	-0.42363	1.58789	374271	1.82	915.6	0.911	4.047	4.388	-0.341	-8%	408771
A6	49.2	49.3	-0.42920	1.77871	381319	3.55	973.5	0.873	4.534	5.174	-0.640	-12%	415819
A7	49.3	49.2	-0.42242	2.79333	375543	1.55	913.5	0.916	7.120	6.829	0.491	7%	410043
A8	49.2	49.3	-0.42542	1.74337	373385	1.41	909.3	0.915	4.444	4.366	0.078	2%	407885
A9	49.2	49.3	-0.42295	2.44724	375890	1.78	920.4	0.910	6.238	5.739	0.498	9%	410390
B1	49.3	49.3	-0.41210	1.99840	379988	3.44	970.2	0.873	5.094	5.207	-0.114	-2%	414488
B2	49.3	49.3	-0.42322	3.40673	375604	2.05	928.5	0.901	8.683	8.219	0.465	6%	410104
B3	49.4	49.4	-0.42737	1.56925	378589	2.96	955.8	0.883	4.000	4.245	-0.245	-6%	413089
B4	49.3	49.3	-0.42243	2.18766	379464	3.37	968.1	0.873	5.576	5.808	-0.032	-1%	413964
B5	49.3	49.4	-0.41972	4.24038	376799	2.10	930.0	0.903	10.808	8.542	2.266	27%	411299
B6	49.4	49.4	-0.42596	2.22151	379456	3.07	959.1	0.881	5.662	5.052	0.610	12%	413956
B7	49.3	49.3	-0.42545	2.80722	379464	3.28	965.4	0.876	7.155	6.107	1.048	17%	413964
B8	49.4	49.5	-0.40801	3.31857	376956	2.46	940.8	0.893	8.459	7.177	1.282	18%	411456
B9	49.3	49.4	-0.42804	2.85356	380174	3.18	962.4	0.880	7.273	6.364	0.909	14%	414674
C1	49.7	49.7	-0.43730	2.07432	378239	2.75	949.5	0.888	5.287	5.248	0.039	1%	412739
C2	49.5	49.6	-0.42548	1.26555	378359	2.84	952.2	0.885	3.226	3.976	-0.750	-19%	412859
C3	49.5	49.6	-0.43087	1.91599	377903	2.44	940.2	0.896	4.884	5.528	-0.645	-12%	412403
C4	49.7	49.7	-0.43520	2.56867	379389	3.01	957.3	0.883	6.547	5.215	1.332	26%	413889
C5	49.6	49.5	-0.41174	1.74719	378230	2.66	946.8	0.890	4.453	4.604	-0.150	-3%	412730
C6	49.7	49.6	-0.43199	1.82447	379819	3.16	961.8	0.880	4.650	5.099	-0.448	-9%	414319
C7	49.7	49.7	-0.43158	2.18930	379317	3.08	959.4	0.881	5.580	4.890	0.690	14%	413817
C8	49.5	49.6	-0.41553	2.95535	378230	2.58	943.8	0.893	7.533	7.231	0.302	4%	412730
C9	49.3	49.4	-0.42495	2.21816	378526	2.00	927.0	0.905	5.654	5.815	-0.162	-3%	411026
												0%	
BR-A0	50.6	50.7	-0.46070	2.36224	420024	3.59	974.7	0.960	6.021	7.080	-1.059	-15%	434024
BR-A1	50.7	51	-0.46538	3.20052	420495	3.58	974.4	0.961	8.158	11.021	-2.863	-26%	434495
BR-A4	51	51	-0.45755	3.31717	419743	3.52	972.6	0.962	8.455	11.453	-2.998	-26%	433743
BR-B0	49.7	49.8	-0.43972	3.22800	411350	0.49	881.7	1.039	8.228	9.599	-1.372	-14%	425350
BR-B2	49.8	49.9	-0.43896	4.30059	411667	0.56	883.8	1.038	10.962	11.668	-0.707	-6%	425667
BR-C0	49.9	49.9	-0.44212	3.42082	412236	0.64	886.2	1.036	8.719	9.697	-0.978	-10%	426236
BR-C0#2	49.9	50	-0.44525	3.22045	411964	0.75	889.5	1.032	8.209	9.084	-0.875	-10%	425964
BR-C3	50	50.1	-0.43681	4.01020	411519	0.87	893.1	1.027	10.222	8.734	1.487	17%	425519
BR-C6	50.1	50.3	-0.44552	4.61373	411800	1.01	897.3	1.023	11.760	10.285	1.475	14%	425800
												-76%	
bulk#1					416500	2.28	935.4	0.992		14000			1-1 flow correction factor (gpm)
bulk#2bkwtr					417856	2.57	944.1	0.986		34500			1-2 flow correction factor (gpm)
A7 test1 not used				slope 1.27E-04									

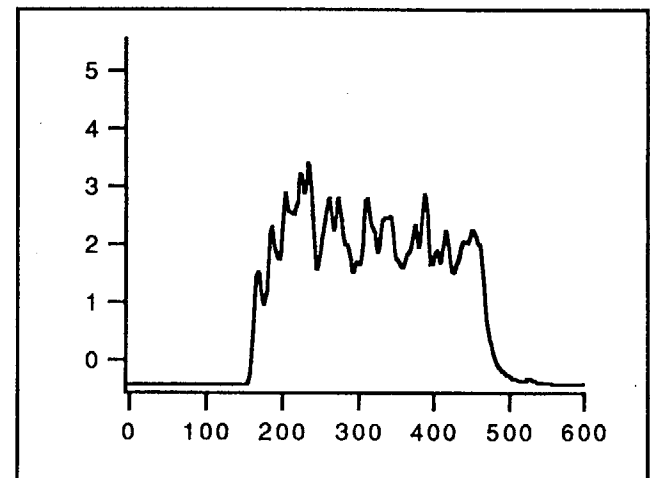
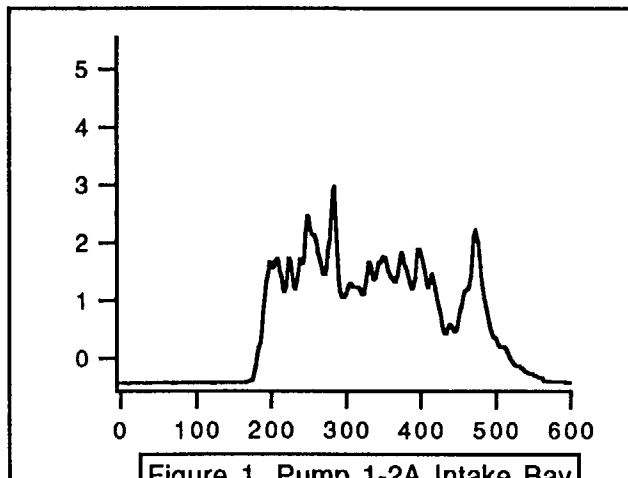
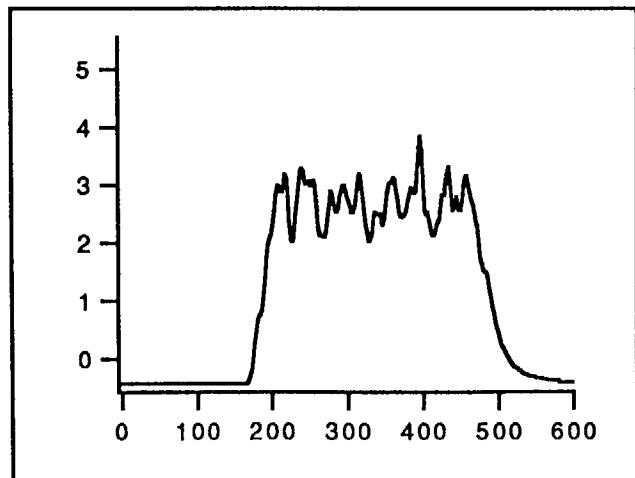
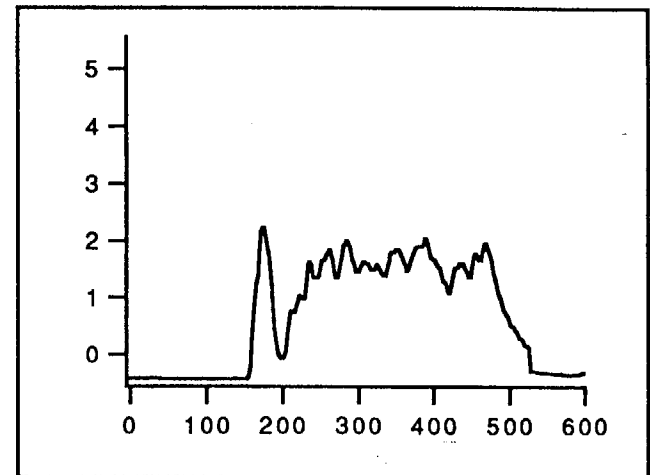
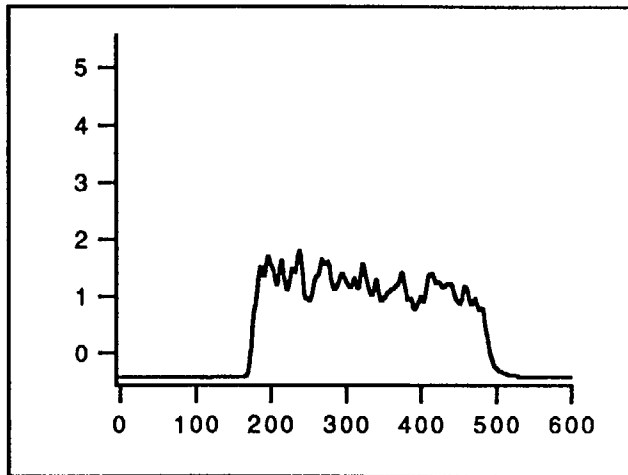
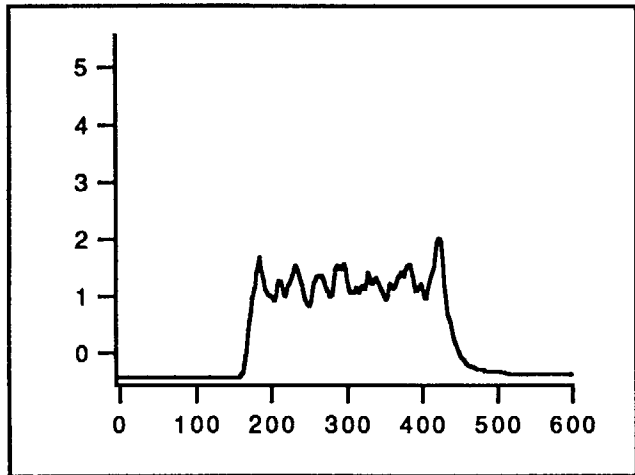
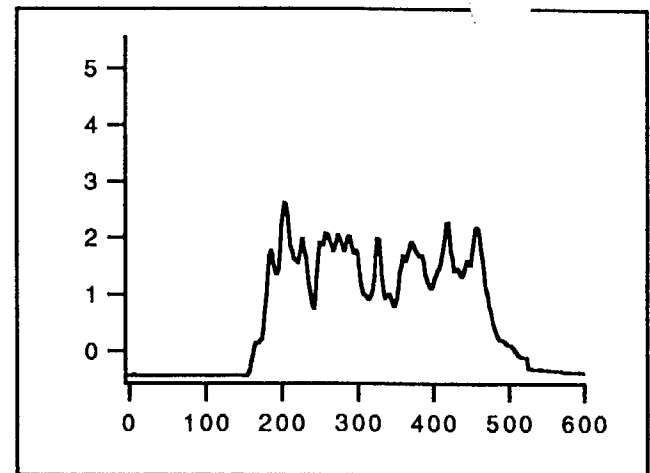
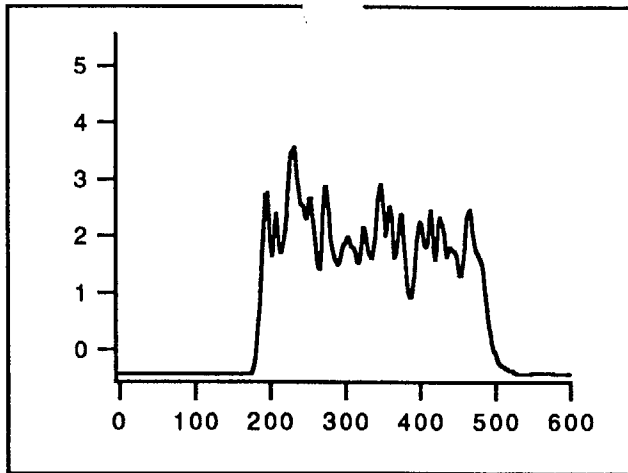
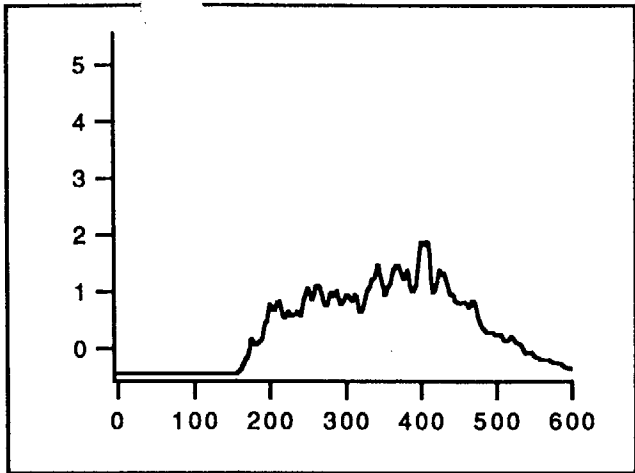


Figure 1. Pump 1-2A Intake Bay

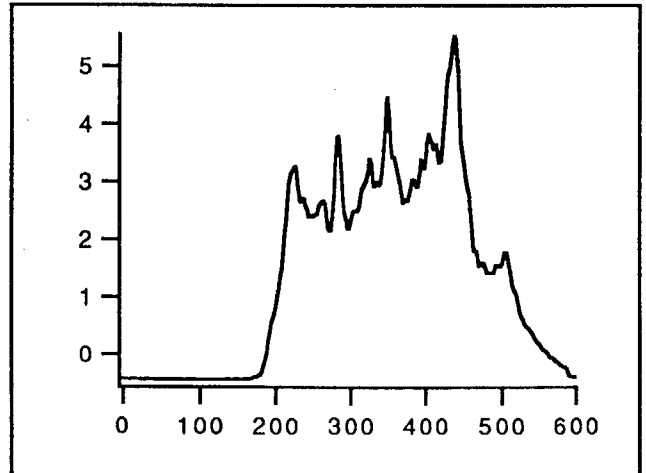
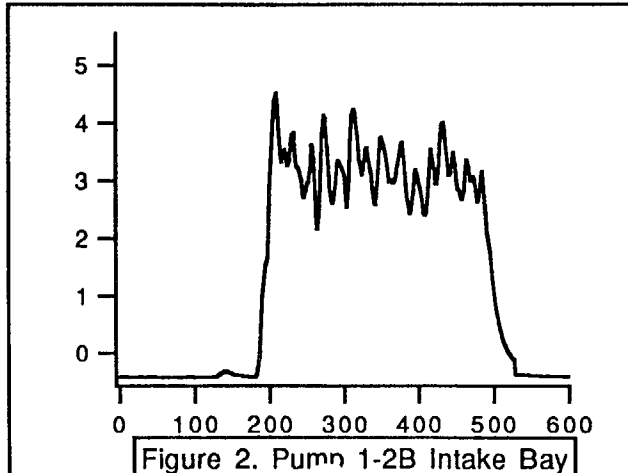
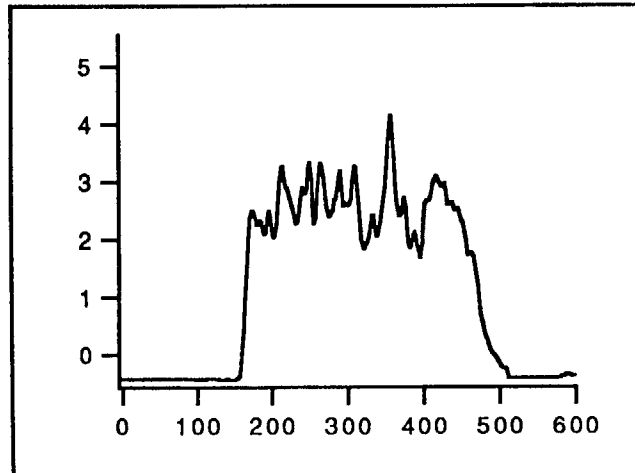
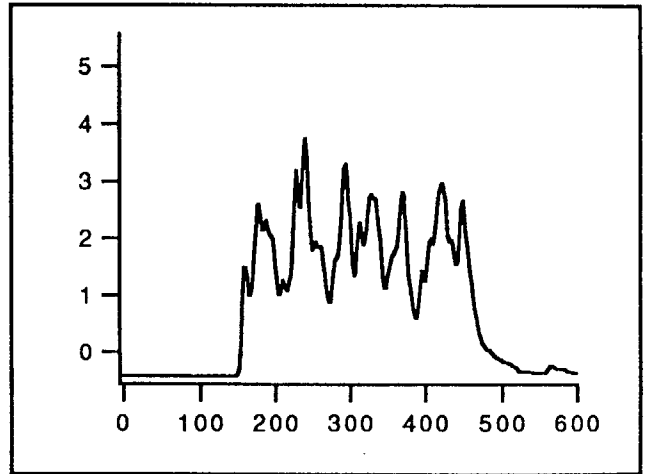
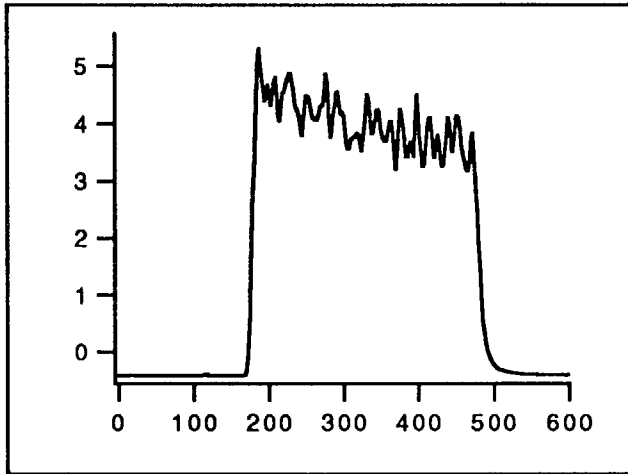
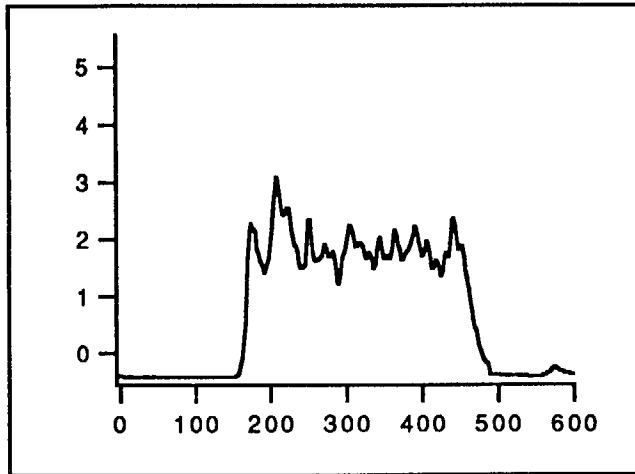
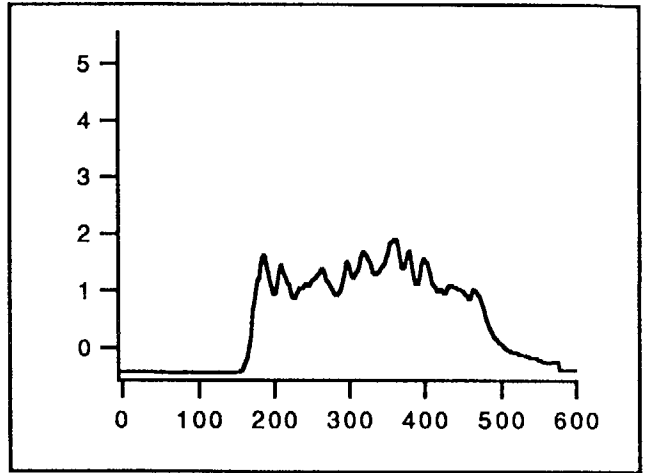
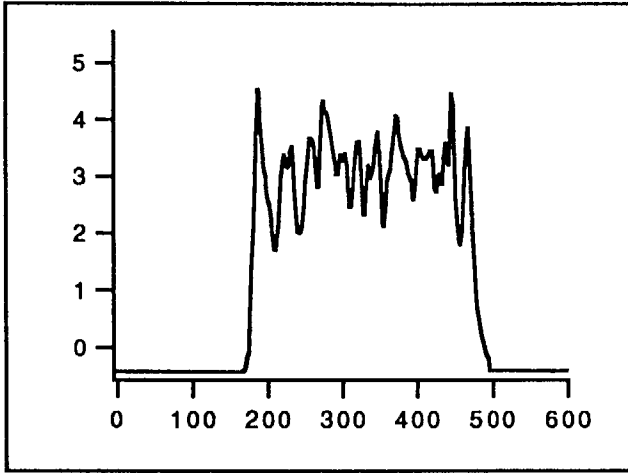
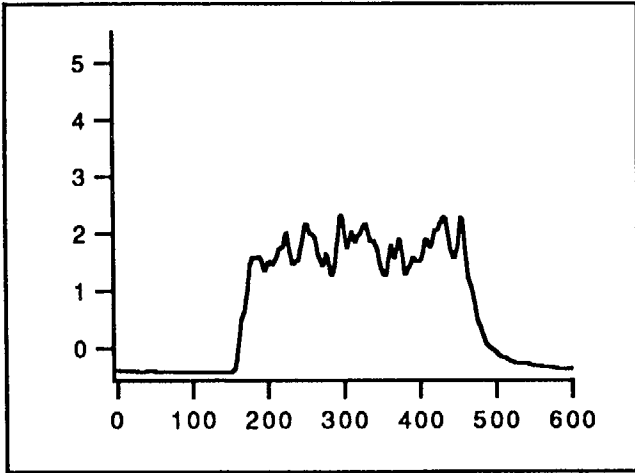


Figure 2. Pump 1-2B Intake Bay

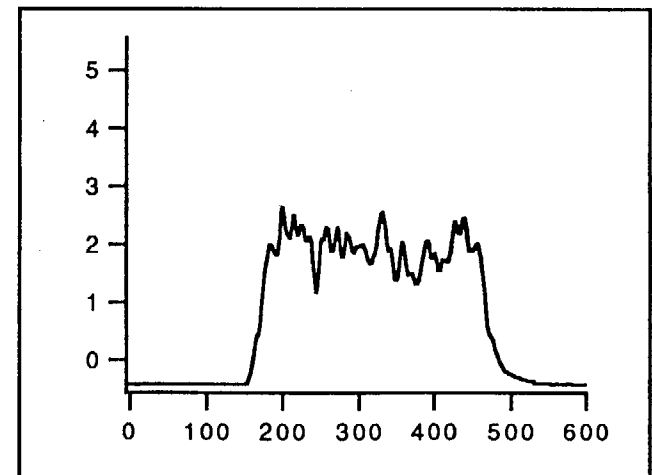
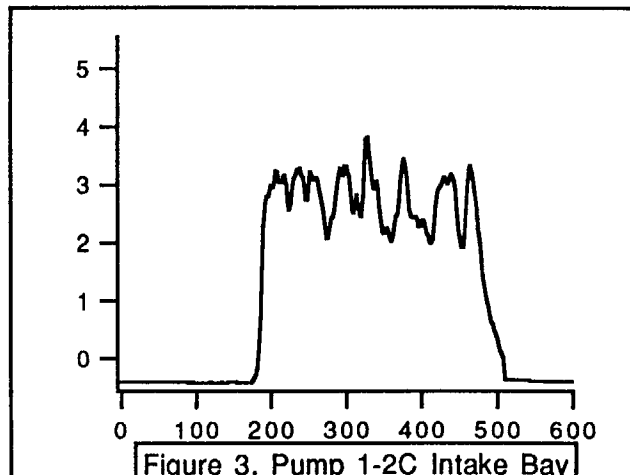
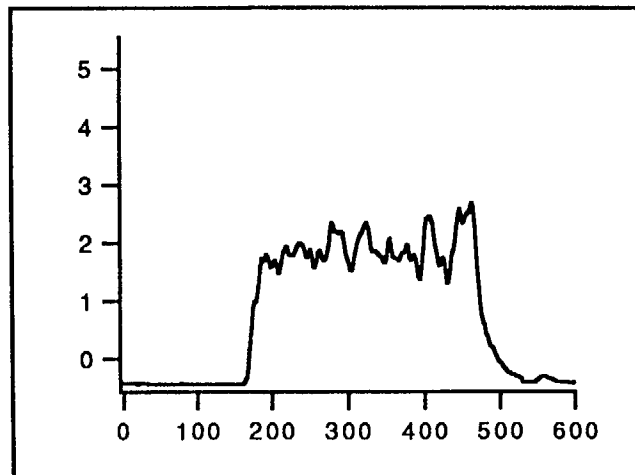
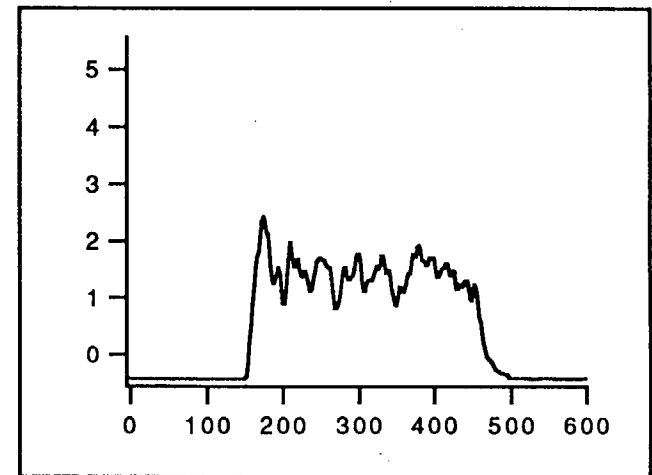
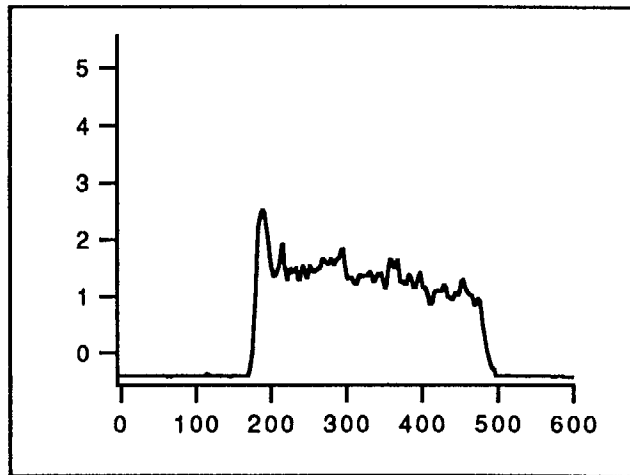
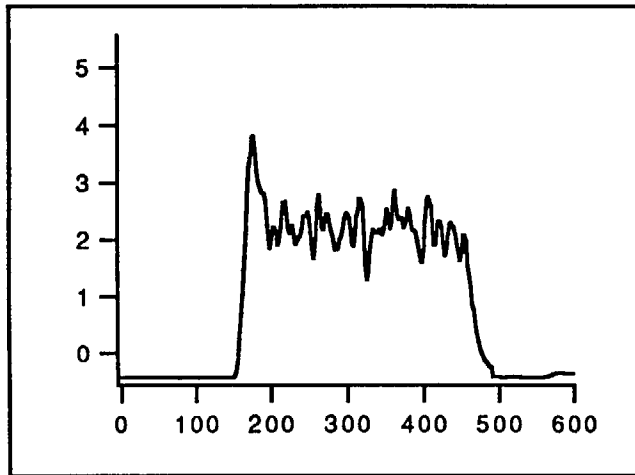
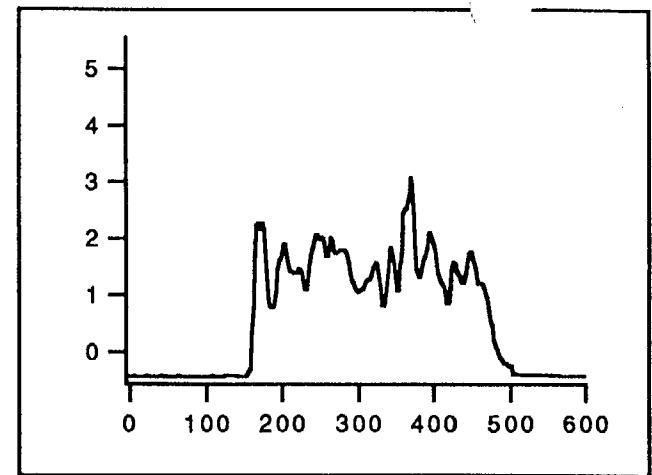
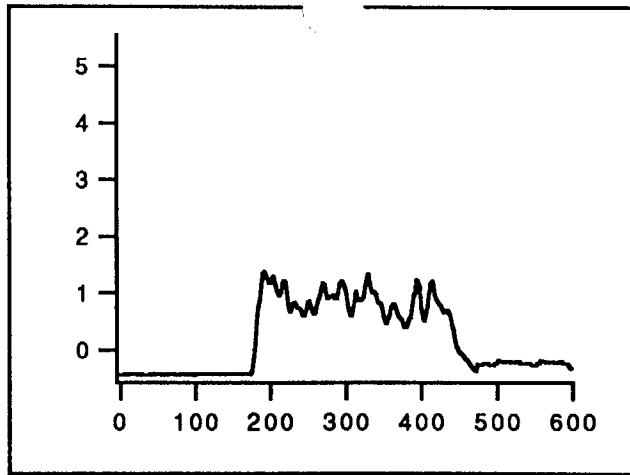
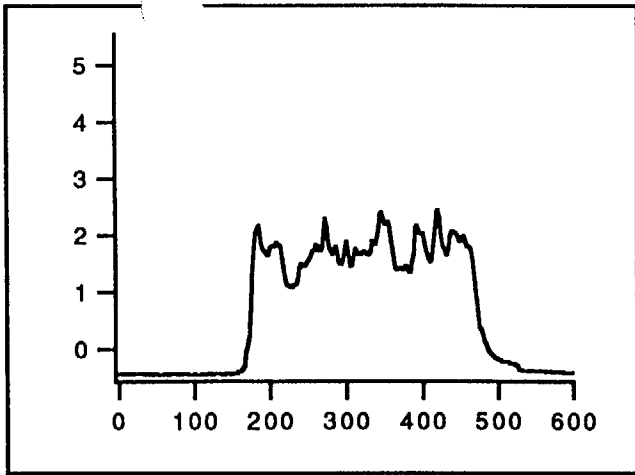


Figure 3. Pump 1-2C Intake Bay

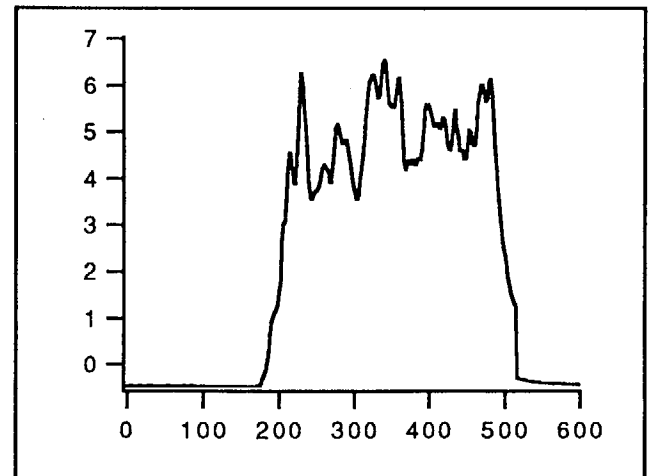
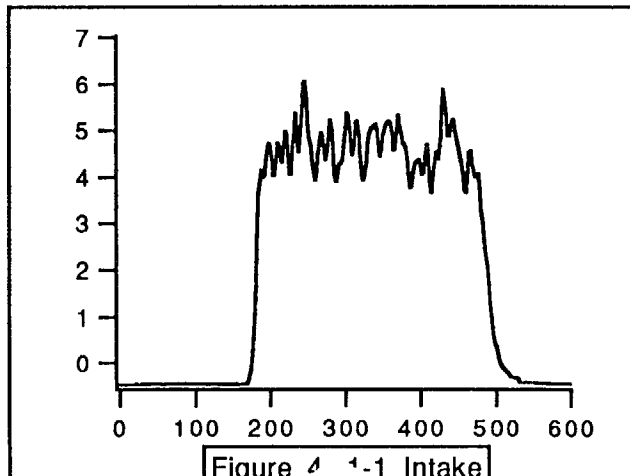
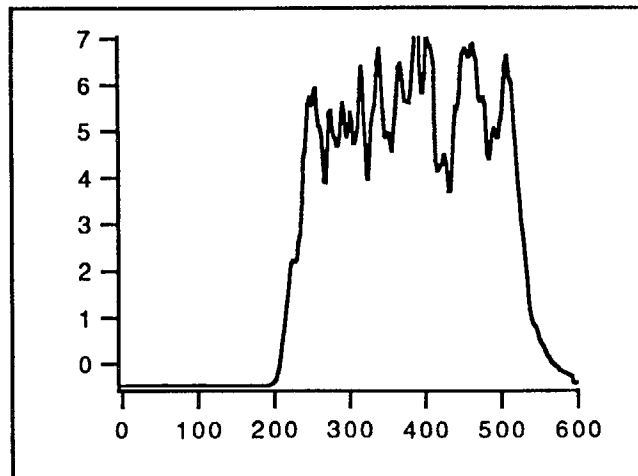
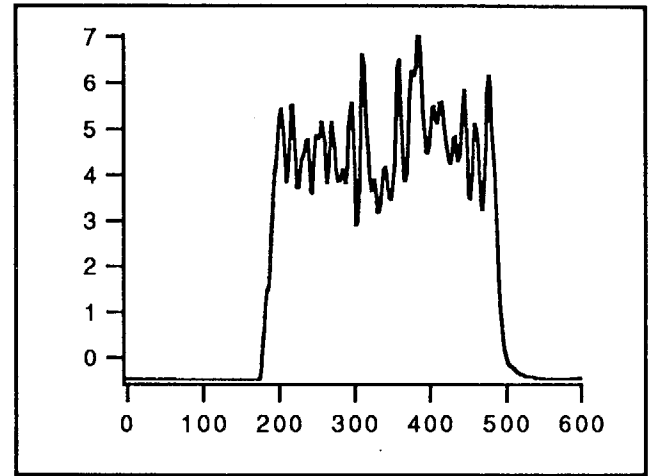
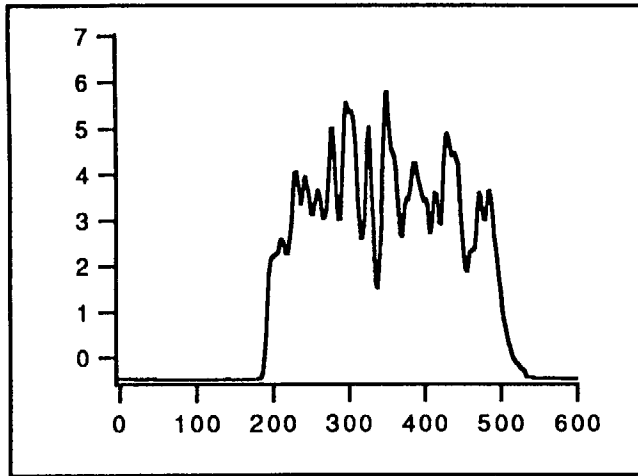
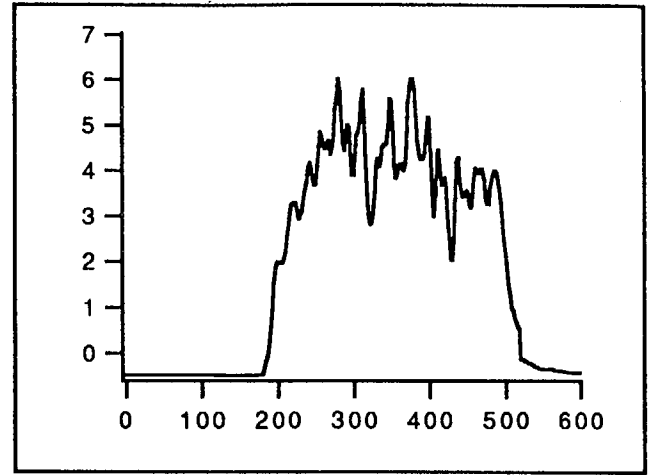
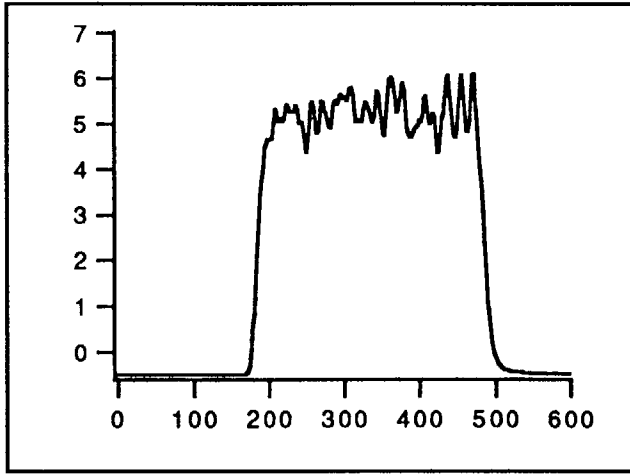
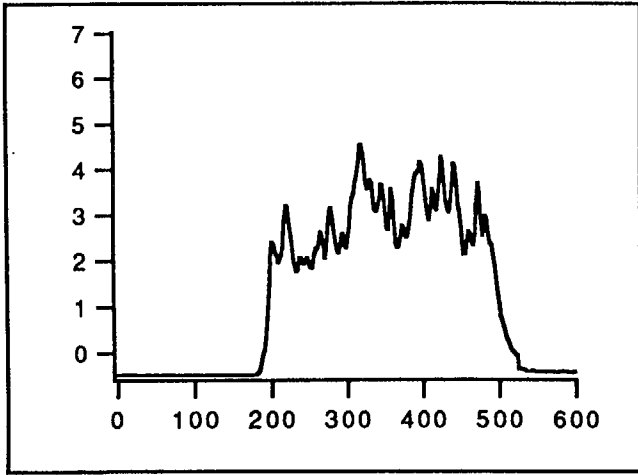


Figure 4 1-1 Intake

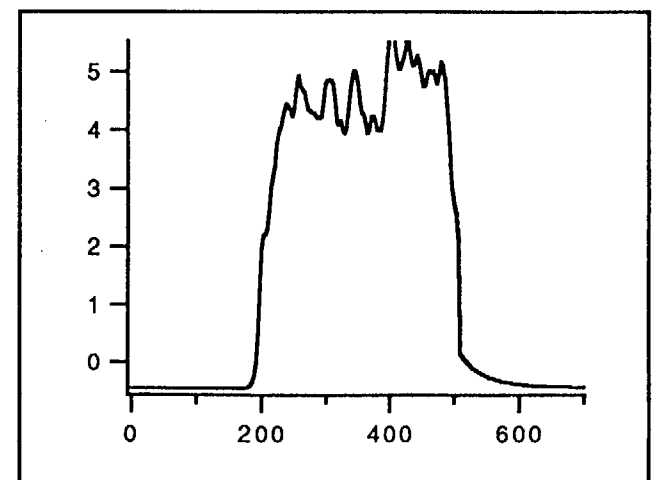
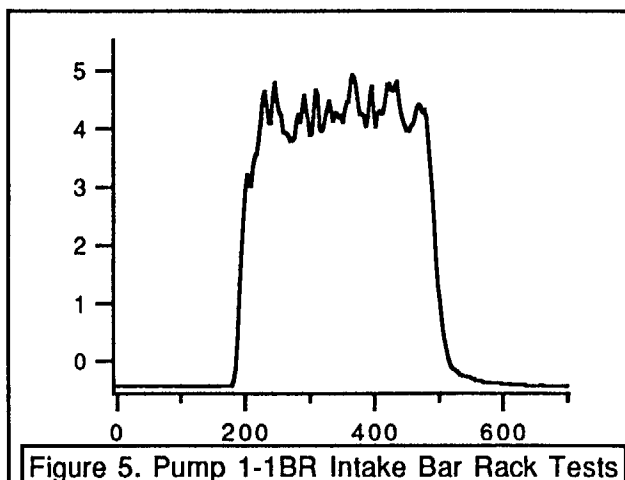
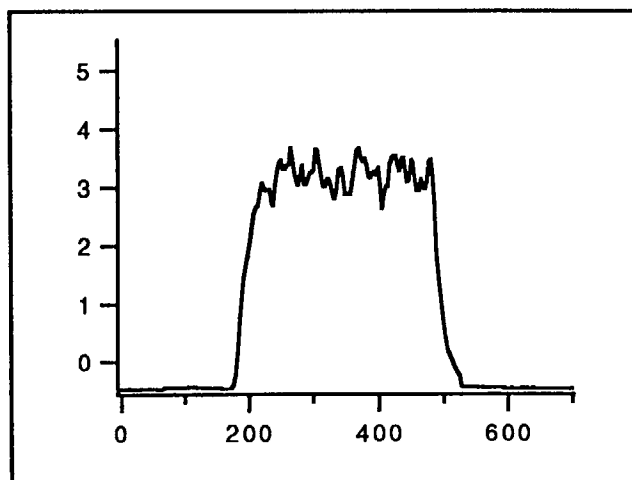
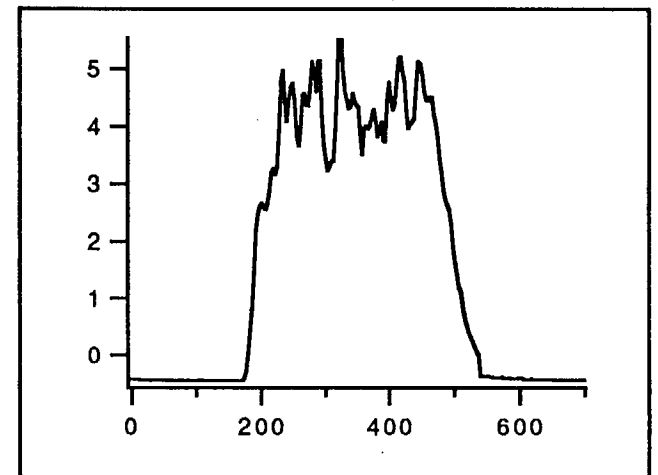
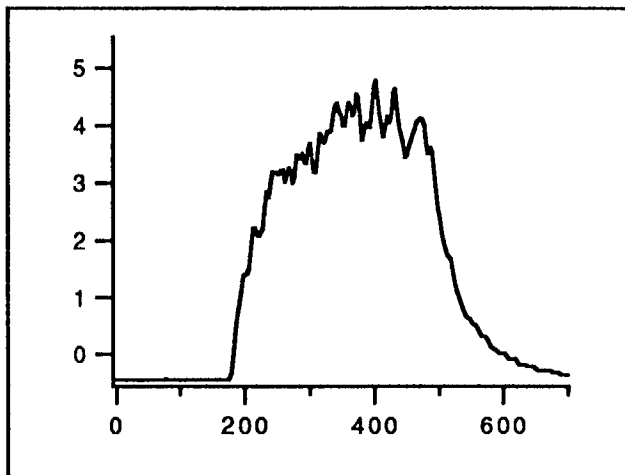
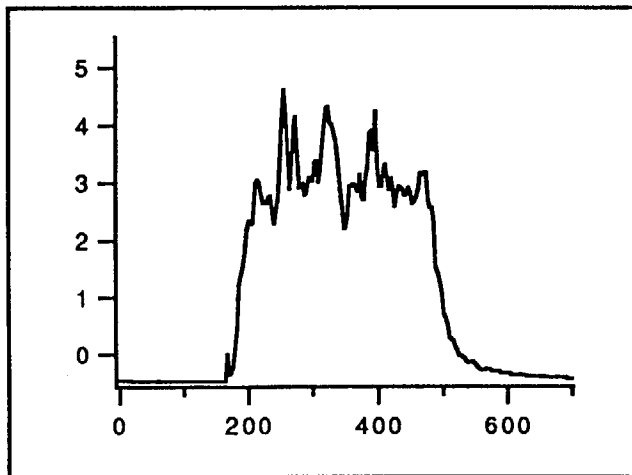
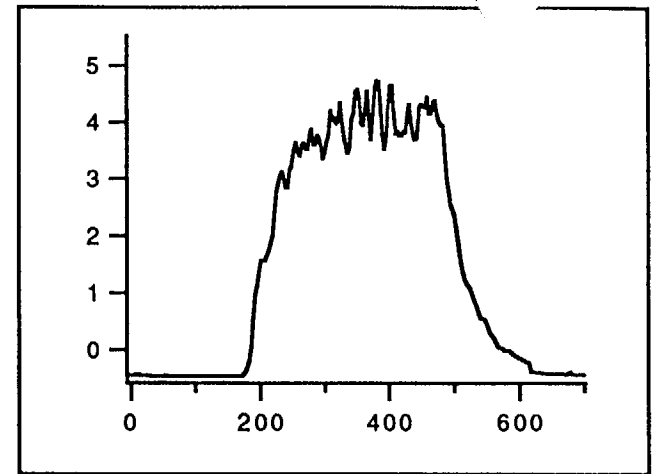
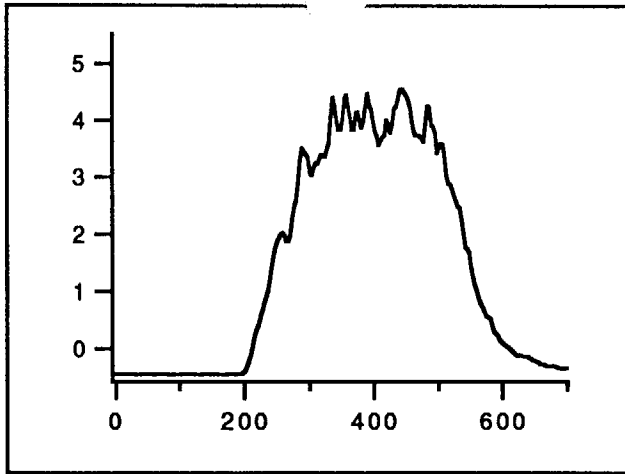
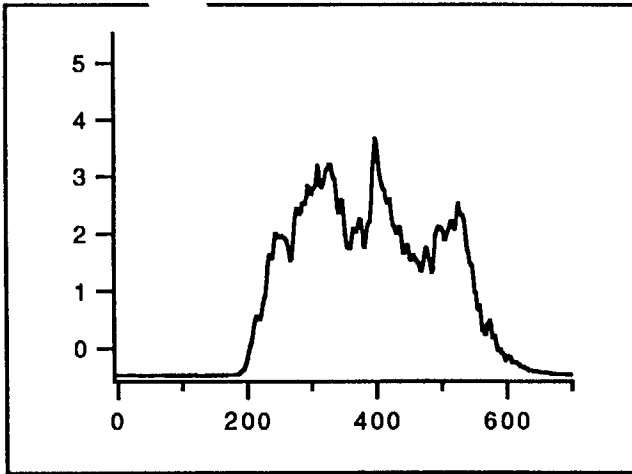


Figure 5. Pump 1-1BR Intake Bar Rack Tests

Time of Travel:

The original time of travel data as summarized in Table 2 is somewhat confusing. Table 3 uses a variety of flow data as well as pipe and hose sizes and lengths to account for the changes in test configurations between successive days. By subtracting out the effects of fixed pipe and hose lengths, an estimated time of travel from a normalized release point may be obtained. These data are summarized in Table 4. Generally, on the 1-2 pump, faster times of travel are associated with proximity to the concrete walls and slower times are shown in the centerline areas of all three bays. However, there is no allowance for removing the effects of velocity caused by tidal variation. By dividing the distance from the dye release point to the centerline of the pump impeller (65 feet or 85 feet for the BR tests) by the estimated time of travel it is possible to project a velocity in feet per second. These data are shown in Table 5. By subtracting expected velocities derived from flow information and cross-sectional area computations based on tidal height, velocity deviations independent of tidal status may be obtained. Summarized in Table 6, these data generally show faster flows (positive values) associated with mid-water depths and centerline areas. It must be realized however, that the variability in these deviations for the entire 1-2 pump intake total only 4.4 inches/second from the highest to the lowest.

Dye Residence Times - Fluorometer Readings:

Figures 1 to 5 display the fluorometer readings obtained during each test sequence and are plotted with the time in seconds since the start of the injection. All graphs represent a ten minute (600 second) record except at the bar rack BR tests where a 650 second display was used. To be consistent, all timing intervals were defined by the transition through the 0.0 reading on the fluorometer. Figures 1 to 3 display 9 individual tests using the layout where test position 1 is at the upper left and test position 9 is at the lower right of the page. In Figure 4 the layout is compressed horizontally with the 1-1A1 test position at the upper left and test position 1-1C9 at the lower right of the page. Figure 5 is similar to the previous layout but is shifted vertically with the 1-1BR-A0 test position at the upper left and test position 1-1BR-C6 at the lower right of the page. Also in this Figure, the replicate test 1-1BR-C0#2 occupies the center graph position.

In these graphs, the shapes of the curves are all fairly similar, showing a strong and well defined response to dye injection. The dye is readily visible at all sites and does not show any dropouts where the dye injection is not visible. Within the tests some choppiness is visible which is characteristic of the rotation of the pump impeller chopping the dye stream into discrete segments containing varying quantities of dye. As the dye plume passes further down the conduit, this choppiness would disappear and would be reflected by a stable flat topped dye peak. However, we are sampling this water before it is fully mixed and must assess the data as it stands.

The subtle shape differences between the dye curves illustrate patterns of swirling and turbulence between each injection location. If we contrast the 1-2A1 location on Figure 1 with the 1-2B5 location on Figure 2, we see that the 1-2A1 location exhibits a weak and ill defined rise, no central plateau, and a gradual shallow tailing off at the end of the test. This comparison reflects a turbulence or eddy associated with this location entraining the dye and both diluting the dye and stretching out the duration of the time that the dye was measured. Rather than examine and subjectively compare every injection graph, the duration of dye measurement provides a ready and quantitative alternative.

Since all tests were a standardized injection time of 300 seconds, these data are all intercomparable and may be interpreted as the degree of eddy and swirling associated with the injection site causing the dye to linger. Extracts of these data are summarized in Table 7 (duration of dye measurement). By subtracting the minimum duration of measurement from

Table 2. time of travel

place	time of travel from dye injection to dye measurement (seconds)		A			B			C	
1-1A1	191	191				175				187
1-1A4	191	191								178
1-1A7	207	207				177				186
1-1B2	175									
1-1B8	177									
1-1C3	187									
1-1C6	178									
1-1C9	186									
A1	174	174	183	163	162	178	169	169	181	159
A2	183	166	174	160	163	174	155	159	175	157
A3	163	174	182	161	161	185	187	171	184	163
A4	166									
A5	174									
A6	160									
A7	174									
A8	182									
A9	161									
B1	162									
B2	178									
B3	169									
B4	163									
B5	174									
B6	155									
B7	161									
B8	185									
B9	187									
C1	169									
C2	181									
C3	159									
C4	159									
C5	175									
C6	157									
C7	171									
C8	184									
C9	163									
BR-A0	204		204			212			186	
BR-A1	176	176				188			185	
BR-A4	182	182								181
BR-B0	212									194
BR-B2	188									
BR-CO	185									
BR-CO#2	186									
BR-C3	181									
BR-C6	194									

Table 3. time of travel calculations

place	time of travel from dye injection to dye measurement (seconds)	cross-sectional water velocity (fps)	pump flow (gpm)	time of travel from pump impeller to intake header opening (seconds)	time of travel through 10" pipe to 4" sample line (seconds)	time of travel through 4" pipe to fluorometer (seconds)	offset distance caused by lean of bar racks (feet)	increase in travel time caused by lean of bar racks (seconds)	time of travel through 25' of 0.5" hose (seconds)	time of travel through 20' of 0.5" hose (seconds)	time of travel through 75' of 0.75" hose (seconds)	time of travel through various injection wands (seconds)	sum of time of travel through fixed pipe and hose systems (seconds)	estimated time of travel from normalized dye release point to pump impeller (seconds)	projected velocities from normalized dye release point to pump impeller using fixed 65 foot distance (fps)	deviations from cross-sectional water velocities (fps)
1-1A1	191	1.033	410434	1.67	7.76	19.36	0	0.00	6.95	5.56	46.94	12.87	101.11	90	0.723	-0.3094
1-1A4	191	1.037	410434	1.67	7.76	19.36	2.7	2.60	6.95	5.56	46.94	12.87	103.72	87	0.745	-0.2926
1-1A7	207	1.043	411248	1.67	7.76	19.36	5.4	5.18	6.95	5.56	46.94	12.87	106.29	101	0.645	-0.3982
1-1B2	175	1.027	410478	1.67	7.76	19.36	0	0.00	6.95	5.56	46.94	12.87	101.11	74	0.879	-0.1481
1-1B8	177	1.025	411914	1.66	7.76	19.36	5.4	5.27	6.95	5.56	46.94	12.87	106.38	71	0.920	-0.1053
1-1C3	187	1.021	412510	1.66	7.76	19.36	0	0.00	6.95	5.56	46.94	12.87	101.11	86	0.757	-0.2638
1-1C6	178	1.016	413251	1.66	7.76	19.36	2.7	2.66	6.95	5.56	46.94	12.87	103.76	74	0.876	-0.1406
1-1C9	186	0.996	412613	1.66	7.76	19.36	5.4	5.42	6.95	5.56	46.94	12.87	106.53	80	0.818	-0.1780
								2.2 flow rate (gpm)								
A1	174	0.877	380412	1.80	7.76	19.36	0	0.00	0.00	5.56	46.94	12.87	94.29	80	0.816	-0.0616
A2	183	0.905	374719	1.83	7.76	19.36	0	0.00	6.95	5.56	46.94	12.87	101.27	82	0.798	-0.1096
A3	163	0.873	380882	1.80	7.76	19.36	0	0.00	0.00	5.56	46.94	12.87	94.29	69	0.946	0.0731
A4	166	0.875	380633	1.80	7.76	19.36	2.7	3.09	0.00	5.56	46.94	12.87	97.36	69	0.947	0.0717
A5	174	0.911	374271	1.83	7.76	19.36	2.7	2.96	6.95	5.56	46.94	12.87	104.24	70	0.931	0.0206
A6	160	0.873	381319	1.80	7.76	19.36	2.7	3.09	0.00	5.56	46.94	12.87	97.36	63	1.038	0.1653
A7	174	0.916	375543	1.82	7.76	19.36	5.4	5.90	0.00	5.56	46.94	12.87	100.21	74	0.880	-0.0355
A8	182	0.915	373365	1.84	7.76	19.36	5.4	5.90	6.95	5.56	46.94	12.87	107.18	75	0.869	-0.0456
A9	161	0.910	375890	1.82	7.76	19.36	5.4	5.93	0.00	5.56	46.94	12.87	100.25	61	1.070	0.1601
B1	162	0.873	379968	1.80	7.76	19.36	0	0.00	0.00	5.56	46.94	12.87	94.29	68	0.960	0.0875
B2	178	0.901	375604	1.82	7.76	19.36	0	0.00	6.95	5.56	46.94	12.87	101.27	77	0.847	-0.0543
B3	169	0.883	378589	1.81	7.76	19.36	0	0.00	0.00	5.56	46.94	12.87	94.30	75	0.871	-0.0119
B4	163	0.873	379464	1.81	7.76	19.36	2.7	3.09	0.00	5.56	46.94	12.87	97.36	66	0.991	0.1172
B5	174	0.903	376799	1.82	7.76	19.36	2.7	2.99	6.95	5.56	46.94	12.87	104.25	70	0.932	0.0291
B6	155	0.881	379456	1.81	7.76	19.36	2.7	3.06	0.00	5.56	46.94	12.87	97.36	58	1.127	0.2456
B7	161	0.876	379464	1.81	7.76	19.36	5.4	6.17	0.00	5.56	46.94	12.87	100.46	61	1.074	0.1881
B8	185	0.893	376956	1.82	7.76	19.36	5.4	6.05	6.95	5.56	46.94	12.87	107.31	78	0.837	-0.0562
B9	187	0.880	380174	1.80	7.76	19.36	5.4	6.14	0.00	5.56	46.94	12.87	100.43	87	0.751	-0.1291
C1	169	0.888	378239	1.81	7.76	19.36	0	0.00	0.00	5.56	46.94	12.87	94.30	75	0.871	-0.0169
C2	181	0.885	378359	1.81	7.76	19.36	0	0.00	6.95	5.56	46.94	12.87	101.26	80	0.816	-0.0698
C3	159	0.896	377903	1.81	7.76	19.36	0	0.00	0.00	5.56	46.94	12.87	94.30	65	1.005	0.1091
C4	159	0.883	379389	1.81	7.76	19.36	2.7	3.06	0.00	5.56	46.94	12.87	97.35	62	1.054	0.1712
C5	175	0.890	378230	1.81	7.76	19.36	2.7	3.03	6.95	5.56	46.94	12.87	104.29	71	0.919	0.0288
C6	157	0.880	379819	1.80	7.76	19.36	2.7	3.07	0.00	5.56	46.94	12.87	97.36	60	1.090	0.2098
C7	171	0.881	379317	1.81	7.76	19.36	5.4	6.13	0.00	5.56	46.94	12.87	100.43	71	0.920	0.0396
C8	184	0.893	378230	1.81	7.76	19.36	5.4	6.05	6.95	5.56	46.94	12.87	107.30	77	0.847	-0.0458
C9	163	0.905	376526	1.82	7.76	19.36	5.4	5.97	0.00	5.56	46.94	12.87	100.28	63	1.036	0.1309
										5 foot hose used					85 foot distance	
BR-A0	204	0.960	420024	1.63	7.76	19.36	-2.7	-2.81	0.00	1.39	46.94	6.13	80.40	124	0.688	-0.2723
BR-A1	176	0.961	420495	1.63	7.76	19.36	0	0.00	0.00	1.39	46.94	6.13	83.21	93	0.918	-0.0458
BR-A4	182	0.962	419743	1.63	7.76	19.36	2.7	2.81	0.00	1.39	46.94	12.25	92.15	90	0.946	-0.0152
BR-B0	212	1.039	411350	1.67	7.76	19.36	-2.7	-2.60	0.00	1.39	46.94	6.13	80.65	131	0.647	-0.3925
BR-B2	188	1.038	411667	1.66	7.76	19.36	0	0.00	0.00	1.39	46.94	6.13	83.24	105	0.811	-0.2264
BR-C0	185	1.036	412236	1.66	7.76	19.36	-2.7	-2.81	0.00	1.39	46.94	6.13	80.64	104	0.815	-0.2217
BR-COM2	186	1.032	411964	1.66	7.76	19.36	-2.7	-2.82	0.00	1.39	46.94	6.13	80.63	105	0.807	-0.2252
BR-C3	181	1.027	411519	1.67	7.76	19.36	0	0.00	0.00	1.39	46.94	6.13	83.24	98	0.870	-0.1571
BR-C6	194	1.023	411800	1.66	7.76	19.36	2.7	2.64	0.00	1.39	46.94	12.25	92.01	102	0.833	-0.1893

Table 4. time of travel (corrected)

place	estimated time of travel from normalized dye release point to pump impeller (seconds)		A			B				C	
1-1A1	89.88	90				74					86
1-1A4	87.30	87									74
1-1A7	100.74	101				71					80
1-1B2	73.91										
1-1B8	70.66										
1-1C3	85.85										
1-1C6	74.23										
1-1C9	79.51										
A1	79.68	80	82	69	68	77	75	75	80		65
A2	81.69	69	70	63	66	70	58	62	71		60
A3	68.72	74	75	61	61	78	87	71	77		63
A4	68.67										
A5	69.79										
A6	62.62										
A7	73.83										
A8	74.78										
A9	60.74										
B1	67.70										
B2	76.74										
B3	74.66										
B4	65.62										
B5	69.76										
B6	57.67										
B7	60.53										
B8	77.70										
B9	86.55										
C1	74.66										
C2	79.70										
C3	64.70										
C4	61.66										
C5	70.74										
C6	59.65										
C7	70.62										
C8	76.74										
C9	62.75										
BR-A0	123.58		124			131				105	
BR-A1	92.83	93				105				104	
BR-A4	89.82	90									98
BR-B0	131.39										102
BR-B2	104.76										
BR-C0	104.33										
BR-CO#2	105.37										
BR-C3	97.75										
BR-C6	102.02										

Table 5. time of travel (velocities)

place	projected velocities from normalized dye release point to pump impeller using fixed 65 foot distance (fps)			A				B			C	
1-1A1	0.72	0.72						0.88				0.76
1-1A4	0.74	0.74										0.88
1-1A7	0.65	0.65						0.92				0.82
1-1B2	0.88											
1-1B8	0.92											
1-1C3	0.76											
1-1C6	0.88											
1-1C9	0.82											
A1	0.82	0.82	0.80	0.95	0.96	0.85	0.87	0.87	0.82	1.00		
A2	0.80	0.95	0.93	1.04	0.99	0.93	1.13	1.05	0.92	1.09		
A3	0.95	0.88	0.87	1.07	1.07	0.84	0.75	0.92	0.85	1.04		
A4	0.95											
A5	0.93											
A6	1.04											
A7	0.88											
A8	0.87											
A9	1.07											
B1	0.96											
B2	0.85											
B3	0.87											
B4	0.99											
B5	0.93											
B6	1.13											
B7	1.07											
B8	0.84											
B9	0.75											
C1	0.87											
C2	0.82											
C3	1.00											
C4	1.05											
C5	0.92											
C6	1.09											
C7	0.92											
C8	0.85											
C9	1.04											
	85 foot distance										0.81	
BR-A0	0.69		0.69			0.65					0.81	
BR-A1	0.92	0.92				0.81						0.87
BR-A4	0.95	0.95										0.83
BR-B0	0.65											
BR-B2	0.81											
BR-C0	0.81											
BR-CO#2	0.81											
BR-C3	0.87											
BR-C6	0.83											

Table 6. time of travel (vel devs)

place	deviations from cross-sectional water velocities (fps)		A			B			C	
1-1A1	-0.3094	-0.309				-0.148				-0.264
1-1A4	-0.2926	-0.293								-0.141
1-1A7	-0.3982	-0.398				-0.105				-0.178
1-1B2	-0.1481									
1-1B8	-0.1053									
1-1C3	-0.2638									
1-1C6	-0.1406									
1-1C9	-0.1780									
A1	-0.0616	-0.062	-0.110	0.073	0.088	-0.054	-0.012	-0.017	-0.070	0.109
A2	-0.1096	0.072	0.021	0.165	0.117	0.029	0.246	0.171	0.029	0.210
A3	0.0731	-0.036	-0.046	0.160	0.198	-0.056	-0.129	0.040	-0.046	0.131
A4	0.0717									
A5	0.0206									
A6	0.1653									
A7	-0.0355									
A8	-0.0456									
A9	0.1601									
B1	0.0875									
B2	-0.0543									
B3	-0.0119									
B4	0.1172									
B5	0.0291									
B6	0.2456									
B7	0.1981									
B8	-0.0562									
B9	-0.1291									
C1	-0.0169									
C2	-0.0698									
C3	0.1091									
C4	0.1712									
C5	0.0288									
C6	0.2098									
C7	0.0396									
C8	-0.0458									
C9	0.1309									
									-0.225	
BR-A0	-0.2723		-0.272			-0.393			-0.222	
BR-A1	-0.0458	-0.046				-0.226				-0.157
BR-A4	-0.0152	-0.015								-0.189
BR-B0	-0.3925									
BR-B2	-0.2264									
BR-C0	-0.2217									
BR-CO#2	-0.2252									
BR-C3	-0.1571									
BR-C6	-0.1893									

Table 7. duration of dye measurement

place	duration of dye measurement (seconds)	increase in duration of dye measurement (seconds)		A			B			C	
1-1A1	327.97	59.96	60				54				103
1-1A4	325.99	57.97	58								54
1-1A7	359.94	91.93	92				60				122
1-1B2	322.01	54.00									
1-1B8	327.97	59.96									
1-1C3	371.00	102.99									
1-1C6	322.01	54.00									
1-1C9	389.92	121.91									
A1	360.03	92.02	92	46	76	62	44	68	48	0	54
A2	314.06	46.05	14	50	94	46	50	62	49	42	42
A3	343.96	75.95	72	68	52	64	66	106	58	54	54
A4	281.92	13.91									
A5	317.95	49.94									
A6	362.02	94.00									
A7	339.98	71.97									
A8	336.01	68.00									
A9	320.03	52.01									
B1	330.05	62.04									
B2	311.99	43.98									
B3	336.01	68.00									
B4	313.98	45.96									
B5	317.95	49.94									
B6	329.96	61.95									
B7	332.04	64.02									
B8	334.02	66.01									
B9	374.03	106.01									
C1	316.05	48.04									
C2	268.01	0.00									
C3	322.01	54.00									
C4	317.00	48.99									
C5	310.00	41.99									
C6	310.00	41.99									
C7	325.99	57.97									
C8	321.75	53.74									
C9	322.01	54.00									
										149	
BR-A0	526.00	257.99		258			128			122	
BR-A1	341.97	73.96	74				56				167
BR-A4	330.05	62.04	62								102
BR-B0	395.97	127.96									
BR-B2	324.00	55.99									
BR-C0	390.01	122.00									
BR-CO#2	417.05	149.04									
BR-C3	435.02	167.01									
BR-C6	369.96	101.95									
Minimum	268.01										

these data, the increases in time stand out and may be associated with increased water turbulence. Variations in the 1-2 pump data are much lower than in the time of travel, and generally suggest that lower eddy currents (shown as lower times) are shown in the centerlines of all three bays. Some weighting is evident toward the left side (shown in the A4 and B4 positions) possibly due to the strong cross-current exerted by the 1-1 pump.

Looking at the 1-1 pump data, the A4 location is much less variable. This probably reflects smoother flow patterns as the cross-current effects are nonexistent at this location. The C3 and C9 locations show more turbulence, possibly due to the cross-current flow from the 1-2 pump cutout. On the 1-1BR tests, the A0, B0, and C0 locations clearly show eddy effects, however, even in the worst area these effects show only about a four minute residence time.

Dye Concentration Values:

This is an attempt to come up with an estimate of dye concentration values that would evaluate the sampling ability of the intake header relative to the entire intake. Please interpret this as an attempt to create a generalized picture of how the intake header is sampling the intake.

In an ideal situation, the pump would perfectly mix the dye no matter where it was injected into the intake. This would produce a single stable dye concentration over the entire time of injection. Unfortunately, the real world variables of turbulence, swirling, and incomplete mixing intrude on this scenario, making it inevitable that some areas of the intake will be oversampled and some areas will be undersampled.

Using the calibration data shown in Figure 6, it is possible to express the fluorometer data described in Figures 1 to 5 in terms of an observed dye concentration expressed in parts per billion. This was done in Table 1 by obtaining the average fluorometer units seen during the time of dye measurement and subtracting the pre-test fluorometer background to obtain the rise in fluorescence during the test. By multiplying this data by the slope of the calibration curve, observed dye concentrations are obtained and are summarized in Table 8. Although helpful, these data are still subject to some internal variability, for example, the quantities of dye used in the 1-1 pump tests are about double those used in the 1-2 pump tests. By distributing the actual dye weights over the durations of dye measurement and diluting the dye by the measured pump flows plus a calculated fixed offset, an expected dye concentration may be obtained in which the turbulence and tidal effects are included (Table 1). The fixed offset was used to normalize the sum of the percent deviations of the 1-1 and 1-2 pumps to zero. This was done because the pump flow data are based on the theoretical pump curve of July 1969 and flow tests conducted in February 1977. Some wear on the pump impeller is expected in the intervening 19 years and the amount of the offset is only 8 percent of rated flow on the 1-2 pump and 3 percent of rated flow on the 1-1 pump. By subtracting the expected concentration data from the observed concentration data, the relative difference in dye concentration is expressed and is displayed in Table 9. These data are converted to percent deviations and are displayed in Table 10.

In Table 10 the percentages may be used to describe the degree to which the intake header under and over samples areas of the intake. For the 1-2 pump data, drawing a line between positive values and negative values illustrates oversampling of the bottom of the bays and the centerline 1-2B intake bay and undersampling of left and right upper bay corners. A more intuitive picture of the information may be expressed in Table 11 in which we ask: "If we obtain a water sample from the intake header, what percentage of the total sample comes from the different sample locations." This table confirms our earlier assertion that the intake header sampling point is adequate for plankton sampling. The variations in sampling are comparatively minor and given the substantial amounts of turbulence and cross-current

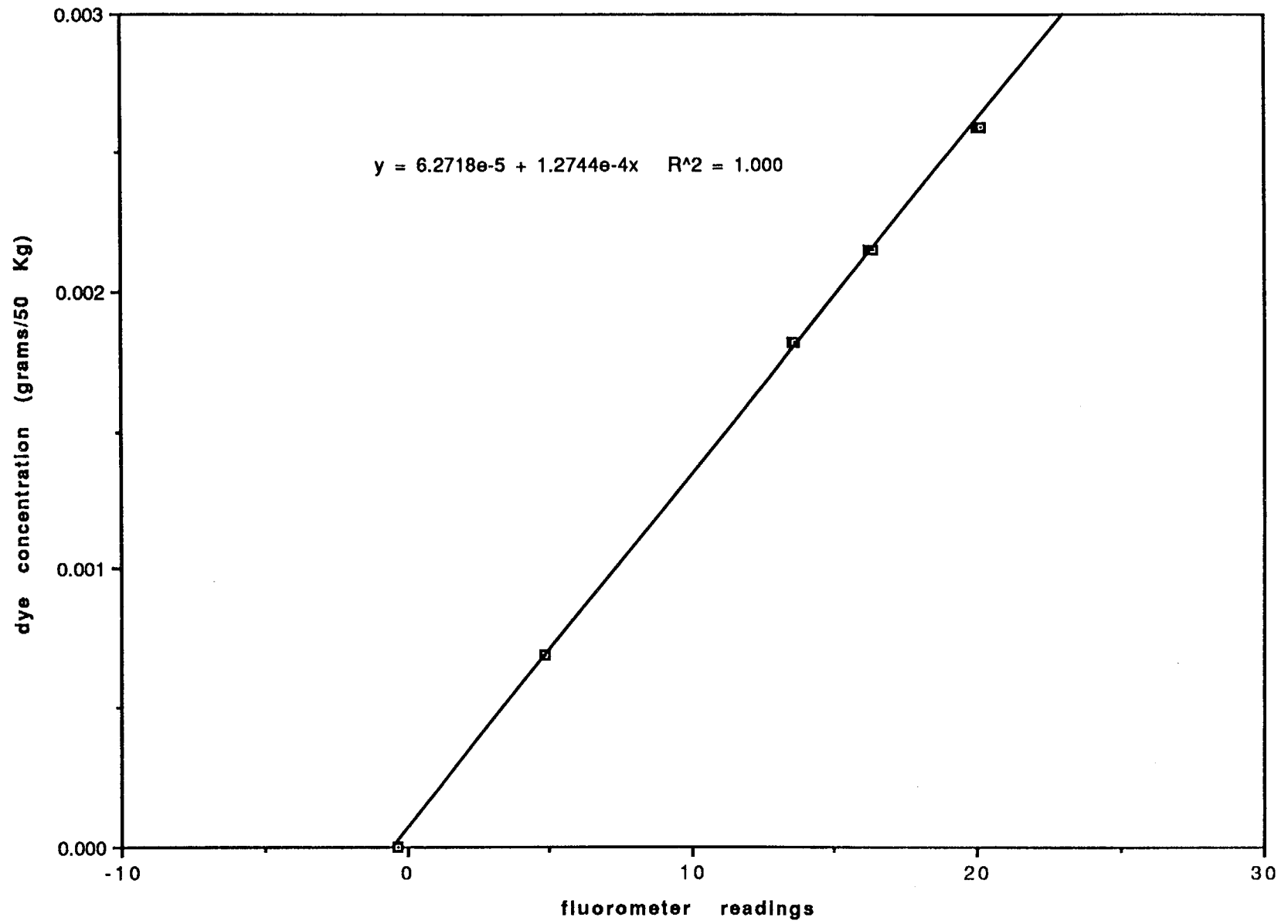


Figure 6. Calibration Data and Equation

Table 8. dye concentration

place	observed dye concentration (µg/Kg) (ppb)		A			B			C	
1-1A1	8.031	8.03				13.56				10.69
1-1A4	9.602	9.60								12.29
1-1A7	12.926	12.93				12.16				12.58
1-1B2	13.555									
1-1B8	12.159									
1-1C3	10.687									
1-1C6	12.288									
1-1C9	12.583									
A1	3.207	3.21	6.01	4.60	5.09	8.68	4.00	5.29	3.23	4.88
A2	6.011	4.09	4.05	4.53	5.58	10.81	5.66	6.55	4.45	4.65
A3	4.596	7.12	4.44	6.24	7.16	8.46	7.27	5.58	7.53	5.65
A4	4.086									
A5	4.047									
A6	4.534									
A7	7.120									
A8	4.444									
A9	6.238									
B1	5.094									
B2	8.683									
B3	4.000									
B4	5.576									
B5	10.808									
B6	5.662									
B7	7.155									
B8	8.459									
B9	7.273									
C1	5.287									
C2	3.226									
C3	4.884									
C4	6.547									
C5	4.453									
C6	4.650									
C7	5.580									
C8	7.533									
C9	5.654									
									8.21	
BR-A0	6.021		6.02			8.23			8.72	
BR-A1	8.158	8.16				10.96				10.22
BR-A4	8.455	8.46								11.76
BR-B0	8.228									
BR-B2	10.962									
BR-C0	8.719									
BR-CO#2	8.209									
BR-C3	10.222									
BR-C6	11.760									

Table 9. dye concentration (obs-exp)

place	obs-exp (µg/Kg) (ppb)		A			B			C	
1-1A1	-3.647	-3.65				1.62				0.31
1-1A4	-2.122	-2.12								0.37
1-1A7	-0.266	-0.27				0.41				2.73
1-1B2	1.617									
1-1B8	0.411									
1-1C3	0.312									
1-1C6	0.369									
1-1C9	2.731									
A1	-1.030	-1.03	-1.47	-0.28	-0.11	0.46	-0.25	0.04	-0.75	-0.64
A2	-1.474	-1.94	-0.34	-0.64	-0.03	2.27	0.61	1.33	-0.15	-0.45
A3	-0.280	0.49	0.08	0.50	1.05	1.28	0.91	0.69	0.30	-0.16
A4	-1.942									
A5	-0.341									
A6	-0.640									
A7	0.491									
A8	0.078									
A9	0.498									
B1	-0.114									
B2	0.465									
B3	-0.245									
B4	-0.032									
B5	2.266									
B6	0.610									
B7	1.048									
B8	1.282									
B9	0.909									
C1	0.039									
C2	-0.750									
C3	-0.645									
C4	1.332									
C5	-0.150									
C6	-0.448									
C7	0.690									
C8	0.302									
C9	-0.162									
									-0.88	
BR-A0	-1.059		-1.06			-1.37			-0.98	
BR-A1	-2.863	-2.86				-0.71				1.49
BR-A4	-2.998	-3.00								1.47
BR-B0	-1.372									
BR-B2	-0.707									
BR-C0	-0.978									
BR-CO#2	-0.875									
BR-C3	1.487									
BR-C6	1.475									

Table 10. dye concentration (% dev)

place	percent deviation from expected dye concentration (%)		A			B			C	
1-1A1	-31%	-31%				14%				3%
1-1A4	-18%	-18%								3%
1-1A7	-2%	-2%				3%				28%
1-1B2	14%									
1-1B8	3%									
1-1C3	3%									
1-1C6	3%									
1-1C9	28%									
A1	-24%	-24%	-20%	-6%	-2%	6%	-6%	1%	-19%	-12%
A2	-20%	-32%	-8%	-12%	-1%	27%	12%	26%	-3%	-9%
A3	-6%	7%	2%	9%	17%	18%	14%	14%	4%	-3%
A4	-32%									
A5	-8%									
A6	-12%									
A7	7%									
A8	2%									
A9	9%									
B1	-2%									
B2	6%									
B3	-6%									
B4	-1%									
B5	27%									
B6	12%									
B7	17%									
B8	18%									
B9	14%									
C1	1%									
C2	-19%									
C3	-12%									
C4	26%									
C5	-3%									
C6	-9%									
C7	14%									
C8	4%									
C9	-3%									
									-10%	
BR-A0	-15%		-15%			-14%			-10%	
BR-A1	-26%	-26%				-6%				17%
BR-A4	-26%	-26%								14%
BR-B0	-14%									
BR-B2	-6%									
BR-C0	-10%									
BR-CO#2	-10%									
BR-C3	17%									
BR-C6	14%									

Table 11. dye percent of total sample

place	percent deviation from expected dye concentration (%)	quantity sampled from 100 units present	percent of total sample from each injection site (%)																
				A				B				C							
1-1A1	-31%	68.77	8.60%	8.60%					14.20%									12.88%	
1-1A4	-18%	81.90	10.24%	10.24%														12.90%	
1-1A7	-2%	97.98	12.26%	12.26%					12.94%									15.97%	
1-1B2	14%	113.54	14.20%																
1-1B8	3%	103.49	12.94%																
1-1C3	3%	103.00	12.88%																
1-1C6	3%	103.10	12.90%																
1-1C9	28%	127.72	15.97%																
	sum	799.506268	100.00%																
A1	-24%	75.69	2.80%	2.80%	2.97%	3.49%	3.62%	3.91%	3.49%	3.73%	3.00%	3.27%							
A2	-20%	80.31	2.97%	2.51%	3.42%	3.25%	3.68%	4.69%	4.15%	4.65%	3.58%	3.38%							
A3	-6%	94.26	3.49%	3.98%	3.77%	4.03%	4.34%	4.37%	4.23%	4.23%	3.86%	3.60%							
A4	-32%	67.78	2.51%																
A5	-8%	92.23	3.42%																
A6	-12%	87.63	3.25%																
A7	7%	107.41	3.98%																
A8	2%	101.79	3.77%																
A9	9%	108.68	4.03%																
B1	-2%	97.82	3.62%																
B2	6%	105.68	3.91%																
B3	-6%	94.23	3.49%																
B4	-1%	99.43	3.68%																
B5	27%	126.53	4.69%																
B6	12%	112.07	4.15%																
B7	17%	117.17	4.34%																
B8	18%	117.86	4.37%																
B9	14%	114.28	4.23%																
C1	1%	100.75	3.73%																
C2	-19%	81.13	3.00%																
C3	-12%	88.34	3.27%																
C4	26%	125.54	4.65%																
C5	-3%	96.73	3.58%																
C6	-9%	91.21	3.38%																
C7	14%	114.11	4.23%																
C8	4%	104.18	3.86%																
C9	-3%	97.22	3.60%																
	sum	2700.04934	100.00%															10.96%	
BR-A0	-15%	85.04	10.32%		10.32%				10.40%									10.91%	
BR-A1	-26%	74.02	8.98%	8.98%					11.40%									14.20%	
BR-A4	-26%	73.83	8.96%	8.96%														13.87%	
BR-B0	-14%	85.71	10.40%																
BR-B2	-6%	93.94	11.40%																
BR-C0	-10%	89.92	10.91%																
BR-C0#2	-10%	90.37	10.96%																
BR-C3	17%	117.03	14.20%																
BR-C6	14%	114.34	13.87%																
	sum	824.196802	100%																

flow directly observed between the bays, that the variability we sampled may be submerged as we move out toward the bar racks and into the area behind the breakwater.

Bulk Dye Release Tests:

On 20 June 1996 at 11:55 a one gallon plastic container containing 1Kg of dye diluted with seawater was ruptured at a location between the two breakwaters and six feet above the bottom. The intention was to watch the dye plume spread out and record the time of travel to the 1-1 pump intakes where the fluorometer was recording data. A few minutes after the dye release a portion of the plume unexpectedly hit the surface approximately 50 feet away from the boat and was observed to travel rapidly toward the 2-2 pump intake. As this was totally unexpected, no precise times were recorded for this test. The visible surface plume reached the 2-2 pump intake in about 15 minutes and was gone by roughly 25 minutes after the release. A portion of the surface plume was observed to be caught in an eddy and to disappear to the Southeast of the intake structure. We recorded data at the 1-1 pump intake for about an hour after the release and saw no dye plume.

A discussion of the preceding test in the afternoon of 20 June 1996 raised a question about the possibility of the North breakwater being porous and water flow entering the 1-1 pump intake through the breakwater. To test this hypothesis, on 21 June 1996 at 12:39 a one gallon plastic container containing 250g of dye diluted with seawater was ruptured at a location adjacent to the 1-1 pump intake outside the North breakwater. The resulting dye plume was observed to spread out along the breakwater mixing with wave action and gradually spread South toward the entrance. After a considerable time period, a gradual rise in dye was observed, consistent with the observation of the plume passing around the breakwater rather than through it.

CONCLUSIONS

Times of travel as expressed by velocity deviations are comparatively minor, representing only about a 4 inch per second range over the entire 1-2 pump intake and less than 5 inches per second at the worst location behind the curtain wall in front of the bar racks.

Dye residence times are useable and demonstrate eddy areas associated with corners and faster free flow areas associated with centerline and mid-depth positions.

Processed dye concentration values demonstrate some preferential selection of the intake but after much processing a sample from the intake header is pretty much representative of the entire intake. I believe the proportions of variability between the sites are low enough to permit its use as a sampling point.

Comparisons between the 1-1 and 1-2 pumps show similar characteristics with most of the differences explainable by the cross-current flows between the travelling screen bays.

Bar rack (BR) tests showed a high turbulence behind the curtain wall but a rapid water turnover and no indications of any lengthy retention in these areas that would influence plankton escape.

Bottom releases of dye between the breakwater demonstrated a rapid surfacing and highly directional passage to the 2-2 pump. The surfacing of the dye is unexpected as the density differential would tend to keep it along the bottom, and may indicate some considerable vertical turbulence. Horizontal turbulence, in contrast, is extremely restricted and further dye testing may reveal extremely narrow bands or channels of water movement in the areas between the breakwaters and in front of the intakes.

No flow was observed through the "Porous Breakwater". Dye readings were obtained, but only after a lengthy interval consistent with the passage of dye around the breakwater.

RECOMMENDATIONS

The intake header appears to be suitable for use as a water sampling point.

A rapid water movement and turbulence behind the bar racks precludes any major dye buildup in eddies. Eddies are present but the turnover rate is high enough that I do not think that they are a problem.

The Flow dynamics of the inlet cove and the areas between the breakwaters are highly stratified and should be studied further with additional dye releases.

Appendix B

DCPP 316(b) Demonstration Study: Phase 1-
Entrainment Study Design, II. Selection of Target
Organisms, Sampling Methods, and Gear Testing.

Diablo Canyon Power Plant

316(b) Demonstration Study

Phase 1 — Entrainment Study Design

**II. Selection of Target Organisms, Sampling
Methods, and Gear Testing**

Final Draft —December 17, 1997

Prepared for:

Pacific Gas and Electric Company

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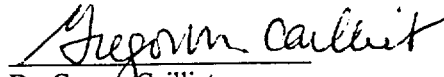
From: RWQCB Multiagency Workgroup
Technical Subgroup for Thermal Effects

RE: Diablo Canyon Power plant 316(B) Demonstration, Phase 1, Part II, Entrainment Study Design-- Selection of Target Organisms, Sampling Methods, and Gear Testing

We, the members of the RWQCB Diablo Canyon 316b Demonstration Technical Work Group, have reviewed and commented on the above-referenced report. Our signatures below signify that our concerns relative to the report have been addressed and the report presents a reasonable scientific approach to the study.



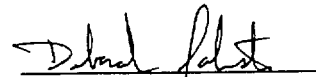
Michael Thomas
Central Coast Regional Water Quality Control Board



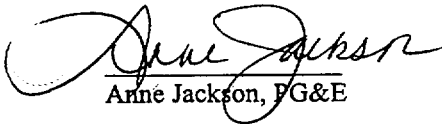
Dr. Gregor Cailliet
Independent Consultant to The Regional Board



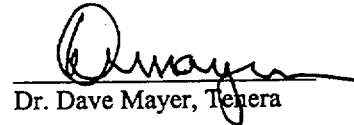
Dr. Pete Raimondi
Independent Consultant to the League for Coastal Protection



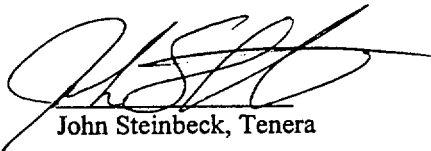
Deborah Johnston
CA Dept. of Fish and Game



Anne Jackson, FG&E



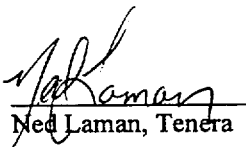
Dr. Dave Mayer, Tenerra



John Steinbeck, Tenerra


EHLE

Chris Ehler, Tenerra



Ned Laman, Tenerra

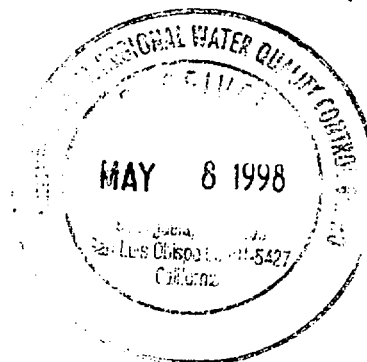


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SUMMARY

The purpose of this report is to document the field methods and testing of gear used in the collection of entrainment samples for larval forms of target organisms at the Diablo Canyon Power Plant (DCPP). We also present ecological information on these larvae related to proposed methods to sample their abundance in the DCPP intake water. The location for entrainment sample collection was described in an earlier report entitled "Phase 1 - Entrainment Study Design, I. Sampling Location" (TENERA 1997). A separate report (Phase 2 - Entrainment Study Plan) will be prepared and will combine the results from Part 1 and Part 2 of the Phase 1 studies and contain the complete overview and details of the field and laboratory procedures for the entrainment sampling.

Targeted groups of organisms for the entrainment study were defined by the DCPP Entrainment Technical Working Group (ETWG) following guidelines established by the Environmental Protection Agency (EPA). These are larval forms of fishes (January 1996), larval *Cancer* spp. crabs (April 1996), and sea urchin larvae (April 1997). A preliminary list of proposed target organisms includes the blue rockfish (*Sebastes mystinus*), cabezon (*Scorpaenichthys marmoratus*), the *Cancer* spp. crab, and red and purple sea urchins (*Strongylocentrotus franciscanus* and *S. purpuratus*). The final list of target organisms will be recommended by the ETWG based on their review of the sampling results.

During initial planning, the DCPP ETWG reached a consensus that larval fishes and *Cancer* crabs could be captured with reasonable efficiency using a 505 μm plankton net. However, during preliminary sampling at DCPP larval fishes were extruded through the 505 μm net mesh; the nets were changed to finer mesh plankton nets (335 μm) for the remaining entrainment sampling. This decision was approved by the DCPP ETWG (January 1997). The ETWG agreed that the 335 μm mesh is fine enough to capture larval fishes, *Cancer* crabs, and recently metamorphosed sea urchin larvae, and that a separate sampling regime could be developed for the smaller abalone larvae. However, upon further literature review and discussions, the ETWG agreed that larval abalone are at low risk of entrainment based on their life history and low abundance of adults in the Diablo region (April & May 1997). A comment was received as to the possibility of entrainment effecting the population of Pismo clam larvae. The available literature on this species lead the ETWG to determine that Pismo clam larvae are at low risk of entrainment at DCPP and did not need to be studied.

Based on the target organisms listed above the ETWG agreed upon the following larval entrainment sampling methods. Plankton samples are collected using a 1.8 m long, 335 μm white Nitex mesh bongo frame and nets fitted with calibrated flowmeters in each net mouth and employed in vertical/oblique hauls from four moored stations directly in front of the intake structure. The target volume of water filtered is approximately 40-50 m^3 per net (sub-sample). Samples are collected over eight three-hour cycles during one 24-hour period each week.

The entrainment plankton nets are similar to those used in California Cooperative Oceanic Fisheries Investigations (CalCOFI) ichthyoplankton surveys. CalCOFI surveys of the California Current system have been conducted for nearly 50 years at various times of the year (Ohman and Smith 1995) and are well documented and tested methods. The 1.8 m length of the DCPP net,

which is shorter than the 3.3 m California Cooperative Oceanic Fisheries Investigations (CalCOFI) net, was selected to minimize the risk of impinging the net on the intake structure. The shorter net used in the present study has been demonstrated to be an effective sampler of plankton and larval fish abundance based on filtration efficiency.

Several concerns arose during the design phase of this 316(b) Demonstration and were addressed either in discussions with the DCPD ETWG, communications with outside experts (e.g., Paul Smith at Southwest Fisheries Science Center, La Jolla, CA), by direct evaluation, or commonly using combinations of all these approaches. The modifications we made to the basic CalCOFI net configuration for the DCPD entrainment sampler raised questions about the new net's filtration efficiency and ability to consistently yield representative samples. These concerns were resolved using direct evaluation of the new net and through discussions with Paul Smith and the DCPD ETWG. Acceleration fronts or 'bow waves' can form ahead of towed nets as a result of resistance of the mesh to the flow of water through it and may extend sufficiently ahead of the sampler to allow mobile zooplankton to sense the nets' approach and avoid capture. Results from observations of the flow characteristics ahead of the towed bongo net at DCPD indicated that pronounced bow waves were visible only after simulated net clogging exceeded 50%. Tow velocity relates directly to net filtration efficiency and was also discussed when these modifications were made. Tranter and Smith (1968) have shown that filtration efficiency is enhanced below 1 knot of approach velocity; approach velocities for the DCPD entrainment sampler under normal sampling operations are <1 knot. In Part 1 of Phase 1 of the present 316(b) Demonstration (TENERA 1997), sampling locations were selected based upon field evaluation of proposed locations using subtidal *in situ* dye release studies. Recent questions about the possibility of vertical or horizontal stratification at the DCPD intake structure have been addressed both in discussions with the DCPD ETWG and by direct evaluation of field data. Tranter and Smith (1968) stated that an obliquely towed sampler, similar to the tow pattern agreed upon by the DCPD ETWG and used in the present 316(b) Demonstration, will integrate vertical stratification during sampling. Field data collected during entrainment sampling indicated that there was no horizontal stratification of diversity or abundance at the sampling locations in front of the intake structure. The tow pattern used in the present entrainment studies at DCPD is supported in the literature and was agreed upon by the DCPD ETWG following a discussion of the physical constraints of the sampling location and has been used in CalCOFI ichthyoplankton surveys for nearly 50 years (Ohman and Smith 1995). Through discussions with the DCPD ETWG, a target volume of water filtered in each bongo net subsample was agreed upon to increase the sample volume and to maintain comparability with existing long term datasets at DCPD (TENERA unpublished data).

1.0 OVERVIEW OF DCPD ENTRAINMENT SAMPLING

1.1 Introduction and Selection of Target Organisms

The purpose of entrainment sampling for the 316(b) Demonstration studies at DCPD is to obtain estimates of the abundance of target organisms entrained in the power plant's cooling water and to assess the application to the intake structure of "best technology available" (BTA) to minimizing "adverse environmental impacts" (EPA 1977). However, there are several factors which make it difficult to accurately estimate the abundance of entrained organisms. Species composition and abundance of planktonic assemblages entrained vary widely over space and time. Intrinsic to the definition of a point source such as the single intake structure at DCPD is a lack of spatial variation. Subsequently, estimates of entrainment density from the moored stations in front of the DCPD intake structure necessarily lack a spatial component of variation. There are four moored stations sampled in front of the intake structure at DCPD to assess any systematic biases that might exist across the width of the structure. These biases could include systematic differences in species composition and/or abundance of the entrained planktonic organisms and potentially incurrent velocity stratification across the face of the intake. This 316(b) Demonstration study design will evaluate the temporal sources of variation affecting entrained target organisms (e.g., seasonal changes in oceanographic conditions and their influence on abundance estimates of entrained organisms) and will assess differences among the four moored sampling locations.

It is not practical to analyze the impacts on all organisms which may be entrained by cooling water intake operations (EPA 1977). Therefore, only selected target organisms will be analyzed in the present 316(b) Demonstration. Target organisms are those having certain characteristics which make them suitable for detecting or forecasting impacts to an ecosystem under investigation (Cairns and Pratt 1989; Jones and Kaly 1996). The criteria used for selection of appropriate target organisms at DCPD were developed by the Environmental Protection Agency (EPA 1977) for what they termed "representative important species." Discussions with the DCPD Entrainment Technical Working Group (ETWG) and the attendees of the Tiburon Impact Assessment Colloquium helped refine these criteria for a site specific application to DCPD. Target organisms are those which meet the following criteria:

1. representative, in terms of their biological requirements, of a balanced, indigenous community of fish, shellfish and wildlife;
2. commercially or recreationally valuable (e.g., among the top ten species landed -- by dollar value);
3. threatened or endangered;
4. critical to the structure and function of the ecological system (i.e., habitat formers);
5. potentially capable of becoming localized nuisance species;
6. necessary, in the food chain, for the well-being of species determined in 1-4;
7. one of 1-6 and have potential susceptibility to entrapment-impingement and/or entrainment (EPA 1977)."

The DCPD ETWG added an additional three criteria for use in selection of target organisms for the entrainment study at DCPD:

8. identifiable to the species level;
9. entrained in sufficient abundance to allow for impact assessment;
10. source (local adult and larval populations) not sink [larval production not local (e.g., northern anchovy)] species in the DCPD area.

These criteria will be reevaluated by the ETWG during the 316(b) Demonstration study to determine their continued appropriateness and effectiveness in meeting the goals of the study and target organism selections may be adjusted as necessary. Typically, five to fifteen target species satisfying the above criteria are selected on a case-by-case basis in 316(b) Demonstrations (EPA 1977).

Discussions with the ETWG, which concur with established EPA guidelines (1977), have identified the following groups of target organisms for the DCPD 316(b) Demonstration: larval fish species; *Cancer* crab larvae; and sea urchin larvae. In the present 316(b) Demonstration, individual larvae of these groups will be identified to the lowest taxonomic level, enumerated, and included in the final report. Results of earlier studies on larval fishes (Icanberry et al. 1978, TENERA 1988, TENERA unpublished data) combined with the ongoing 1996-97 DCPD entrainment samples have been used to create a preliminary list of target fish taxa (see Appendix A and B). The final list of target organisms used for the DCPD 316(b) Demonstration will be determined by the ETWG based on the above listed criteria and the data collected during the study.

Other potential target organism groups reviewed and rejected by the ETWG include the following: kelp spores; fish eggs; abalone larvae; squid, and recently, Pismo clams. The risk of a significant impact on adult kelp populations by entrainment of kelp spores is negligible due to the large number of spores produced along the coast. Additionally, it is not possible to identify the species of kelp based on gametes or spores. Most of the adult fishes in the DCPD area that the ETWG assumes will be included in the final entrainment evaluation have egg stages which are not likely to be entrained; they either have demersal/adhesive eggs or are internally fertilized and extrude free-swimming larvae. Upon examination of life history traits, abalone larvae are at low risk for entrainment and cannot be effectively sampled or identified during these early life stages when they are susceptible to entrainment (see Section 5.0 in this report for further information). Young squid are also unlikely to be entrained because they are competent swimmers when they hatch.

Recent comments received as part of the public review process suggested that Pismo clam larvae may be entrained at DCPD. California Department of Fish and Game (CDF&G) records (Coe and Fitch 1950; Wendell et al. 1986; Leet et al. 1992) document large populations of Pismo clams, *Tivela stultorum*, on sandy beaches about 20 km (12 miles) north and south of DCPD. Legal (>5 inch SL) and sub-legal size clams are fecund, producing 0.4 to 15 million eggs each year, depending upon the female size (Morris et al. 1980). Eggs range from 70 to 80 μ m in diameter (Morris et al. 1980). Eggs develop as free swimming veliger larvae in approximately 48 hours and settle to the bottom in 60-72 hours post-hatch in laboratory culture. Developing larvae remained attached to sand grains by a byssal thread which degenerates after 22 to 50 days when metamorphosis is complete and the small clams burrow into the sediment (Leet et al. 1992). Pismo clams were plentiful in these areas until 1979 when sea otters (*Enhydra lutris*) repopulated the central California coast and began foraging heavily on *T. stultorum*. Wendell et al. (1986) concluded that sea otters were directly responsible for the end of the Pismo clam sport fishery. Pismo clam populations were further depleted by storms along California beaches in

1982-1983. In 1990, recruitment of young Pismo clams was widespread along southern and central California beaches (San Diego to Pismo Beach; Leet et al. 1992). Based on the available data on larval development and distribution of suitable habitat, it was decided that Pismo clam larvae are at low risk of entrainment at the DCPD intake. In addition, Pismo clam larvae in the vicinity of DCPD would not find suitable substrate locally nor would the duration of their pelagic phase enable them to reach appropriate settling habitat in significant numbers from the Diablo Canyon region (Sandy Owen, CDF&G, Long Beach, CA personal communication).

1.2 Entrainment Sampling Design

The present 316(b) Demonstration study methods and sampling gear used at DCPD are modified from ichthyoplankton survey methodology developed by CalCOFI over the last 50 years (Ohman and Smith 1995). At DCPD we use similar vertical/oblique tow profiles, an identical bongo net frame, but a shorter net of finer mesh. CalCOFI survey techniques are the best documented and field tested sampling methods for ichthyoplankton surveys in the California Current system (see Smith and Richardson 1977). CalCOFI samples were collected from 1949-1978 using a 1.0 m diameter ring-net at which time the sampler was changed to the 0.71 m diameter bridleless paired bongo net because of this net's improved efficiency collecting mobile zooplankton and larval fishes (McGowan and Brown 1966; Ohman and Smith 1995). Net mesh consisted of 550 μm silk until 1969 when the use of 505 μm nylon monofilament mesh was instituted. The use of 335 μm mesh was considered and discarded due to the increased cost associated with longer sorting times for the plankton samples (Ohman and Smith 1995).

High variation in plankton abundance from field samples is typically attributed to the inherently patchy distribution of these organisms. Variation may also arise from biases associated with the sampling methodology (e.g., bridle effect; mesh size; tow speed; volume filtered). The bongo net used by CalCOFI was designed to reduce disturbance created by the towed bridle ahead of the net which could both affect filtration efficiency and warn mobile zooplankton (e.g., larval fishes) of the net's approach (McGowan and Brown 1966) so they might evade capture. As an obliquely towed sampler, it also minimizes the sampling bias known to occur with vertical sampling procedures (McGowan and Brown 1968; Tranter and Smith 1968). For instance, variations in vertical current stratification or distribution of planktonic organisms are integrated by the representative sampling of each sampling stratum (Simpson 1959; Smith et al. 1968). The mesh size currently in use in the DCPD 316(b) Demonstration can effectively collect organisms greater than 335 μm . Greater tow velocities capture more mobile zooplankton and larval fishes, but also increase extrusion without increasing filtration efficiency over 1 knot of approach velocity. On the other hand, lower tow speeds (<1 knot) allow greater escapement and enhance filtration efficiency (Tranter and Smith 1968).

Physical constraints of the sampling location have been accounted for in this 316(b) Demonstration sampling design. The intake structure at DCPD is oriented roughly east-west and is about 80 m long with rock outcroppings present at both ends (Figure 1-1). Sampling locations are shallow, depths range from 6 to 11 m in front of the intake, and the greatest likelihood of sampling water to be entrained is directly in front of this structure. Because of these physical constraints, standard vertical/oblique tows like those used in CalCOFI ichthyoplankton surveys (Smith and Richardson 1977) were modified for the present entrainment sampling operations; hauls are made from moored stations rather than towed by a boat underway. These constraints

were discussed with the DCPD ETWG and also resulted in the selection of fixed sampling stations and reduced net length to avoid entanglement on the intake structure. For further description of the physical sampling location see Phase 1 - Entrainment Study Design, I. Sampling Location (TENERA 1997).

The sampling gear currently employed in the entrainment studies at DCPD is a modified version of the standard bongo net sampler used in CalCOFI studies (Figure 1-2). Both sampling programs use a standard 0.71 m diameter bongo net frame (Ocean Instruments, Inc.) with a calibrated flowmeter mounted in each of the net openings. At DCPD sampling is conducted with a 1.8 m long cone-shaped net made of 335 μm white Nitex™ mesh. Standard CalCOFI bongo nets are 3.3 m cylinder-cone nets which consists of 505 μm black Nitex™ mesh (McGowan and Brown 1966; Smith and Richardson 1977). Smith and Richardson (1977) concluded that black mesh nets were preferable to lighter colored nets to reduce avoidance by visually cued, motile zooplankters. Recent discussions with Paul Smith of the National Oceanic and Atmospheric Administration Southwest Fisheries Science Center (NOAA/SWFSC) have subsequently modified this conclusion to some degree. Despite the reduction in disturbance ahead of the towed bongo sampler resulting from its lack of a bridle, it is likely that planktonic organisms can sense the net's approach from up to 1 m ahead of the net regardless of color (P. Smith, SWFSC, personal communication). During night sampling operations, bioluminescence generated by the net's movement through the water will also warn visually cued, motile zooplankton of its approach independent of net color.

The selection of entrainment sampling gear, methods, and locations involved consideration of the approach velocity of the cooling water entrained. Each of the four main circulating water pumps draws water into forebays located subtidally about 20 m (60 ft) in front of each pump (Figure 1-3). Once water has passed through the bar racks of each forebay, it can move laterally through openings in the septa separating the intake bays. The designed approach velocity at the bar racks was 0.9 feet/second (Wyman 1987). Details of the velocity patterns at the Unit 1 bar racks have been measured with current meters at several positions over a period of several hours (Wyman 1987). Wyman's observations are presently the only available velocity profiles at the DCPD intake structure. Individual velocity measurements in this study were collected at different times and thus the results (Figure 1-3) illustrate a summary of these observations rather than a picture of the conditions at an instant in time. The general pattern of highest velocities in the upper one-third quadrant measured at the bar racks of each forebay are consistent with the projected angle of the main circulator pumps' core suction velocities (Jim Doyle, retired PG&E oceanographer, personal communication). The reduced velocities at the edges and particularly along the bottom area of each forebay are also consistent with expected reductions in velocities due to turbulent flow and to drag along the intake opening's approach surfaces. The profiles noted within centimeters of the bar racks (Figure 1-3) likely do not extend outward to the sampling locations ca. 10 m away. Additionally, small variations in the approach velocity of cooling water to the intake caused by tides, waves, bar rack occlusion, or pump operations are taken into account by the 24-hour time scale of ongoing entrainment sampling.

Collection of the DCPD entrainment samples takes place once per week at four permanently moored sampling stations located in front of the intake structure. The order in which the fixed stations are sampled is randomized for each cycle of each survey. Samples are collected over a 24-hour period from a boat moored approximately 10 m from the intake structure using a 0.71 m diameter standard CalCOFI style bongo frame with 335 μm white Nitex™ mesh nets. The bongo frame and nets are fished from the top to the bottom and back to the surface a total of eight times

to target a volume filtered per net of approximately 50 m³ for each sample. At the surface, the net is turned as the upper portion of the frame hits the surface, and is turned within approximately 13-25 cm of the bottom. The vertical lift speed of the nets is held constant at approximately 0.3 m/s (~0.6 knots). The downward speed of the nets (0.3-0.45 m/s) is determined primarily by gravity acting on the mass of the bongo frame and the drag resistance of the nets. The 24-hour sample period is divided into eight sampling cycles; each station is sampled once per cycle. The sample contents of each net are preserved separately in a 5% buffered formalin solution with seawater except for the first sample of each cycle which is preserved in 70% ETOH. There is a total of 64 sub-samples collected per day with an approximate water volume filtered of 40-50 m³. This totals approximately 2,560-3,200 m³ filtered / 24-hour survey period.

The fact that the net is turned several times at the top and bottom of the water column in the present entrainment sampling method potentially introduces a bias in our estimates of entrainment density. If fine-scale stratification of the target organisms coincides with the benthic or surface interface and is persistent, then sampling may not be representative for two reasons. The first is that these are planar interfaces and only a portion of the round frame passes through these strata, thus under-sampling the interface. Second, the net mouth spends a relatively longer period of time in these areas relative to other strata because of the time it takes to make the turn. The effect of differential sampling of these strata is presently unknown and cannot be determined with the present sampling method.

Abundance of planktonic organisms in entrainment samples varies diurnally due to such factors as vertical migration and daily larval production. Thus, sampling over a 24-hour period accounts for diurnal variations and weekly sampling accounts for temporal variation over a broader scale. Mean abundance and associated variance from the eight cycles within each day will be used to obtain weighted estimates for each weekly sample. These estimates will be combined among surveys to obtain weighted estimates of the seasonal and annual abundance of each entrained taxon.

1.3 Design Justification

Several concerns arose during the design phase of this 316(b) Demonstration and were addressed either in discussions with the DCPD ETWG, communications with outside experts, by direct evaluation, or using combinations of all these approaches. The modifications we made to the basic CalCOFI net configuration for the DCPD entrainment sampler raised questions about the new net's filtration efficiency and ability to consistently yield representative samples. These concerns were resolved using direct evaluation of the new net (presented below) and through discussions with Paul Smith at Southwest Fisheries Science Center, La Jolla, CA and the DCPD ETWG. Tow velocity relates directly to net filtration efficiency and was also discussed when these modifications were made. Tranter and Smith (1968) have shown that filtration efficiency is enhanced below 1 knot of approach velocity; approach velocities for the DCPD entrainment sampler under normal sampling operations are <1 knot. In Part 1 of the Phase 1 report for the present 316(b) Demonstration (TENERA 1997), sampling locations were selected based upon field evaluation of proposed locations using subtidal *in situ* dye release studies. Recent questions about the possibility of vertical or horizontal stratification at the DCPD intake structure have been addressed both in discussions with the DCPD ETWG and by direct evaluation of field data. Tranter and Smith (1968) stated that an obliquely towed sampler, similar to the tow pattern agreed upon by the DCPD ETWG and used in the present 316(b) Demonstration, will integrate

vertical current stratification during sampling. Data from entrainment sampling suggest that neither diversity or abundance of larval fishes are horizontally stratified at the sampling locations directly in front of the intake structure (see below). The oblique tow pattern used in the present entrainment studies at DCPD is supported in the literature and was agreed upon by the DCPD ETWG following a discussion of the physical constraints of the sampling location and has been used in CalCOFI ichthyoplankton surveys for nearly 50 years (Ohman and Smith 1995). A target volume of water filtered in each bongo net subsample was also agreed upon through discussions with the DCPD ETWG as an attempt to increase the sample volume, generate more accurate estimates of water column abundance of target organisms, and to maintain comparability with existing long term datasets at DCPD (TENERA unpublished data).

Alternatives to the present sampling design were considered and discussed with the ETWG. As mentioned above, the physical constraints of the sampling location preclude the use of horizontal net tows. This tow profile would also introduce its own suite of biases and difficulties to estimating entrainment density. The use of fixed pumps was discussed and eliminated as an alternative by the ETWG (TENERA 1997). Ultimately, the present sampling method and net configuration were selected in discussions with the ETWG on the basis of their practicality, proven methodology, and comparability with other plankton survey databases (e.g., CalCOFI).

Filtration Efficiency and Tow Velocity

Three processes which can affect the collection efficiency of bongo net samplers are escapement, extrusion, and avoidance. Escapement occurs when larvae swim out of the net. This is dependent on age and development of the larvae and the net tow velocity. Developmentally advanced, larger larvae are generally better swimmers than younger larvae and are capable of escaping the net. Escapement by competently swimming larvae cannot be avoided without increasing net speed which may increase extrusion of smaller larval forms. Larger larvae are at less of a risk for entrainment because of their swimming ability. Larger, more capably swimming larvae will be under sampled in plankton surveys like the present study where tow velocity is relatively low.

Extrusion occurs when organisms are forced through the net mesh as a result of the normal filtration process. Organisms which do not have hard skeletons (e.g., salps, chaetognaths) or are pliable (e.g., some larval fishes) are uniquely susceptible to extrusion through the net mesh. Lenarz (1972) demonstrated that anchovy and sardine larvae greater than 4.75 mm standard length (SL) were 100% retained in 505 μm nylon mesh nets and larvae greater than 3.75 mm SL were retained better than 60% of the time. Retention rates are assumed to increase with decreasing mesh size. In the present study 335 μm mesh nets are used and probably result in enhanced retention of larval forms relative to 505 μm mesh nets.

During sample collection at DCPD on November 25, 1996, using 505 μm mesh nets, larval fish were seen partially extruded through the net mesh, both in the body of the net and in the codend. The larvae were collected and identified as cabezon which have been discussed as a probable target organism by the DCPD ETWG. These observations prompted a change in sampling gear from 505 μm to 335 μm mesh nets. This change in gear was discussed and approved by the ETWG (January 1997). A pilot study to compare differences in the density of captured larvae between the two net mesh sizes was abandoned when it was deemed prudent to only sample with the 335 μm net and because of the low statistical power associated with the comparison (see Appendix C) and the enhanced retention of larval forms due to smaller mesh size. Extensive

comparison studies with nets of two mesh sizes would be required to conclusively demonstrate differences between them and are beyond the scope of the 316(b) Demonstration.

The third process affecting collection efficiency is the avoidance behavior of motile zooplankton such as larval fishes. Mobile zooplankton and larval fishes can possibly avoid net capture by sensing water disturbance caused by the towing bridle or by sensing a bow wave (acceleration fronts) ahead of the net. The bongo net was designed to minimize avoidance by reducing turbulence caused by towing a bridle ahead of the nets (McGowan and Brown 1968). If the net mesh becomes occluded as with phytoplankton (algae) or numerous jellies (e.g., ctenophores), a bow wave can be established ahead of the sampler (Smith et al. 1968). Bow waves form ahead of towed nets from the resistance of the net to water flow through the mesh (Tranter and Smith 1968). The bow wave will cause water and planktonic organisms to slip around the front edge of the net and avoid capture. Additionally, some mobile larval organisms may sense the bow wave and initiate an escape response in time to avoid capture. Avoidance can affect samples to such a degree that the resulting composition and abundance estimates are no longer representative or reliable. Both practically and theoretically, sampling will become problematic during periods of substantial net clogging and may be discontinued until conditions improve.

The evaluation of gear efficiency undertaken in the present study addresses the issue of net avoidance. The reduction in net length and mesh size of the DCPD bongo net relative to the CalCOFI nets increased the possibility of creating a bow wave ahead of the DCPD bongo net sampler necessitating the need for further study. Escapement was not evaluated in the present study due to the difficulty in gathering meaningful data on the subject and since larvae that can escape the net by swimming out of the mouth are also at low risk for entrainment. Escapement is a life stage-dependent characteristic and will lead to under sampling of later stage larval fishes and other mobile zooplankton. Extrusion of relatively small larvae (greater than 3.75 mm SL) ranged from 40 to 0% as larval length increased using a 505 μm mesh net (Lenarz 1972). The 335 μm mesh plankton nets used in the DCPD entrainment sampling program will further decrease extrusion of the early life stages of fishes due to the finer mesh size.

Initially, field studies were attempted to determine differences in flow rate past and through the bongo net frame with fixed levels of simulated clogging while towing the net. An *ad hoc* cost-benefit analysis of this field effort indicated that the high variation in measured flow volumes and the difficulties in adequately controlling the experiment made continuation impractical. Therefore, it was determined that a mathematical comparison of filtration efficiency was more appropriate. *In situ* subtidal dye studies of the water flow characteristics around the DCPD net at various levels of simulated clogging were also undertaken. These studies will assess when net clogging using normal DCPD sampling procedures will affect the precision and accuracy of field samples.

DCPD Bongo Net Filtration Efficiency

Calculation of the initial filtration efficiency (F_i) of the modified DCPD bongo net sampler follows the methods of Tranter and Smith (1968) and allows for direct comparison with F_i for a standard CalCOFI bongo net. Initial filtration efficiency is defined as the filtering efficiency of an unclogged net (prior to fishing). The principal parameters of filtration efficiency in net samplers are porosity of the net mesh and its surface area in relation to the mouth area. Tranter and Smith (1968) established that filtration efficiency at the start of a tow (F_i) could be approximated by the empirical equation,

$$F_i \approx \frac{1}{1 - (0.01 \cdot K)} \quad (1)$$

where, K , is a function of the porosity of the mesh (β) and Reynold's number (Re) following the equation,

$$K \approx \left(\frac{1 - \beta}{\beta^2} \right) \cdot \left(6 \cdot Re^{\frac{1}{3}} \right) \quad (2)$$

The porosity of the net (β) is determined as,

$$\beta = \frac{m^2}{(d + m)^2} \quad (3)$$

where, m , is the mesh width and, d , is the diameter of the strands of the net. Reynold's number can then be derived from the equation,

$$Re \approx \left(\frac{V}{\beta} \right) \cdot \left(\frac{d}{\nu} \right) \quad (4)$$

where V , is the flow velocity and ν is the kinematic viscosity of water ($\nu \approx 0.01$). Alternatively, F (observed filtration efficiency) may be calculated as the ratio of the volume of water filtered by the sampler to the volume swept by the sampler mouth. That is,

$$F = \frac{w}{A \cdot D} \quad (5)$$

where, w , is the volume filtered as measured by the flowmeter, A is the mouth area of the sampler, and D is the distance towed. Finally, the open area ratio (R) of the sampler is an index of the initial area available for filtration and is calculated as,

$$R = \frac{a \cdot \beta}{A} \quad (6)$$

where, a , is the surface area of the net; β and A are as defined above in equations 3 and 5.

For a standard CalCOFI bongo net prior to towing with an open area ratio (R) of 6.8, the published initial filtration efficiency (F_i) calculated from equation 1 above is 0.96 (Tranter and Smith 1968). Initial filtration efficiency for the DCPD bongo net with 335 μm mesh ($R=3.9$) was determined to be about 1.03; also from equation 1. The slightly higher F_i value for the DCPD net can be accounted for by the slower approach velocity of water to the net in the DCPD entrainment samples (slower net haul speed) when compared with standard CalCOFI towing protocols. Approach velocities for the CalCOFI nets must be inferred from published sampling protocol (Smith and Richardson 1977) and are likely greater than 3 knots at the net mouth. At present, approach velocities to the DCPD net are probably slightly faster than the net haul speed (~ 0.6 knots) due to the horizontal water flow approaching the intake structure.

Additionally, calculation of observed filtration efficiency (F , equation 5) from DCPD field data yielded a range of F -values. Volume filtered (w) was measured by calibrated flowmeters mounted in the center of each net mouth, mouth area was 0.40 m^2 , and distance towed (D) was estimated from tidal depth. These data show that, on average, F for the 335 μm mesh is $81\% \pm$ a standard error of 1% and for the 505 μm is $91\% \pm 1\%$ standard error. It is clear that with an R only slightly more than half that of the CalCOFI standard bongo net, despite the higher F_i of the DCPD entrainment net, clogging of the net mesh will occur more rapidly in the latter. However, based on observations in the field, it appears that the shorter net used at DCPD should not become clogged during most sampling efforts (Ehrler, TENERA, personal communication). If the nets become clogged during sampling, they will be removed from the water and the material clogging them will be rinsed off the net mesh and into the codend to decrease the chance of producing a bow wave. The sampling will then continue until eight complete circuits with the nets relatively unclogged have been achieved. Historically at DCPD, there have been periods when sampling was not possible due to high concentrations of phytoplankton which clogged the net mesh (Ehrler, TENERA, personal communication). If these conditions occur during the present study, sampling will be postponed until conditions improve.

DCPD Bongo Net Flow Characteristics (Dye Studies)

Using the DCPD 316(b) Demonstration sampling procedures, field testing was conducted to determine the profile of bow waves generated by resistance of the net to water flow through the 335 μm mesh. A dye-injector system was mounted on the bongo net sampler (Figure 1-4) for *in situ* evaluation of flow profiles. The system consisted of a stainless steel tube manifold on an adjustable mount positioned at varying distances ahead of the net mouths with 3 mm diameter holes drilled in it through which the dye was released. The distance from the net mouth was

extended from 15 cm to 35 cm to be certain that dye injected in the water column ahead of the net was outside the zone of influence of the bow wave. The holes were positioned to allow dye release across the complete net mouth and edges of the frame in addition to a reference stream positioned outside of the net frame. Dye was delivered by an onboard pump via several meters of surgical tubing which was attached to the manifold. The nets were fished in the same manner as the current entrainment sampling (see above) while SCUBA divers videotaped and photographed flow patterns of the dye streams in front of the net opening.

In situ video and still photography of dye injected into the water column ahead of the net were used to analyze flow profiles at the mouth of the bongo net sampler used at DCP. Figure 1-5 is a still photograph of dye injected 35 cm ahead of a non-constricted net. The likely result of a pronounced bow wave ahead of the net would be chaotic flow indicated by the dye not passing directly into the net mouth. Results from video analysis demonstrate that there is no visible bow wave ahead of a 0% constricted net using the standard sampling protocols. Although there was some indication of slightly chaotic flow around the mouth of the 50% constricted net, all of the dye released 35 cm ahead of the net still appeared to enter the net mouth. The greatest effects on flow profiles were observed ahead of the maximum mechanically-constricted net (~85% occluded). In this case, dye injected 35 cm ahead of and 15 cm inside the edge of the net frame was diverted outside of the frame. Similar results were seen when the dye was released at a distance of 15 cm ahead of the net.

DCP Entrainment Sampling Locations (Dye Studies)

Divers conducted subtidal studies of velocity patterns in the approach area of the intake by releasing dye approximately 1 and 9 m from the bottom at various locations along a line 10 m from and parallel to the entrance to the intake structure (Figure 1-6). Entrainment sampling locations were positioned along this line (at the X's in Figure 1-6) by selecting those points from which dye flowed into the center of the circulating water pump forebays. Moorings were placed beyond this 10 m line to allow the boat to be moored over the sampling location. The patterns of the relatively rapid dye movement and dispersion confirmed the presence of generally uniform flow of intake water from each of the release locations to the central bay in front of each pump as well as the lack of any obvious stagnant water zones at the proposed sampling locations. Fine-scale velocity patterns within centimeters of the intake structure's bar racks (Wyman 1987) are not likely to project out to the entrainment sampling locations approximately 10 m away.

Water Column Stratification at the DCP Intake Structure

Horizontal or vertical stratification at the point of intake of incurrent water velocity or of target organism distribution could bias estimates of entrained abundance. The potential stratification of water velocity and of plankton density was considered in the development of the present sampling design. Vertical stratification in the water column is integrated in bongo net samples by the nature of the vertical/oblique tow profile employed. Subtidal dye release studies were used to select sampling locations based on flow into the intake structure. In addition, these dye studies indicated that there were no stagnant current zones under these sampling locations.

Vertical stratification of horizontal flows at the intake structure are induced by frictional bottom drag as well as the interaction of pump suction with the structure itself. Surface flows may also vary relative to velocity in subsurface strata due to changes in water density with depth. An obliquely towed bongo net will vertically integrate the water column if stratification exists. The

amount of water filtered from each stratum varies directly with the velocity within a stratum. Thus, the contributions of stratified flows and planktonic organisms (assumed) to an overall density estimate are integrated into the total estimate when using an oblique tow profile. However, there is a built-in bias associated with the point at which the net is turned to complete a circuit between the surface and bottom. The stratum in which the net is turned is necessarily planar while the bongo net mouth is circular leading to a partial sample of the ca. 0.5 m thick stratum at the benthic and surface interface. This potential bias results from the fact that the net mouth remains in this stratum slightly longer than other strata because of the time it takes to complete the turn. The present sampling design of multiple circuits between the surface and bottom requires several turns at these two interfaces. Despite these biases, the ETWG have agreed that this net configuration and sampling design are the most practicable and allow us to maintain comparability with the CalCOFI database, providing a wider context to the data.

Intake approach velocity also varies horizontally across the front of the intake structure (i.e., between pump forebays; Wyman 1987). Small clockwise and counterclockwise gyres are known to exist at each end of the intake structure (Monopolis and Boudreau 1981). Neither of these current gyre patterns appear to directly affect approach velocities at the moored sampling locations based on analyses of existing data presented below. As discussed above, dye studies showed that there were no stagnant flow zones at the present sampling locations. Additionally, the sampling stations are located at a distance from the intake where it is unlikely that turbulent flow or reflection from the structure could lead to localized velocity stratification.

Density of entrained organisms may be horizontally or vertically stratified at the intake structure. A systematic pattern of horizontal stratification might bias estimates of entrainment density if we employed a single sampling station. The present design with four sampling locations across the intake will detect any horizontal stratification (see below). However, vertical stratification will not be detected using this sampling design. The entrainment sampling method is designed to sample the water column. Plankton abundance is standardized by the sample volume filtered yielding units of density ($\#/m^3$) to account for variations in length of tow and flow rates at the net mouth.

Some alternative sampling methods that could sample the surface or bottom of the water column have been discussed. The use of pumps to collect discrete-depth samples was eliminated due to the difficulties associated with handling the equipment, maintaining a particular depth in rough seas, and obtaining samples with adequate volume (TENERA 1997). Horizontal tows cannot be employed in the physically constrained environment of the DCP intake structure because there is not enough room to initiate and complete a tow. Sampling methods which could target the surface neuston layer (0-10 cm depth) or benthic interface might not sample the water column with equal efficiency and would be difficult to compare with the present entrainment sampling method due to issues of standardization. As discussed above, the present method of vertical/oblique tows using bongo net gear to sampled fixed moored stations was selected from many alternatives as the best method considering all of the issues of sampling (e.g., practicality, accuracy, and comparability).

Analyses of species composition and abundance data for larval fishes collected from the four entrainment stations detected no horizontal stratification among the sampling locations (Figure 1-7). Species richness (number of taxa) of the ichthyoplankton assemblage from 13 completely processed surveys to date (Surveys 3-12, 17, 19, and 21; Table 1-1) was compared using analysis of variance (ANOVA). There were no significant differences in the species richness standardized

for volume filtered of samples collected among the four moored sampling locations ($\alpha=0.05$, $p=0.13$).

Ichthyoplankton density ($\#/m^3$) among the four moored entrainment sampling stations was analyzed using ANOVA. No statistically significant differences were detected ($\alpha=0.05$, $p=0.07$) in mean larval density among the four stations which ranged from ca. 0-4.5 m^{-3} which can be seen in graphical comparisons of densities among stations for each survey cycle (Figure 1-8). Lines connecting the density measures were included to connect 3-hour cycle results and do not imply any other relationship between the points. Outlying density values shown on the graph at stations C and D represented <2% of all samples collected at those stations.

DCPP Bongo Net Tow Profile

Physical constraints of the chosen entrainment sampling location (TENERA 1997) and consideration of plankton sampling literature (Simpson 1959; Tranter and Smith 1968; Smith et al. 1968; Smith and Richardson 1977) led to the use of vertical/oblique tow profiles for the present 316(b) Demonstration sampling. Tranter and Smith (1968) stated that an obliquely towed sampler will integrate vertical current stratification during sampling. Additionally, CalCOFI has used this tow profile for nearly 50 years (Ohman and Smith 1995).

Target Water Volume Filtered

As the result of discussions with the DCPP ETWG, a target water volume filtered of 40-50 m^3 per bongo net subsample was agreed upon as an adequate sample size to accurately characterize plankton densities. This target volume was achieved by sending the net to the bottom from the surface for a total of 8 complete circuits. The targeted volume will also reduce the variation associated with estimates of density from smaller sample volumes which becomes important when those estimates are expanded by the volume of water entrained in the power plant per day. This target volume was also chosen to remain volumetrically comparable to existing long term plankton datasets at DCPP from weekly plankton tows dating back to February 1990 (TENERA unpublished data).

Table 1-1

All completely processed surveys to date from which ichthyoplankton data was used for analysis of variance (ANOVA) of diversity and abundance (density) between moored sampling station.

<u>SURVEY</u>	<u>COLLECTION DATES</u>
3	Oct. 23-24, 1996
4	Oct. 30-31, 1996
5	Nov. 6-7, 1996
6	Nov. 13-14, 1996
7	Nov. 18-19, 1996
8	Nov. 25-26, 1996
9	Dec. 2-3, 1996
10	Dec. 3-4, 1996
11	Dec. 9-10, 1996
12	Dec. 16-17, 1996
17	Jan. 20-21, 1997
19	Feb. 3-4, 1997
21	Feb. 17-18, 1997

Figure 1-1.

Diagram of DCPD Power Plant, Intake Cove and Entrainment Sampling Locations

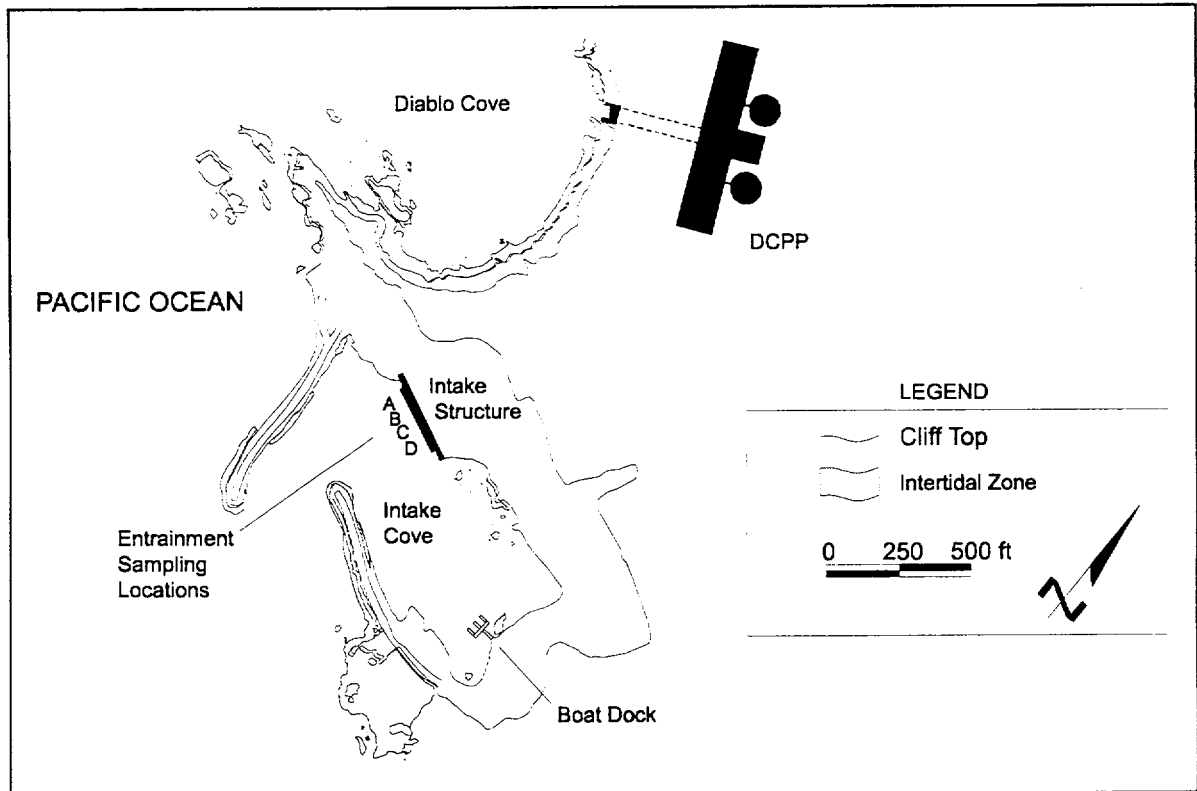
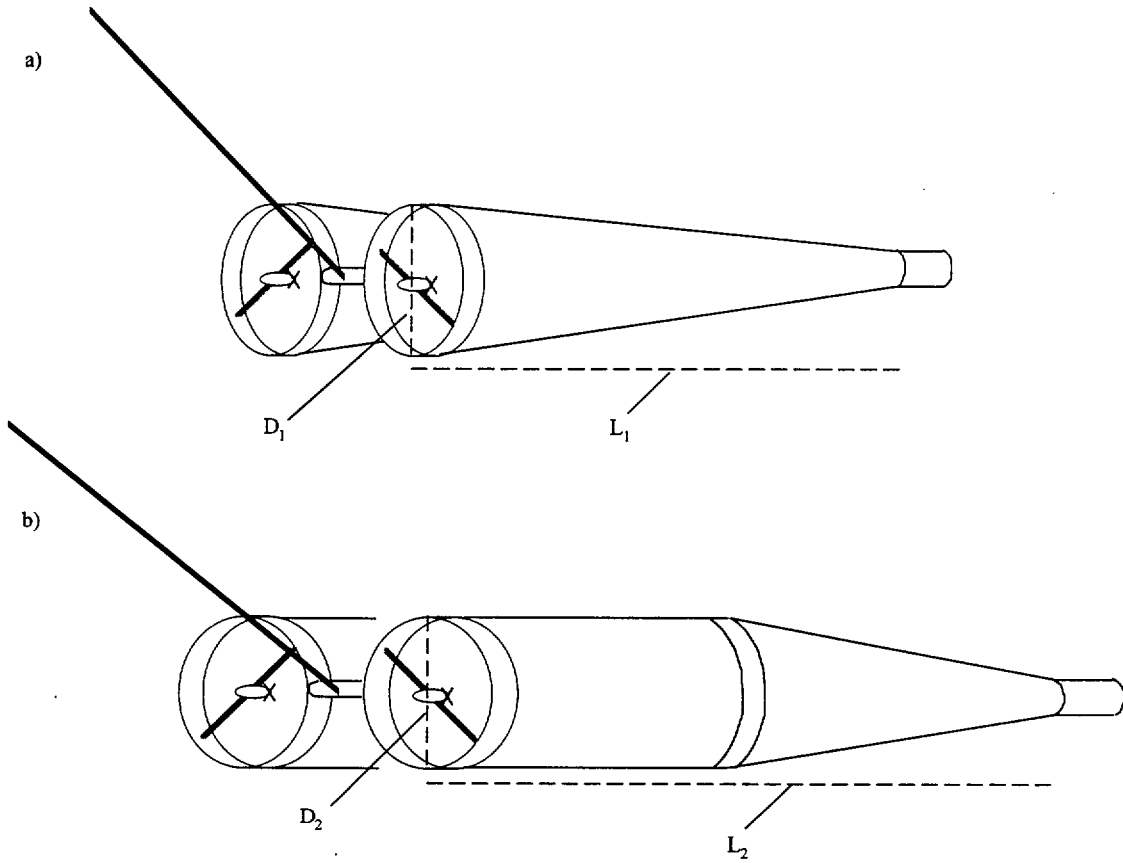


Figure 1-2.

a) Bongo net used in entrainment sampling at DCP: $D_1 = 0.71$ m; $L_1 = 1.8$ m; mesh size = 335 μ m. b) Standard CalCOFI Bongo net configuration for ichthyoplankton surveys in the California current: $D_2 = 0.71$ m; $L_2 = 3.3$ m; mesh size = 505 μ m.



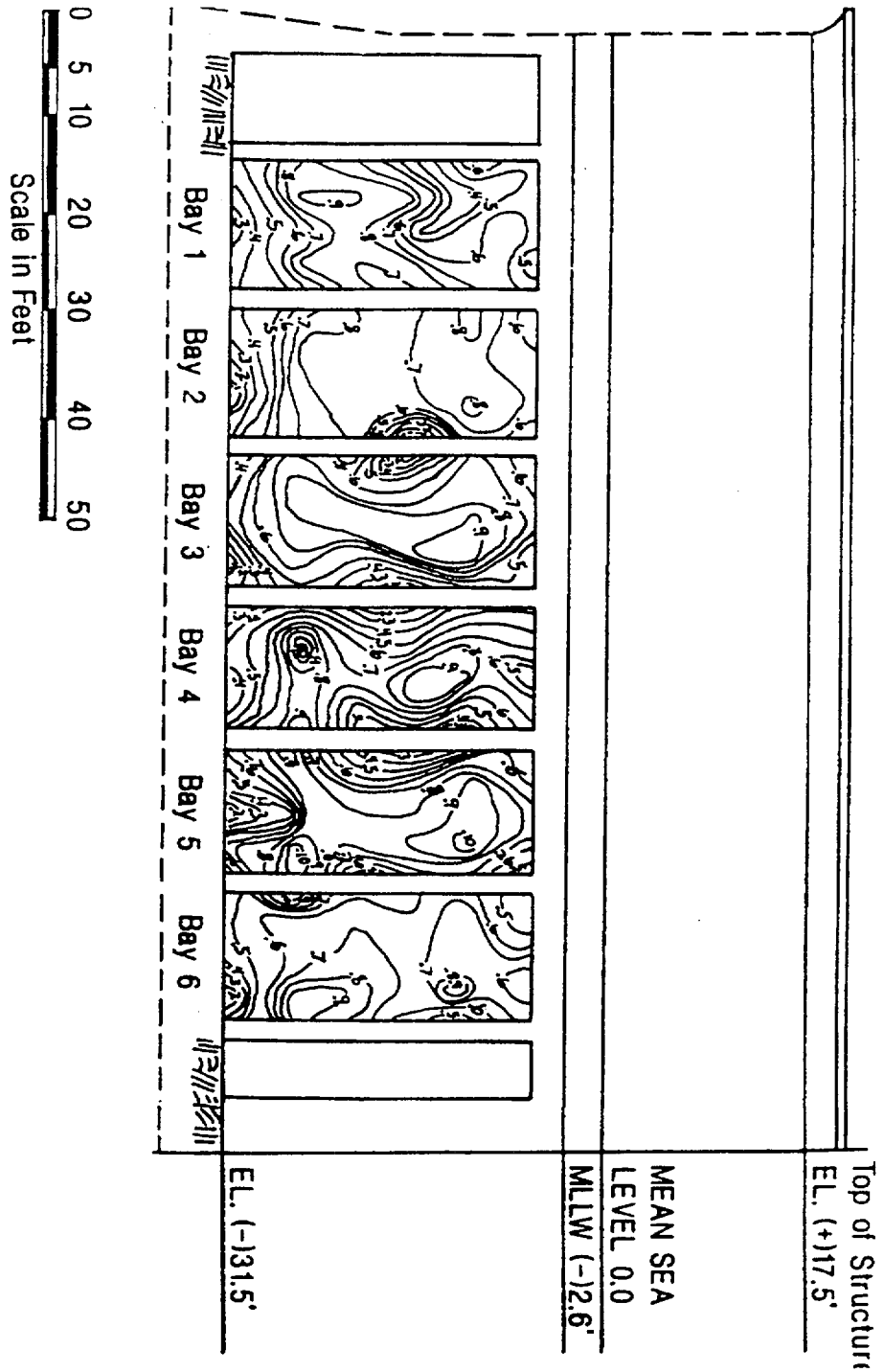


Figure 1-3

Unit 1 intake bay velocity profiles measured near the bar racks (units of ft·sec⁻¹; modified from Wyman 1987).

Figure 1-4.

Plankton net flow test apparatus. Arrows indicate dye release points and directions. Field tests conducted with manifold both 15 and 35 cm ahead of the net mouth.

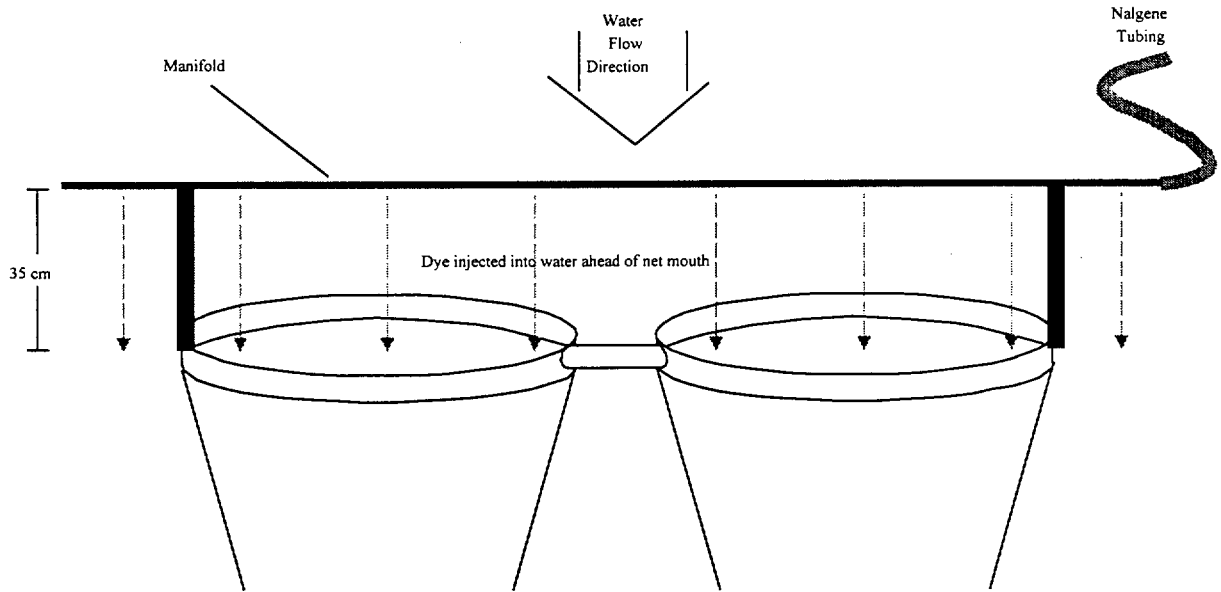
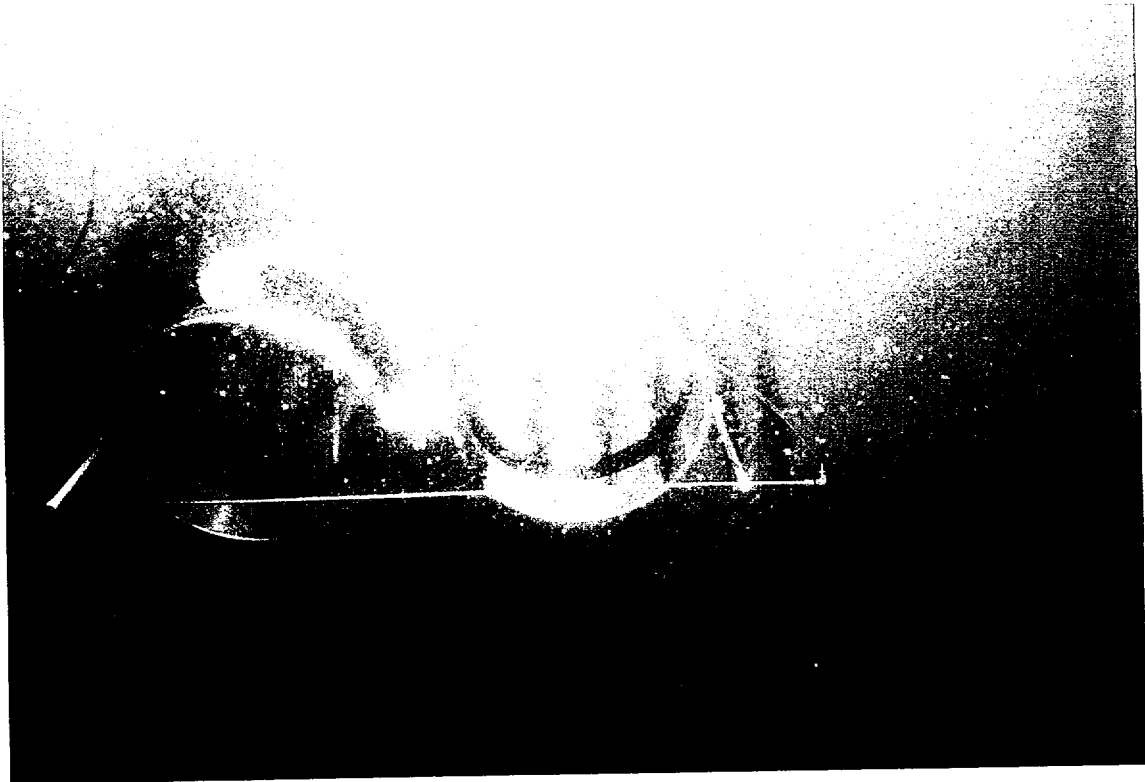


Figure 1-5.

Photograph of dye released 35 cm ahead of net mouth



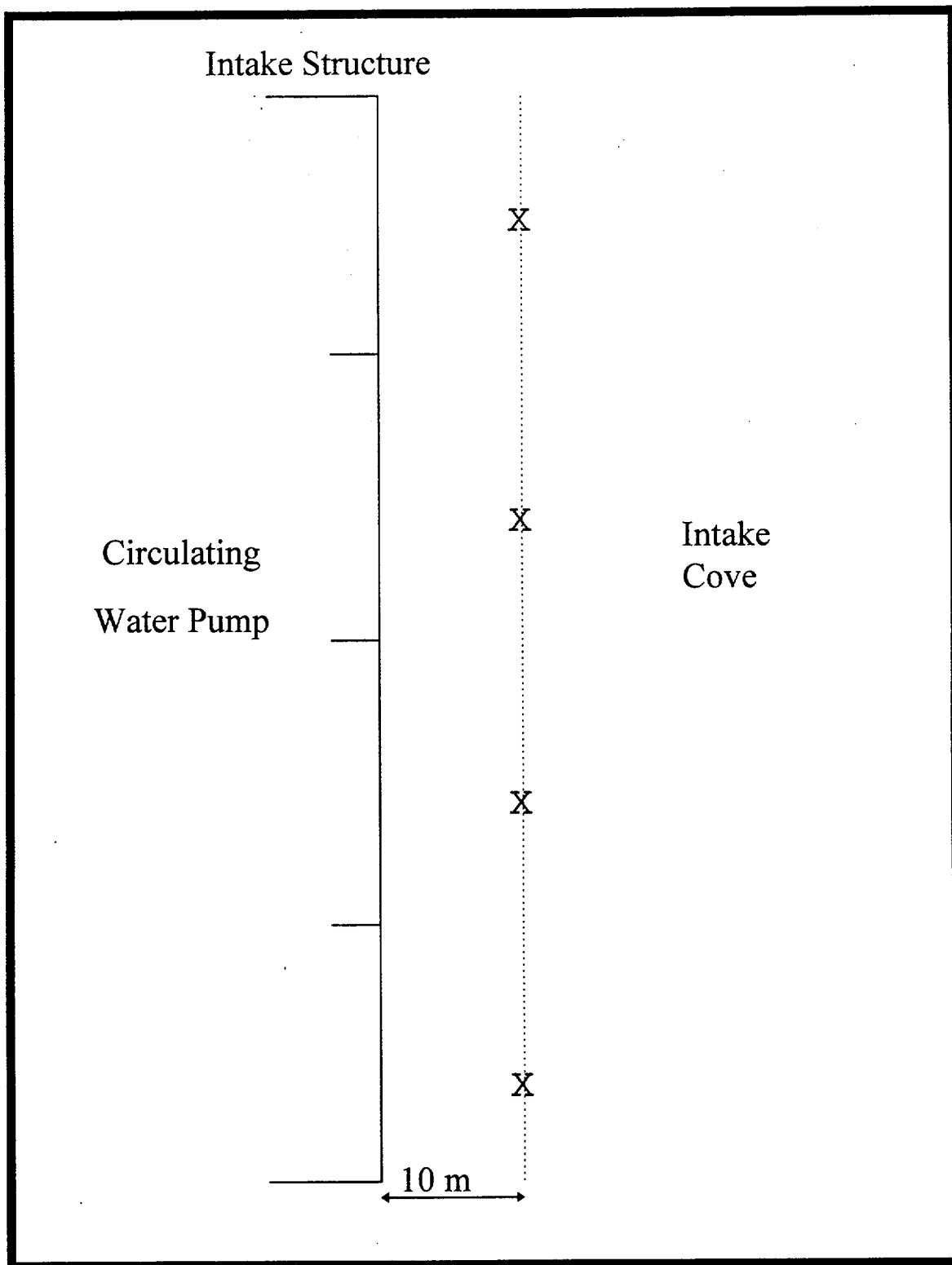


Figure 1-6

Plan view of intake structure and entrainment sampling locations as determined by subtidal dye release/flow studies.

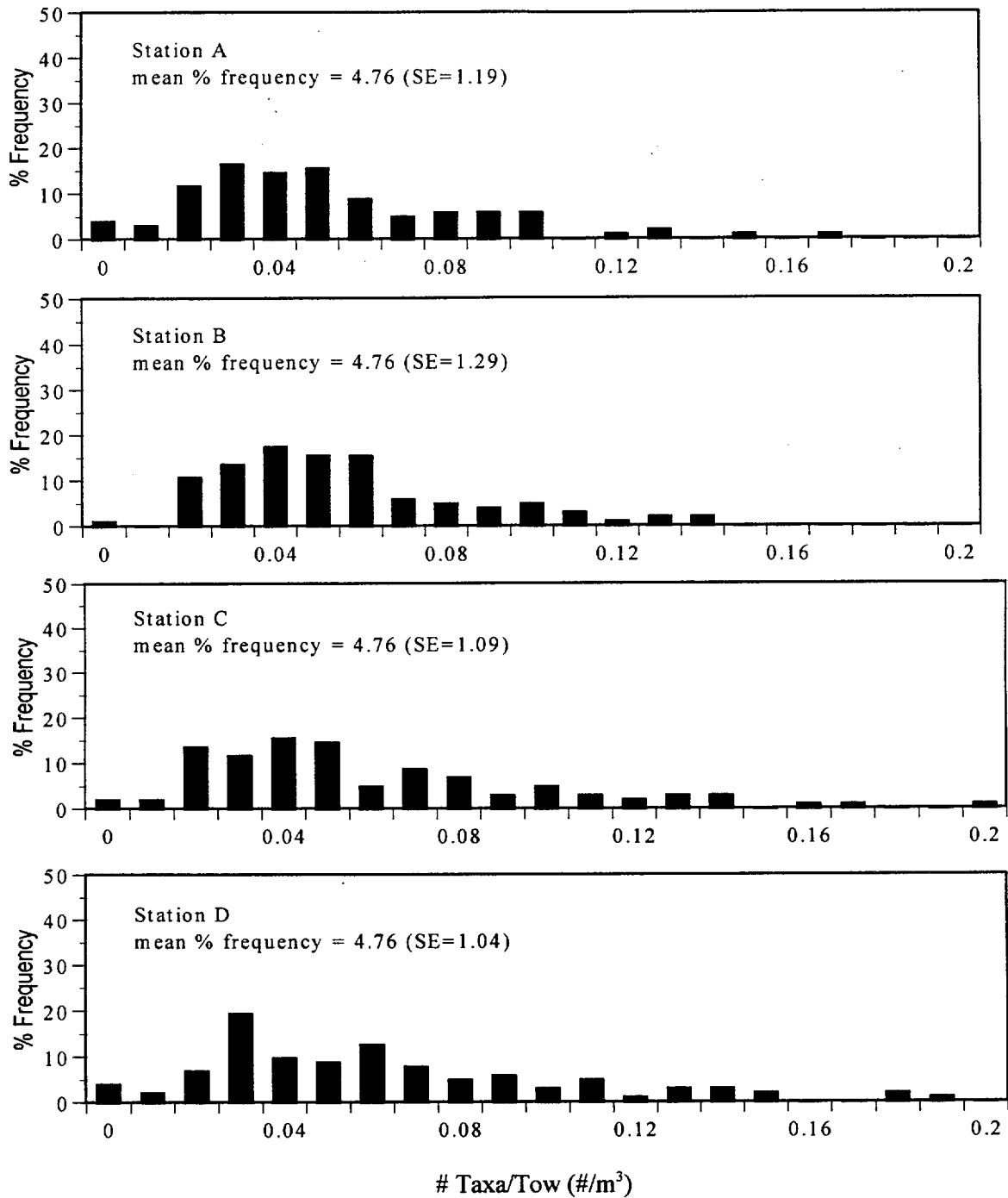


Figure 1-7

Percent frequency of occurrence of species richness (number of taxa standardized for volume filtered) at each of the four moored entrainment sampling locations (A-D) indicates similar and overlapping occurrence of taxonomic diversity at all stations; means and standard errors (SE) are included.

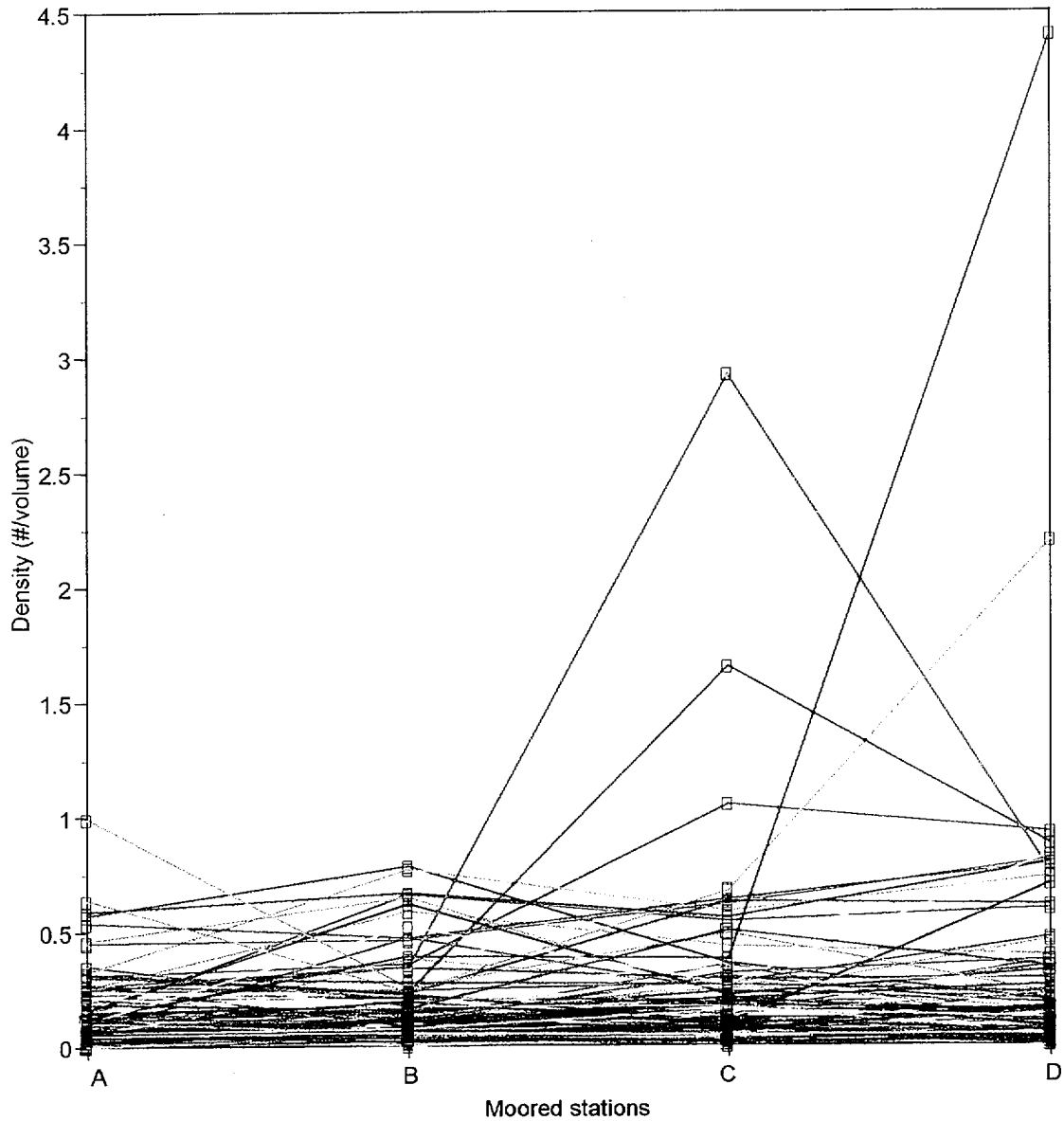


Figure 1-8.

Density of all taxa combined by sampling cycle at each moored station for 13 entrainment surveys (3-12, 17, 19, and 21); density is relatively homogeneous across the four moored stations indicating no horizontal bias in larval fish abundance. Lines connect samples collected in the same 3-hour cycle and do not indicate relationships between stations.

2.0 LARVAL FISH ECOLOGY AND COLLECTION METHODS

2.1 Introduction

Mortality during early life stages of fishes is high and can be attributed to many factors: food availability (Hjort 1914; Lasker 1975); larval transport (Bakun and Nelson 1977; Parrish et al. 1981); wind and storm events (Walsh et al. 1980); and predation (Lillelund and Lasker 1971; Theilacker and Lasker 1974). Feeding success can be defined as obtaining sufficient energy from exogenous sources which in early life stages is critical to future development and survival of larval fishes. Transport of larval fishes away from areas favorable for settlement can result in mortality if not reversed (e.g., larval fishes transported offshore during upwelling events can be returned toward shore during relaxation events; Wing et al. 1995, Yoklavich et al. 1996). Larvae transported too far from favorable habitat to benefit from these relaxation events are lost to the population. Some studies (Walsh et al. 1980; Lasker 1981) have shown direct relationships between larval mortality and duration, frequency, and intensity of storm and wind events. Effects of these events range from issues of transport and food availability to mechanical damage of the larvae. Predation on fish larvae is generally agreed upon as an important source of mortality (Lasker 1981) and can contribute to poor year-class strength.

An additional source of mortality to the early life stages of fishes can be entrainment. Susceptibility of early life stages of fishes to entrainment varies with larval development. Planktonic organisms without the ability to effectively swim away from the incurrent cooling water into the intake structure (< 1 foot/sec) are vulnerable to entrainment mortality. These organisms include any passive drifters (fish eggs) or weakly swimming larval forms. Fishes with demersal, adhesive eggs (e.g., cabezon, greenlings, or gobies) do not experience entrainment mortality during the egg stage. Fishes in the genus *Sebastes* (rockfishes) are internally fertilized and extrude live larvae. The swimming ability of larval fishes increases with development and ultimately older larvae and juveniles can swim away from the intake.

There are many fish species in the Diablo Canyon area that are commercially, recreationally, and ecologically important and whose larval stages maybe be vulnerable to entrainment in the cooling water intake at DCP. An important part of the present research is to estimate larval entrainment losses and their impacts to the source populations so that assessment of the application of "best available technology" by DCP can be undertaken (EPA 1977). Constraints on resources, finances, time, and energy preclude studying every species that might be entrained (Jones and Kaly 1996) leading to the concept of "indicator organisms" (Soule and Kleppel 1988, Root 1990); or 'target organisms' as used in this study.

The sampling techniques used at DCP will collect representative samples of larval fishes in the water column using the methods described above and in Phase 1 Entrainment Study Design, I Sampling Location (TENERA 1997) for the purposes of impact evaluations as described by the EPA guidelines for 316(b) Demonstrations (EPA 1977). All fishes in every sample will be removed, identified to the lowest possible taxonomic level and enumerated. Analysis of the effects of entrainment on several potential target fish species have been discussed by the DCP ETWG. The early life histories for two of these are summarized below as representative examples of the current state of knowledge on some fishes in the DCP region (blue rockfish, *Sebastes mystinus*, and cabezon, *Scorpaenichthys marmoratus*). It is anticipated that the ETWG

will add additional fish species to the final evaluation of the DCP 316(b) Demonstration based on the data that are collected during the course of the study.

2.2 Early Life Histories of Some Target Fish Species

Blue rockfish (*Sebastes mystinus*)

Blue rockfish, *Sebastes mystinus*, range from the Bering Sea to Punta Banda, Baja California (Eschmeyer et al. 1983), and have been found from the surface to a maximum depths of 549 m. Adults reach a maximum size of 53 cm and can live approximately 24 years. Age at first spawning is protracted for both sexes. Only about 10 percent spawn for the first time at age three. At five years of age (26 cm) half of the males have spawned, while at six years (28 cm) half of the females have spawned (Love 1991).

Eggs begin maturing in females from July to October. The males generally transfer sperm to the females in October. The stored sperm fertilizes the eggs several weeks later and development of the embryos generally begins in December. The eggs develop and hatch inside the female (Boehlert et al. 1986) with release of swimming larvae into the water beginning in January. Rockfishes have fairly unique reproductive adaptations which include high fecundity, extrusion of developmentally advanced larvae, and prolonged residence in the plankton. Extrusion of larvae coincides with the upwelling season along the west coast of North America to take advantage of both the elevated levels of primary production associated with seasonal upwelling and dispersal by long-shore currents. Larval blue rockfish are usually the first of the rockfishes to appear as larvae in plankton samples. Larvae reside in the plankton for a period of up to five months (Dave VenTresca, CDF&G, personal communication). Juveniles appear in the kelp canopy and shallow rocky areas by April or May when they are between 3 and 3.5 cm in length (Love 1991).

Cabezon (*Scorpaenichthys marmoratus*)

Cabezon, *Scorpaenichthys marmoratus*, range from Sitka, Alaska to Punta Abreojos, Baja California (Eschmeyer et al. 1983), and are found from the surface and in tide pools to depths of 110 m. Adults are frequently found associated with subtidal rocky reefs and kelp forests. These fish may reach ages in excess of 20 years. The largest recorded size is 99 cm and weighed 11 kg. Juveniles can reach a size of nearly eight inches in two years, at which time the males become sexually mature; by three years of age all males have matured. Some females begin to mature in their third year when they are between 25 and 48 cm in length, and by the fifth year all females are mature (Wilson-Vandenberg 1992).

In California, spawning commences in late October, peaks in January, and continues until March. There is some evidence to suggest that females may spawn more than once in a season. Females spawn adhesive, demersal eggs on algae-free, rocky substrata where they are fertilized and subsequently guarded by a male cabezon. Fecundities of up to 152,000 eggs are not uncommon. Development of the fertilized eggs takes from two to three weeks. Upon hatching, larvae spend three to four months in the plankton before settling out as juveniles at a size of about 4 cm (Wilson-Vandenberg 1992).

2.3 Larval Fish Identification

Marine fishes have evolved an array of forms, specialized morphology, and pigment patterns that are useful as identifying characteristics. These characteristics typically change as the larvae develop. Effective use of these characters for identification requires knowledge of their intra- and interspecific variation and an understanding of how each character varies among higher taxonomic categories. The proportion of larvae that can be identified to species varies regionally although most species in plankton samples can be identified at least to the family level.

Three general references will be used for the identification of larval fishes in the DCPD area (Matarese et al. 1989; Moser 1996; Wang 1986) as well as additional specific references for specialty groups not covered in the general references. The larvae of several fish species in the DCPD area are presently either poorly known or undescribed. This will necessitate combining taxa into higher taxonomic categories, such as at the genus or family level.

The genus *Sebastes* includes at least 72 species and 11 subgenera along the eastern Pacific coast of North America (Moreno 1993). Because of the relatively recent speciation that has occurred in this genus, many larval characteristics are shared over a wide range of species making identification within this genus problematic. Identification of larval *Sebastes* to the species level relies heavily on pigment patterns which change as the larvae develop. This further complicates identification when early stages of *Sebastes* predominate in the samples. Currently, it is accepted that as many as five of these 72 species can be reliably identified to the species level at certain developmental stages: *Sebastes mystinus* (blue rockfish), *S. jordani* (shortbelly rockfish), *S. levis* (cowcod), *S. paucispinis* (bocaccio; Yoklavich et al. 1996); and *S. saxicola* (stripetail rockfish) (Laidig et al. 1995). Other species within this genus can only be resolved to broad sub-generic groupings based on pigment patterns (Nishimoto in prep.).

2.4 Larval Fish Population Studies - Historical Perspective

Field studies of larval fish populations in the California Current are exemplified by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). The CalCOFI data set on pelagic larval fish populations is the most comprehensive of its kind (1949-present) and CalCOFI sampling protocols (Smith and Richardson 1977) are widely accepted for ichthyoplankton surveys along this coast. Standard survey methodology consists of towing bongo nets through the water column using an oblique profile. In this manner, different depth strata are sampled equally and representatively throughout the tow. This time series has been used to identify distribution and abundance patterns of larval fish species in the California Current system as well as for the identification of trends resulting from climatological changes.

One recent study of nearshore larval rockfish assemblages (Scorpaenidae: *Sebastes*; Yoklavich et al. 1996) gives some indication of the year-to-year variability in species abundance during a prolonged El Niño event. Larval *Sebastes* abundance during the El Niño was substantially higher than estimates from CalCOFI surveys off central California (1951-1984). During the first year of sampling, elevated larval rockfish abundance at nearshore stations coincided with the onset of El Niño. During the second year of sampling, initiation of upwelling and attendant offshore transport led to lower abundances of rockfish larvae at nearshore stations. Similar results for the top five most abundant species, including larval *Sebastes* spp., were obtained by Nishimoto (1996). Overall, Yoklavich et al. (1996) conclude that larval rockfish abundance was not

adversely affected by the extended El Niño, but it is possible that this oceanographic event led to the overestimation of larval rockfish abundance relative to the CalCOFI estimates.

Icanberry et al. (1978) and Icanberry and Warrick (1978) described the seasonal abundance of larval fishes in the waters off Diablo Canyon prior to the start of power plant operations. The greatest larval abundance in these studies occurred from January to March 1975. The ten most common larvae found in their samples were *Sebastes* spp. (rockfishes), *Sciaenidae* (croakers), *Cottidae* unknown (sculpins), *Artedius* spp. (also sculpins), *Engraulis mordax* (northern anchovy), *Stenobranchius leucopsaurus* (northern lampfish), *Scorpaenichthys marmoratus* (cabezon), *Gobiidae* unknown (gobies), and *Blennioidei* unknown (blennies), respectively. All of these taxa are represented in taxonomic lists from the current field studies. Ambrose et al. (1988) found similar trends in seasonal abundance for the Diablo Canyon region in the CalCOFI data sets.

2.5 Proposed DCPD Larval Fish Sampling

The following is an overview of the proposed sampling. The actual detailed procedures will be presented in the Phase II report.

Entrainment samples are collected using a 1.8 m long, 335 µm white Nitex mesh bongo net fitted with calibrated flowmeters positioned in each net mouth and employed in vertical/oblique hauls from four moored stations directly in front of the intake structure. Samples are collected by lowering and then raising the bongo frame and nets a total of eight times at each mooring during each of the three-hour cycles conducted during one 24-hour period each week. The samples are preserved soon after collection and then transferred to the laboratory. In the laboratory, all larval fishes are removed from each of the samples. An on-site quality control program ensures that each of the sorters maintains a high level of accuracy in removal of the larval fishes from the samples. All larval fishes are identified by on-site staff. On-site and off-site quality control programs verify the identification and enumeration of the collected larval fishes. All data pertaining to the collection and laboratory processing of each of the samples is tracked via a computer database.

3.0 LARVAL CRAB ECOLOGY AND COLLECTION METHODS

3.1 Introduction

There are seven species of *Cancer* crabs in central California, collectively referred to as 'rock crabs' or 'market crabs'. These species are, in order of descending maximum size (and preferred common name): *Cancer magister* (Dungeness crab); *C. productus* (red rock crab); *C. anthonyi* (yellow crab); *C. antennarius* (brown rock crab); *C. gracilis* (slender crab); *C. jordani* (Jordan's hairy cancer crab); and *C. branneri* (Branner's hairy cancer crab). There is a commercial trap fishery for the first four species listed above (Leet et al. 1992).

All species have larval stages that are planktonic for up to two months. Larvae are vulnerable to entrainment into the DCPD cooling water system during that time. It is not known which larval stages are the most susceptible to entrainment. The first stages are most abundant in the vicinity of the intakes because they have had less time to be dispersed by offshore and longshore currents.

In the Diablo Canyon nearshore study area, *C. antennarius* is the most abundant species, followed by *C. productus*, and *C. anthonyi* (TENERA unpublished data). *Cancer magister* account for a very minor part of the crab fishery locally (Leet et al. 1992) although there are good commercial landings in Santa Barbara and as far south as San Diego (Deborah Johnston, CDF&G, personal communication). *Cancer gracilis* and *C. anthonyi* are most abundant on sand substrata (which occurs offshore, and north and south of DCPD). *Cancer jordani* and *C. branneri* seldom exceed 3 cm in width and are mainly found in the rocky intertidal zone or among kelp holdfasts. Carroll and Winn (1989) reviewed the life histories and environmental requirements of *C. productus*, *C. anthonyi*, and *C. antennarius*. *Cancer magister*, the species with greatest commercial value, has been studied extensively (Wild and Tasto 1983; Melteff 1985) as to descriptions (including larvae of *C. gracilis*), basic ecological requirements, and distributions (Morris et al. 1980).

3.2 Larval Crab Life History

All seven *Cancer* crab species in the DCPD area have similar life histories. Females brood a mass of small eggs which are attached to the pleopods beneath the abdominal flap. Each egg mass can contain up to several million eggs, although female body size largely determines reproductive output (Hines 1982). After a developmental period of approximately 6-8 weeks, depending upon species and environmental conditions, eggs hatch and the larval crabs assume a planktonic existence. The planktonic larvae develop through a pre-zoeal stage, five zoeal stages, and a single megalopal stage before undergoing metamorphosis into the first crab instar (juvenile crab). Although the larvae of *C. jordani* and *C. branneri* have not been described, it is assumed they follow the same basic pattern as the other *Cancer* species. Because larvae hatch directly from eggs carried by the female, the relative abundances of larvae in the sampling area, particularly the earliest stages, should be linked to the relative abundances and types of species of ovigerous female crabs in the area.

As with all crustaceans, growth is accomplished by a step-wise molting process involving a cycle of physiological changes. Initially, the crab's hardened exoskeleton splits along external suture lines and the next 'soft shell' stage emerges. The crab rapidly expands and grows during the

short period before the new integument hardens (Hartnoll 1982). The crab then enters a longer intermolt period during which there is little or no growth. This process continues through all life stages, from the time the larvae hatch until the adult crab attains maximum size.

Development through all of the larval stages may take several weeks, again depending upon species and environmental conditions. Hines (1986) reported an average larval period of 65 days for the Cancridae family. This extended larval phase enables the zoea to potentially disperse over great distances with the prevailing ocean currents.

The pre-zoeal stage lasts only a matter of minutes, but each of the five successive zoeal stage lasts a week or longer (Roesijadi 1976). Later stage larvae are capable, to some extent, of behaviorally positioning themselves in the water column to enhance shoreward transport (Shanks 1985). Megalopal stages of *C. magister* were found to be most abundant in the neuston (surface) layer at dawn and dusk, presumably using light intensity as an environmental cue (Booth et al. 1985). Pre-settlement megalopae of *C. antennarius* and *C. anthonyi* (and presumably other species) were able to distinguish settlement substrata by using environmental cues, thus enhancing their survival after metamorphosis to the first crab stage (Winn 1985).

3.3 Larval Crab Identification

The larval stages of five of the seven *Cancer* species in the DCPD vicinity have been described in scientific studies: *C. magister* (Poole 1966); *C. productus* (Trask 1970); *C. anthonyi* (Anderson 1978); *C. antennarius* (Roesijadi 1976); and *C. gracilis* (Ally 1975). The early life stages of *C. jordani* and *C. branneri* have not yet been described. Hart (1971) provided keys to some cancrid species of British Columbia, and unpublished keys from California Department of Fish and Game have been used to distinguish between California cancrid crab larvae (Paul Reilly, CDF&G, personal communication). Larval cancrid crabs can be distinguished from other co-occurring crab families (e.g. Grapsidae, Majidae, Pinnotheridae, Xanthidae) by a unique combination of morphological traits (Hart 1971).

All of the described species have certain common traits in the zoea stage, and it is the subtle variation in these traits (e.g. shape of the body segments, length of spines) and relative sizes at each stage that distinguish the species. Stage 1 zoea of *C. antennarius*, *C. anthonyi* and *C. gracilis* are sufficiently similar to prevent positive identification to the species level (Graham 1989). Each successive zoeal stage increases in size over the previous one (size ranges from ca. 1.5-3.5 mm), and develops features such as increased numbers of setae, more complex appendages, and stalked eyes. Many of the characteristics are so minute as to require high power magnification, considerable manipulation, and precise measurements for positive identification. In general, *C. magister* can be readily distinguished among the species by its greater size at each stage. Identification of the other species requires a number of specimens of the various stages to compare relative differences between traits. *C. jordani* and *C. branneri* are probably quite small in size relative to the other species, based on their small adult size, but the larvae are undescribed.

The megalopal stages are somewhat easier to identify to species by virtue of their greater size (carapace lengths of ca. 5-6 mm). There is, however, known to be significant morphological variation within some species which can complicate identification (DeBrosse et al. 1990). Furthermore, they noted that larval studies primarily report characters found in specimens raised

under laboratory conditions, and that differences in size and characteristics can occur in natural populations.

3.4 Larval Crab Population Studies - Historical Perspective

Previous field studies estimating the abundance of larval *Cancer* species have typically used standard towed plankton nets of with mesh sizes from 335 μm to 1000 μm . Graham (1989) quantified *Cancer* species of all stages in Monterey Bay using a single 500 μm mesh net with a 0.5 m radius that was towed in the upper 5 m for 4-5 minutes. A calibrated flowmeter was attached to the mouth of the net, and zooplankton densities were standardized to number per 100 m^3 . Maximum densities of larval *Cancer* were recorded in April 1988 at 667 zoea per 100 m^3 .

Booth et al. (1985) targeted only *C. magister* megalopae and used a combination of neuston and bongo nets with net meshes ranging from 500 μm to 1000 μm . The bongo nets were towed in three different patterns: 1) surface tows; 2) oblique tows between the surface and 3 m off the bottom; and 3) undulating tows in which the net was repeatedly lowered and raised over the course of one tow. Megalopae are usually found near the surface, and neuston nets were the most effective sampling gear for this larval stage.

In previous larval invertebrate entrainment sampling at DCP, samples were collected from seawater pumped at a rate of approximately 900 liters/min. and filtered through 335 μm mesh plankton nets (TENERA 1988). Based on a 90% recovery efficiency of experimentally released larval fish and brine shrimp, it was determined that 335 μm mesh retained 100% of larval macroinvertebrates identified as key target organism (including *Cancer* spp. larvae) for the 316(b) program.

3.5 Proposed DCP Larval Crab Sampling

All larval stages of *Cancer* crabs can be present in the nearshore plankton and can therefore be susceptible to entrainment. The five zoeal stages and single megalopae stage are typically represented in samples mostly by first stage zoea, and progressively smaller proportions of later stage larvae. This is largely the result of natural mortality and offshore dispersion of later-stage larvae.

Cancer larvae will be collected using the same methodology as described for collection of larval fishes (see Section 2.5 - *Proposed DCP Larval Fish Sampling*). The methods should ensure a representative sample of larvae from all water depths in front of the intake structure. The 335 μm mesh should retain all stages of *Cancer* crab larvae with no extrusion losses based on the minimum body size of first zoea stage exceeding the stretch mesh diagonal dimension of the net. Avoidance losses should be minimized by the bongo net design, relatively large net mouth diameters, and limited mobility of early stage larvae.

All *Cancer* megalopae larvae will be removed from all of the samples using the same sorting methods used for larval fishes. The internal QC program will be used to assure sorter accuracy in megalopae removal from the samples. All megalopae larvae will be identified to the species level, based on published taxonomic keys.

All *Cancer* zoeal stages will be removed from one (1) randomly selected entrainment sample from each of the 3-hour cycles resulting in 8 samples for zoea per sampling day. Processing of the larvae from these samples will be the same as the processing of the fish samples. Stage 1 zoea will only be identified to genus. Subsequent stages (2-5) will be identified to the species level when possible and practical based on the quality of each specimen. This subsampling protocol has been discussed and approved by the DCP ETWG (May 1997).

Samples containing more than 200 *Cancer* zoea will be split with a plankton splitter so that the subsample contains approximately 100-200 *Cancer* zoea larvae. If splitting is required, the total number of zoea for the entire sample will be estimated based on the number removed from the sorted subsample. For example, if the sample is divided into four parts and one part is sorted, then the number of each of the larval stages identified and enumerated will be estimated to be 4 times greater for the entire sample. To verify the splitting technique, estimates will be made of the total number of zoea in five samples that are split based on each of the splits. For each sample, if the estimated sample total based on the sorted fraction is within 10% or less of the actual sample total, then sample splitting will be considered an accurate method for processing.

4.0 LARVAL SEA URCHIN ECOLOGY AND COLLECTION METHODS

4.1 Introduction

There are two species of sea urchins in the Diablo Canyon area, *Strongylocentrotus purpuratus* (purple sea urchin) and *S. franciscanus* (red sea urchin). Most of the urchins seen in the Diablo Canyon area are *S. purpuratus* (TENERA unpublished data). Adult *S. purpuratus* are usually purple in color, while juveniles can be greenish. Purple urchins are generally found on rocky substrata from the shallow intertidal to approximately 160 m depth and are distributed from Vancouver Island, British Columbia to Cedros Island, Baja California (Morris et al. 1980). The bodies of sea urchins are housed within hard calcareous tests with an exterior covered by hard spines. Purple urchins may live to be 30 years old and achieve test diameters of about 50 mm, but size is not an accurate indicator of age. Red urchins are found in rocky habitats from the mid- to low intertidal to a depth of 125 m. They are distributed from Sitka and Kodiak, Alaska to the tip of Baja California, and along the Asiatic coast to the southern tip of Hokkaido Island (Kato and Schroeter 1985). *S. franciscanus* test and spines are generally red or reddish-brown in color and large individuals have a diameter of about 180 mm (Kato and Schroeter 1985) with spine length of 50 mm or more (Morris et al. 1980). Pearse and Hines (1987) stated that they grew to a size of 20-40 mm test diameter in their first year of life. Large adults can be up to 37 years of age (Ebert et al. 1993).

Schroeter (1978) in Kato and Schroeter (1985) found that purple urchins dominate in harsh habitats (habitats exposed to waves and surge) while reds dominate in benign habitats (sheltered habitats), with distributions of both species being clumped. When present, red urchins were in higher abundance at the edge of kelp beds as compared to the inside. Those living inside are generally larger in size than those on the outside, with the maximum size being influenced directly by the availability of food (Kato and Schroeter 1985).

There has been a commercial fishery for red sea urchins since the early 1970s in southern California. The commercial fishery began in northern California in 1985. The peak annual landing was in 1988-89 when over 50 million pounds were landed (CDF&G 1994).

4.2 Sea Urchin Life History

Purple urchins become sexually mature at 2 years of age, at a size of about 25 mm test diameter. Spawning occurs from January through March although ripe individuals can be found from September to July (Morris et al. 1980). Ebert et al. (1994) found that settlement was seasonal and episodic, with variation seen between years. In addition, *S. purpuratus* maximum spawning potential both north and south of Pt. Conception is in the winter-spring period.

In central California red urchins have enlarged gonads during the winter, with main spawning taking place during April and May (Morris et al. 1980). *S. franciscanus* spawn episodically throughout their range with the settlement period varying between years (Ebert et al. 1994). In southern California they spawn during the winter-spring period while north of Pt. Conception the potential season shifts to later in spring and summer with increasing latitude (Ebert et al. 1994). Kato and Schroeter (1985) state that red urchins can spawn for the first time at two years of age. They also found that red urchin roe can account for up to 20% of total body weight with an

increase in gonad size not being related to an intrinsic reproductive cycle but rather to feeding (Kato and Schroeter 1985).

The sexes are separate and fertilization is external in the water column for both purple and red urchins. Minimum densities for successful fertilization are at least 2 spawners/m² (1 female : 1 male) (Botsford et al. 1993; CDF&G 1994). An even higher density is required in areas with substantial water flow (Botsford et al. 1993). In the Diablo Canyon area, purple urchins are in high enough abundance to meet this minimum requirement for successful spawning while abundance of red urchins is not sufficient (TENERA unpublished data).

Strongylocentrotus develop larvae known as echinoplutei. There are three stages in the echinopluteus life (referred to as 4-armed, 6-armed and 8-armed larval stages). The 8-armed stage metamorphoses into a recognizable urchin. All stages of the echinoplutei are planktonic and susceptible to entrainment mortality. Initial sampling at DCPD has shown that newly metamorphosed urchins can be captured by a plankton net used to sample the water column in front of the intake structure. These larval stages are found in plankton samples in Oregon from March to July with newly settled urchins being found from April to August, with peak settlement in June (Miller and Emler in press). Ebert et al. (1994) found that urchins settled episodically from February to July in northern and southern California. Year-to-year variation was seen in the length of the annual settlement season by Ebert et al. (1994) who also found significantly more variability in settlement between years in northern study areas (north of Point Arena) than in the southern areas studied (south of Point Conception).

Laura Rogers-Bennett (University of Washington, personal communication) stated that the larval morphology of the echinoplutei stages are affected by the concentration of food that is available. Low concentrations of food will cause the arms to grow longer than if there are high concentrations of food. Rough estimates of the size of the three different armed stages of the red sea urchin based on Rogers-Bennett's laboratory studies for average larvae size are as follows:

<u>STAGE</u>	<u>TOTAL LENGTH</u>	<u>WIDTH</u>
4-armed	200-360 µm	150-180 µm
6-armed	240-320 µm	150-200 µm
8-armed	300-500 µm	170-210 µm

In laboratory studies, purple urchin larvae metamorphose as early as 30 days after fertilization with a peak at about 38 days, while larvae of red urchins metamorphose after around 40 days with a peak at 50 days (Cameron and Schroeter 1980). Laura Rogers-Bennett (personal communication) stated that the speed of larval development in the laboratory for red urchins is related to the water temperature and quantity of available food. Ebert et al. (1994) state that in the field urchin larvae are in the plankton for at least 5 weeks and can be transported hundreds or thousands of kilometers from their site of fertilization.

The adult rudiment develops inside the echinopluteus larva over a period of about one month (Chia and Burke 1978). Chia and Burke (1978) also stated that the metamorphosis of the larvae into an urchin takes place in about one hour, and metamorphosis of the echinopluteus occurs after settlement. At metamorphosis, the adult rudiment is everted and the larval body is resorbed into the dorsal surface of the juvenile (Chia and Burke 1978).

Laura Rogers-Bennett (personal communication) stated that there is no information presently available on echinopluteus larval mortality rates in the field. However, Miller and Emlet (in press) found that percent survival of lab-reared and outplanted early juvenile *S. franciscanus* placed on subtidal substrata was 80.7% after seven days and 46.7% after fourteen days.

4.3 Larval Sea Urchin Identification

Strongylocentrotus purpuratus and *S. franciscanus* echinoplutei can be separated from each other based on the larval skeleton (Strathmann 1979; Laura Rogers-Bennett personal communication). Newly settled *Strongylocentrotus* can be identified to the species level based on the presence or absence of dorsal pedicellariae. *Strongylocentrotus franciscanus* has dorsal pedicellariae while *S. purpuratus* does not for a period of one to two weeks after settlement (Steve Schroeter, San Diego State University, personal communication; Ebert et al. 1994).

4.4 Larval Sea Urchin Population Studies - Historical Perspective

Pearse and Hines (1987), working subtidally in a kelp bed at a depth of about 10 meters in Pacific Grove, California during the period 1972-1981, found only a single large recruitment event of purple urchins. Red urchin density remained low and did not change significantly during their study. During 1975-76, purple urchin densities increased approximately 25-times from about 2 to about 50 per 10 m². This single recruitment event during this 10 year study resulted in only a temporary increase in the purple urchin density, with many of the recruits dying within one year after their settlement. Mortality was assumed to be due to sea star feeding.

Ebert et al. (1994) and Steve Schroeter (personal communication) have worked with settlement of urchin larvae on brush-type settlement collectors since at least 1990. The settlement patterns have been assumed to represent the availability of larvae in the water column. They have found about 20 purple urchins settled for every one settled red urchin, which might be explained by the shallow placement of the collectors (6-8 meters deep).

Strathmann (1978) summarizes urchin settlement work by other researchers by stating that juveniles of *Strongylocentrotus* are generally found in close association with adults but the adults do not appear to release a chemical that would enhance settlement. Rowley (University of California, Santa Barbara, personal communication) found that urchins settled preferentially on coralline algae, but also found newly metamorphosed urchins in plankton samples. He stated that urchin metamorphosis can take place in as little as 20 minutes, and that he thinks that the disturbance caused by being captured by the net could induce metamorphosis which might then take place before chemical fixation of the sample.

4.5 Proposed DCPP Sea Urchin Sampling

Larval sea urchins will be collected using the same methodology as described for collection of larval fishes (see Section 2.5. - *Proposed DCPP Larval Fish Sampling*). The methods ensure a sample of larvae from the complete water column in front of the intake structure. Miller and Emlet (in press) found urchin larvae from the surface to 18 m in water depths of 22-30 m. Densities at depths sampled were variable with no particular strata containing the greatest number of echinoplutei. Based on the size of laboratory raised echinoplutei (above table), only the later stage larvae will be collected by the 335 μm mesh net used for the entrainment sampling. Steve Schroeter (personal communication) stated that newly metamorphosing urchin larvae will be captured by 335 μm mesh. Rowley (1989) stated that newly metamorphosed red and purple urchins are about 0.4 mm in size. Preliminary analysis of samples collected at DCPP shows that late stage echinoplutei and metamorphosing and metamorphosed urchins are captured by the 335 μm mesh net. Due to the small size of the early larval stages, only the larger, late stage larvae will be captured with the 335 μm net used at DCPP. Avoidance losses should be minimized by the bongo net design, relatively large net mouth diameters, and limited mobility of the larvae.

In order to capture all stages of the echinopleutus, Miller and Emlet (in press) and Laura Rogers-Bennett (personal communication) stated that a 202 μm mesh net is required. Due to the difficulty of net clogging while filtering a large volume of water through this fine mesh, the ETWG decided that the assessment of urchins entrained would be based on the abundance of echinoplutei and metamorphosing and metamorphosed urchins captured by the 335 μm mesh net.

All sea urchin echinoplutei, newly metamorphosing, and metamorphosed urchins will be removed from one randomly selected entrainment sample from each of the 3-hour cycles. Thus, 8 samples collected during each of the weekly collection surveys will be sorted for sea urchins. This subsampling protocol has been discussed and approved by the DCPP ETWG (May 1997). Handling of the individuals from these samples will be the same as the handling of the fish samples. Larval identification will be based on the key developed by Strathmann (1979).

Samples containing more than 200 sea urchin echinoplutei and newly metamorphosing or metamorphosed urchins will be split with a plankton splitter so that the subsample contains approximately 100-200 individuals of these groups. If splitting is required, the total number of individuals for the entire sample will be estimated based on the number removed from the sorted subsample. For example, if the sample is divided into four parts and one part is sorted, then the number of each of the stages identified and enumerated will be estimated to be 4 times greater for the entire sample. To verify the splitting technique, estimates will be made of the total number of zoea in five samples that are split based on each of the splits. For each sample, if the estimated sample total based on the sorted fraction is within 10% or less of the actual sample total, then sample splitting will be considered an accurate method for processing.

5.0 - LARVAL ABALONE ECOLOGY AND COLLECTION METHODS

5.1 Introduction

DCPP is located within the known geographical ranges of four abalone species: the red abalone, *Haliotis rufescens*; the black abalone, *H. cracherodii*; the threaded abalone (also known as the northern or the pinto), *H. kamtschatkana*; and the flat abalone, *H. walallensis* (Lindberg 1992). Between June 1969 and July 1970, a total of 7,544 *H. cracherodii*, 6,235 *H. rufescens*, 51 *H. kamtschatkana*, five *H. walallensis*, and one *H. assimilis* (currently a subspecies of *H. walallensis*; Lindberg 1992) were transplanted to outlying areas as a result of construction activities at the power plant intake, discharge, and breakwater (PG&E 1972). In 1982-83, 214 abalone (112 *H. cracherodii*, 97 *H. rufescens*, four *H. kamtschatkana*, and one *H. walallensis*) were removed from the west breakwater prior to repair of winter storm damage and transplanted to other areas (PG&E 1983). The only adult abalone currently seen in the Diablo Canyon region are *H. cracherodii* and *H. rufescens* (TENERA unpublished data).

Historically, the central coast region of California was the center of a large commercial red abalone fishery (Owen et al. 1971; Gates and Bailey 1982). However, since the mid-1960's abalone stocks have been significantly reduced due to fishing pressure and the re-introduction of sea otters into the area. Commercial landings of red abalone taken from Morro Rock to Avila Beach have declined steadily from 1964 (730,947 pounds) to 1975 (82,486 pounds). At present, no commercial fisheries exist for any abalone species in the region (Gotshall et al. 1979; TERA Corporation 1980).

Continuing studies on local black abalone populations have been conducted at Diablo Canyon since 1976. This work is part of the Thermal Effects Monitoring Program, which has primarily focused on growth, movement, recruitment, and ecology of black abalone. Additional studies of the effects of temperature on early development of black abalone larvae and juveniles as well as other aspects of their early life history were also conducted at DCPP (PG&E 1982).

5.2 Abalone Life History

All species of abalone are dioecious broadcast spawners, undergo seasonal reproductive cycles annually which are preceded by gametogenesis, and spawning events are spontaneous and episodic (McShane 1992). Periodicity and duration of spawning events varies among abalone species (Cox 1962; Shepard and Laws 1974; McShane et al. 1986; Tutshulte and Connell 1981). Black abalone follow an annual cycle of reproduction; spawning occurs during the late summer and fall months and coincides with an increase in water temperature (Cox 1962; Leighton 1974). Red abalone may or may not follow regular patterns of spawning. Boolootian et al. (1962) observed spawning year-round in some populations while other researchers have found that red abalone spawning cycles are similar to that proposed for black abalone; seasonal cycles with spawning related to an increase in water temperature (Cox 1962; Young and DeMartini 1970; Price 1974).

Abalone adults are capable of producing a large quantity of gametes. For example, one 190 mm female was estimated to possess 12,575,000 eggs (Giorgi and DeMartini 1977). Not all eggs may be released at spawning, and an individual abalone might release gametes over an extended period (Tutshulte and Connell 1981, McShane et al. 1988). Egg release by female abalone acts as

a cue for males of the same species to release sperm (Breen and Adkins 1980). Fertilization is external and takes place in the water column.

The ecology and behavior of abalone larvae are not yet fully understood, but progression of the larvae through the early life stages is well established. Fertilized abalone eggs are negatively buoyant and generally hatch within 24 hours following fertilization (Leighton 1974; Mottet 1978). An upward-swimming trochophore larva emerges which then develops into a negatively buoyant veliger larva. Pete Raimondi (University of California, Santa Cruz, personal communication) stated that the trochophore larvae is negatively buoyant and a weak swimmer and on average does not disperse very far from the site of fertilization. The duration of the trochophore stage typically lasts between 24 to 48 hours (Clogston 1965; Leighton 1974). The veliger stage lasts for 5 to 15 days (Leighton 1974; McShane 1992) and is characterized by downward swimming behavior (Thorson 1964, as cited in McShane 1992). During this stage, it has been hypothesized that veliger larvae terminate their swimming behavior when suitable substratum is encountered and that settlement on the proper substratum induces development to the juvenile life-stage (Morse and Morse 1984). Abalone larvae are not strong swimmers and can be treated as passive drifters where any currents exist (McShane 1992). Veligers appear to search for suitable substrata by "hopping" above the bottom and drifting for short distances before resettling (Clogston 1965). Research on red and black abalone indicate that the presence of crustose coralline algae is an important chemical/substratum cue (Morse et al. 1979). The observations of these researchers indicate that dispersal of reproductive products primarily occurs during the planktonic trochophore larvae because veligers effectively "drop out" of the plankton to search for suitable settlement habitat.

Despite the relatively large number of gametes produced by individual abalone, the odds of reaching reproductive maturity are very low; mortality at all early life stages is high with survivorship on the order of < 1% (Haaker et al. 1986; McShane et al. 1988). This type of reproductive strategy is typical of gastropods and other invertebrate groups which produce large numbers of gametes coupled with external fertilization (Barnes 1980). This is also true for other target organisms with stable age distributions since, on average, a female's offspring only needs to replace herself and one male. Planktonic abalone larvae are probably consumed by a variety of organisms including planktivorous zooplankton, ichthyoplankton, and filter-feeding invertebrates such as clams, mussels, anemones and barnacles. Additionally, many planktonic larval stages may never settle and develop into juveniles due to failure to locate suitable substratum (McShane 1992).

5.3 Larval Abalone Identification

Abalone share a morphologically similar trochophore larval stage with many other gastropods. Thus, trochophore larvae are difficult to identify beyond the level of phylum in wild-caught samples. Abalone veligers have a small amount of a greenish-colored nutrient mass in their velum which remains for at least a few months after preservation (Young and DeMartini 1970; Price 1974) which can be used to identify veliger larvae to the genus *Haliotis*. At present, identification of abalone veligers to the species level is not possible.

5.4 Larval Abalone Population Studies -- Historical Perspective

Zooplankton studies previously conducted at Diablo Canyon detected very few abalone larvae. Icanberry and Adams (1974) conducted zooplankton sampling approximately every two weeks from June 1972 to June 1973 to gather baseline data on zooplankton assemblages in the Diablo Canyon region. Once each week, sea water was pumped via a small submersible pump from the "seaward side of the cofferdam that surrounded the cooling water intake structures while under construction" through a 150 μm plankton net (Icanberry and Adams 1974). Each sample consisted of 0.05 m^3 of seawater. Trochophore larvae consisted of a very small percentage of the taxa collected and no abalone veligers were reported. In a later study (Icanberry and Warrick 1978), seasonal trends of zooplankton and phytoplankton densities were assessed using 150 μm mesh nets, 30 cm in diameter. Samples were collected with oblique tows performed twice each week at inshore (300 m from shore) and offshore (1,500 m from shore) stations. A total of 168 plankton tows were conducted; 46 phytoplankton genera and 94 zooplankton taxa were reported. Unidentified trochophore larvae made up 0.2% of the total zooplankton abundance (49.4% occurrence); unidentified veliger larvae were reported as < 0.01% of the total composition (2.4% occurrence).

McShane (1992) states, "studies of coastal hydrodynamics have accentuated the difficulty of finding a small, mobile larval patch by sampling at random. This difficulty, and the fact that larvae are generally released episodically and unpredictably, mean that the probability of finding abalone larvae in the open sea is low." Field surveys for abalone larvae within days of a spawning event (Breen and Adkins 1980; McShane et al. 1988) yielded no larvae; a similar survey by Tomita et al. (1977) yielded only a few veliger larvae. In these efforts, sampling was conducted by either towing plankton nets of 200 μm mesh (Tomita et al. 1977) or by pumping seawater through a 200 μm mesh screen (McShane et al. 1988). Tanaka et al. (1986 as cited in McShane 1992), did find abalone larvae in surface waters, but in most samples none were found. These larvae were supposedly found in "surface waters" (Tanaka et al. 1986 as cited in McShane 1992), but no explanation is given as to the depth in the area. They concluded that eddy formation in the coastal waters probably concentrated the larvae. It is important to note that all of these studies were conducted in and around abalone spawning grounds.

Prince et al. (1987, 1988) conducted field experiments to determine if the present of mature abalone affected the abundance of recruitment of larval abalone. He removed mature *Haliotis rubra* from some subtidal areas in Tasmania, while leaving them in other areas, and then watched for settlement of new abalone. He found that recruitment was highly localized and was greatest in the areas where the adult abalone had not been removed. He concluded that abalone larvae are "strongly benthic with limited patterns of dispersal".

Shepard et al. (1992) working with *Haliotis laevigata* in Australia stated that recruitment was independent of adult densities. He stated that the differences between his and Prince's (1987, 1988) work was probably due to differences in larval behavior of the two abalone species or to water movement differences.

5.5 Justification For Not Sampling Larval Abalone at DCP

An integral part of the 316(b) Demonstration at Diablo Canyon is the determination of target organisms' susceptibility to entrainment as well as the extent to which these organisms are

entrained by the cooling water intake. Abalone are commercially and economically important and a small population of adults reside in the Diablo Canyon region (TENERA unpublished data). However, due to the larval early life history, and since spawning events are highly episodic, occurring over a relatively brief temporal scale (McShane 1992), abalone larvae are at minimal risk for entrainment. As stated above, abalone trochophores are upwardly swimming, but are in the water column only briefly (24-48 hours: Clogston 1965; Leighton 1974). The more extended veliger stage (4-15 days: Leighton 1974; McShane 1992) is characterized by downward swimming behavior (Thorson 1964) with occasional excursions back up into the water column while searching for suitable settlement substrata (Clogston 1965). Risk of entrainment is further reduced by the low numbers of resident adults in the Diablo Canyon region (TENERA unpublished data) and postulated low levels of local larval production. McShane (1992) indicates that directed sampling for abalone larval stages in the field has a very low probability of success. Additionally, the use of 80-105 μm mesh nets to ensure capture of these small life stages and the large volumes of water required to increase the probability of encountering these larvae preclude any reasonable sampling effort due to net clogging. Based on these facts, the ETWG had determined that abalone larvae are at minimal risk of entrainment by the DCPD cooling water intake system and that field studies to assess entrainment impacts are not required for this genus (DCPD ETWG April & May 1997).

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APPENDIX A

Percent composition and density (mean # /m³) of the dominant larval fish species collected in the DCPD study area summarized from ichthyoplankton studies at the Intake Cove and Offshore stations (1974-1975^a from Icanberry *et al.* 1978; 1986-1987^b from TENERA 1988; 1990-91^c from TENERA, unpublished data).

Intake Cove

TAXA	1986-1987 ^b	1990-1991 ^c
Clinidae	17.3 (0.07)	19.4 (0.14)
Cottidae (less <i>S. marmoratus</i>)	35.1 (0.15)	18.3 (0.14)
<i>Sebastes</i> spp.	7.7 (0.03)	17.9 (0.13)
Sciaenidae	5.5 (0.02)	13.2 (0.10)
Stichaeidae	9.3 (0.04)	7.3 (0.05)
Gobiidae	9.8 (0.04)	6.5 (0.05)
Myctophidae	1.0 (0.004)	4.1 (0.03)
<i>Engraulis mordax</i>	2.0 (0.01)	3.3 (0.02)
Pleuronectidae/Bothidae	4.4 (0.02)	2.9 (0.02)
<i>Scorpaenichthys marmoratus</i>	0.5 (0.002)	2.0 (0.01)
Pholididae	1.1 (0.01)	1.3 (0.01)
Others/unknown	7.2	5.3

Offshore

TAXA	1974-75 ^a	1986-1987 ^b	1990-1991 ^c
<i>Sebastes</i> spp.	38.0	21.7 (0.06)	35.3 (0.17)
<i>Engraulis mordax</i>	8.6	7.4 (0.02)	14.5 (0.07)
Sciaenidae	20.4	7.4 (0.02)	13.6 (0.07)
Pleuronectidae/Bothidae	not present	13.8 (0.04)	10.6 (0.05)
Cottidae (less <i>S. marmoratus</i>)	not present	22.0 (0.06)	4.9 (0.02)
Clinidae	not present	3.1 (0.01)	5.2 (0.02)
<i>Scorpaenichthys marmoratus</i>	1.2	1.8 (0.01)	5.5 (0.03)
Stichaeidae	not present	3.4 (0.01)	1.8 (0.01)
Gobiidae	not present	8.4 (0.02)	1.5 (0.01)
Myctophidae	not present	1.1 (0.003)	1.6 (0.01)
Pholididae	not present	0.3 (0.001)	>0.1 (.00)
Blenniodei	17.3	9.9	5.5
<i>Artedius</i> spp.	3.5	not present	not present
<i>Stenobranchius leucopsarus</i>	3.2	not present	not present

APPENDIX B

Taxa / Common Names	Survey																			
	Methods	Start Date	1	2	3	4	5	6	7	8	9	10	10	10	11	12	17	19		
	Number of Samples	Start Date	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	
	Total # of Ind. / Species		10 16	10 17	10 24	10 30	11 6	11 11	11 18	11 25	12 2	12 3	12 3	12 3	12 3	12 16	12 16	12 16	12 16	
<i>Callinectes</i> spp.	1502	0.015	0.028	0.012	0.018	0.018	0.018	0.018	0.014	0.022	0.019	0.012	0.015	0.015	0.062	0.021	0.076	0.105	0.105	
<i>Scorpaenidae</i> spp.	855	0.045	0.045		0.008	0.008	0.008	0.008	0.022	0.016	0.022	0.026	0.026	0.026	0.019	0.079	0.050	0.017	0.017	
<i>Sebastes</i> spp.	307	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.011	0.002	0.012	0.001	0.001	0.001	0.015	0.002	0.004	0.008	0.008	
<i>Sebastes</i> spp.	378																			
<i>Sebastes</i> spp.	284																			
<i>Sebastes</i> spp.	227																			
<i>Sebastes</i> spp.	214																			
<i>Sebastes</i> spp.	207																			
<i>Sebastes</i> spp.	205																			
<i>Sebastes</i> spp.	141																			
<i>Sebastes</i> spp.	127																			
<i>Sebastes</i> spp.	97																			
<i>Sebastes</i> spp.	75																			
<i>Sebastes</i> spp.	73																			
<i>Sebastes</i> spp.	71																			
<i>Sebastes</i> spp.	65																			
<i>Sebastes</i> spp.	47																			
<i>Sebastes</i> spp.	41																			
<i>Sebastes</i> spp.	31																			
<i>Sebastes</i> spp.	25																			
<i>Sebastes</i> spp.	23																			
<i>Sebastes</i> spp.	20																			
<i>Sebastes</i> spp.	16																			
<i>Sebastes</i> spp.	15																			
<i>Sebastes</i> spp.	12																			
<i>Sebastes</i> spp.	9																			
<i>Sebastes</i> spp.	9																			
<i>Sebastes</i> spp.	9																			
<i>Sebastes</i> spp.	7																			
<i>Sebastes</i> spp.	6																			
<i>Sebastes</i> spp.	5																			

Table continued

APPENDIX C

Total count and mean number per cubic meter of larval fish taxa from 64 paired samples of 335 μm and 505 μm mesh nets collected December 3-4, 1996.

Family / Taxa / Common Name			505 μm MESH		335 μm MESH	
			Count	Mean Density/ m^3	Count	Mean Density/ m^3
Atherinidae						
Atherinidae unid.	silversides	1	>.001			
Clinidae						
<i>Gibbonsia</i> spp.	clinid kelpfishes	123	.042	120	.045	
<i>Heterostichus rostratus</i>	giant kelpfish	3	.001	6	.002	
Cottidae						
<i>Artedius lateralis</i>	smoothhead sculpin	3	.001	1	>.001	
Cottidae unid.	sculpins	11	.004	5	.002	
<i>Leptocottus armatus</i>	staghorn sculpin	1	>.001	1	>.001	
<i>Oligocottus snyderi</i>	fluffy sculpin	40	.014	20	.008	
<i>Orthonopias triacis</i>	snubnose sculpin	3	.001	4	.002	
<i>Scorpaenichthys marmoratus</i>	cabezon	78	.026	71	.026	
Engraulidae						
<i>Engraulis mordax</i>	northern anchovy	4	.001	3	.001	
Gobiidae						
<i>Acanthogobius flavimanus</i>	yellowfin goby			1	>.001	
<i>Clevelandia ios</i>	arrow goby	2	.001			
<i>Coryphopterus nicholsii</i>	blackeye goby			2	.001	
Gobiidae unid.	gobies			1	>.001	
<i>Lepidogobius lepidus</i>	bay goby	3	.001	2	.001	
<i>Typhlogobius californiensis</i>	blind goby			1	>.001	
Hexagrammidae						
<i>Oxylebius pictus</i>	painted greenling	2	.001	4	.002	
Myctophidae						
<i>Stenobranchius leucopsarus</i>	northern lampfish	5	.002	9	.003	
Pleuronectiformes						
Pleuronectidae unid.	flatfishes	1	>.001	5	.002	
Paralichthyidae						
<i>Citharichthys</i> spp.	sanddabs	1	>.001	1	>.001	
<i>Paralichthys californicus</i>	California halibut	1	>.001			
Sciaenidae						
<i>Genyonemus lineatus</i>	white croaker	3	.001			
larval fish fragment		5	.002	1	>.001	
larval/post-larval fish, unid.		2	.001			
TOTAL COUNT:			292		258	
TOTAL MEAN DENSITY/m^3:				.098	.096	

Appendix C

DCPP 316(b) Study: Phase 3-Sampling Plan and Modelling Evaluation.

Diablo Canyon Power Plant
316(b) Study

**Phase 3 — Sampling Plan
and Modelling Evaluation**

November 23, 1998

Prepared for:
Pacific Gas and Electric Company
77 Beale Street
San Francisco, CA 94105

TENERA Project Manager:
Chris Ehrlar



TENERA Environmental
Services

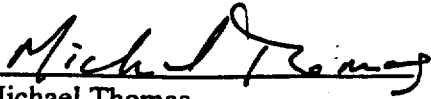
One Market, Spear Tower, Suite 1850, San Francisco, CA 94105
(415) 536-4744, FAX (415) 536-4714

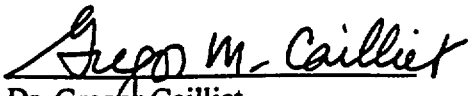
P.O. Box 400, Avila Beach, California 93424
(805) 595-2407, FAX: (805) 595-2106

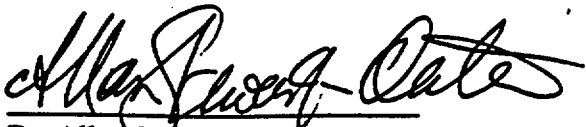
From: RWQCB Multiagency Workgroup
Technical Subgroup for Entrainment

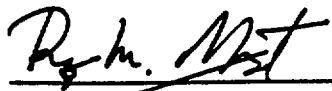
RE: DIABLO CANYON POWER PLANT 316(B) STUDY; PHASE 3—SAMPLING PLAN AND
MODELLING EVALUATION


We, the members of the Diablo Canyon, Entrainment Technical Working Group, have reviewed and commented on the above-referenced report. Our signatures below signify that our concerns relative to the report have been addressed and the report presents a reasonable scientific approach to the study.

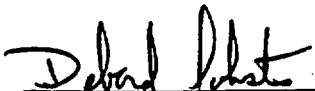

Michael Thomas
Central Coast Regional Water Quality Control Board

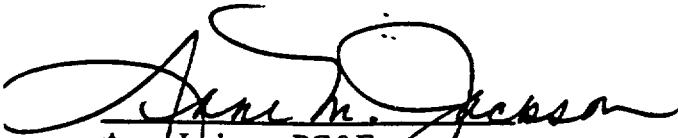

Dr. Gregg Cailliet
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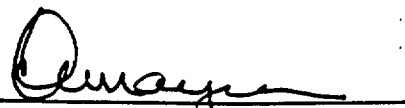

Dr. Dave Mayer, TENERA

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1.0 INTRODUCTION TO SAMPLING PLAN AND MODELLING EVALUATION

The purpose of this report is to evaluate three biological resource assessment methods that will be used to determine the effects of entrainment caused by the Diablo Canyon Power Plant (DCPP) intake system. Models and approaches, such as those described in this report, have been employed to estimate intake effects and to assess impacts at other power plants (e.g.: Horst, 1975; Boreman et al., 1978, 1981; Goodyear, 1978; Parker and DeMartini, 1989; Summers, 1989; Cowan et al., 1993; VanWinkle et al., 1993; Saila et al., 1997). As advised in the USEPA (1977) draft document entitled *Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) Public Law 92-500*,

“...The overall goal of conducting intake studies [316(b) demonstration studies] should be to obtain sufficient information on environmental impact to aid in determining whether the technology selected by the company is the best available to minimize adverse environmental impact. In the case of existing plants, this goal will be accomplished by providing reliable quantitative estimates of the damage that is or may be occurring and projecting the long-range effect of such damage to the extent reasonably possible.”

Information from one or more of the approaches evaluated in this report will, in conjunction with other sources of resource management and ecological information, provide an assessment of adverse environmental impact.

1.1 Entrainment Technical Work Group

The Central Coast Regional Water Quality Control Board (RWQCB) assembled a team of experts to assist the Board's staff in their review of the design and implementation of the 316(b) intake studies at DCPP. This team, the Entrainment Technical Work Group (ETWG), meets periodically to discuss topics relevant to ongoing efforts at DCPP to assess entrainment effects. The ETWG has approved a design for the DCPP 316(b) study focusing on entrained larvae of fishes, *Cancer* spp. crabs, and metamorphosing and juvenile *Strongylocentrotus* spp. sea urchins. The plan calls for the identification to the lowest possible taxonomic level and enumeration of specimens in these larval groups. All of the data collected from sampling activities in this study and concerning the above larval groups will be included in the final report. Results of earlier studies on larval fishes at DCPP (Icanberry et al., 1978; Tenera, Inc., 1988, 1997a) combined with the ongoing DCPP entrainment sampling, have been used to create a preliminary list of potential target fish taxa (Tenera, Inc., 1997b). While sample collection to estimate entrainment effects cannot be focused on any particular taxon, the final assessment of entrainment impact will be conducted on taxa from the groups listed above. These taxa will be chosen by the ETWG based on criteria agreed to and described by Tenera, Inc. (1997b) including the statistical qualities of the data and the availability of suitable life-history information to meet model requirements.

1.2 Study Plan Rationale

Considerable effort among regulatory agencies and the scientific community has been expended on the evaluation of power plant intake effects over the past two decades. These efforts have helped to establish the context for the modelling approaches proposed to estimate entrainment effects at DCPP. The variety

of approaches developed reflects the many differences in power plant locations and resource settings. MacCall et al. (1983), in their review of the various approaches, divided them into those that offer a judgment on the presence or absence of impact and those that describe the sensitivity of populations to varying operational conditions. MacCall, along with other resource and regulatory representatives, fishery scientists, biostatisticians, and ecologists, discussed these views and other methodological details of impact assessment approaches commonly employed in fisheries resource management in a colloquium held at the Romberg Tiburon Research Center in 1996 to specifically consider and recommend a DCP 316(b) study rationale. Results of the colloquium, as well as the refinement work of the ETWG, have helped to shape the approach of the DCP 316(b) study and guide its implementation. Background, experience, and findings in related 316(b) studies that formed the context for the colloquium, established the basis for discussions with the ETWG, and have ultimately focused field and laboratory efforts that are briefly summarized below.

Discussions on impact assessment approaches were initially focused by a proposal to employ an approach termed “proportional entrainment” (*PE*); alternative approaches also were presented. The colloquium concluded with a consensus that using more than one model would yield the most convincing interpretation of intake effects. Specifically, three approaches were proposed and discussed: (1) a proportional entrainment (*PE*) approach similar to that described by MacCall et al. (1983), used by Parker and DeMartini (1989), and described by Dave Mayer, Tenera, Inc. (Appendix A); (2) an adult-equivalent loss approach (Horst, 1975; Goodyear, 1978); and, (3) a fecundity hindcasting (*FH*) approach proposed by Alec MacCall, NOAA/NMFS, which also is related to the adult-equivalent loss approach. These approaches can be placed under the umbrella of two general models: the empirical transport model (*ETM*; Boreman et al., 1978) that requires *PE* as an input; and the equivalent adult model (*EAM*; Horst, 1975; Goodyear, 1978) including adult equivalent loss (*AEL*) and fecundity-hindcasting (i.e., the demographic approaches). The *PE* can also be interpreted as “conditional fishing mortality” as defined by Ricker (1975).

Early forms of adult/recruitment relationships and discrete-time-modelling for populations has evolved to more complex present-day forms of individual-based modelling. For example, large-scale research efforts have been expended on striped bass, *Morone saxatilis* (Cowan et al., 1993; Van Winkle et al., 1993). The resulting models are species- and site-specific, incorporating precise descriptions of life-histories, growth, survivorship, as well as ecological, water quality, and trophic conditions. Such detailed information is not available for species potentially impacted by DCP. Therefore, a more empirically based modelling approach is proposed for this 316(b) study.

The first step in estimating the effects of entrainment losses in the DCP intake structure is to estimate the densities of organisms being entrained. The methods for achieving these estimates have been described in detail in the two previous Phase 1 reports: *Diablo Canyon Power Plant 316(b) Demonstration Study: Phase 1-Entrainment Study Design, Part I-Sampling Location* (Tenera, Inc., 1997a); *Diablo Canyon Power Plant 316(b) Demonstration Study: Phase 1-Entrainment Study Design, Part II- Selection of Target Organisms, Sampling Methods, and Gear Testing* (Tenera, Inc., 1997b). Briefly, entrainment density is estimated from bongo-net plankton samples collected at stations positioned directly in front of the DCP intake structure. These density estimates represent the “damage that is or may be occurring” (USEPA, 1977) as the result of DCP’s cooling water intake. The second step in this process is to place these data in a context that allows “projecting the long range effects” (i.e., the impact assessment; USEPA, 1977).

The physical characteristics of DCP’s location differ from those of previous studies at other power plants (e.g., San Onofre, CA; Salem, NJ) and will require the application of several methods for

estimating impacts which have not been applied on open coasts, including *PE*. The application of several models to estimate power plant effects is not unique (Murdoch et al., 1989; PSE&G, 1993). Adult-equivalent loss is an accepted method that has been applied in other 316(b) demonstrations (PSE&G, 1993) and will be applied at DCPD as well; the *FH* proposed in this document is analogous to *AEL*. The advantage of these latter two approaches is that they translate larval losses into adult fishes which are familiar units to fishery managers. However, without fishery data or some other basis for comparison (e.g., "a geographically well-defined population"; Saila et al., 1997), the relative value of the adults lost to the resource will be difficult to ascertain. Because the life histories of potentially affected species vary, boundaries of the population(s) affected by DCPD cooling water intake must be determined through discussions with the ETWG and other fishery and resource managers. Diablo Canyon Power Plant is located on a rocky coastline exposed to dynamic hydrographic conditions without obvious oceanographic boundaries, such as those defined at San Onofre (i.e., the Southern California Bight; Murdoch et al., 1989). While the *PE* method can be expanded upon, it may be employed to avoid this potential difficulty by estimating a relative loss of individuals in a defined area (e.g., the study grid proposed for the *PE* sampling below). Estimating *PE* also presents the advantage of comparing larvae directly to larvae without the mortality estimates needed to convert larval losses to equivalent adults and yields a direct estimate of conditional mortality on the taxa affected by entrainment.

An important issue that will arise when "estimating long range effects" is density-dependence (sometimes called compensation) of the vital rates of impacted organisms. Density-dependence is not confined to acting through mortality; growth and fecundity may also be density-dependent. Some entrainment studies have assumed that compensation is not acting between entrainment and the time when adult recruitment would have taken place, and further, that this specific assumption resulted in conservative estimates of projected adult losses (Saila et al., 1997). Others, such as Parker and DeMartini (1989), did not include compensatory mortality in estimates of equivalent adult losses, because of a lack of consensus on how to include it in the models and, more importantly, uncertainty about how compensation would operate on the populations under study. The uncertainty arises because the effect of compensation on the ultimate number of adults is directly related to which of the vital processes (fecundity, somatic growth, mortality) and which life stages are being affected. In particular, Nisbet et al. (1996) showed that neglecting compensation does not always lead to conservative long-term estimates of equivalent adult losses.

2.0 METHODS FOR ESTIMATING EFFECTS

The location, description, and justification for the sampling design to estimate entrainment losses at DCPD (Figure 2-1) is detailed in a previous technical report (Tenera, Inc., 1997a). The following sections describe how to estimate the effects of these entrainment losses by estimating proportional losses to a defined study area (*PE*) or through the use of demographic modelling (*AEL* and *FH*). Estimating *PE* requires an additional level of field sampling which is also detailed below.

2.1 Proportional Entrainment Sampling Design

2.1.1 Study Design

A preliminary study grid was designed to provide information on the abundance and distribution of planktonic organisms in the vicinity of Diablo Canyon and to estimate *PE* for those larvae entrained from the grid. As described by Tenera, Inc. (1997b), impacts will ultimately be assessed for taxa chosen by the ETWG from groups of larval fishes, *Cancer* spp. crabs, and metamorphosing and juvenile sea urchins (*Strongylocentrotus* spp.). The information from the two months of survey data presented in this report will be used to assess the effectiveness of the sampling design for providing estimates of target organism densities in the study grid and the usefulness of the estimates when combined with larval entrainment to assess DCPD effects.

Data provided by the sampling program will be used to estimate an index of entrainment loss (*PE*). This index is the ratio between the number of larvae entrained and the number estimated in the study grid. The number of larvae entrained will be estimated from sampling at the DCPD intake structure (Tenera, Inc., 1997a, b). The number of larvae in the source water will be estimated from plankton surveys conducted in the study grid (Figure 2-2) that is a defined portion of the source water.

2.1.2 Selection of Study Grid

Initial efforts to design a study to estimate *PE* centered on defining the boundaries of the study grid. The boundaries and shape of the study grid were chosen based on the following criteria:

- 1) The grid would be large enough to characterize the larvae from the target groups (larval fishes, *Cancer* spp. crabs, metamorphosing and juvenile *Strongylocentrotus* spp. sea urchins) that are potentially influenced by DCPD's cooling water intake operations;
- 2) The grid would include a representative variety of local nearshore habitats.

Assuming zero current flux in the study grid adjacent to DCPD, the daily intake of cooling water by the power plant is ca. 0.6% of the volume contained in the study grid. This value is based on the power plant's normal estimated daily intake volume compared to the volume of water in the study grid region of the source water body. The study area volume was determined from volumetric calculation using 11,426 depth measurements in the study grid found in the National Ocean Service Hydrographic database (formerly the U.S. Coast and Geodetic Survey; Figure 2-3). Based on these measurements, the volume of the study grid was calculated by multiplying its mean depth by its surface area.

Based on these criteria and on gear limitations (cable length vs. depth), Point Buchon, a prominent rocky headland at the northwest corner of the selected study area, was selected as the northern extent of the

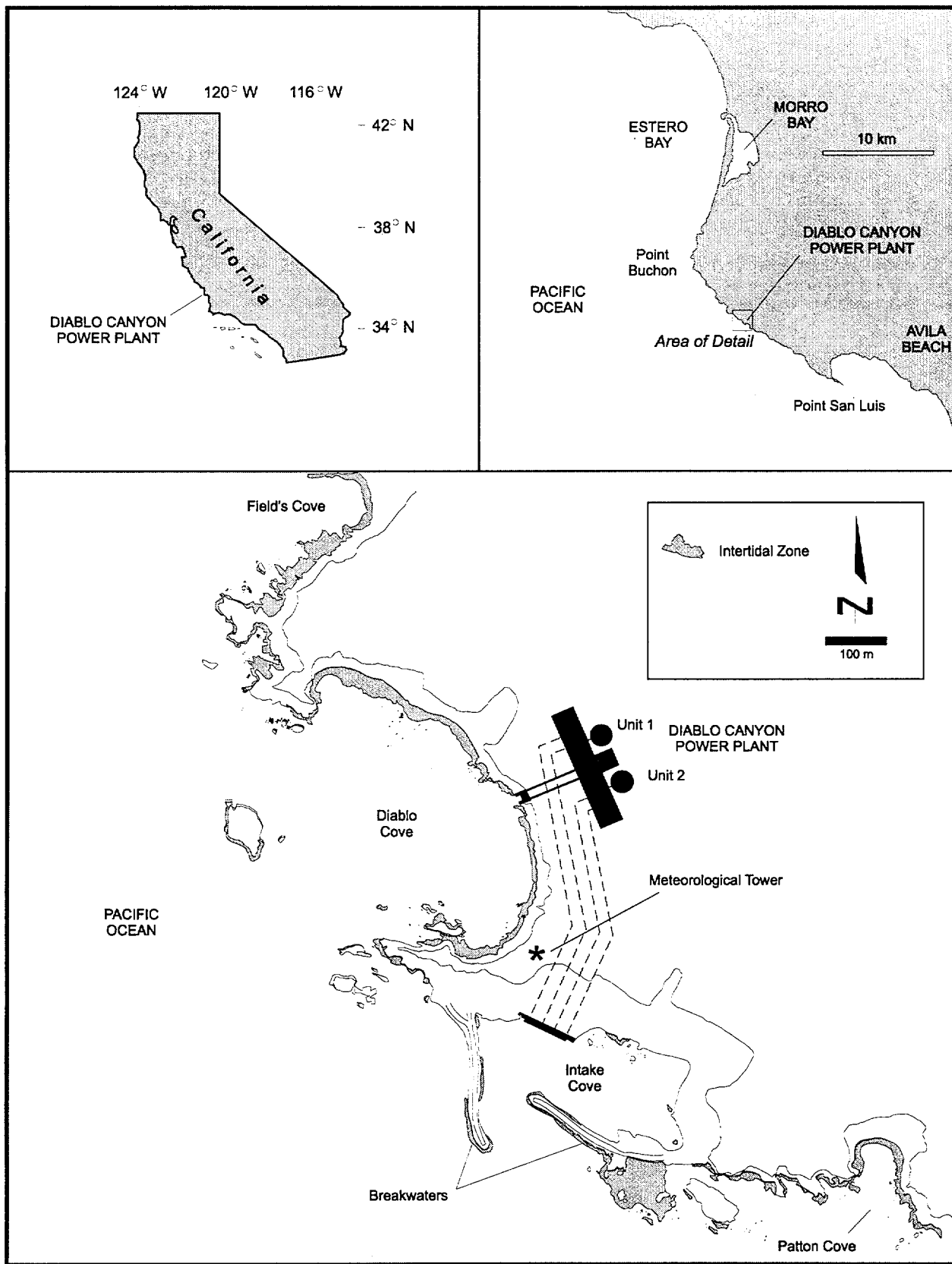


Figure 2-1. Location map of Diablo Canyon Power Plant.

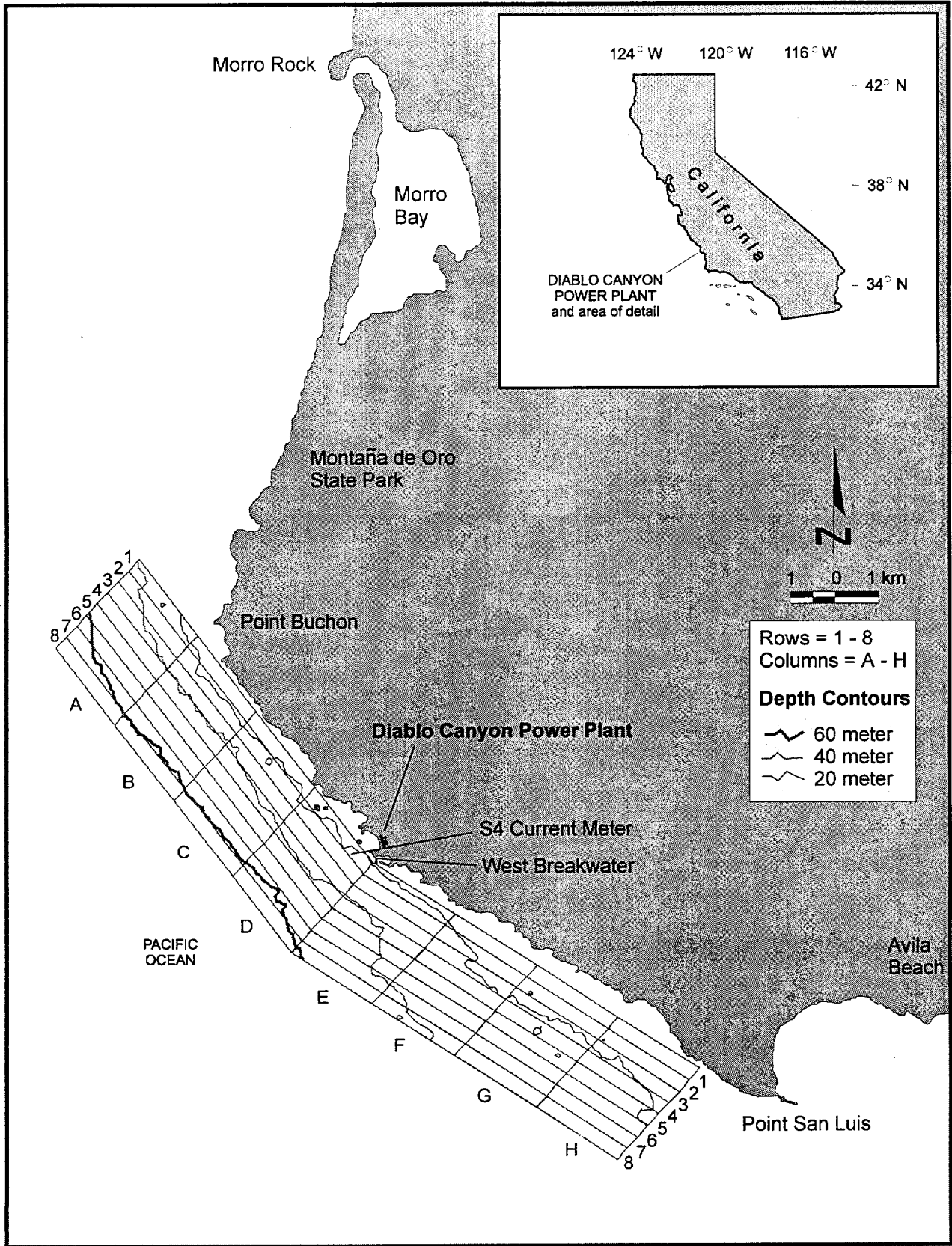


Figure 2-2. Diablo Canyon Power Plant 316(b) study design grid.

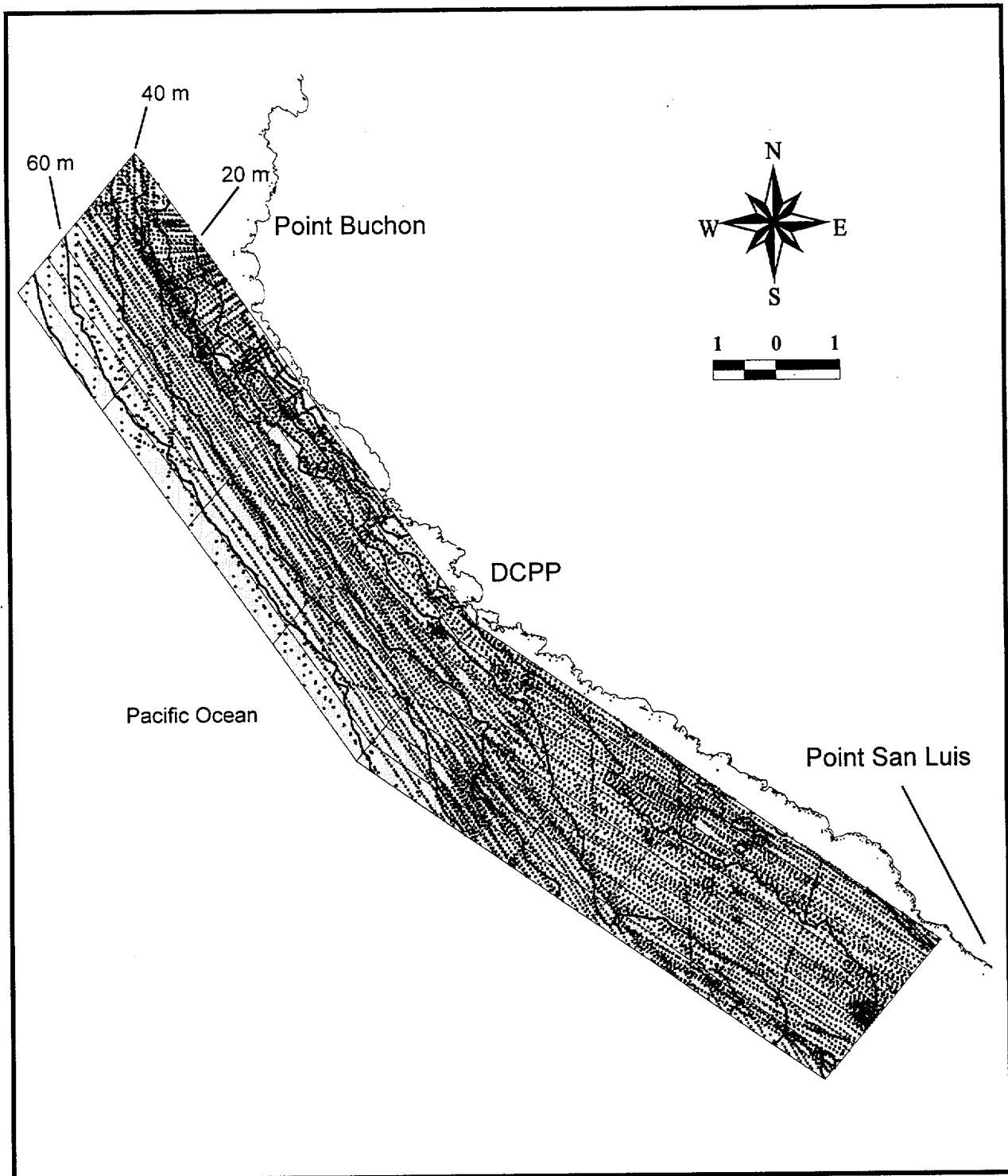


Figure 2-3. Position of depth measurements ($n=11,426$) used to calculate the volume of the study grid for comparison to DCP cooling water withdrawal rate which represents ca. 0.6% of the total grid volume daily.

study grid (see Figure 2-2). Additionally, centering the grid on the Intake Cove where entrainment sampling occurs provides a clear geographic link between the Intake Cove and the local area. The southern half of the grid was designed as a mirror image of the northern half. The selection of the study grid was further justified by the fact that ocean currents in the area generally move both up and down coast of DCPD although inshore/offshore oscillations also occur less frequently. Another consideration when selecting the area in which to place the study grid was the possibility that data collected from this region could define taxon-specific zones of entrainment risk in the DCPD vicinity by comparing species composition from grid cells with that at the entrainment sampling location. The coastline between Point Buchon and Point San Luis makes a slight bend (approximately 10°) at DCPD. Thus, the inner grid lines were drawn tangentially along the coastline from the West Breakwater running approximately ESE and NW to a distance of 8.8 km from DCPD. Regions located inshore of the inner grid dimensions were considered unsafe for boat operations, were not included within the study grid, and will not be sampled.

The stratification selected for the design of the study grid was an eight cell by eight cell (8x8) grid. This design was selected for two reasons. First, the symmetrical number of cells in the grid does not assume an *a priori* bias toward a particular axis of variation (up/down coast or inshore/offshore). Second, the number of samples that can be collected in the arbitrarily selected time frame for a single survey (72 hrs) with some level of replication for estimation of error, was a 64-cell stratified random sampling program employing two randomly positioned sampling stations within each grid cell. This number was also based on the logistics of lab processing, sorting, and identification of the target organisms given the time frame for completion of this study.

One of the primary goals of this report is to demonstrate that the selected study grid size, location, and proposed sampling frequency are appropriate to deliver reliable estimates of larval abundance from the study area that will be useful for estimating entrainment effects. Examination of the preliminary results of completed grid surveys indicates that the distributions of some taxa appear to be largely contained within the grid while others may be distributed beyond its boundaries. This illustrates the point that evaluations of entrainment effects must be conducted on a taxon-by-taxon basis and then discussed by the ETWG. Furthermore, the apparent compromise of the grid sampling between favoring taxa with distributions inside or beyond the grid is acceptable for a study which is targeting a planktonic assemblage and not individual species. Examination of preliminary weekly entrainment densities (Appendix B) has led to the conclusion that sampling the study grid monthly is an appropriate frequency to capture a majority of the peaks in larval fish abundance. Preliminary estimates of abundance from the study grid vary seasonally, but do not appear to demonstrate any significant sampling bias which could be corrected using different sampling methods. Alternative locations to the existing entrainment sampling site have been explored in Tenera, Inc. (1997a).

2.1.3 Study Grid Sampling

Two randomly positioned stations within each of the 64 cells of the 8x8 grid were sampled using a bongo frame with 0.71 m diameter net openings (McGowan and Brown, 1966) and standard California Cooperative Oceanic Fisheries Investigations (CalCOFI; Smith and Richardson, 1977) length (3.3 m) nets made from 335 µm white mesh. The study grid was sampled continuously over 72 hours using a "ping-pong" transect to limit temporal and spatial biases in the sampling pattern and to optimize shipboard time (Figure 2-4). Station locations were randomly positioned for each monthly survey based on latitude/longitude coordinates displayed on a Global Positioning System (GPS) plotter. The starting cell, constrained to the 28 cells on the perimeter of the grid, and initial direction of the transect, constrained to the two adjacent diagonals, was selected using a random-number generator. When the adjacent diagonal cell had previously been sampled (e.g., cell D1 in Figure 2-4) one of the two adjacent

H	G	F	E	D	C	B	A
8	8	8	8	8	8	8	8
7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6
5	5	5	5	5	5	5	5
4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1

DCPP
INTAKE Cove

Figure 2-4. An example of the “ping-pong” sampling track employed in grid cell sampling; the starting cell (F1) and the initial southward direction of the transect were randomly selected. All 64 cells are sampled during the 72-hour survey period, weather permitting. DCP’s Intake Cove is located east of the juncture between cells E1 and D1.

cells in the direction of travel (E1 or E3) was randomly selected to be sampled next. Nets were fished in an oblique fashion following CalCOFI protocol (Smith and Richardson, 1977). The sampling depth was limited to within 3 m of the bottom depth to avoid damage or loss of sampling equipment and for safe operation of the vessel. One bongo net sub-sample was fixed in 5% buffered-formalin and seawater for abundance and composition analyses and the second sub-sample was fixed in ca. 80% ethanol (ETOH) to be archived for future use in possible larval fish age and growth analyses. To minimize temporal variation between entrainment and study grid sampling, grid surveys were scheduled to bracket the 24-hour entrainment survey, overlapping by one day before and after the collection of entrainment samples. The paired sampling from July 1997 reported in this document (Section 3) was an exception to this design; entrainment sampling occurred during the first 24 hours of the 72-hour grid survey.

Ichthyoplankton are vertically and horizontally distributed in the water column (Ahlstrom, 1959; Brewer et al., 1981) seasonally (Bailey et al., 1977; Boehlert et al., 1985), diurnally (Babcock and Merrett, 1976), and on the basis of behavior (Ellertsen et al., 1977). Boehlert et al. (1985) reported limited evidence for diurnal migration of *Psettichthys melanostictus* to surface waters and migration of *Gadus macrocephalus* larvae to deeper waters at night. Thus, the effects of larval activity on vertical distribution may not be the same among different taxa. Fortier and Leggett (1983) demonstrated that in estuarine environments larval fishes are subjected to varying levels of transport as a result of their vertical migration patterns. These vertical distributions will have an unmeasured effect on abundance estimates from oblique plankton tows. Furthermore, because safety concerns prohibit sampling closer than 3 m to the bottom, larvae in this depth stratum will not be collected in the present design. This differs from the entrainment sampling where the net consistently samples within ca. 0.3 m of the bottom (Tenera, Inc., 1997b). The effect of this disparity in near-bottom-sampling between the two locations is unmeasured. However, there are two factors that lead to an assumption that the effect is negligible. The first is that the water entering the DCP intake structure appears to be well-mixed during most of the year (Tenera, Inc., 1997b). The second is that pelagic, deep water, and vertically migrating larval fish taxa collected in the study grid are also represented in the entrainment samples (e.g., myctophids, stomiiformes, argentinids, phosichthyids, bathylagids, melamphaeids, sternoptychidae; Tenera, Inc., 1998).

2.2 Estimating DCP Entrainment Effects

The entrainment and grid sampling outlined here and in Tenera, Inc. (1997a, b) will provide an estimate of total larval entrainment for a taxon, as well as an estimate of proportional entrainment. The estimate of entrainment loss, in conjunction with demographic data collected from ongoing literature searches, will permit modelling of equivalent adult losses (*AEL*) and fecundity hindcasts (*FH*). Estimates of proportional entrainment in conjunction with these demographic approaches will be used to estimate entrainment effects on groups of organisms described previously (i.e., larval fishes, crabs and urchins; Tenera, Inc., 1997a). Considering the guidelines established in the EPA draft document (USEPA 1977) and given the constraints of the data and available demography for the larvae entrained, the ETWG will determine which taxa within these groups will be included in more detailed analyses of entrainment effects when sufficient data have been collected. The data requirements, assumptions, outputs, advantages, and disadvantages of these approaches are summarized in Tables 2-1 and 2-2. In the DCP 316(b) study, we will use each approach as appropriate for each taxon to assess effects of entrainment losses.

2.2.1 Proportional Entrainment (*PE*)

The *PE* approach yields an estimate of incremental (conditional; Ricker, 1975) mortality imposed by DCP on local (study grid) larval populations by using empirical data (plankton samples) rather than relying solely on hydrodynamic calculations. Consequently, *PE* requires an additional level of field sampling to characterize abundance and composition of larvae using the study grid defined in this document (Figure 2-2). These estimates of species-specific entrainment from the study grid can then be expanded to predict regional effects on appropriate adult populations. The ability to expand *PE* estimates to varying spatial scales of inference could be aided by additional hydrographic characterization of the study grid. Data describing local current patterns are being collected to aid the ETWG in potentially defining areas of larval origin (i.e., areas of adult reproductive activity) and areas 'downstream' that may be affected by power plant withdrawals. Furthermore, estimates of larval ages, combined with length data that are presently being collected, could be combined with current speed and direction to indicate how far a larva might have traveled before being entrained, thus defining the boundaries of potential source (adult) populations. The plankton sampling in the study grid which is required to estimate *PE* provides another, complementary approach to the others presented here which is the description of the distribution and abundance of larvae adjacent to DCP; patterns in entrainment abundance can be interpreted within the context of the biology and distribution of the taxa entrained. Required parameters for the *PE* approach include the rate of cooling water withdrawal, estimates of entrainment density, and estimates of the density of organisms in the study grid.

The use of *PE* as an input to the empirical transport model (*ETM*) has been proposed by the U.S. Fish and Wildlife Service to estimate mortality rates resulting from cooling water withdrawals at power plants (Boreman et al., 1978) and subsequently in Boreman et al. (1981). Variations of this model have been discussed in MacCall et al. (1983) and used to assess impacts (Parker and DeMartini, 1989). The *ETM* has been used to assess impacts at the Salem Nuclear Generating Station in Delaware Bay, New Jersey (PSE&G, 1993) as well as other power stations along the East Coast. Empirical transport modelling permits the estimation of annual conditional mortality due to entrainment while accounting for the spatial

Table 2-1. Data requirements and outputs for three approaches proposed to estimate effects of cooling water withdrawals at DCCP.

Approach	Data Required	Assumptions	Output
Proportional Entrainment (<i>PE</i>)	<ul style="list-style-type: none"> • Taxon-specific estimates of entrainment losses. • Comparable life-stage estimates of taxon's abundance (density) in study grid. 	<ul style="list-style-type: none"> • Grid samples are representative of the composition and abundance of larvae in the study area. • Entrainment samples are representative of the organisms entrained in the cooling water. 	<ul style="list-style-type: none"> • Estimated fraction of larval density removed from the study grid by entrainment.
Adult Equivalent Loss (<i>DEL</i>)	<ul style="list-style-type: none"> • Taxon-specific estimates of entrainment and impingement losses¹. • Age-specific mortality schedules for selected taxa from entrainment-impingement to some predetermined life stage (e.g., recruitment). • Fishery resource abundance estimates for relative impact assessments. 	<ul style="list-style-type: none"> • Age-specific mortality rates are constant for the population. • Population at long-term equilibrium for relative impact assessments (not required for calculations). • Entrainment samples are representative of the organisms entrained in the cooling water. 	<ul style="list-style-type: none"> • Number of animals that would have survived to adulthood had they not been entrained and/or impinged by the intake.
Fecundity Hindcast (<i>FH</i>)	<ul style="list-style-type: none"> • Taxon-specific estimates of entrainment and impingement losses¹. • Species- and age-specific adult fecundity. • Age-specific mortality schedules for selected taxa from parturition/hatch to entrainment/impingement. 	<ul style="list-style-type: none"> • Age-specific mortality and fecundity rates are constant for the population. • Population at long-term equilibrium for relative impact assessments, but not required for calculations. • Entrainment samples are representative of the organisms entrained in the cooling water. 	<ul style="list-style-type: none"> • Number of sexually mature females represented by the losses of reproductive output due to entrainment and/or impingement¹.

1. Review and discussion of impingement at DCCP are presented in Appendix F.

Table 2-2. Advantages and disadvantages of the three approaches proposed to estimate effects in the DCP 316(b) assessment.

Approach	Advantages	Disadvantages
Proportional Entrainment (PE)	<ul style="list-style-type: none"> • Empirical estimate of PE compares larvae entrained to larvae in the study grid. • Age- and species-specific survivorship data not required. 	<ul style="list-style-type: none"> • Shoreline taxa (e.g., <i>Gibbonsia</i> spp.) not adequately sampled in present design. • Local adult population sizes not well described by fishery catch data which can be for mixed species (e.g., <i>Sebastes</i> spp.). • Scaling intake effects up to population level impacts will be problematic.
Adult Equivalent Loss (AEL)	<ul style="list-style-type: none"> • Entrainment/impingement losses are expressed as adults facilitating the interpretation of population-level impacts. • Common usage in 316(b) studies. 	<ul style="list-style-type: none"> • Difficult to interpret for entrained organisms in broad taxonomic categories (e.g., <i>Sebastes</i> spp.) containing multiple life-histories. • Age- and species-specific mortality data are little known or unavailable for many organisms that are entrained/impinged by the intake. • Local adult population sizes not well described by fishery catch data which can be for mixed species (e.g., <i>Sebastes</i> spp.). • Scaling intake effects up to population level impacts will be problematic.
Fecundity Hindcast (FH)	<ul style="list-style-type: none"> • Entrainment/impingement losses are expressed as adults facilitating the interpretation of population-level impacts. 	<ul style="list-style-type: none"> • Age- and species-specific mortality data are little known or unavailable for many organisms that are entrained/impinged by the intake. • Local adult population sizes not well described by fishery catch data which can be for mixed species (e.g., <i>Sebastes</i> spp.). • Scaling intake effects up to population level impacts will be problematic. • Age- and species-specific fecundity data have not been previously reported for many organisms that are entrained/impinged by intake.

and temporal variability in distribution and vulnerability of each life stage to power plant withdrawals. The generalized form of the *ETM* incorporates many time-, space-, and age-specific estimates of mortality as well as information regarding spawning periodicity and duration, most of which are limited or unknown for the marine taxa being investigated at DCP. The applicability of the *ETM* (Boreman et al. 1978) to the present study at DCP will be limited by a lack of either empirically derived or reported demographic parameters needed as input to the model. However, the concept of summarizing *PE* over time that originated with the *ETM* can be used to estimate entrainment effects over appropriate temporal scales either by modelling or making assumptions about species-specific life histories. We will employ a *PE* approach that is similar to the method described by MacCall et al. (1983) and used by Parker and DeMartini (1989), while under contract to the Marine Review Committee (MRC), in their final report to the California Coastal Commission (Murdoch et al., 1989) for San Onofre Nuclear Generating Station (SONGS) on the coast of southern California. This estimate can then be summarized over appropriate blocks of time in a manner similar to that of the *ETM* (Appendix A).

For the examples of *PE* calculation and use given here, density rankings were used as a criterion for choosing larvae used in the estimates (Appendix C). In general, all length classes of larvae collected in these two surveys were used to calculate *PE*. In certain cases this may not always be possible (e.g., when a particular developmental stage is collected from the survey grid but is not entrained). Thus, data are screened to ensure that fishes of similar developmental stages, assumed to be at similar risks to entrainment and having undergone similar mortality, are compared to estimate entrainment effects. There are four developmental stages which we can identify: yolk-sac; pre-flexion; flexion; and post-flexion (Moser et al., 1996). If developmental stages that are present in the study grid and not in the entrainment samples are included in *PE* estimates, then *PE* will underestimate entrainment effects. In another scenario, larvae could be entrained that are not available in the study grid and this would require some interpretation based on the biology or developmental stages of the entrained larvae. Overall, knowledge of the proportions of different developmental stages represented in samples from both locations will be valuable when interpreting taxon-specific entrainment effects.

2.2.2 Calculation and Interpretation of Proportional Entrainment

The general equation for proportional entrainment is as follows:

$$\hat{P}E = \frac{\hat{N}}{\hat{R}} \quad (1)$$

where, \hat{N} (estimated number of larvae entrained per day)

= (estimated number of entrained larvae) • (design-specified daily cooling water intake at DCP);

\hat{R} (estimated number of larvae in the study grid during the same day);

= $\sum_{n=1}^{64}$ [(estimated average density of larvae per cell) • (cell volume)];

n = number of grid cells (see Appendix A).

The estimate of proportional entrainment during the i th survey (i.e., $\hat{P}E_i$) approximates the conditional probability of entrainment. Proportional entrainment defined in this way characterizes the end effect of a number of rate processes operating over a day; it can thus legitimately be interpreted either as an approximation to an instantaneous rate, or as a probability. Formally, the choice of interpretation has implications for estimation. For example, the probability interpretation requires careful accounting of movement of individuals in and out of the study area, while the rate interpretation does not. There was

considerable difference of opinion among members of the ETWG as to the more appropriate interpretation; however given the large size of the study grid, these different approaches to interpretation are unlikely to be important in practice. The only exception is the investigation in Section 3.2 of the effects of varying the number of grid cells used in the calculation where the results for the smallest number of cells may be affected.

The purpose of the entrainment study is not to only estimate the effects within the study grid, but also to attempt to extrapolate those effects to a population of inference. The population of inference (i.e., the population affected by entrainment losses) will be determined by the ETWG using the data collected at DCP. For some species, the number of larvae within the study grid may represent the population of inference. For other species, the population of inference may be smaller or larger than that estimated from the study grid. Let P_S equal the proportion of the population of inference represented by the number of larvae at risk in the study grid; then the probability of a larva being entrained from the population of inference per day is the product

$$P\hat{E}_i \cdot P_S$$

The proportion of larvae that escape entrainment during the D_i days ($i=1\dots K$) of the i th survey period is then

$$(1 - P\hat{E}_i \cdot P_S)^{D_i}$$

Over the course of K survey periods, the population-wide proportional entrainment estimate ($P\hat{P}E$) is

$$P\hat{P}E = 1 - \prod_{i=1}^K (1 - P\hat{E}_i \cdot P_S)^{D_i} \quad (2)$$

This estimate of the population-wide probability of entrainment is the essence of the *ETM* approach of MacCall et al. (1983). If this population is stable and stationary, then $P\hat{P}E$ is also an indicator of the effects on fully recruited age classes when uncompensated natural mortality is assumed. The scope of the affected population will be defined by the ETWG for each taxon of interest. The boundaries of the population affected by entrainment could vary from local (e.g., subset of study grid or total study grid) to regional (e.g., fishery management units, zoogeographic range). Note that in the case where the boundaries of effects correspond to the study grid boundaries, $P_S = 1$.

During the impact assessment phase, entrainment mortality may be estimated for several geographic scales, representing local as well as regional aspects of each taxon's distribution and abundance. These different scales would be characterized by different values of P_S . Values of P_S may be obtained from data on the zoogeography and distribution of the species over its range and/or habitat. A geographic perspective may provide the best estimates of P_S because while abundance may vary widely over time, the fraction of the population at risk of entrainment within the study grid may be relatively stable. On the other hand, determining values of P_S may be easier than estimating the abundance of adults (\hat{P}) and/or collecting survivorship data (i.e., S) because \hat{P} may be more temporally variable than P_S .

Initially, there were two methods proposed for estimating PE ; a volume-based and a flux-based approach. After analyses and discussion of these preliminary results, the ETWG decided during the May 1, 1998 meeting that it was not feasible at the present time to estimate PE using a flux-based

approach. Although the ETWG agreed that this latter approach will not be pursued at this time, they stipulated that it could be discussed again if the data warrant.

2.2.3 Evaluation of Proportional Entrainment Approach

The relationship between expected *PE* based on cooling water intake volumes and empirically measured *PE* was analyzed for the data from these two surveys. Based on withdrawal and grid volumes and on the assumption of passively drifting larval fishes that are uniformly distributed, *PE* expected based on volume alone for the entire 64-cell study grid is 0.57%. By calculating *PE* based on sequentially varying combinations of grid cells and volumes in the study grid, it can be shown that *PE* varies with selected grid size relative to that expected based on passive transport alone. The numbers of cells included in the calculation were varied using two methods (Figure 2-5): a) The study grid was expanded outward concentrically starting with the two cells directly in front of the power plant, and eventually including all 64 cells; and b) The study grid was expanded outward row by row starting with the row of cells closest to shore, and then adding another row expanding the grid by 8 cells with each iteration.

If larvae were passive drifters uniformly distributed in the water column, then *PE* could be expected to parallel cooling water intake volumes. However, this is unrealistic since larvae have patchy spatial distributions and are temporally variable in both diversity and abundance. Therefore, the approach we are proposing uses a ratio between empirical estimates of entrainment and study grid larval abundance to calculate *PE*. Using *PE* as one estimate for assessing DCPD entrainment losses is based on several advantages of the approach. These include its acceptance among regulatory and resource agencies as input to the *ETM* (Boreman et al., 1978, 1981) and the fact that it can be spatially expanded to account for the fraction of the larvae outside of the study grid, if known, to predict resource-level impacts (i.e., fractional losses). A third advantage of the approach, when combined in an *ETM* format, is that it enables the user to combine estimates of the probability of entrainment across larval season and developmental stages to produce appropriate temporal scale estimates (e.g., annual or monthly) of conditional entrainment mortality for each target taxa.

The results for the *PE* calculations present the number of cells included in each calculation and the pattern in which cells were added. The measured *PE* will be greater than the expected (volume only) value if more larvae are entrained than expected based on a uniformly distributed population, and passive, non-selective entrainment. For example, the *PE* for a species with a predominately nearshore larval distribution will be greater than expected if it is calculated using the furthest row of cells offshore.

2.2.4 Demographic Approaches

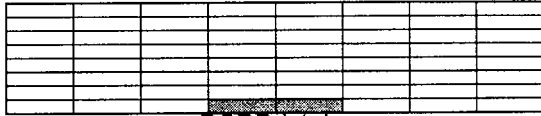
Equivalent adult loss models evolved from impact assessments which compared power plant losses to commercial fisheries harvests and/or estimates of the abundance of adults. In the case of adult fishes impinged by intake screens, the comparison was relatively straightforward. To compare the numbers of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

Demographic approaches, exemplified by the *EAM*, produce an absolute measure of loss beginning with simple numerical inventories of entrained or impinged individuals and increasing in complexity when the inventory results are extrapolated to estimate numbers of adult fishes or biomass. By ignoring compensation in our example calculations of *AEL* and *FH* we do not assume that the results lead to

Figure 2-5. Two patterns of grid-cell combinations for the comparison between measured *PE* and that expected by hydrodynamic principles alone.

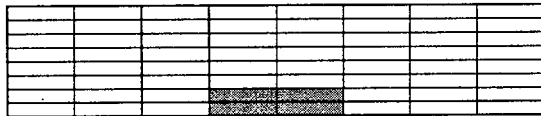
a) Expanded outward from the intake concentrically by cell.

n=2



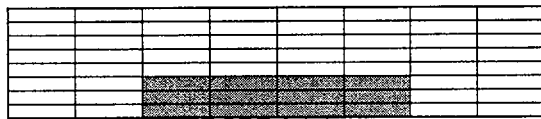
DCPP Intake

n=4



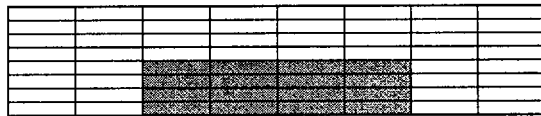
DCPP Intake

n=12



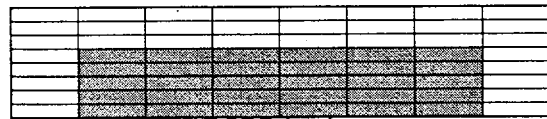
DCPP Intake

n=16



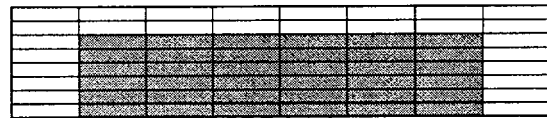
DCPP Intake

n=30



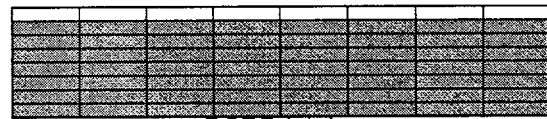
DCPP Intake

n=36



DCPP Intake

n=56



DCPP Intake

n=64



DCPP Intake

b) Expanded outward from the shore by row.

n=8



DCPP Intake

n=16



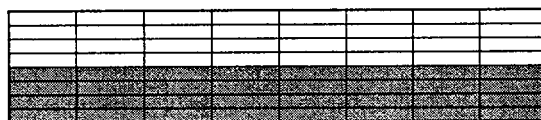
DCPP Intake

n=24



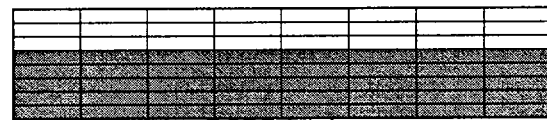
DCPP Intake

n=32



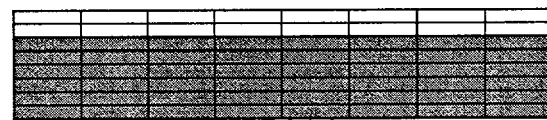
DCPP Intake

n=40



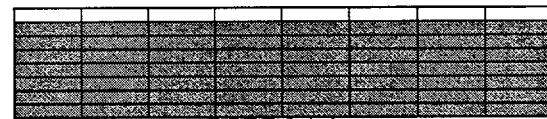
DCPP Intake

n=48



DCPP Intake

n=56



DCPP Intake

n=64



DCPP Intake

conservative estimates of entrainment effects since it is not known which vital rates (e.g., mortality, natality) undergo compensation as the result of these losses. We discuss the use of two approaches in this category to determine entrainment effects at DCP: *AEL*, which expresses effects as absolute losses of number of adults; and, *FH*, which estimates the number of adult females whose reproductive output has been eliminated by entrainment of larvae.

Age-specific survival and fecundity rates are required for *AEL* and *FH*. These can be calculated fairly simply by assuming a constant survivorship rate (MacCall et al., 1983). Adult-equivalent loss estimates require survivorship estimates from the age at entrainment to adult recruitment; *FH* requires egg and larval survivorship estimates until entrainment. Furthermore, to make estimation practical, the affected population is assumed to be stable and stationary and age-specific survival and fecundity rates are assumed to be constant over time. Each of these approaches provide estimates of adult fishes lost which may still need to be placed in a framework of some larger scale of inference (e.g., Saila et al.'s (1997) "well-defined geographic population"). Deliberations defining the area(s) affected for each taxa will be undertaken by the ETWG once the entrainment effects have been estimated.

Species-specific survivorship information (e.g., age-specific mortality) from egg and/or larvae to adulthood is limited for many of the taxa likely to be considered in this assessment. Thus, in many cases, these rates must be inferred from the literature along with their measures of uncertainty. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large should be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., the northern anchovy, *Engraulis mordax*), portions of their early mortality schedules and fecundity have been reported (e.g., Parker, 1980; Zweifel and Smith, 1981; Hewitt, 1982; Hewitt and Methot, 1982; Hewitt and Brewer, 1983; Lo 1983, 1985, 1986; McGurk, 1986). Since the accuracy of estimated entrainment effects from *AEL* and *FH* will depend on the accuracy of age-specific mortality and fecundity estimates, lack of validated ages for the taxa under study may limit the utility of these approaches.

The data for the monkeyface eel (*Cebidichthys violaceus*) was used to illustrate calculation of both the *AEL* and *FH* approaches (see Section 3.3). This species is collected at DCP and has a typical amount of life-history information available from the literature. Since there are gaps in the available demography, estimates of survivorship published for northern anchovy (*Engraulis mordax*) the larvae of which are also collected at DCP, have been substituted for the missing monkeyface eel values. Therefore, the results of these calculations are heuristic and are not accurate estimates of *AEL* or *FH* for either of these two species. However, using both species illustrates two types of scenarios for the amounts of life-history information available; monkeyface eel with many gaps in its demography and the case of a well-described early life history for northern anchovy.

The reproductive and early life-histories of these two species are very different. The monkeyface eel spawns a demersal, adhesive egg batch annually (Baxter, 1974) which is attached to a rock and guarded until hatching; fecundity ranges from 6,000 eggs (Fitch and Lavenberg, 1971) to 46,000 eggs (Love, 1991). Northern anchovy females are broadcast spawners capable of producing multiple egg batches per year (Starr et al., 1998) with fecundity values on the order of 20,000-30,000 annually (Baxter, 1967). Monkeyface eel larvae are relatively well developed upon hatching with functional eyes, mouths, and gills; northern anchovy larvae do not have functional eyes, mouths, or gills upon hatching. Their hatch sizes are also different. Monkeyface eel presumably hatch at a size of 5-6 mm notochord length (NL; near the smallest size observed in our study) and northern anchovy hatch at 2.5-3.0 mm (Moser et al., 1996). Love (1991) reports a longevity for monkeyface eel of at least 18 years with maturation occurring at 4-7 years of age; Fitch and Lavenberg (1971) give maturation as 3-4 years of age. Northern anchovy

can live to 7 years, but commonly die between 4-5 years of age (Love, 1991); about 50% are sexually mature by 2 years of age (Clark and Phillips, 1952; Leet et al., 1992). Thus, the eggs and larvae of these two species likely experience very different levels of mortality.

Precursors to the calculation of *AEL* and *FH* below are the estimation of total larval entrainment (\hat{E}_T) and, in the case of *AEL*, of survivorship from entrainment to adulthood. Total larval entrainment was estimated following the formula:

$$\hat{E}_T = \sum_{i=1}^L \hat{E}_i d_i \quad ; \quad (3)$$

where, \hat{E}_i = estimated daily entrainment for the i th time stratum ($i=1, \dots, L$);
 d_i = number of days in the i th time stratum ($i=1, \dots, L$).

The standard error of the estimate is calculated according to the formula

$$\hat{V}ar(\hat{E}_T) = \sum_{i=1}^L \hat{V}ar(\hat{E}_i) d_i^2 \quad . \quad (4)$$

Differences in the number of days between sampling periods (in the i th stratum) result primarily from bad weather delaying sampling operations. No reported survivorship estimates have been found in the literature for the monkeyface eel. So purely for the purposes of illustration, published survivorship data on the northern anchovy (*Engraulis mordax*) will be used as an alternative to species-specific data. Lo (1986) reported egg survival probabilities and daily instantaneous mortality rates for the years 1980-1983 (Table 2-3). Subsequent calculations will use average values from Lo (1986) to approximate survival for larvae to the time of entrainment at DCP. Life-history comparisons suggest these northern anchovy data will overestimate egg and early larval mortality rates for monkeyface eel. Survivorship from entrainment to adulthood (S_A) was estimated from the formula for total survivorship below

$$S_T = (\text{egg survival}) \cdot (\text{larval survival to entrainment}) \cdot (\text{survival to recruitment}) = S_E \cdot S_L \cdot S_A$$

by substituting northern anchovy data for egg and early larval survivorship as described above and from total survivorship estimated from age-specific fecundity, age at maturity, and longevity of *C. violaceus* reported in the literature (Love, 1991).

Thus, estimation of *FH* is formulated as

$$\hat{F}H = \frac{\hat{E}_T}{\hat{S}_E \cdot \hat{S}_L \cdot \hat{F}_T} \quad . \quad (5)$$

Standard errors can be calculated for these estimates following the delta method (Seber, 1984) detailed in Appendix C.

2.2.5 Adult-Equivalent Loss (AEL)

The *AEL* approach uses estimates of the abundance of entrained or impinged organisms to project the loss of equivalent numbers of adults based on mortality schedules and age at recruitment. The primary

advantage of this approach is that it translates power plant-induced early life-stage mortality into numbers of adult fishes which are familiar units to resource managers. Adult equivalent loss does not require source water estimates of larval abundance in addition to entrainment estimates, as required in

Table 2-3. Survival probabilities for northern anchovy from Lo (1986). Alternatively, McGurk (1986) reports a 20-day survival rate of 0.0128 with no standard error.

Year	Egg Survival (S_E)	20-Day Larval Survival (S_L)
1980	0.3396	0.0882
1981	0.4867	0.1618
1982	0.4867	0.1026
1983	0.3829	0.0091
Mean	0.4240	0.0904
SE	0.0373	0.0314

PE. This latter advantage may be offset by the need to gather age-specific mortality rates to predict adult losses and the need for information on the adult population of interest for estimating population-level effects (i.e., fractional losses). However, the need for age-specific mortality estimates can be reduced by various forms of approximation as shown by Saila et al. (1997). They describe an *AEL* and apply it to six years of entrainment and two years of impingement data for winter flounder (*Pleuronectes americanus*), red hake (*Urophycis chuss*), and pollock (*Pollachius virens*) at the Seabrook Station, in New Hampshire and contrast these with equivalent adult losses of winter flounder at Pilgrim Station, another coastal power plant. Their model assumes an adult population at equilibrium, a stable age distribution, a constant male:female ratio, and an absence of density-dependent (i.e., compensatory) mortality between entrainment and recruitment to the adults.

2.2.6 Calculation of Adult-Equivalent Loss

Starting with the number of age class i larvae entrained (\hat{E}_i), it is conceptually easy to convert their numbers to an equivalent number of adults lost ($A\hat{E}L$) at some specified age class from the formula:

$$A\hat{E}L = \sum_{i=1}^n \hat{E}_i S_i \quad (6)$$

where,

n = number of age classes;

\hat{E}_i = estimated number of larvae lost in age class i ; and

S_i = survival rate for the i th age class to adult (Goodyear, 1978).

Age-specific survival rates from larval stage to recruitment into the fishery must be included in this assessment method. For some commercial species, natural survival rates are known after the fish recruit into the commercial fishery. For the earlier years of development, this information is not well known and may be lacking for non-commercial species.

An alternative expression of adult-equivalent loss would be to standardize $A\hat{E}L$ by the size of the adult population of interest to estimate the relative magnitude of the equivalent adult loss such that,

$$RA\hat{E}L = \frac{A\hat{E}L}{\hat{P}} \quad (7)$$

where \hat{P} = estimated size of the adult population of interest. There may be limitations in available information on the number of adults and the ultimate value of $RA\hat{E}L$ is highly dependent on the size of the population of interest. It may be preferable to calculate $RA\hat{E}L$ for a range representing local and regional populations.

2.2.7 Fecundity Hindcasting (FH)

The *FH* approach compares larval entrainment losses with adult fecundity to estimate the amount of adult female reproductive output eliminated by entrainment and thereby hindcasts the numbers of adult females effectively removed from the reproductively active population. The accuracy of these estimates of effects, as with those of *AEL* above, are dependent upon accurate estimates of age-specific mortality from the egg and early larval stages to entrainment. If it can be assumed that the adult population has been stable at some current level of exploitation and that the male:female ratio is constant and 50:50, then fecundity and mortality are integrated into an estimate of loss by converting entrained larvae back into females (i.e., hindcasting). For the purpose of the resource assessment, if DCP-induced entrainment losses are to be equated to population level units in terms of fractional losses, it is still necessary to estimate the size of the population of interest.

A potential advantage of *FH* is that survivorship need only be estimated for a relatively short period of the larval stage (i.e., egg to larvae). As with *AEL*, this method does not require sampling in addition to that needed to estimate larval entrainment density, but does require age-specific mortality rates and fecundities to estimate entrainment effects and some knowledge of the abundance of adults to assess the fractional losses these effects represent. This method assumes that the loss of a single female's reproductive potential is equivalent to the loss of adults which may be inaccurate.

2.2.8 Calculation of Fecundity Hindcasting

In the *FH* approach the total amount of larval entrainment for a species (\hat{E}) will be projected backward to estimate the number of breeding females required to provide the numbers of larvae seen in the entrainment samples. The estimated number of breeding females ($\hat{F}H$) whose fecundity is equal to the total loss of entrained larvae would be calculated as follows:

$$\hat{F}H = \frac{1}{\hat{F}_T} \sum_{j=1}^w \frac{\hat{E}_j}{S_j} \quad (8)$$

where, w = number of weeks the larvae are vulnerable to entrainment;

\hat{E}_j = estimated total entrainment for the j th week ($j = 1, \dots, w$);

S_j = survival rate from eggs to larvae of the stage present in the j th week ($j = 1, \dots, w$);

\hat{F}_T = average total life time fecundity for females, equivalent to the average number of eggs spawned per female over their reproductive years.

Equation (8) is based on the simplified case of a single synchronized spawning by a species. For species with overlapping or continuous spawning, larval abundance would have to be specified by week and age class (i.e., \hat{E}_{ji}).

The two key input parameters in equation (8) are average fecundity (\hat{F}_T) and very early survival rates (S_j) from spawning to week j of the survey. Descriptions of these parameters may be limited for many species and are a possible limitation of the method.

The estimation of the number of equivalent losses in the fecundity of \hat{FH} females of the adult population may be unsatisfactory because the relative magnitude of the effect is still unknown. For this reason, \hat{FH} may be best interpreted as a measure of the relative loss in fecundity ($R\hat{FH}$) by taking the ratio

$$R\hat{FH} = \frac{\hat{FH}}{\hat{P}_F} \quad (9)$$

where \hat{P}_F = an estimate of the abundance of breeding adult females in the area of interest. Here the fecundity hindcasting estimate ($R\hat{FH}$) is the proportion of the breeding adults whose fecundity was lost due to entrainment by DCP.

Although the estimator $R\hat{FH}$ is perhaps more meaningful and interpretable than estimates of absolute loss in fecundity (\hat{FH}), it suffers from the additional need for more specific information. First, the estimator is highly dependent upon how the population of inference is defined. The larger the spatial expanse of the breeding population, the larger the value of \hat{P}_F , (e.g., near field, fish management zone or species range). Second, accurate estimates of adult abundance will be rare, adding to the difficulties in estimating $R\hat{FH}$.

3.0 PRELIMINARY RESULTS AND DISCUSSION

3.1 Study Grid

3.1.1 Sampling

Two paired study grid and entrainment surveys were processed and the results presented in the following section. The two grid sampling surveys were conducted July 21-24, 1997 and August 25-28, 1997 and will be compared to entrainment sampling on July 21-22, 1997 and August 26-27, 1997, respectively. It should be noted that these two study periods coincide with an oceanic period that is typically the lowest in larval fish abundance and diversity (Moser et al., 1996), but it was necessary to use these data to design the sampling program and initiate the study in a timely manner.

Varying atmospheric and oceanographic conditions between the two survey periods may partly account for the low similarity in taxonomic composition between surveys; current direction demonstrated the greatest change between survey periods (Table 3-1). During the second survey period, increased mixing

Table 3-1. Atmospheric and oceanographic conditions during July and August survey periods.

Physical Variable	Survey Date	
	July 21-24, 1997	August 25-28, 1997
Current speed (cm/sec)	~9	~12
direction (degrees magnetic)	297	59
Wind speed (knots)	5-20	5-25
direction	variable	variable
Water temperature (°C)	~14	~15

of coastal waters may also have affected larval distribution and abundance. Given the prevailing wind, little or no upwelling would be expected under these conditions. Note that current speed, direction, and water temperature are average values over the survey periods.

Based on seawater temperatures collected from 64 separate conductivity-temperature-depth (CTD) recorder casts within the study grid during the July survey, a distinct thermocline was visible between the surface waters and a depth of 10 meters. During the August survey, however, the shallow thermocline was not readily visible based on similar temperature measurements.

3.1.2 Results

Three general patterns of larval distribution in the study grid were observed among the following taxa. Monkeyface eel (*Cebidichthys violaceus*; Figure 3-1), the clinid kelpfishes (*Gibbonsia* spp.; Figure 3-2), and the painted greenling (*Oxylebius pictus*; Figure 3-3) have inshore distributions. Distribution of the larvae of the cottids (*Orthonopias triacis*, the snubnose sculpin; Figure 3-4 and *Artedius lateralis*, the smoothhead sculpin; Figure 3-5) appears to track the 20 m and 40 m isobaths. The larvae of three taxa were more broadly distributed over the survey grid: blackeye goby, *Coryphopterus nicholsi* (Figure 3-6); snailfishes, *Liparis* spp. (Figure 3-7); and the sanddabs, *Citharichthys* spp. (Figure 3-8). Observed larval distributions reflect, in varying degrees, the distributions of the adults of these taxa. Abundance of all taxa except painted greenling were lower in the second survey (Appendix C).

monkeyface eel (*Cebidichthys violaceus*)

a) July 1997

b) August 1997

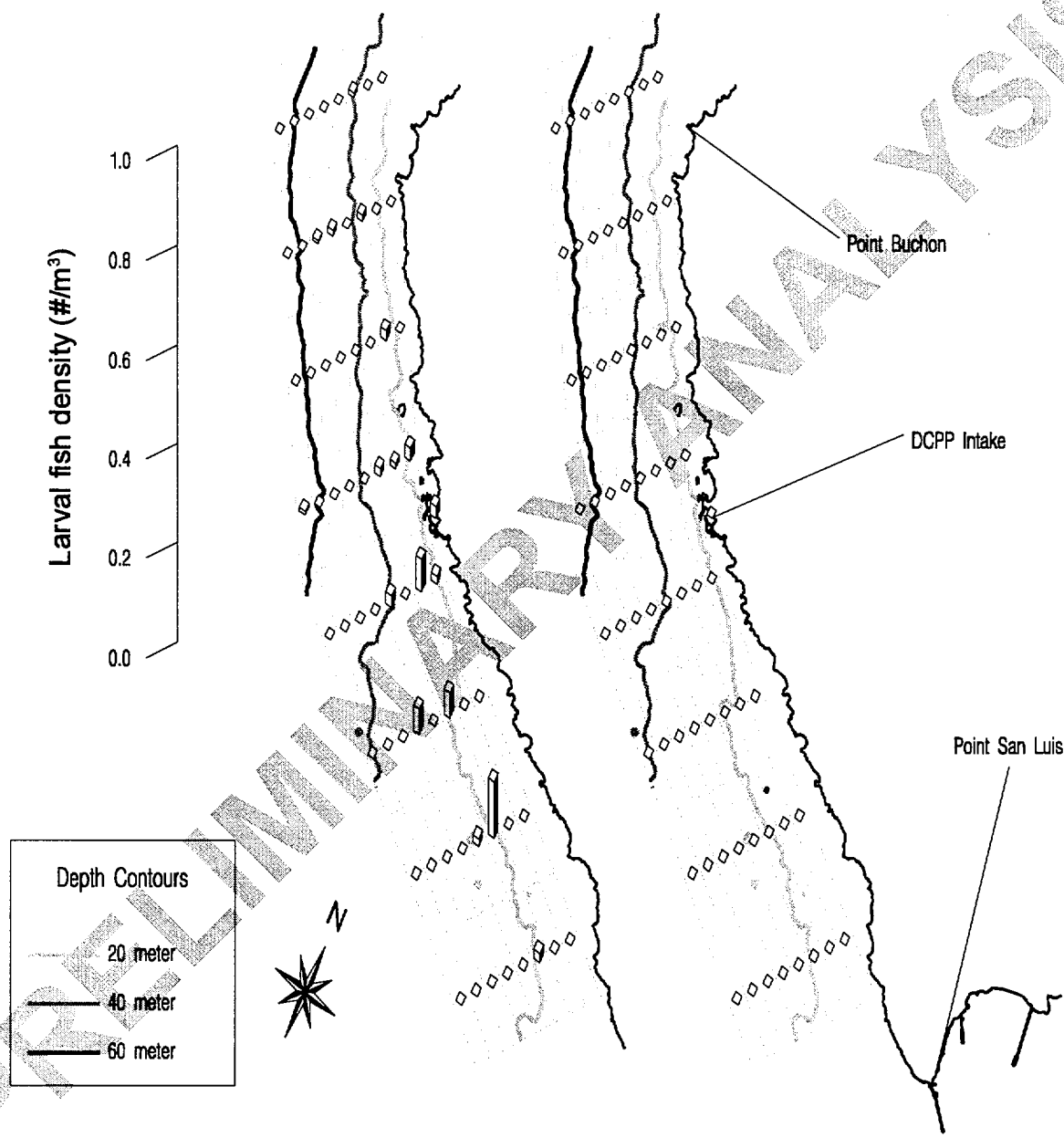


Figure 3-1. Vertical bars represent the mean density of monkeyface eel (*Cebidichthys violaceus*) across the study grid: a) Survey 02, July 21-24, 1997; b) Survey 03, August 25-28, 1997. NOTE: Data are preliminary and not intended for use in any context other than this report.

clinid kelpfishes (*Gibbonsia* spp.)

a) July 1997

b) August 1997

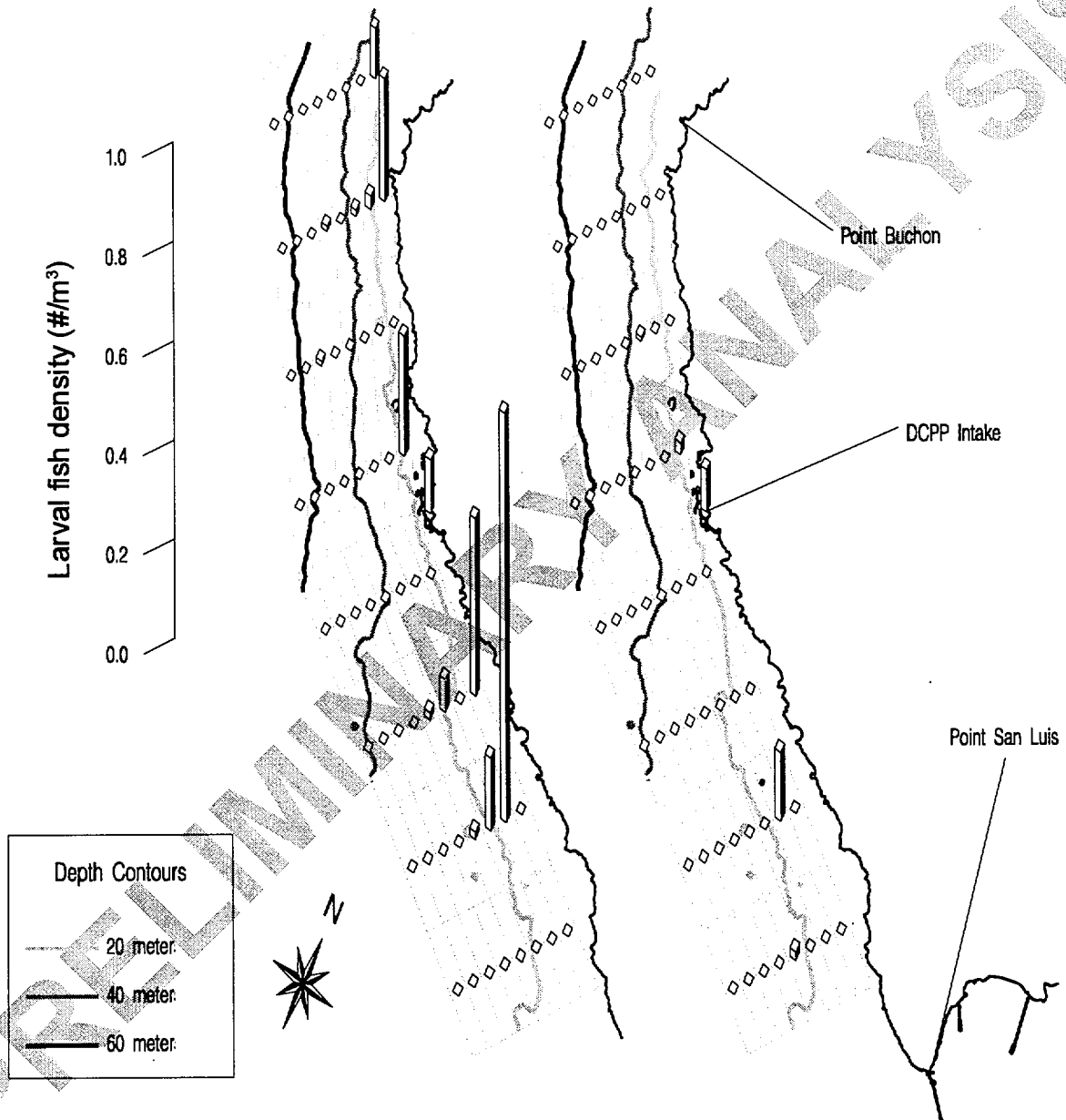


Figure 3-2. Vertical bars represent the mean density of clinid kelpfishes (*Gibbonsia* spp.) across the study grid: a) Survey 02, July 21-24, 1997; b) Survey 03, August 25-28, 1997. NOTE: Data are preliminary and not intended for use in any context other than this report.

painted greenling (*Oxylebius pictus*)

a) July 1997

b) August 1997

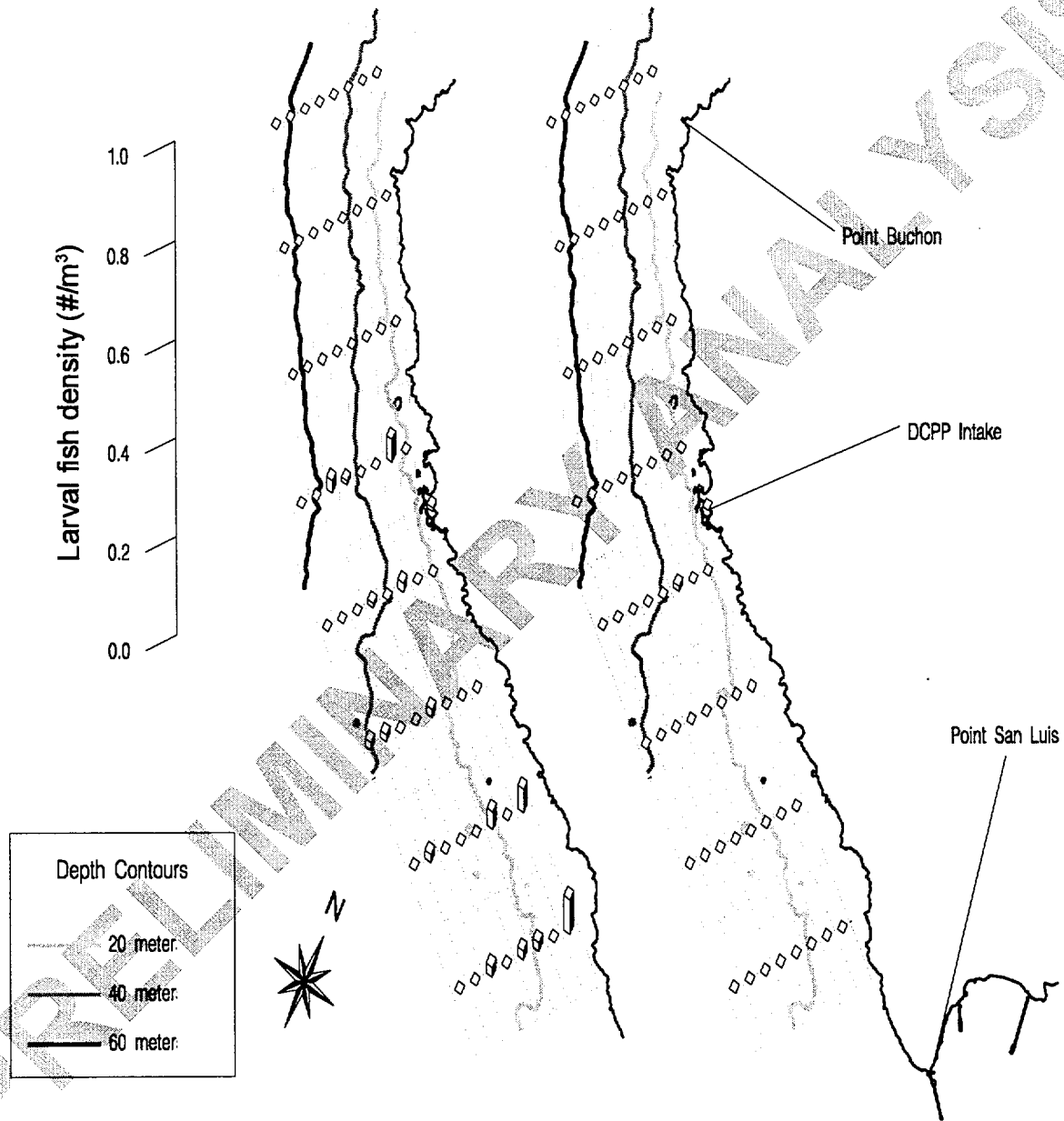


Figure 3-3. Vertical bars represent the mean density of painted greenling (*Oxylebius pictus*) across the study grid: a) Survey 02, July 21-24, 1997; b) Survey 03, August 25-28, 1997. NOTE: Data are preliminary and not intended for use in any context other than this report.

snubnose sculpin (*Orthonopias triacis*)

a) July 1997

b) August 1997

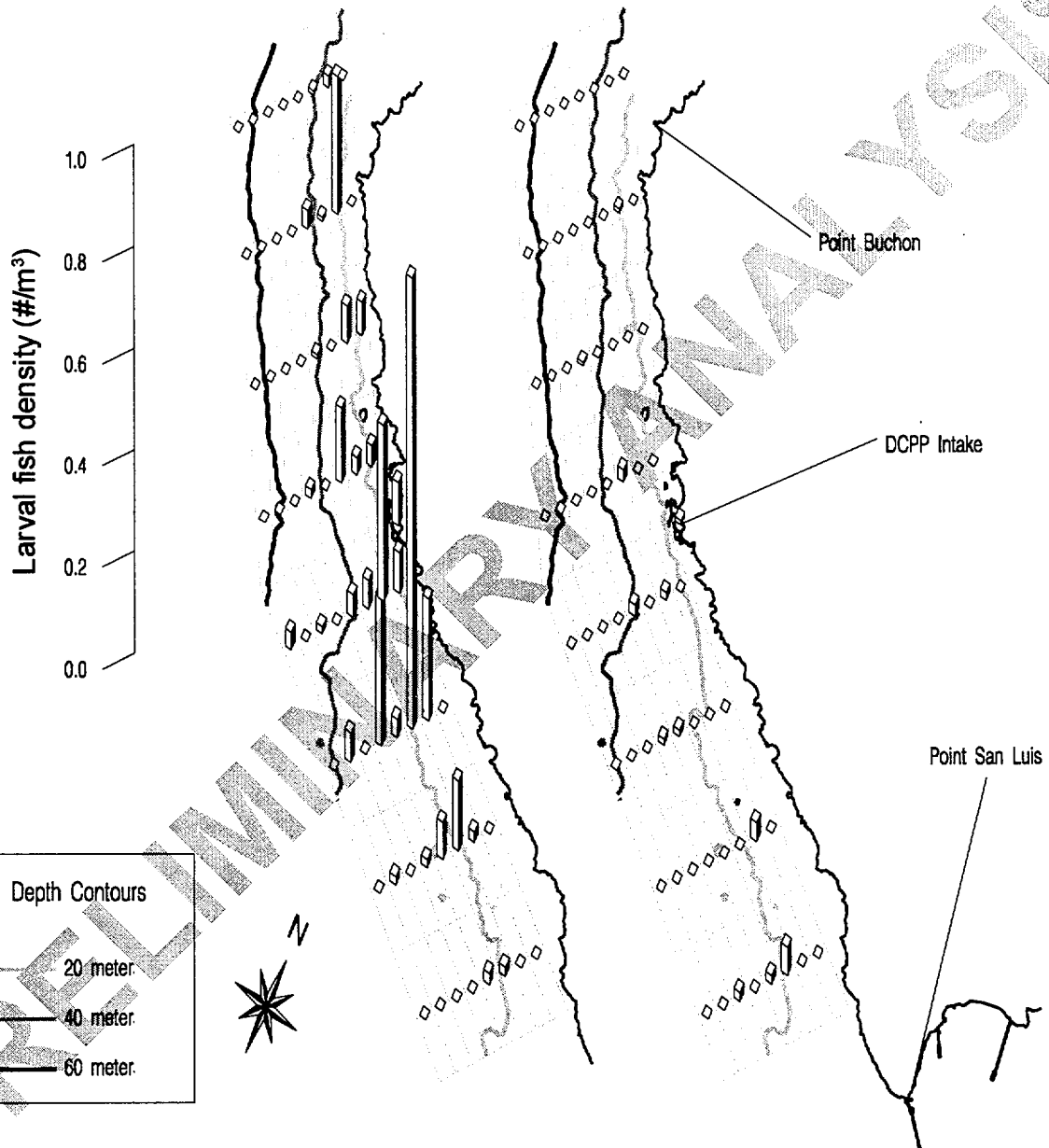


Figure 3-4. Vertical bars represent the mean density of snubnose sculpin (*Orthonopias triacis*) across the study grid: a) Survey 02, July 21-24, 1997; b) Survey 03, August 25-28, 1997. NOTE: Data are preliminary and not intended for use in any context other than this report.

smoothhead sculpin (*Artedius lateralis*)

a) July 1997

b) August 1997

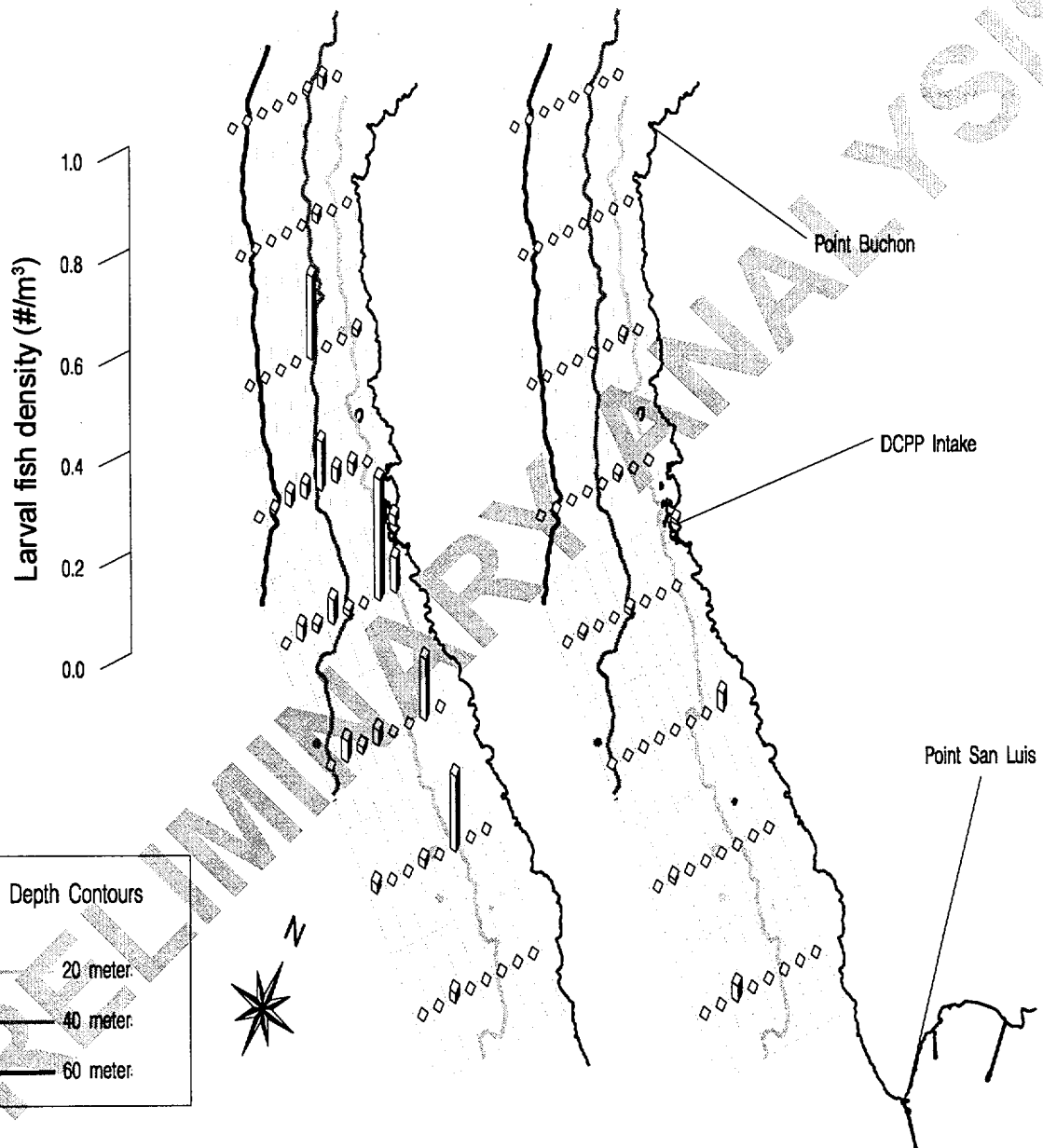


Figure 3-5. Vertical bars represent the mean density of smoothhead sculpin (*Artedius lateralis*) across the study grid: a) Survey 02, July 21-24, 1997; b) Survey 03, August 25-28, 1997. NOTE: Data are preliminary and not intended for use in any context other than this report.

blackeye goby (*Coryphopterus nicholsi*)

a) July 1997

b) August 1997

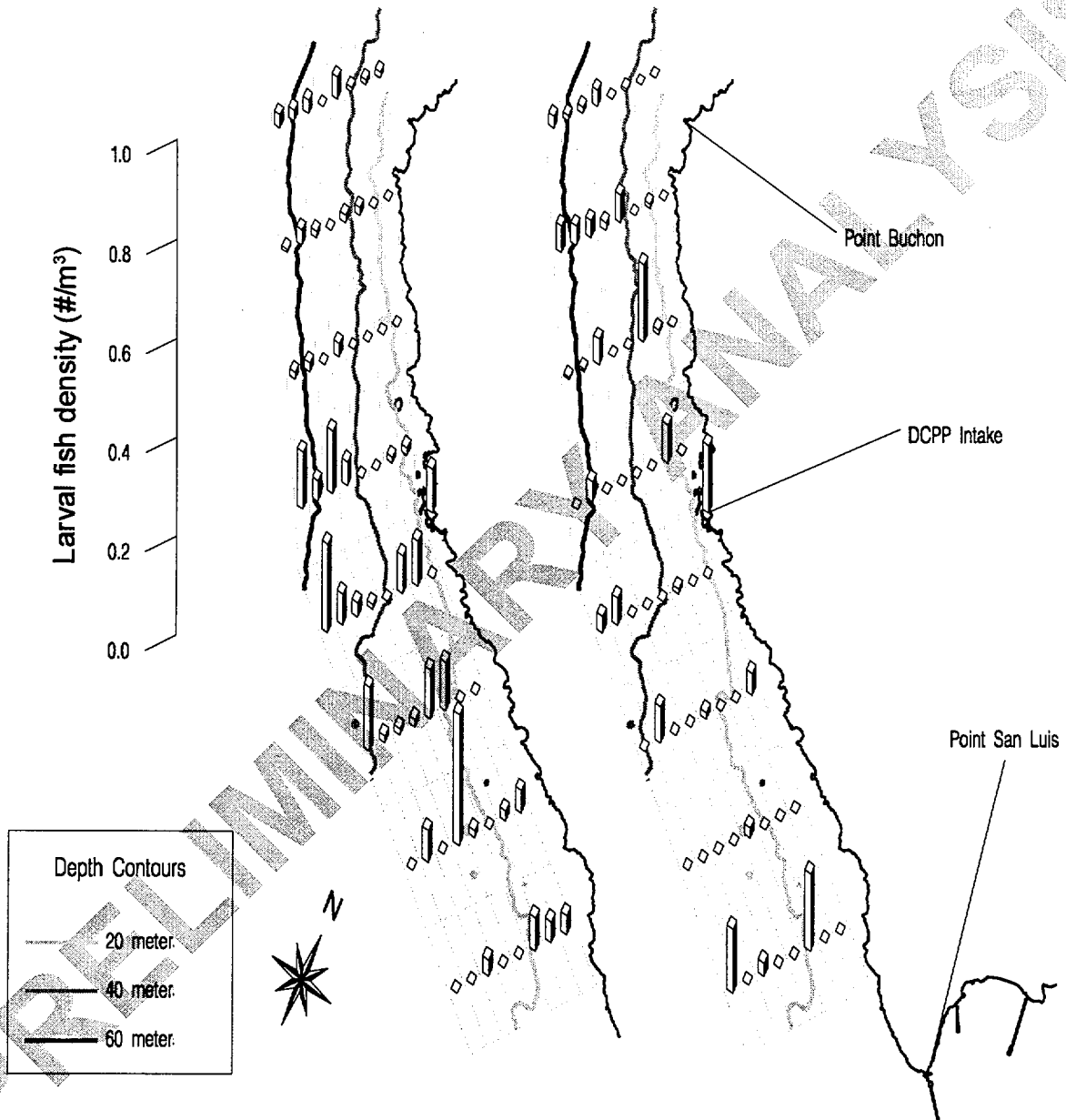


Figure 3-6. Vertical bars represent the mean density of blackeye goby (*Coryphopterus nicholsi*) across the study grid: a) Survey 02, July 21-24, 1997; b) Survey 03, August 25-28, 1997. NOTE: Data are preliminary and not intended for use in any context other than this report.

snailfishes (*Liparis* spp.)

a) July 1997

b) August 1997

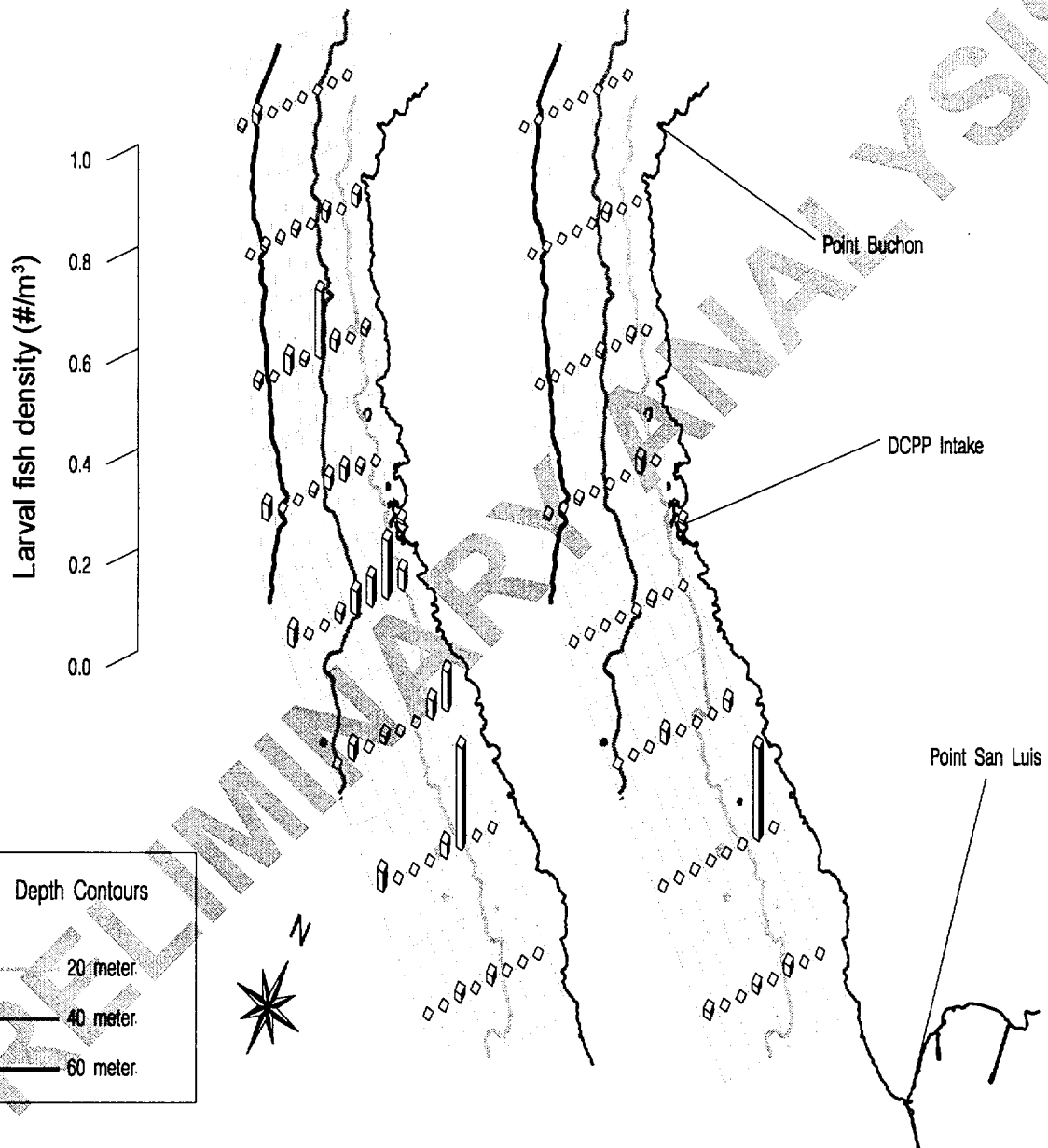


Figure 3-7. Vertical bars represent the mean density of snailfishes (*Liparis* spp.) across the survey grid: a) Survey 02, July 21-24, 1997; b) Survey 03, August 25-28, 1997. NOTE: Data are preliminary and not intended for use in any context other than this report.

sanddabs (*Citharichthys* spp.)

a) July 1997

b) August 1997

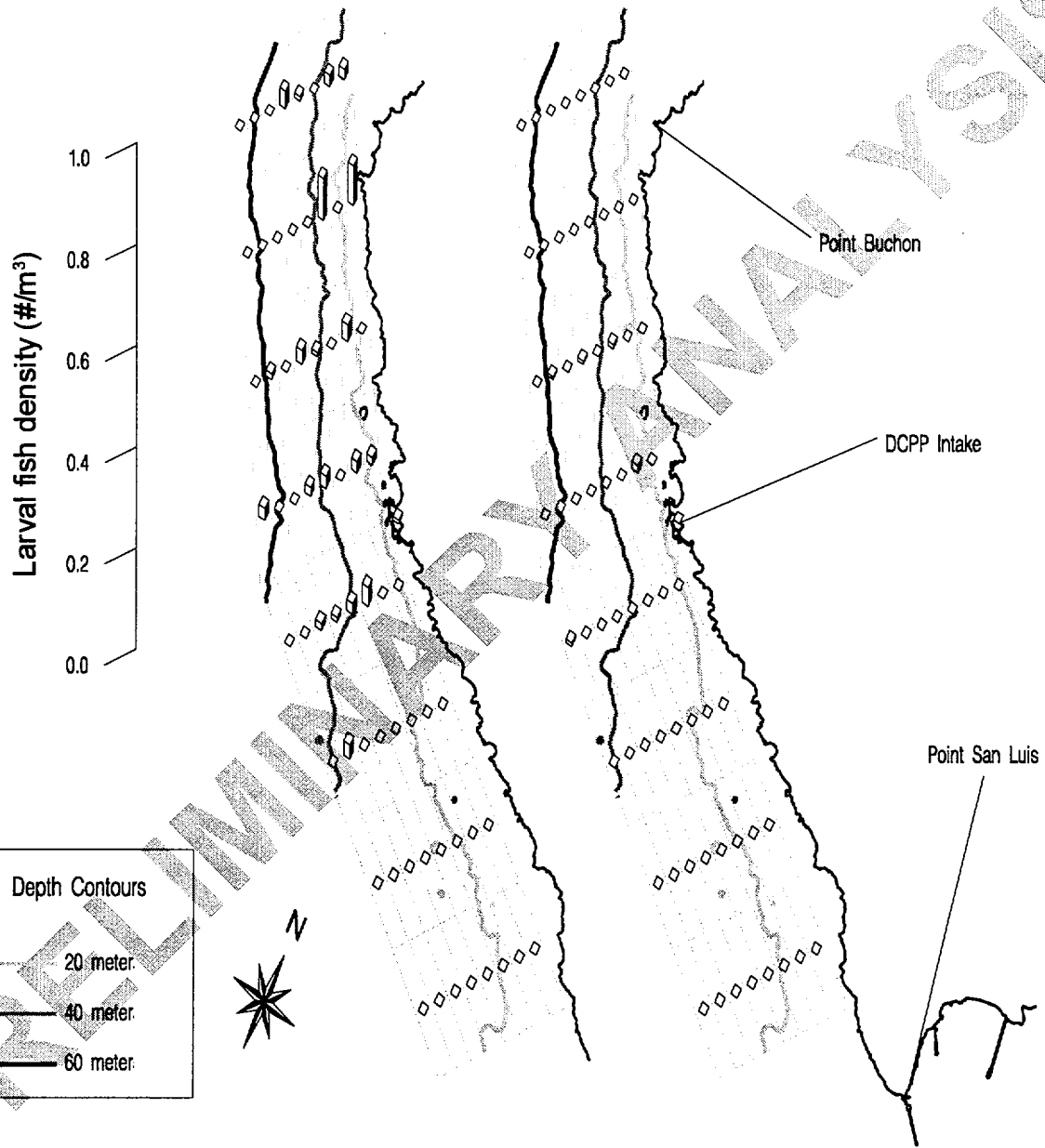


Figure 3-8. Vertical bars represent the mean density of sanddabs (*Citharichthys* spp.) across the study grid: a) Survey 02, July 21-24, 1997; b) Survey 03, August 25-28, 1997. NOTE: Data are preliminary and not intended for use in any context other than this report.

Length-frequency histograms were plotted for each of the eight taxa used in the example *PE* calculations for each survey where they occurred (Figures 3-9 to 3-16). For this example, larval lengths were used as an approximation to developmental stages as described previously in this document. For future *PE* estimates, larval fishes will be compared primarily on the basis of developmental stages. In this case, the conclusion reached by comparing the length-frequency histograms of these taxa was to include all larvae from each taxon within a survey.

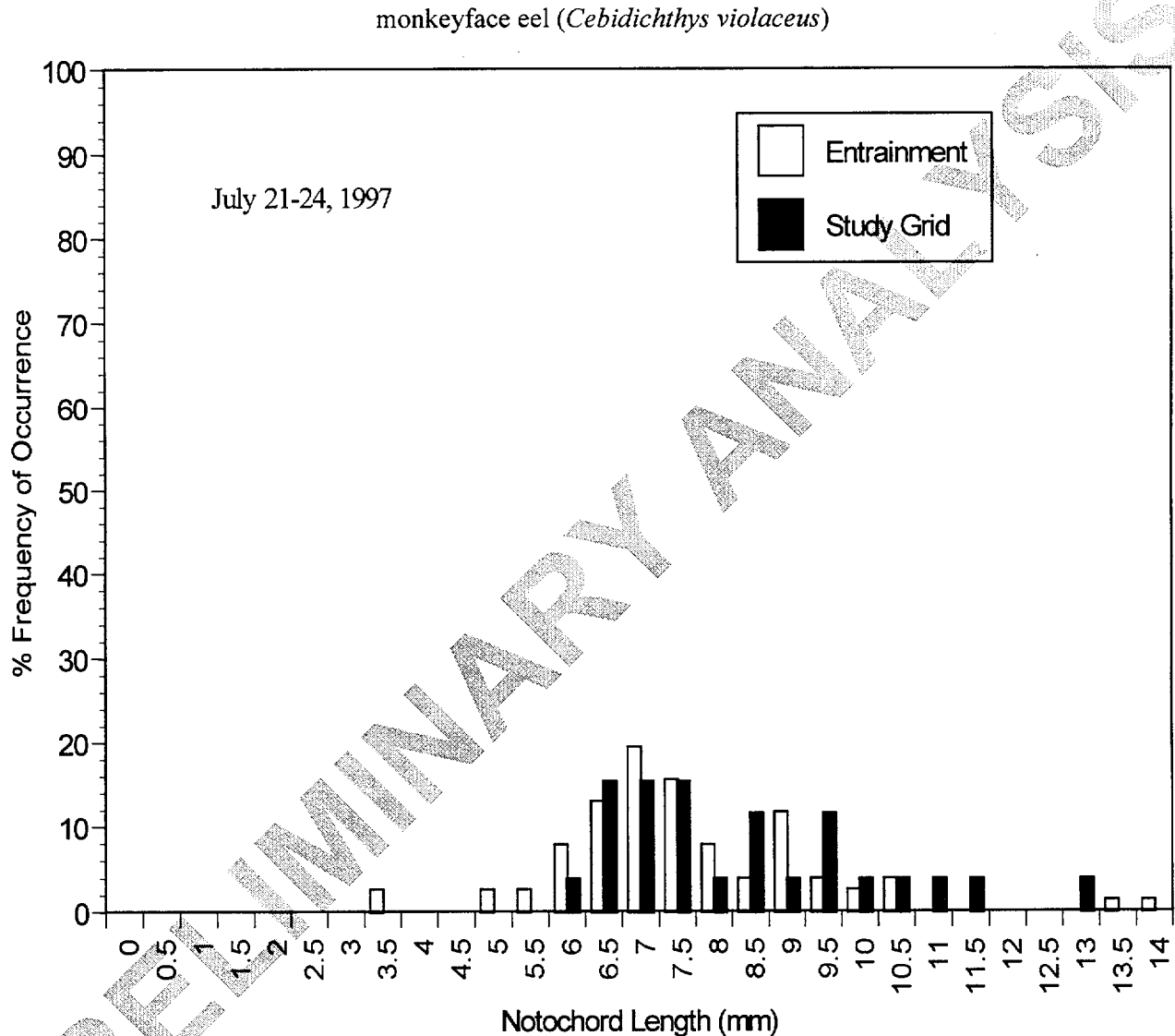


Figure 3-9. Percent frequency of occurrence of larval length classes (mm) for monkeyface eel (*Cebidichthys violaceus*) at entrainment sampling locations and in the study grid for the first paired survey; no *C. violaceus* larvae were collected during the paired August surveys. NOTE: Data are preliminary and not intended for use in any context other than this report.

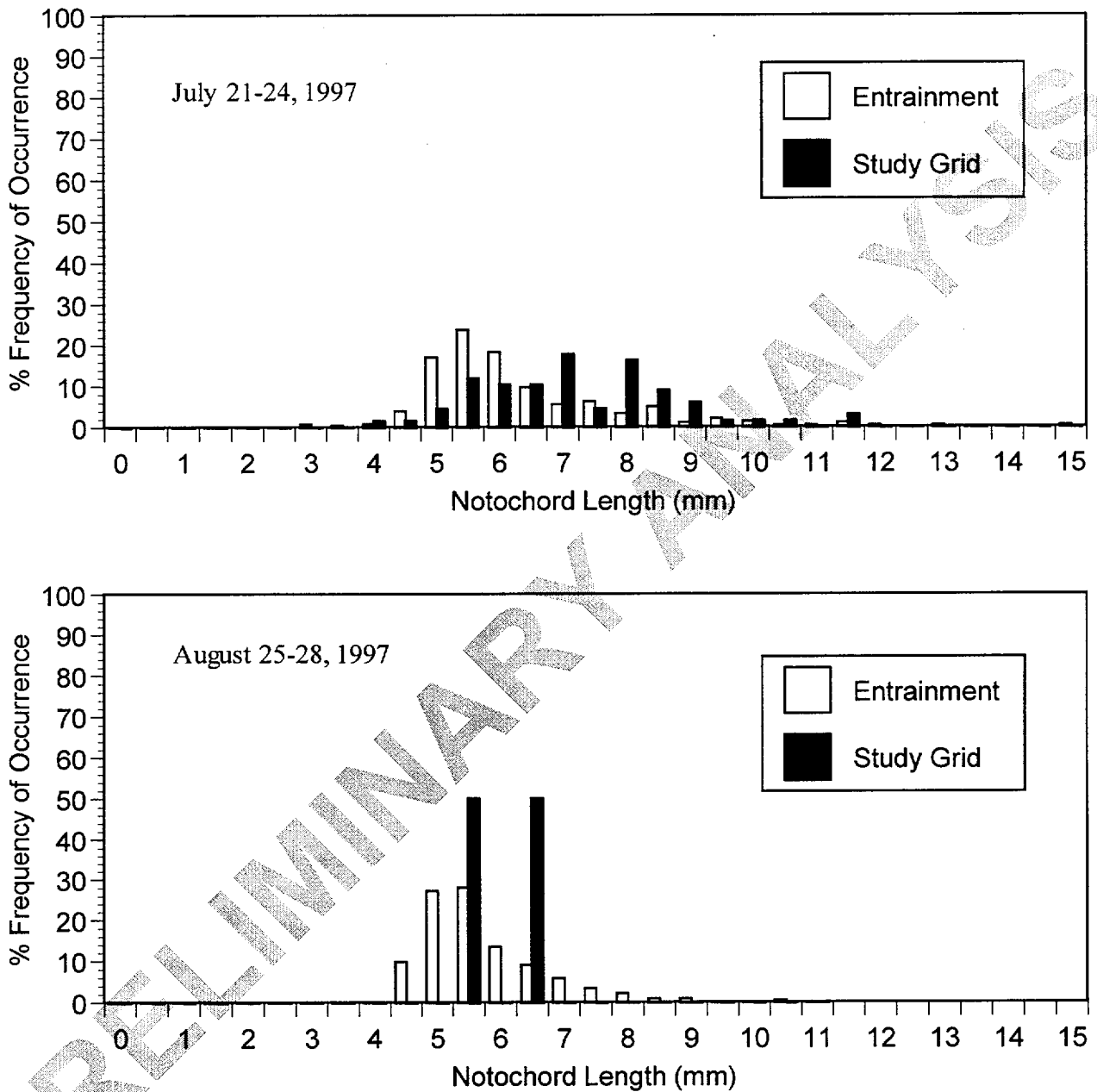
clinid kelpfishes (*Gibbonsia* spp.)

Figure 3-10. Percent frequency of occurrence of larval length classes (mm) for clinid kelpfishes (*Gibbonsia* spp.) at entrainment sampling locations and in the study grid for two paired surveys. NOTE: Data are preliminary and not intended for use in any context other than this report.

Painted Greenling (*Oxylebius pictus*)

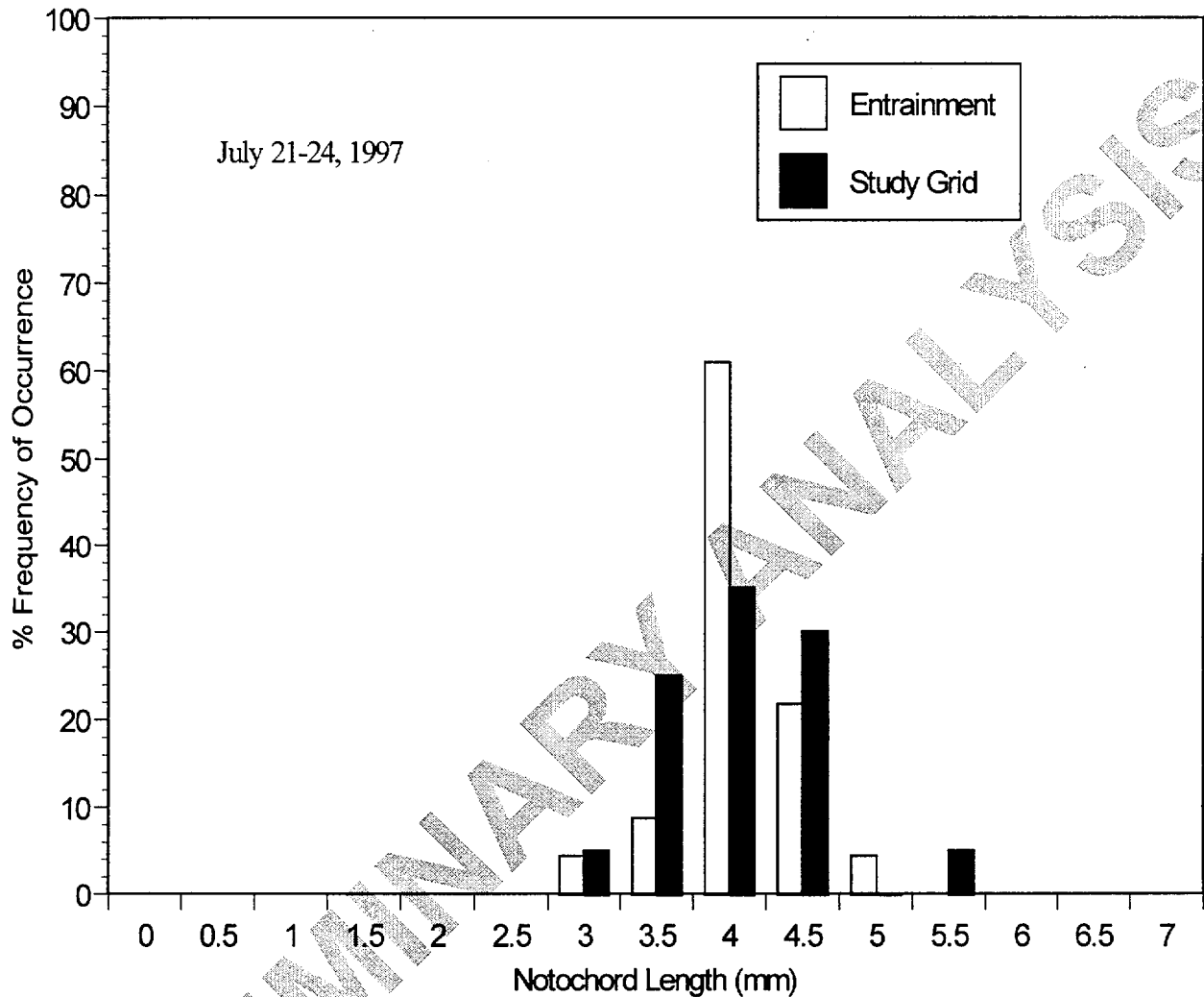


Figure 3-11. Percent frequency of occurrence of larval length classes (mm) for painted greenling (*Oxylebius pictus*) at entrainment sampling locations and in the study grid for the first paired survey. Insufficient numbers of *O. pictus* larvae were collected during August to calculate PE (n=1 at intake; n=1 in study grid). NOTE: Data are preliminary and not intended for use in any context other than this report.

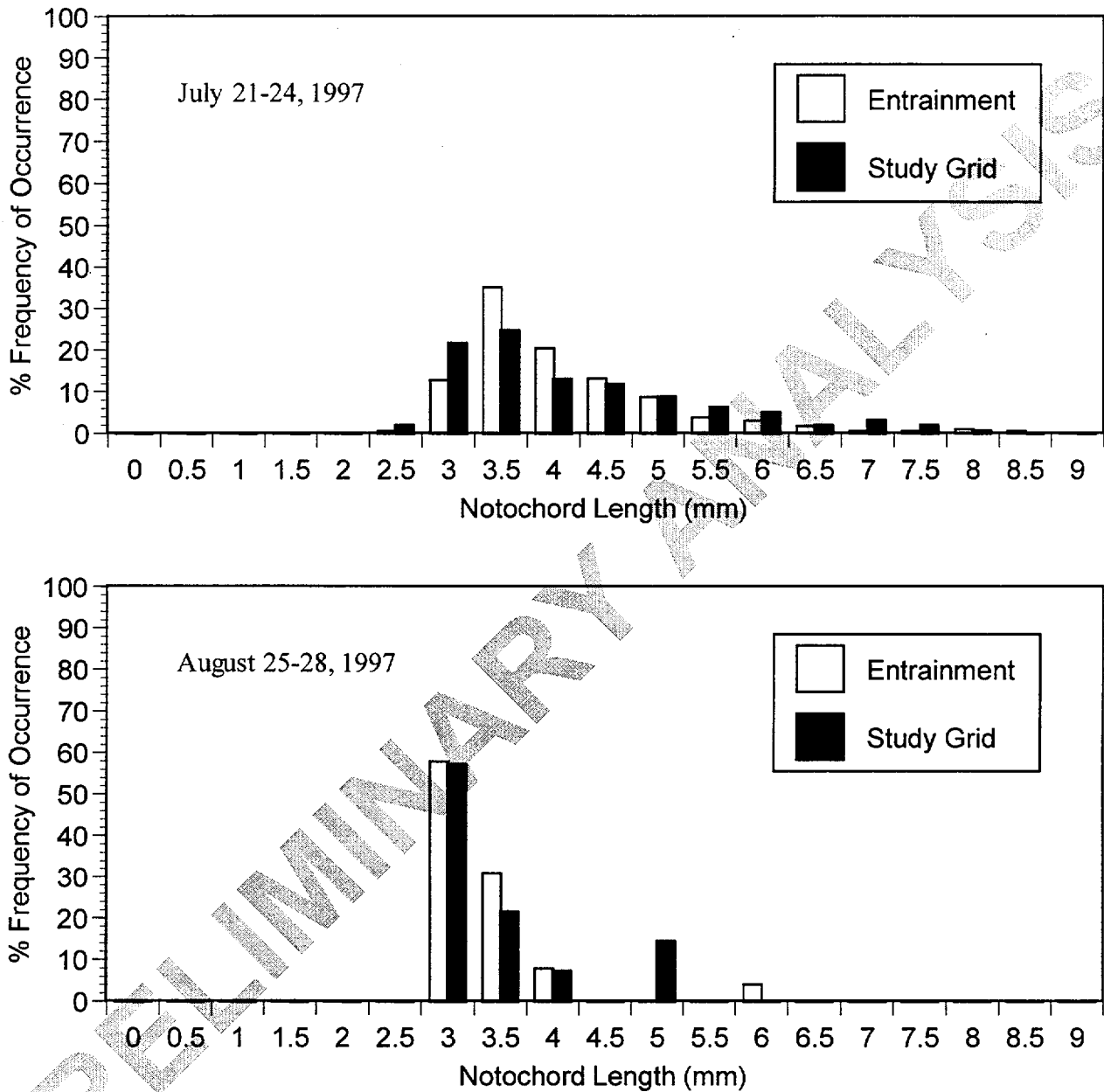
snubnose sculpin (*Orthonopias triacis*)

Figure 3-12. Percent frequency of occurrence of larval length classes (mm) for snubnose sculpin (*Orthonopias triacis*) at entrainment sampling locations and in the study grid for two paired surveys. NOTE: Data are preliminary and not intended for use in any context other than this report.

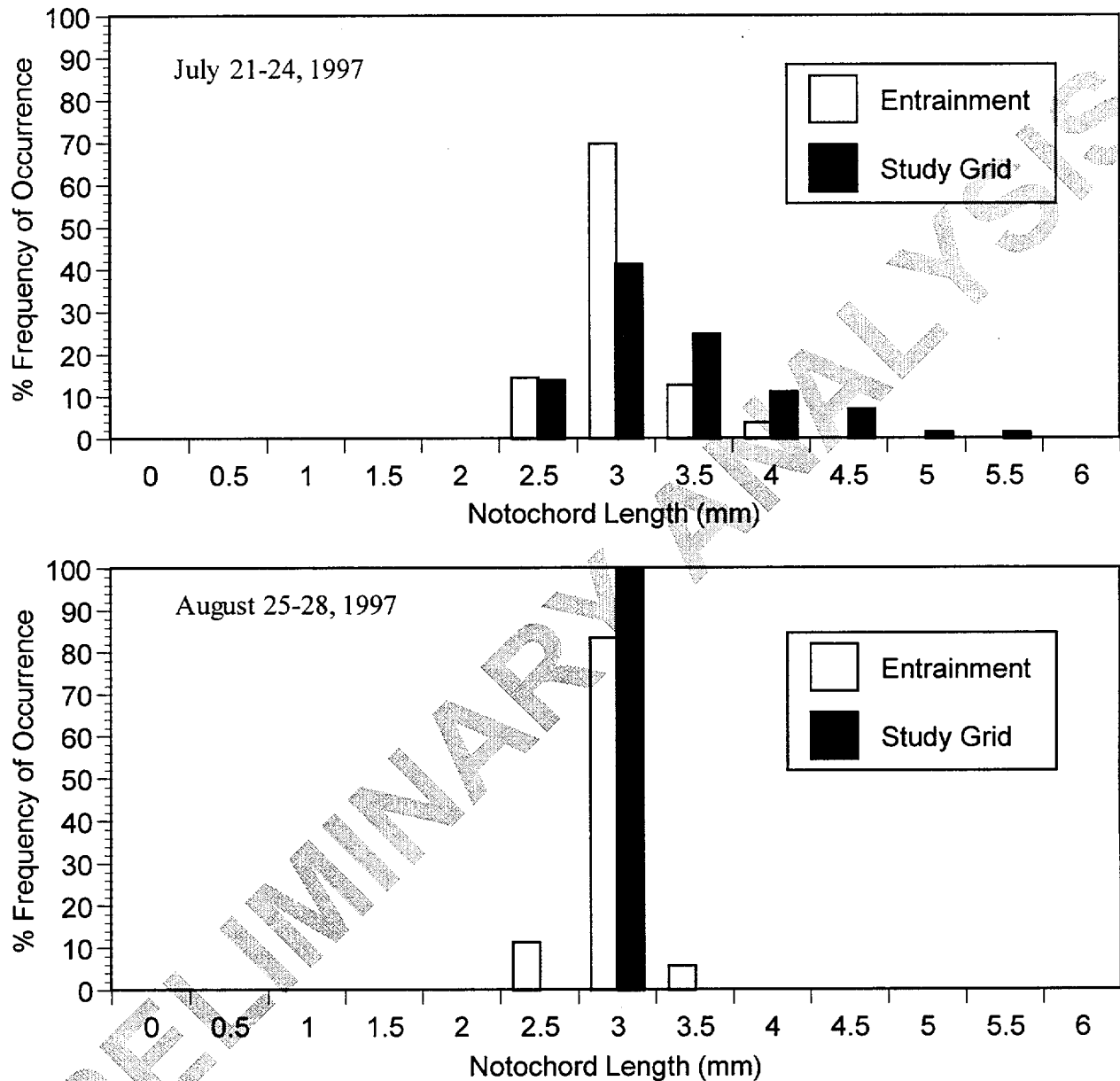
smoothhead sculpin (*Artedius lateralis*)

Figure 3-13. Percent frequency of occurrence of larval length classes (mm) for smoothhead sculpin (*Artedius lateralis*) at entrainment sampling locations and in the study grid for two paired surveys. NOTE: Data are preliminary and not intended for use in any context other than this report.

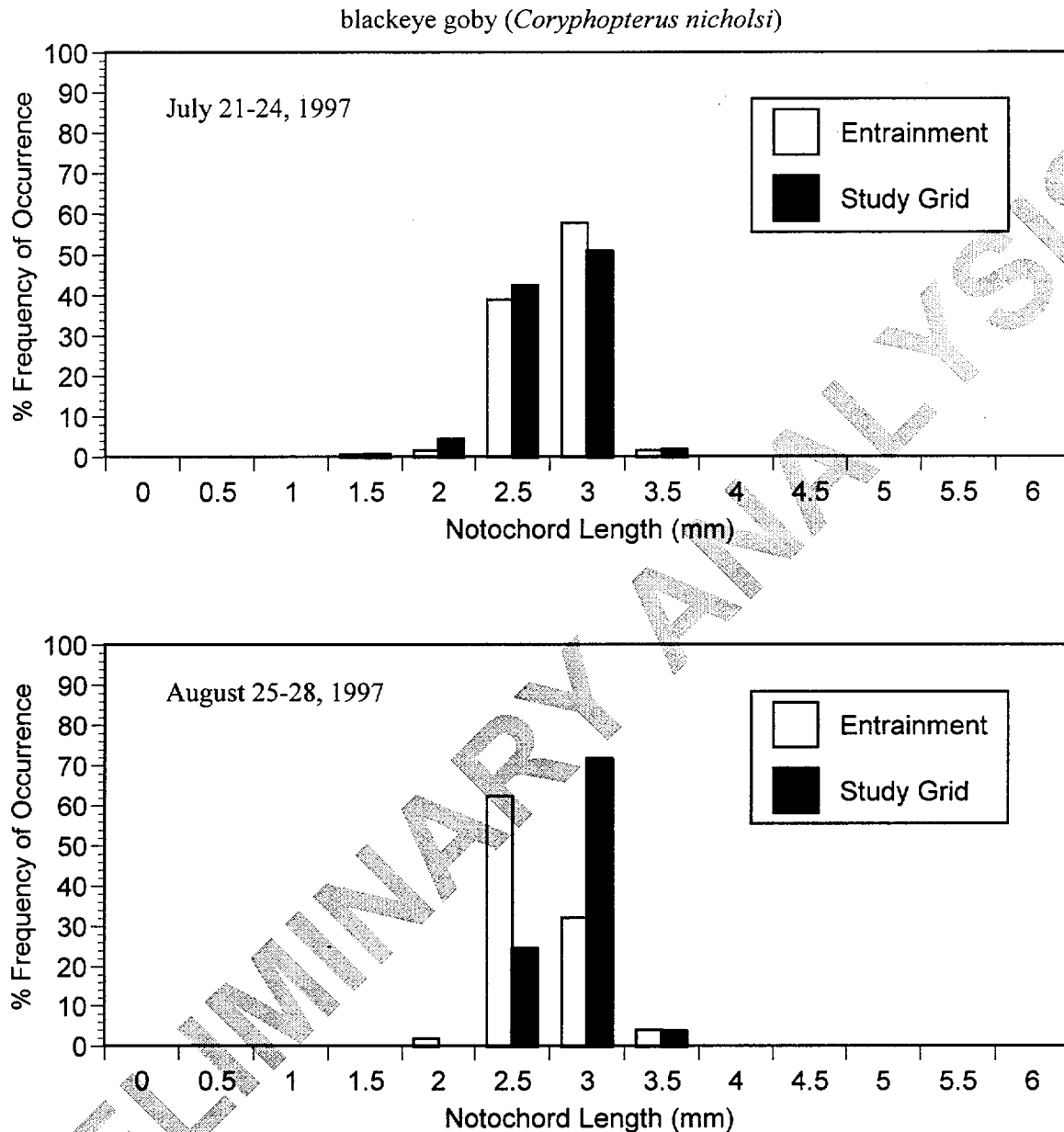


Figure 3-14. Percent frequency of occurrence of larval length classes (mm) for blackeye goby (*Coryphopterus nicholsi*) at entrainment sampling locations and in the study grid for two paired surveys. NOTE: Data are preliminary and not intended for use in any context other than this report.

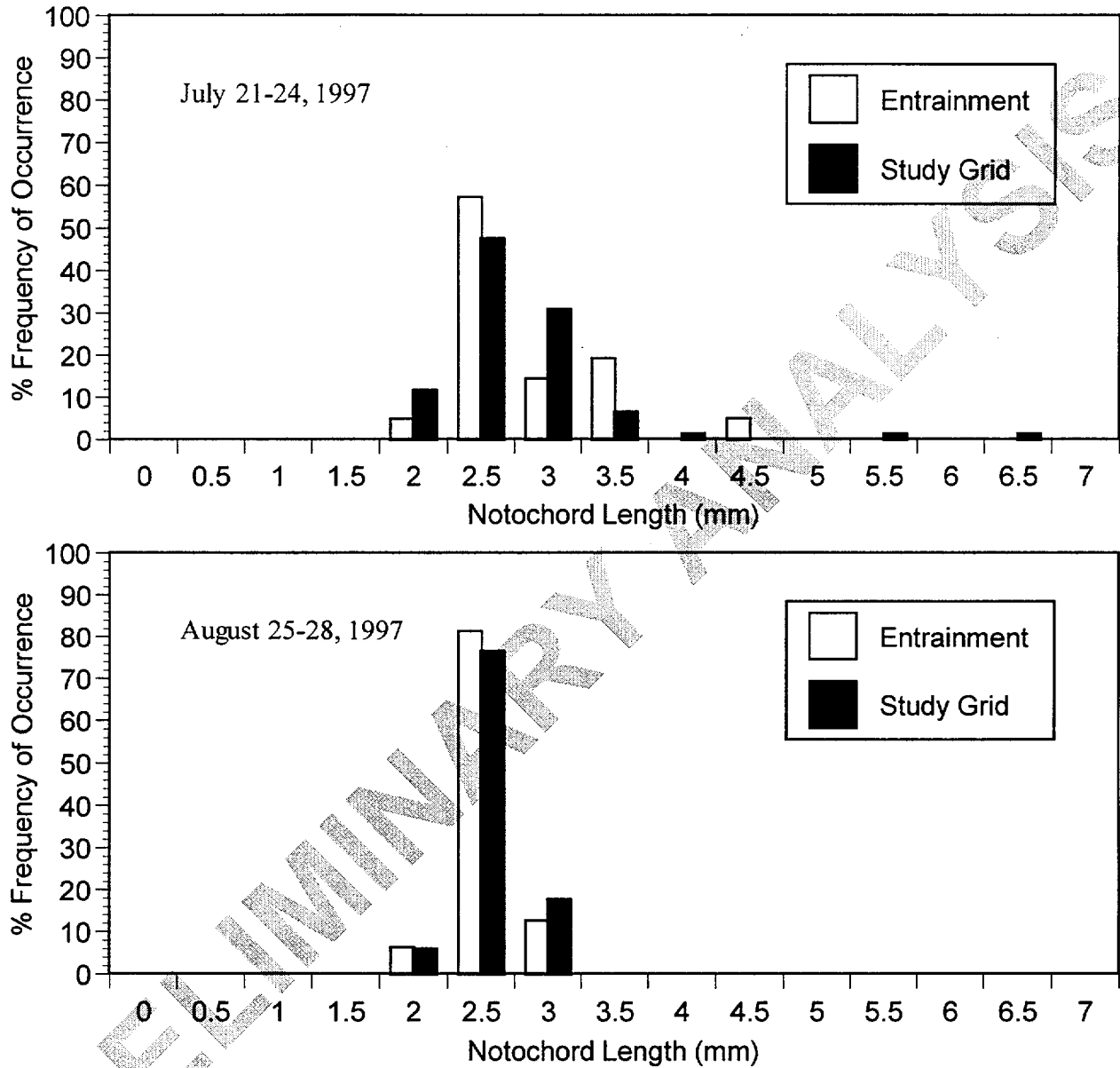
snailfishes (*Liparis* spp.)

Figure 3-15. Percent frequency of occurrence of larval length classes (mm) for snailfishes (*Liparis* spp.) at entrainment sampling locations and in the study grid for two paired surveys. NOTE: Data are preliminary and not intended for use in any context other than this report.

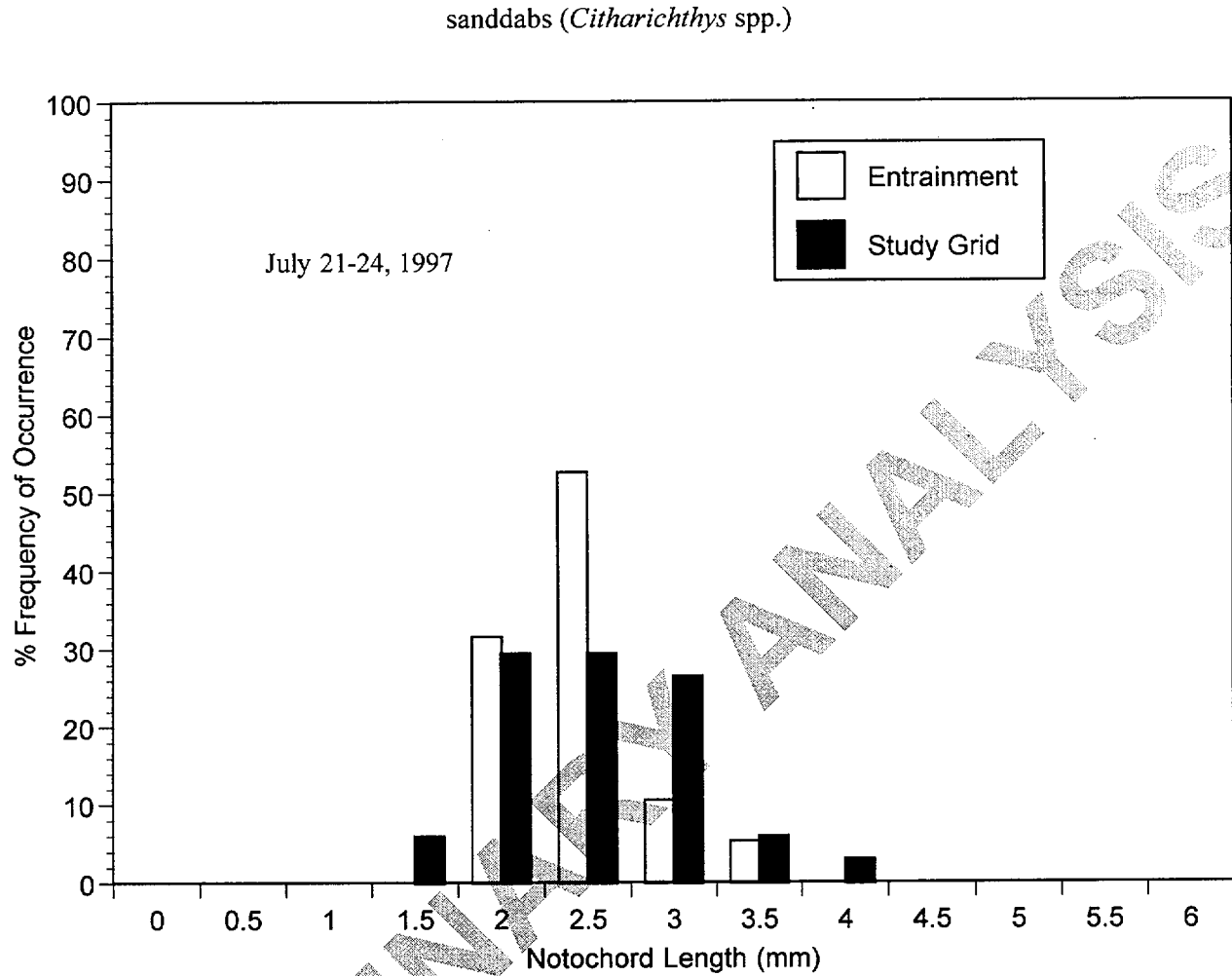


Figure 3-16. Percent frequency of occurrence of larval length classes (mm) for sanddabs (*Citharichthys* spp.) at entrainment sampling locations and in the study grid for the first paired survey. Insufficient numbers of *Citharichthys* spp. larvae were collected during August to calculate *PE* ($n=1$ at intake; $n=5$ in study grid). NOTE: Data are preliminary and not intended for use in any context other than this report.

3.2 Proportional Entrainment (*PE*) Estimates

Preliminary estimates of *PE* based on eight taxa ranged widely both within and between the two survey periods (Table 3-2). During the July survey, values of *PE* ranged from <1% for snailfishes to 5% for clinid kelpfishes, and during the August survey *PE* ranged from <1% for sanddabs to 44% for clinid kelpfishes. These wide ranges of proportional entrainment from the study grid reflect the change in abundance estimates between sampling periods which, in turn, results from larval distribution and abundance that vary temporally as well as spatially. The exceptionally high *PE* estimate for clinid kelpfish larvae during the August survey (44%) is clearly the result of their high abundance at the DCP intake and low abundance combined with their sparse distribution in the study grid (Figure 3-2b). The distribution observed in August could result from a patch of recently spawned clinid kelpfish larvae in Intake Cove that were not sampled as part of the survey grid; the majority of those collected at the intake structure were near their reported hatching length of 4.5 mm notochord length (Moser et al., 1996; Figure 3-10). Estimates of error around *PE* were $\geq 50\%$ of the *PE*-estimate for all taxa examined. The intrinsic variability that results from temporal and spatial variation of the distribution and abundance of larvae will become less pronounced as more replicate surveys are completed and analyzed.

Larval distribution and abundance across the study grid can have a profound influence on the resulting *PE* estimates. Therefore, to better understand this relationship, the number of grid cells used to estimate *PE* was sequentially varied in an outwardly-expanding concentric pattern (Figure 2-5a; Appendix E) and compared with the same sequential expansion based on volume alone. Two patterns of estimated relative to expected *PE* were evident in the data presented in this document for blackeye goby (*Coryphopterus nicholsi*) and clinid kelpfishes (*Gibbonsia* spp.); parallels expected *PE* and diverges from expected *PE*, respectively. Estimated proportional entrainment of blackeye goby in the July survey ranged from ca. 600% when the two grid cells closest to the power plant were used, to ca. 2% when all 64 cells were included. Comparing these estimates with the distribution of blackeye goby larvae across the study grid (Figure 3-6), it becomes apparent that many more of these larvae were entrained than were available in the first two cells adjacent to Intake Cove and that, as more cells were incorporated in the estimates (i.e., effective grid volume increased), more larvae were added from the survey grid causing *PE* of the larvae to parallel *PE* expected by volume alone (Figure 3-17a) despite changes in larval density between survey months. Discrepancies between the calculated and volumetrically predicted *PE* estimates for *Gibbonsia* spp. ranged from ca. 1 time higher for $n=2$ in July to ca. 60 times higher for $n=16$ in August. This illustrates a pattern of divergence from expected *PE* (Figure 3-18a) where abundance is zero throughout much of the grid but is high close to Intake Cove (Figure 3-2). Proportional entrainment estimates level off quickly after the majority of *Gibbonsia* spp. larvae in the cells near the intake have been included in the estimate, but expected *PE* continues to decline as more water volume is included with the additional cells. The values of $PE \geq 100\%$ reflect violations to assumptions of normality that arise when varying the area of effects (i.e., the study grid). The large error estimates around *PE* result from the intrinsic variation associated with sampling planktonic assemblages.

A second method of varying the size and shape of the grid from which *PE* was calculated consisted of expanding the grid outward from shore by accumulating rows (Figure 2-5b). For most taxa, this approach resulted in a *PE* estimate that exhibited a steady decline in magnitude as more cells were incorporated in its calculation (Appendix E). In the cases of clinid kelpfishes and blackeye goby (Figures 3-2 and 3-6, respectively), *PE* estimates were high when n was small ($n=8$ or $n=16$) and declined as the sequential estimates incorporated more of the study grid (Figures 3-17b and 3-18b). Interestingly, and despite

Table 3-2. Preliminary estimates of proportional entrainment (*PE*) and standard error (SE; ± 2 SE = 95% confidence interval) for eight taxa entrained at DCP with numbers entrained and from grid sampling given in 100,000's. NOTE: Data are preliminary and not intended for use in any context other than this report.

PE - July 1997

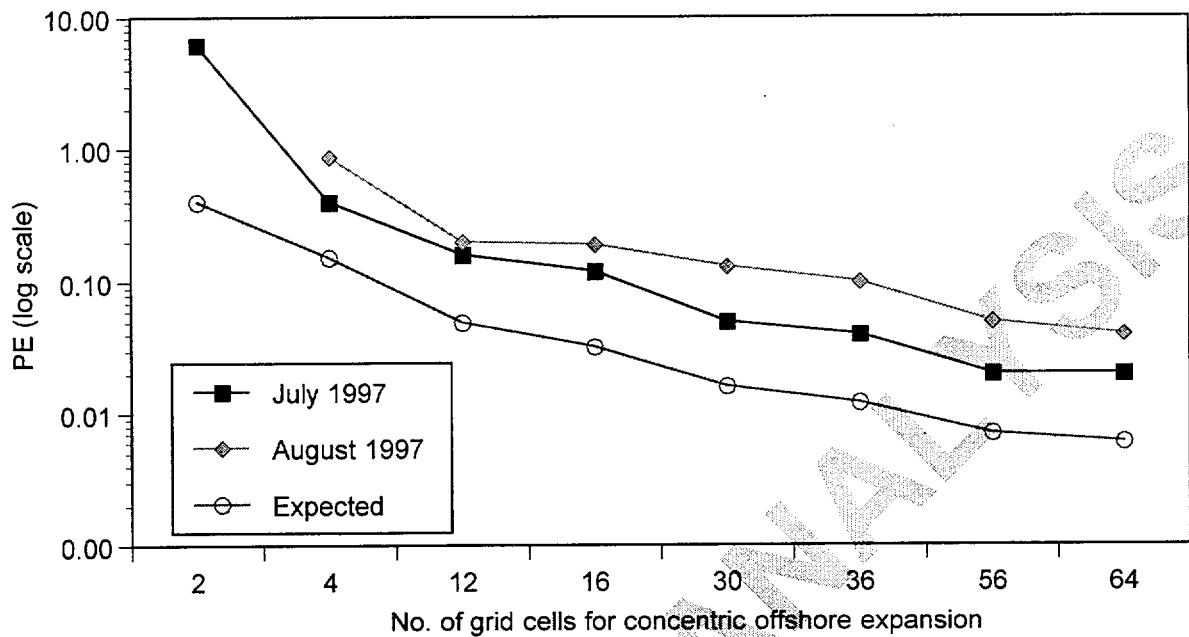
Taxon	# Entrained ($\times 10^5$)	2 SE ($\times 10^5$)	# in Grid ($\times 10^5$)	2 SE ($\times 10^5$)	PE (%)	2 SE (%)
<i>Artedius lateralis</i>	1.8	1.3	279.7	123.7	1	1
<i>Cebidichthys violaceus</i>	2.3	1.2	86.1	28.3	3	2
<i>Citharichthys</i> spp.	0.7	0.4	132.5	59.4	1	<1
<i>Coryphopterus nicholsi</i>	8.3	9.3	562.8	86.8	1	2
<i>Gibbonsia</i> spp.	10.2	4.1	196.3	158.8	5	5
<i>Liparis</i> spp.	0.7	0.3	278.1	70.4	<1	<1
<i>Orthonopias triacis</i>	8.0	4.1	515.7	244.4	2	1
<i>Oxylebius pictus</i>	0.7	0.9	63.8	26.0	1	1

PE - August 1997

Taxon	# Entrained ($\times 10^5$)	2 SE ($\times 10^5$)	# in Grid ($\times 10^5$)	2 SE ($\times 10^5$)	PE (%)	2 SE (%)
<i>Artedius lateralis</i>	0.7	0.3	21.3	12.5	3	2
<i>Cebidichthys violaceus</i>	0	-	0	-	0	-
<i>Citharichthys</i> spp.	<0.1	0.1	12.5	11.2	<1	1
<i>Coryphopterus nicholsi</i>	12.8	8.8	338.8	92.3	4	3
<i>Gibbonsia</i> spp.	8.1	2.3	18.3	24.4	44	59
<i>Liparis</i> spp.	0.1	<0.1	52.0	23.9	1	1
<i>Orthonopias triacis</i>	0.8	0.3	39.1	23.7	2	2
<i>Oxylebius pictus</i>	<0.1	0.1	2.7	5.5	1	3

changing the pattern of accumulation of sequential *PE* estimates, the general patterns of estimated *PE*'s relative to expected *PE* remained consistent (i.e., *C. nicholsi* paralleled expected *PE* and *Gibbonsia* spp. diverged from expected *PE*). Part of the reason for this behavior of *PE* is explained by the fact that a greater proportion of the temporal variation arising from the sampling method ("ping-pong" transect; Figure 2-4) and that associated with the spatial distribution of the larvae is incorporated in each iteration by accumulating entire rows moving offshore.

a) Grid expanded concentrically offshore: *Coryphopterus nicholsi* (blackeye goby).



b) Grid expanded by row. *C. nicholsi* (blackeye goby).

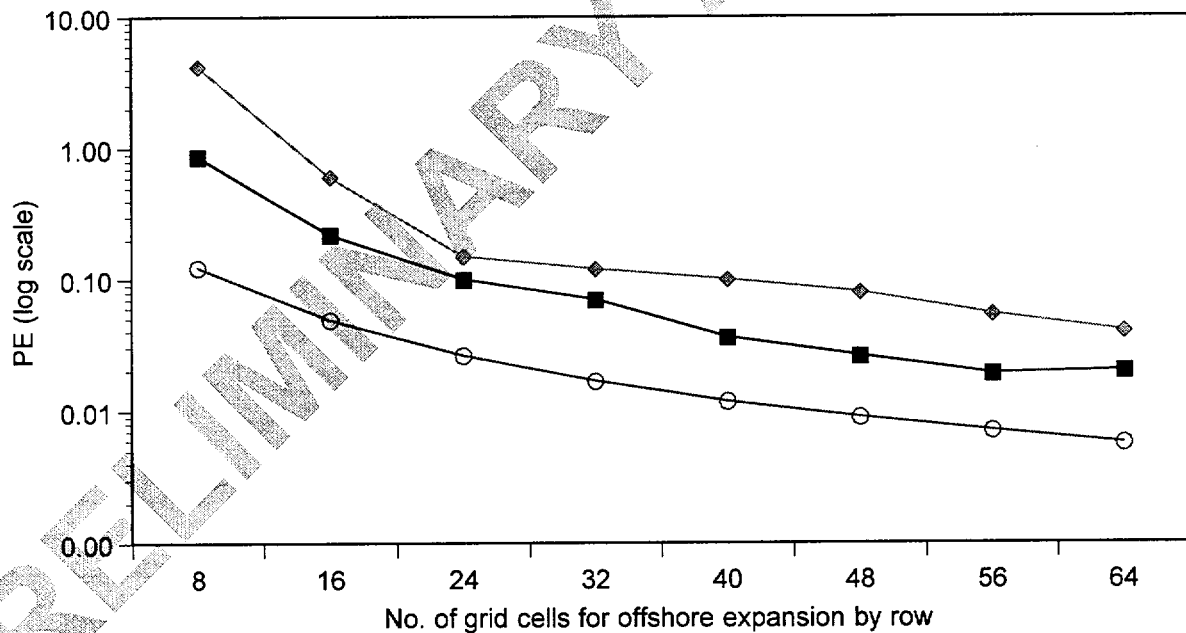
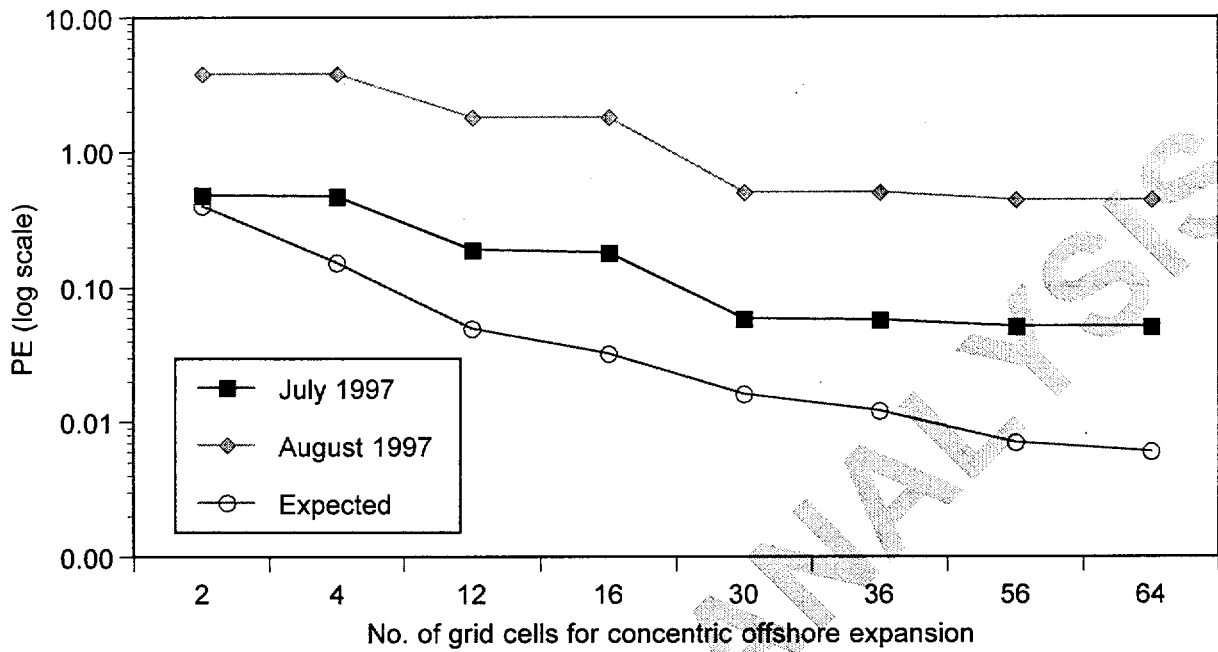


Figure 3-17. Proportional entrainment estimated by sequentially expanding the number of grid cells offshore from DCPD for blackeye goby (*Coryphopterus nicholsi*) in July and August of 1997 a) concentrically (Figure 2-5a) and b) by row (Figure 2-5b) compared to *PE* expected from entrained water volume alone. NOTE: Data are preliminary and not intended for use in any context other than this report.

a) Grid expanded concentrically offshore: *Gibbonsia* spp. (clinid kelpfishes).



b) Grid expanded by row: *Gibbonsia* spp. (clinid kelpfishes).

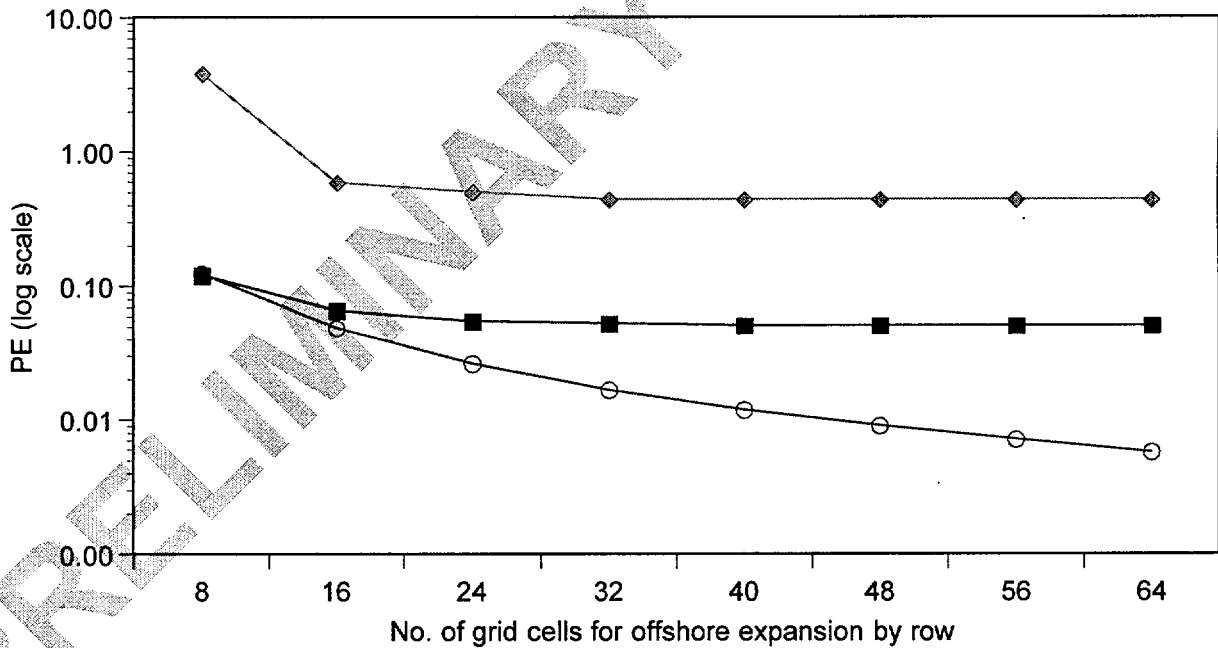


Figure 3-18. Proportional entrainment estimated by sequentially expanding the number of grid cells offshore from DCPD for clinid kelpfishes (*Gibbonsia* spp.) in July and August of 1997 a) concentrically (Figure 2-5a) and b) by row (Figure 2-5b) compared to *PE* expected from entrained water volume alone. NOTE: Data are preliminary and not intended for use in any context other than this report.

Two general patterns appeared common in proportional entrainment modelling results. First, with only one exception, the *PE* estimates for all species, all choices of grid configuration (see Figures 2-5a and 2-5b), and both surveys, were higher than would be expected from volumetric considerations alone (i.e., the ratio (volume of water entrained)/(volume of water in the grid or sub-grid)). The exception was snailfishes from the July survey using all 64 cells. Thus, larvae appear to be entrained at a greater rate than they would be if the power plant's intake water were chosen randomly from the grid, or from any of the sub-grids in Figures 2-5a or 2-5b. One possible explanation for this is that significant numbers of larvae in the field are inshore of the grid, where we are unable to sample. Such larvae might contribute heavily to the numbers entrained, but would not contribute at all to our field population estimates. The other pattern was that proportional entrainment results for each species were generally consistent with expectations based on the distribution patterns observed in the grid sampling. For example, if a species is mainly distributed offshore, we expect its entrainment to be low and its field population to be low for the small sub-grids (near the shore) and high for the large sub-grids; thus its *PE* should be (1) moderate for the small sub-grids because it equals (small entrainment)/(small field population) and (2) lower for the bigger sub-grids which contain more larvae. If a species is mainly distributed inshore, we expect its entrainment to be high (possibly very high if augmented by larvae from inshore of the grid) and its field population to be high for the small sub-grids (near the shore) but not to increase for the large sub-grids; thus its *PE* should be (1) moderate to high for the small sub-grids but (2) not to change much as we use the bigger sub-grids. Although they generally conformed to these patterns, the July and August results were very different from each other. Possible reasons for such variation include diel behavior, oceanographic conditions (e.g., currents, waves) and time lags (e.g., some of the larvae in the intake cove may have arrived there many days earlier, so the cove population represents the field population partly as it was in the past as well as in the present).

3.3 Adult-Equivalent Loss (*AEL*) and Fecundity Hindcasting (*FH*) Estimates

As a precursor to the estimation of *AEL* and *FH*, total larval entrainment (\hat{E}_T) and survivorship from larvae to adulthood based on reported monkeyface eel fecundity were calculated. For the monkeyface eel, entrainment samples detected larvae from December 23, 1996-July 21, 1997 during its annual cycle of reproduction. The weekly estimates of daily entrainment (i.e., \hat{E}_i) were used in the calculation of total entrainment. For the months of June-August 1997, where not all of the weekly entrainment samples have been analyzed, the next available survey data were used. The total entrainment for the monkeyface eel was estimated to be

$$\hat{E}_T = 160,000,000 \text{ larvae in 1996-1997} \quad .$$

Variance in estimating the daily entrainment numbers (i.e., sampling error) does not incorporate daily variance (i.e., within strata temporal variability). Hence, the estimated variance based on Equation (4) is an underestimate of the true variance. For monkeyface eel, the estimated standard error is calculated to be

$$\hat{SE}(\hat{E}_T) = 193,000,000 \quad .$$

An estimate of mortality between the larvae and adults can be obtained by applying an assumption of a stable adult population to reported fecundity estimates. First, calculating the median egg count from a

reported range of 18,000-46,000 eggs (Love, 1991) and assuming a single annual spawning effort, annual fecundity (\hat{F}) is estimated to be

$$\hat{F} = \frac{18,000 + 46,000}{2} = 32,000 \text{ eggs/year,}$$

with a reproductive life expectancy (\hat{R}) calculated as the midrange between median reported ages of maturation (4-7 years) and longevity (18 years; Love, 1991) of

$$\hat{R} = \frac{\left(\frac{4+7}{2}\right) + 18}{2} = 11.75 \text{ years.}$$

Total lifetime fecundity F_T for a monkeyface eel is then calculated to be

$$F_T = 32,000 \cdot 11.75 = 376,000 \text{ eggs.}$$

It is interesting to note that Fitch and Lavenberg (1971) reported a fecundity range of 6,000-8,000 eggs that does not overlap the range reported by Love (1991). Unfortunately, these fecundity estimates are the only ones available for monkeyface eel. In addition, Fitch and Lavenberg (1971) report maturation at 3-4 years of age. These estimates of fecundity and age at maturation do not come from peer-reviewed research, but are the only estimates presently available for monkeyface eel. It should also be noted that no measure of variance for these parameters was given in the literature. A rough approximation is to assume a normal distribution in which case, ± 3 standard deviations include 99% of the distribution (range reported by Love, 1991) of the random variable. Using the fecundity estimates from Love (1991) and applying this approximation gives a standard error estimate of 4,667 eggs and 2.08 years for egg mass and reproductive years, respectively.

Under the assumption of a stable adult population, a reproductive female must ultimately produce two adults from its progeny. Hence, an estimate of the overall survival rate (S_T) for the monkeyface eel can be estimated as

$$S_T = \frac{2}{376,000 \text{ eggs}} = 0.000005319.$$

The overall survival, in turn, is equivalent to

$$S_T = (\text{egg survival}) \cdot (\text{larval survival to entrainment}) \cdot (\text{survival to recruitment}) = S_E \cdot S_L \cdot S_A.$$

Using northern anchovy survival estimates from Lo (1986; Table 2-3), survival from entrainment to adulthood (S_A) would be calculated as follows:

$$0.000005319 = (0.4240) \cdot (0.0904) \cdot \hat{S}_A$$

$$\hat{S}_A = 0.0001388$$

with a standard error of

$$\hat{SE}(\hat{S}_A) = 0.00005905$$

calculated using the delta method (Seber, 1984) detailed in Appendix D. The uncertainty surrounding published demographic parameters, while seldom reported, is likely very large and should be considered when interpreting results from these modelling exercises.

Thus, estimation of annual *AEL* for monkeyface eel (*Cebidichthys violaceus*) combining demographic parameters from northern anchovy (*Engraulis mordax*) follows the formulation

$$\begin{aligned} \hat{AEL} &= \hat{E}_T \cdot \hat{S}_A \\ &= 160,000,000(0.0001388) \\ &= 22,000 \text{ adults / year} \end{aligned}$$

with a standard error (Appendix D) of

$$\hat{SE}(\hat{AEL}) = 31,000 \text{ adults / year.}$$

Following the formulation of lifetime fecundity and survivorship from entrainment to adulthood above, combined with estimates of northern anchovy egg mortality (Lo, 1986; Table 2-3), estimation of *FH* for monkeyface eel (*Cebidichthys violaceus*) is as follows:

$$\begin{aligned} \hat{FH} &= \frac{\hat{E}_T}{\hat{S}_E \cdot \hat{S}_L \cdot \hat{F}_T} \\ &= \frac{160,000,000}{(0.4240)(0.0904)(376,000)} ; \\ &= 11,000 \text{ adult females / year} \end{aligned}$$

standard error (Appendix D) of $\hat{SE}(\hat{FH}) = 14,000$ adult females / year. By assuming monogamous breeding, the total loss in fecundity can be considered $\hat{FH} = \frac{\hat{AEL}}{2}$ because the *FH* approach only accounts for females.

The use of the higher egg and larval mortality rates of northern anchovy in the monkeyface eel calculations would tend to overestimate the loss based on *FH* calculations. These same overestimates of egg and larval mortality would also tend to overestimate losses based on the *AEL* calculations. In the heuristic example given above, both calculations are totally non-robust (i.e., sensitive) to survival parameters used in the analyses. Ultimately, inclusion in demographic models will require careful consideration of the available life-history information and its contribution to the nature of the final output. Where the calculations are sensitive to the survival parameters employed, sensitivity analyses would be recommended in conjunction with the model outputs.

3.4 Discussion

The data used in calculating *PE* estimates were based on surveys conducted during the summer when larval fish diversity and abundance are typically low (Moser et al., 1996). This likely contributed to the high variability for some of the estimates among surveys and the absence of any estimates for some species, especially during the August survey (e.g., monkeyface eel, *Cebidichthys violaceus*). Larvae of potential target taxa (Tenera, Inc., 1997b), such as rockfishes (Genus: *Sebastes*) or cabezon (*Scorpaenichthys marmoratus*), are typically not present in high abundance during the summer months (Moser et al., 1996).

Results from entrainment and study grid sampling will help determine the appropriate approaches to estimating effects on individual species or taxonomic groups; the ETWG will aid in this determination. Information needed to complete the demographic analyses may be unavailable for some taxa of interest which will not allow their inclusion in *AEL* or *FH* estimates of the potential entrainment effects at DCP. For many species, lack of age-specific survivorship data will preclude the use of an *AEL* or *FH* approach to estimate effects, while the *PE*-based approach can be calculated without these data. Ages, mortality and fecundity estimates, and larval and adult abundances, are limited or unknown for many of the species in these samples. Additionally, for species where this information is available, reported estimates of age, growth, and mortality may vary requiring discussion with the ETWG to decide on the most appropriate survivorship estimates to be included in the final analyses. For broad taxonomic groupings (e.g., rockfishes, Genus: *Sebastes*) which can include several species with varying life-histories, a *PE*-based approach is a viable assessment method. These considerations and other factors will need to be evaluated for each target organism when choosing the modelling approaches used for the impact assessment.

There are several advantages to the *PE* method. One is the intuitive appeal of the geographic link to estimating relative entrainment losses to local populations. As mentioned above, there also may be a practical advantage to this approach in the absence of geographically well-defined populations continuous with the study grid that can be used to estimate impacts. Another advantage to collecting plankton from the adjacent coastal zone is that the data on local and seasonal patterns of distribution and abundance will aid in the interpretation of entrainment effects. Relative to *AEL* and *FH*, *PE* does not require mortality estimates or other life-history parameters to estimate losses. It also is advantageous to collect larval abundance data compared to assessing the abundance of adults. This facilitates the use of site-specific empirical information to estimate entrainment effects (Boreman et al., 1981).

For all of these approaches, value must be assigned to the larval entrainment losses to ultimately understand the 'long-range effect' of those losses. For *PE* as formulated, the fraction of the total abundance of a target taxon represented within the study grid must be known. For *AEL* or *FH*, other researchers indicate that the results must be compared to a finite source or affected population (Summer, 1989; Sails et al., 1997) to understand the relative value of the estimated loss of equivalent adults.

Because the cooling water intake at DCP is located on the shoreline and we are unable to sample this habitat in the study grid for safety reasons, it follows that there are potential biases in the data generated from the study grid (Figure 2-2). This is due to the possibility that areas inshore of the eastern edge of the study grid may contain high densities of shoreline taxa such as intertidal fishes in the families cottidae (sculpins), clinidae (kelpfishes), pholididae (gunnels), stichaeidae (pricklebacks), and gobioidae (clingfishes) whose abundance may be underestimated in this sampling design. Consequently, these potential underestimates of shoreline abundance could lead to an overall underestimate of abundance in the total study grid. One of the potential problems that could arise from this situation is that *PE* may overestimate the effects of entrainment on shoreline taxa that occur in high abundance at DCP's intake

structure, but occur in low abundance, or not at all, in the study grid. Another is that certain developmental stages or taxa may occur in the study grid, but not in entrainment samples which could lead to an underestimate of entrainment effects by *PE*. This latter case is easily resolved by only calculating *PE* for those taxa that are entrained and by comparing the developmental stages present in both sampling areas so as not to include those that are found in the study grid and not at the intake.

A second concern remains, that the abundance of larvae distributed nearshore will potentially not be adequately sampled by the present grid design if they remain near shore. There is some evidence that intertidal fish larvae are retained inshore (Marliave, 1986), but the high energy coastal zone adjacent to the study grid (e.g., exposed rocky coastline, open ocean swells, pronounced seasonal mixing) likely helps disperse larvae into the study grid. Our preliminary results support this latter supposition because nearly all of the taxa with adult distributions extending into the intertidal and represented by larvae in the entrainment samples are also collected in the study grid samples. Thus, despite the potential biases associated with estimating *PE* as described above, overall it appears that the size of the grid and design of the sampling program are sufficient to characterize the distribution and taxonomic composition of larval fishes in the study grid so that the ETWG can evaluate the effects of entrainment losses on each taxon that is collected at the DCP intake. However, *PE* estimates could be suspect when high values are calculated and it is not known whether these result from an inshore distribution that has not been sampled or some other type of changing vulnerability (e.g., diel or tidal influence on patchiness or larval susceptibility to capture). Thus, a high *PE* may not necessarily indicate large negative effects on the global population but could reflect unique local distributions and must, therefore, be interpreted on a taxon by taxon basis both locally and in the context of the larger population of inference.

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APPENDIX A

**Statistical Overview for Estimating Proportional Entrainment
by Dr. J.R. Skalski
University of Washington, School of Fisheries.**

APPENDIX A

Statistical Overview for Estimating Proportional Entrainment
by Dr. J.R. Skalski, University of Washington, School of Fisheries.

I. Introduction

One potential measure of the effects of entrainment is an estimate of proportional entrainment, defined as the ratio of:

$$PE = \frac{\text{number of larvae entrained per day}}{\text{number of larvae in the grid at risk of entrainment}}$$

Periodic and season-wide estimates of proportional entrainment could be used as measures of the relative effect of the Diablo Canyon Power Plant (DCPP) on local larval populations.

The purpose of this report is to characterize the nature of alternative estimators of proportional entrainment (\hat{PE}) and the sampling program needed to provide data for the estimates. Critical assumptions will be identified and discussed. The general form of the variance estimator will also be developed for a single survey and a composite estimator across surveys.

II. Estimator of Proportional Entrainment

The parameter proportional entrainment can be formally expressed as

$$PE_i = \frac{N_i}{R_i} \quad (1)$$

where:

PE_i = proportional entrainment for the i th survey period ($i = 1 \dots s$);

N_i = abundance of entrained larvae sampled during the i th survey period ($i = 1 \dots s$);

R_i = abundance of larvae in the study grid during the i th survey period ($i = 1 \dots s$).

The parameter PE_i measures proportional entrainment over a specified period of time, say, one day. Then N_i and R_i are abundance levels over that same one-day period of time.

A heuristic estimator of PE_i would naturally follow as

$$PE_i = \frac{\hat{N}_i}{\hat{R}_i}$$

where

\hat{N}_i = estimated abundance of larvae entrained during the i th survey period ($i = 1 \dots s$);

\hat{R}_i = estimated abundance of larvae in the study grid during the i th survey period

($i = 1 \dots s$).

The estimator \hat{N}_i is a well-defined concept that can be estimated by periodic sampling at the DCPD intake over time and space during the i th survey period. Details of estimating N_i will be presented below. On the other hand, R_i also has spatial and temporal dimensions that must be defined over the course of the survey. The spatial and temporal dimensions of R_i , however, are not as self-evident.

Spatially, R_i encompasses the regional waters around DCPD that are susceptible to potential entrainment. The specific zone of potential entrainment is not readily defined by existing hydrographic data. At least two approaches will be used to help define this zone. As an initial step, the spatial area associated with R_i was defined for the purposes of survey design as a zone about DCPD such that <1% of the water volume is entrained daily. This grid was constrained to a point offshore of Pt. Buchon by limits of the sampling gear and by the desire to initially sample the largest area reasonably possible. For purposes of survey design, this is the initial target population of inference. The number of grid cells included in the estimation of PE may be decreased based on distribution data of target taxa as appropriate.

The temporal dimension of R_i is equivalent to the time entrainment is estimated at the intake (i.e., 24 hours). What this implies is that R_i is the number of larvae within the zone of potential entrainment (the study grid) over the 24-hour period. Hence, R_i may be rewritten as

$$R_i = (1 + f_i)A_i$$

where

A_i = instantaneous abundance of larvae within the entrainment zone during the i th survey period ($i = 1 \dots s$);

f_i = fractional exchange rate of the larval population within the entrainment zone during the one-day survey period ($i = 1 \dots s$).

For example, if 25% of the water mass within the entrainment zone exchanges within a one-day period, then $R_i = (1 + 0.25)A_i = 1.25A_i$.

Hence, the estimator of proportional entrainment can now be written as

$$PE_i = \frac{\hat{N}_i}{(1 + \hat{f}_i)\hat{A}_i} \quad (2)$$

suggesting the study design consists of three distinct survey elements associated with the estimation of f_i , N_i , and A_i . An assumption of $f_i = 0$, should result in either an equal or overestimate of PE_i . From a practical standpoint it is unlikely that f_i could be zero and impossible for f_i to be negative, but it remains a mathematical possibility that f_i could lead to an underestimate of PE_i . By assuming $f_i = 0$ because we do not know its true value, we are estimating a first approximation of PE_i that could be elaborated upon if measurements of f_i were incorporated in the calculations.

Boreman et al. (1981) take organism and water movement patterns in the study area into account with their parameter D that defines the proportion of the larval standing crop that was in the entrainment region during the survey period. Using our notation, the proportion of the standing larval crop that were in the study area during a survey would be expressed as

$$D = \frac{(1+f)A_i}{P_T}$$

where P_T = total abundance of the standing crop of larvae. They then define the population-wide probability of entrainment mortality as

$$\begin{aligned} PPE &= 1 - DS \\ &= 1 - \left(\frac{(1+f)A_i}{P_T} \right) \left(\frac{P_T - N_i}{(1+f)A_i} \right) \\ &= 1 - \frac{P_T - N_i}{P_T} \\ &= \frac{N_i}{P_T} \end{aligned}$$

where we define it as

$$\begin{aligned} PPE &= PE \cdot P_S \\ &= \frac{N_i}{(1+f)A_i} \cdot \frac{(1+f)A_i}{P_T}, \\ &= \frac{N_i}{P_T} \end{aligned}$$

which are equivalent. In both formulations the fact that the study are is not a closed system with respect to water movement and larval numbers is being taken into account. The use of f assumes larval abundance is well-mixed such that a 25% water exchange per day is equivalent to a 25% larval exchange per day. The parameter D can avoid this assumption on a theoretical basis, but must practically resort to this sample assumption in computing a value for the parameter under typical survey circumstances.

Treating the three survey elements as independent survey tasks, the variance of PE_i is approximated using the delta method (Seber, 1984) as

$$Var(PE_i) = (PE_i)^2 [CV(\hat{N}_i)^2 + CV(1+f_i)^2 + CV(\hat{A}_i)^2] \quad (3)$$

where CV denotes the coefficient of variation [i.e., $SE(\hat{\theta})/\theta$] for a parameter estimate (Appendix D). Inspection of variance formula (3) indicates the overall precision of PE_i depends on the precision of the three separate survey elements as defined by CV.

The next section outlines the survey design to estimate \hat{N}_i and \hat{A}_i .

III. Survey Sampling Design

Survey to Estimate N_i

The survey to estimate numbers of entrained larvae at DCPD will consist of a 24-hour study conducted once weekly. During the 24-hour period, the time will be stratified into eight 3-hour blocks. Within a 3-hour block of time, four intake locations are each sampled twice during the block. These eight samples

will be assumed to be a simple random sample (SRS) of entrainment, although in reality they more closely approximate a replicated systematic survey. Typically, assuming an SRS when data are collected using a systematic survey will result in the overestimation of sampling error (Wolter, 1984).

Let

x_{ijk} = larval density (i.e., number/m³) for the k th sample ($k=1\dots 8$) in the j th block of time ($j=1\dots 8$) in the i th survey ($i=1\dots s$).

Mean larval density within a block would then be estimated by

$$\bar{x}_{ij} = \frac{\sum_{k=1}^8 x_{ijk}}{8} .$$

The estimate of entrainment during the j th block of time would then be estimated as

$$\hat{N}_{ij} = V_{ij} \bar{x}_{ij}$$

where

V_{ij} = volume of daily water intake (i.e., m³) during the j th block ($j=1\dots 8$) in the i th survey ($i=1\dots s$).

Daily water cooling water intake by DCPD is from reported design specifications for the power plant (PG&E 1998). The estimate of daily entrainment abundance would then be estimated by

$$\hat{N}_i = \sum_{j=1}^8 V_{ij} \bar{x}_{ij}$$

with the associated variance estimator

$$\hat{V}ar(\hat{N}_i) = \sum_{j=1}^8 V_{ij}^2 \frac{(1 - C_{ij}) \hat{S}_{x_{ijk}}^2}{8}$$

where

$$\hat{S}_{x_{ijk}}^2 = \frac{\sum_{k=1}^8 (x_{ijk} - \bar{x}_{ij})^2}{8 - 1}$$

C_{ijk} = finite population correction, i.e., fraction of water volume sampled to water intake during the 3-hour block.

The values of C_{ijk} 's will be near zero; hence, the variance would be estimated by

$$\hat{V}ar(\hat{N}_i) = \sum_{j=1}^8 \left[\frac{V_{ij}^2 \hat{S}_{x_{ijk}}^2}{8} \right] .$$

Survey to Estimate A_i

A first approximation of the zone affected by entrainment, the effective entrainment zone, will be

defined as an area 2.8 km by 17.6 km = 48.9 km². This area will be subdivided into 64 grid rectangles termed 'cells'. Stratified random sampling would be used to estimate larval abundance within each cell and subsequently estimate total abundance in the region.

Assuming a minimum of two net tows per cell, the sampling design would consist of 128 samples from the total study grid. This should be considered the minimum effort. Additional effort and optimal allocation could be assessed after initial months of survey data have been collected. Let

y_{ijk} = density of larvae (i.e., per m³ water) for the k th sample ($k = 1-2$) in the j th cell ($j = 1 \dots 64$) of the i th survey ($i = 1 \dots s$).

Then, mean density within a cell would be estimated by

$$\bar{y}_{ij} = \frac{\sum_{k=1}^2 y_{ijk}}{2}$$

and larval abundance in the j th cell as

$$\hat{A}_{ij} = V_{ij} \bar{y}_{ij}$$

where again V_{ij} is the water volume in the j th cell of the i th survey. Total larvae abundance would then be estimated by

$$\hat{A}_i = \sum_{j=1}^{64} V_{ij} \bar{y}_{ij}$$

The variance for \hat{A}_i then follows directly from stratified random sampling where

$$\begin{aligned} \text{Var}(\hat{A}_i) &= \sum_{j=1}^{64} V_{ij}^2 \text{Var}(\bar{y}_{ij}) \\ &= \sum_{j=1}^{64} V_{ij}^2 \frac{(1 - C_{ij}) \hat{S}_{y_{ijk}}^2}{2} \end{aligned}$$

Where

C_{ij} = finite population correction (≈ 0),

$$\hat{S}_{y_{ijk}}^2 = \frac{\sum_{k=1}^2 (y_{ijk} - \bar{y}_{ij})^2}{(2 - 1)}$$

Considerations in conducting the survey to estimate \hat{A}_i include the following:

1. Nets will be lowered to the bottom to sample the entire water column, assuming in doing so, the sampling process negates the diel vertical movements of larvae.
2. Sampling during hours when larvae are more evenly distributed vertically may provide more precise but not necessarily more accurate estimates of larvae density.
3. Sampling may take more than one day; in which case, larvae distributions are assumed to be

homogeneous over time or temporally invariant over the course of the survey.

4. Sampling to estimate A_i should be coincident or centered about the monthly estimation of N_i .
5. The accurate estimation of PE_i , is largely dependent on accurately defining the zone of entrainment used in estimating A_i .

The above analysis to estimate A_i is based on survey design principles of SRS and can be considered nonparametric. An alternative analysis approach using kriging is a potential model-based approach which could improve the precision of the estimates A_i . This option should be considered and evaluated.

Survey to Estimate f_i

A hydrographic survey will be required to estimate the water exchange rate (f_i) within the zone of potential entrainment. Details of the survey design to estimate f_i must be found elsewhere. Presently, f_i is assumed to be $\cong 0$ as a conservative estimator of flux rate within the study grid.

Annual or Season-wide Estimates of Proportional Entrainment

Besides estimating a monthly value of PE and associated precision, there may be the desire to combine estimates over time to provide either annual or seasonal estimates. The estimates of annual PE would be calculated as

$$PE_{\hat{E}} = \frac{\sum_{i=1}^s d_i \hat{N}_i}{\sum_{i=1}^s d_i (1 + \hat{f}_i) \hat{A}_i} \tag{4}$$

where

d_i = number of days in i th month ($i = 1 \dots s$)

The proposed survey design samples only once monthly; hence, intramonth variability cannot be estimated or incorporated into annual calculations of PE . A conservative but valid estimate (i.e., overestimate) of the intra-monthly variability could be estimated from among the monthly estimates if so desired.

Ignoring the slight differences in period length and assuming a constant f_i over time, then estimator (4) reduces to

$$PE_{\hat{E}} = \frac{\sum_{i=1}^s \hat{N}_i}{(1 + f_i) \sum_{i=1}^s \hat{A}_i}$$

or assuming f_i varies over time

$$PE_{\hat{E}} = \frac{\sum_{i=1}^s \hat{N}_i}{\sum_{i=1}^s (1 + \hat{f}_i) \hat{A}_i} \tag{5}$$

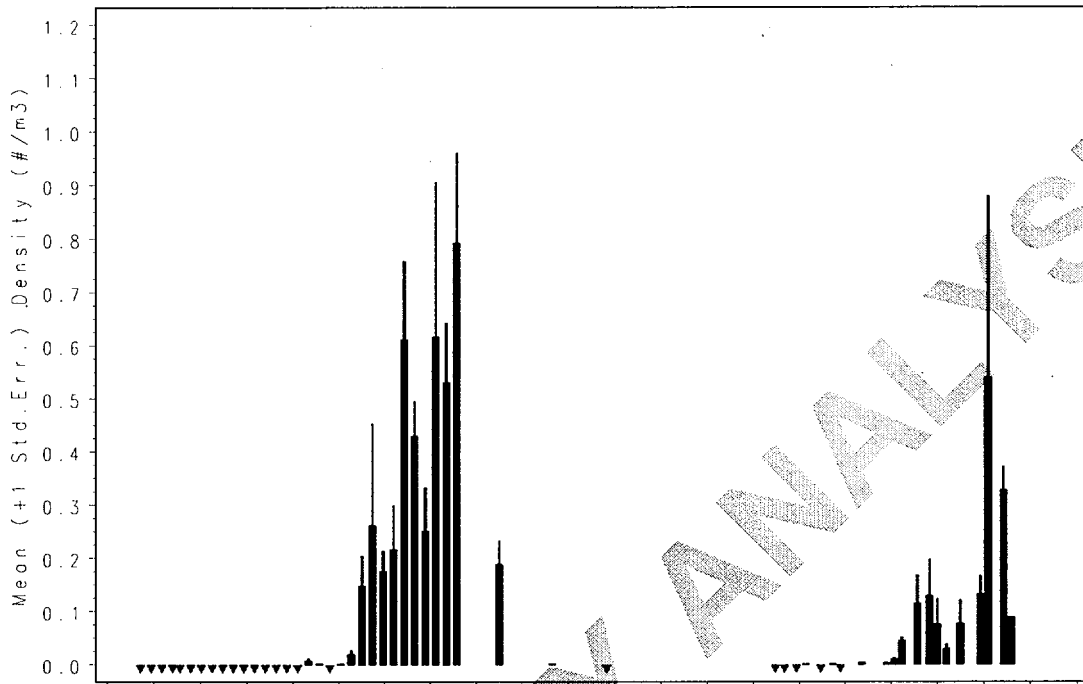
APPENDIX B

Weekly Mean Densities and Standard Errors of Larval Fish Taxa Collected at the DCPD Intake

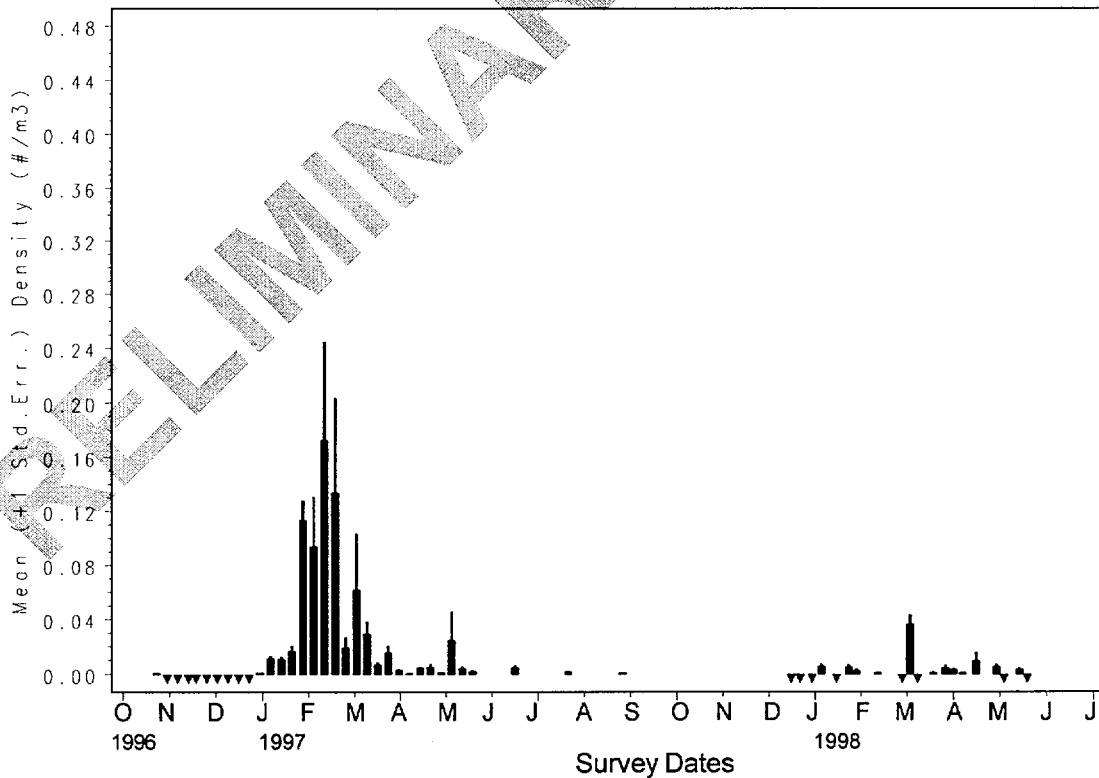
Weekly mean density of larval fishes ($\#/m^3 + 1$ Std. Err.) at DCPD from surveys for which preliminary laboratory analyses have been completed by June 24, 1998. The value-axis (y-axis) scale varies between figures. NOTE: Data are preliminary and not intended for use in any context other than this report.

APPENDIX B

B-1) rockfishes (*Sebastes* spp. V_De; larval pigment group)

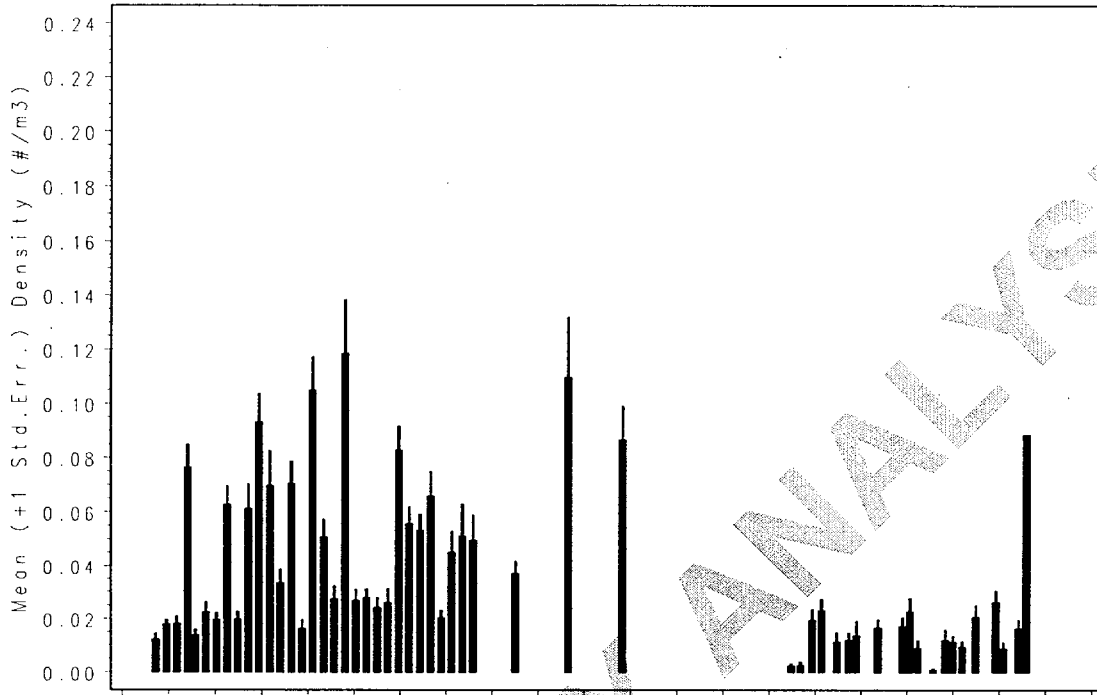


B-2) rockfishes (*Sebastes* spp. V; larval pigment group)

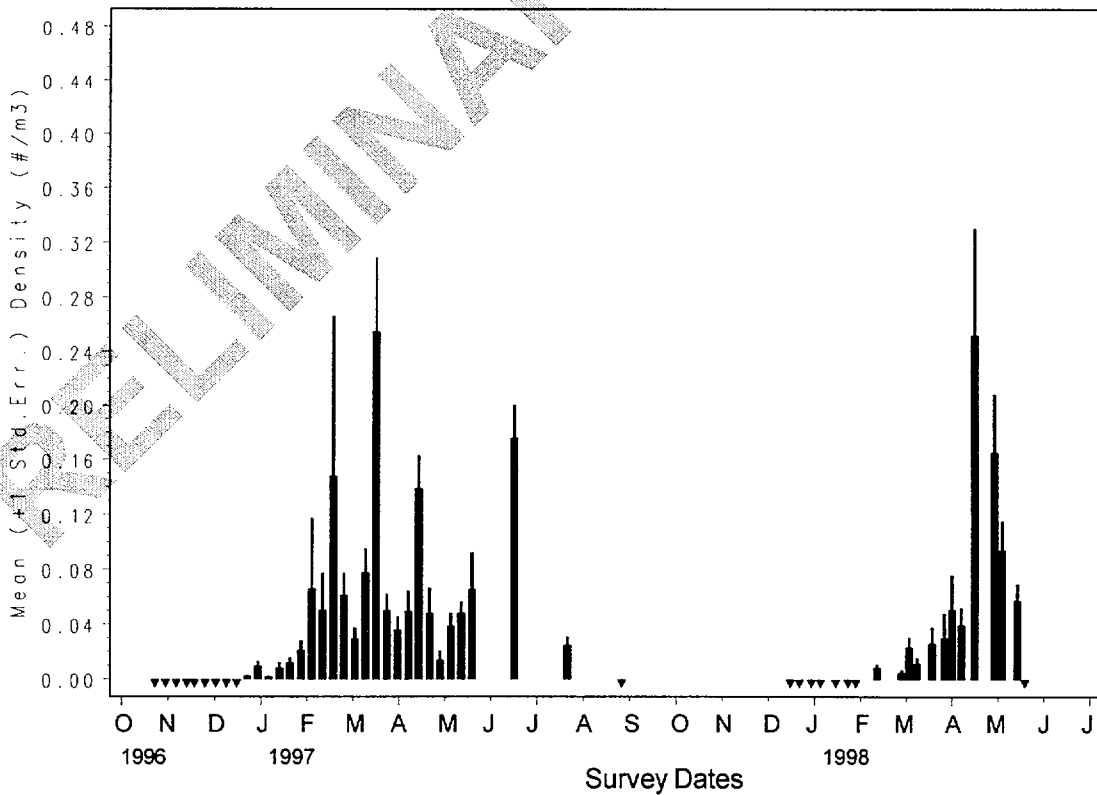


▼ - designates survey with density = 0

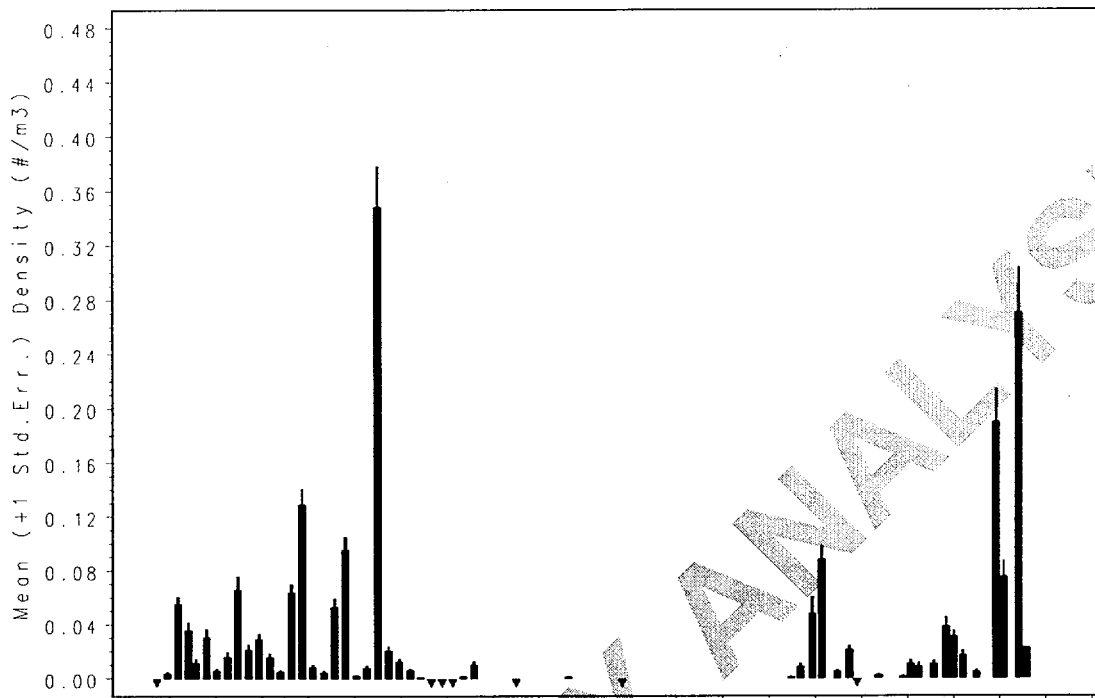
B-3) clinid kelpfishes (*Gibbonsia* spp.)



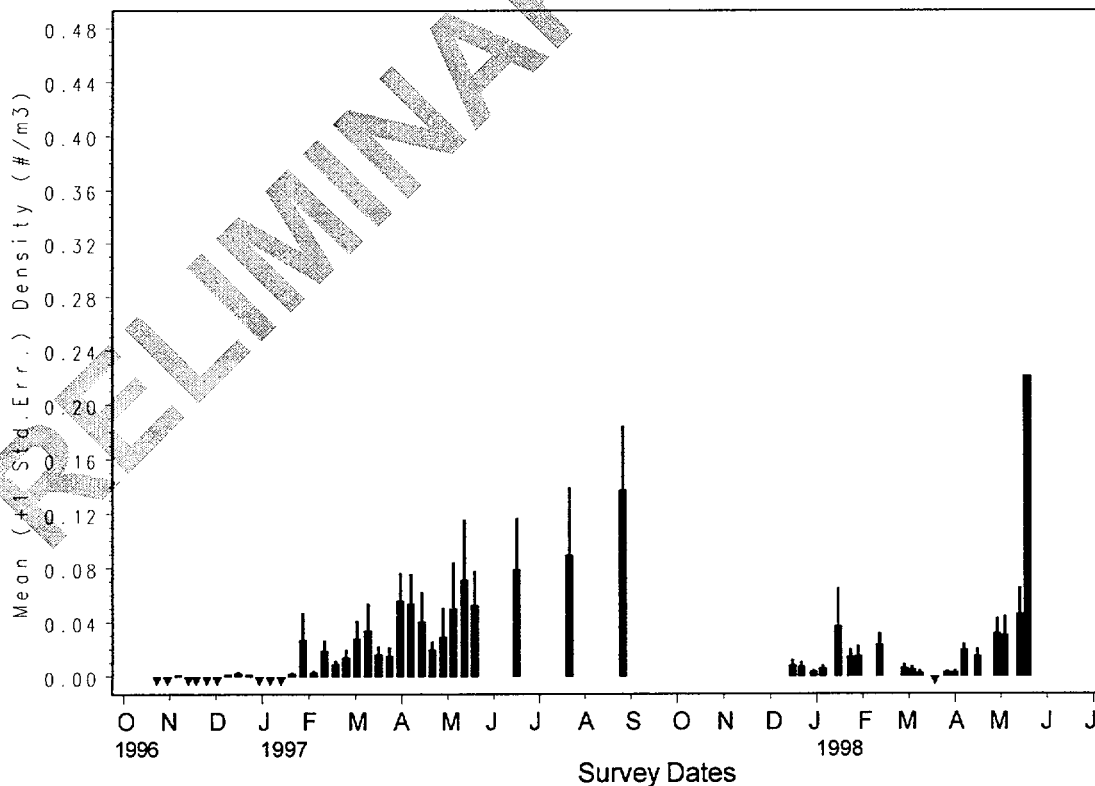
B-4) monkeyface eel (*Cebidichthys violaceus*)



B-5) white croaker (*Genyonemus lineatus*)

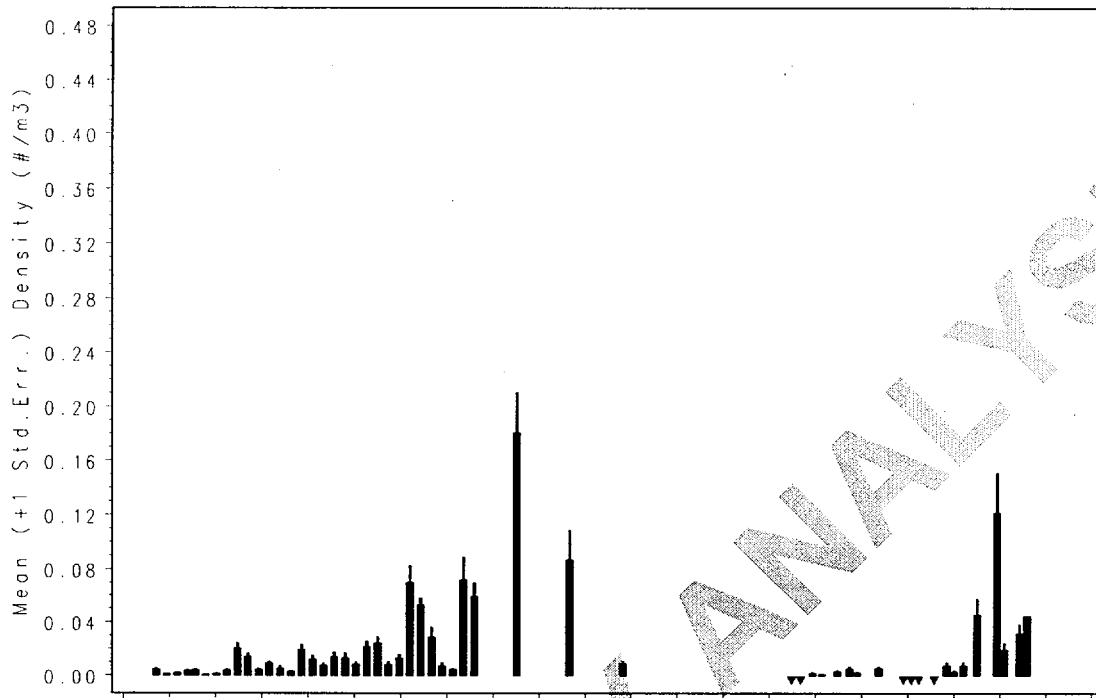


B-6) blackeye goby (*Coryphopterus nicholsi*)

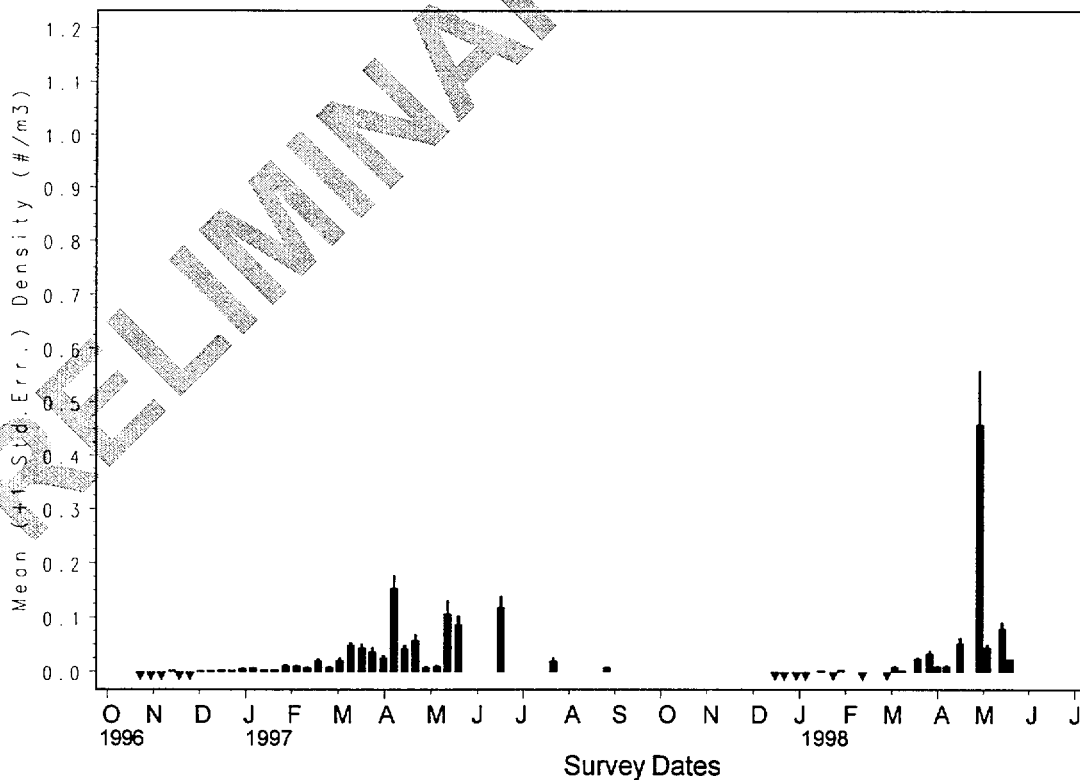


▼ - designates survey with density = 0

B-7) snubnose sculpin (*Orthonopias triacis*)

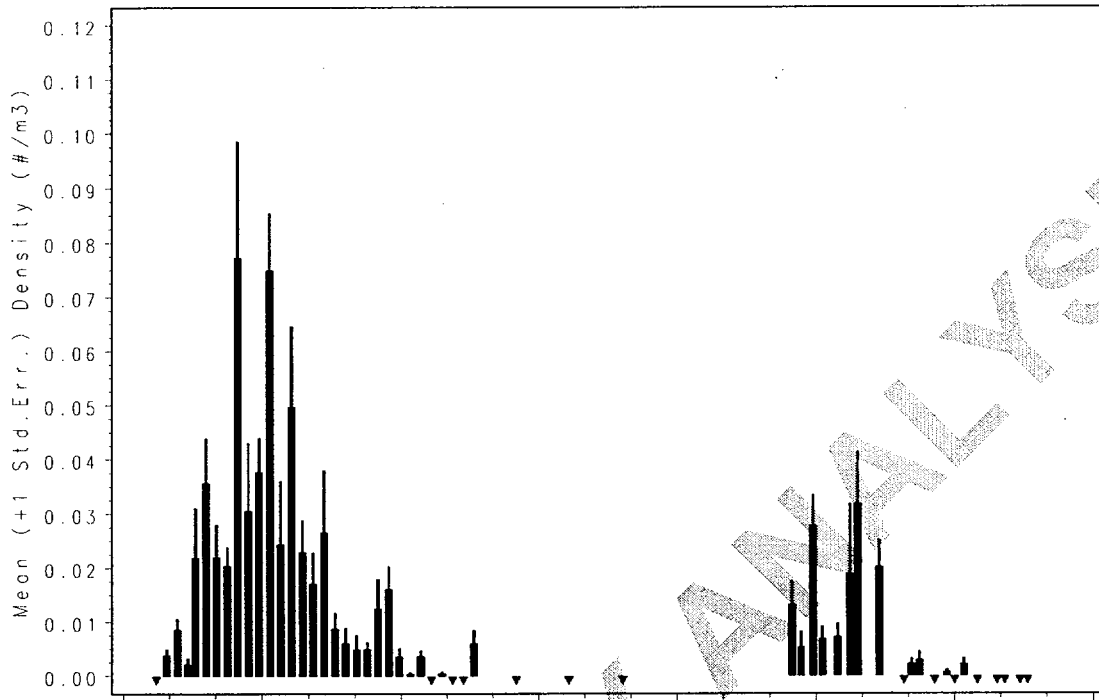


B-8) smoothhead sculpin (*Artedius lateralis*)

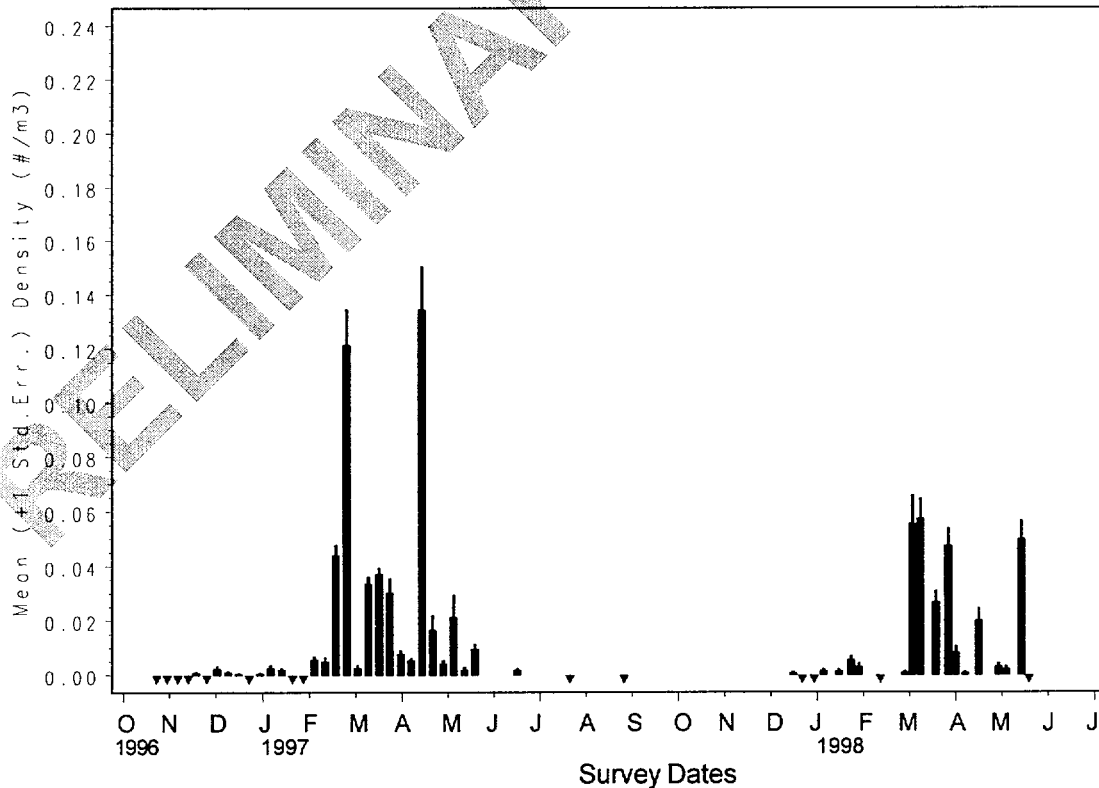


▼ - designates survey with density = 0

B-9) cabezon (*Scorpaenichthys marmoratus*)

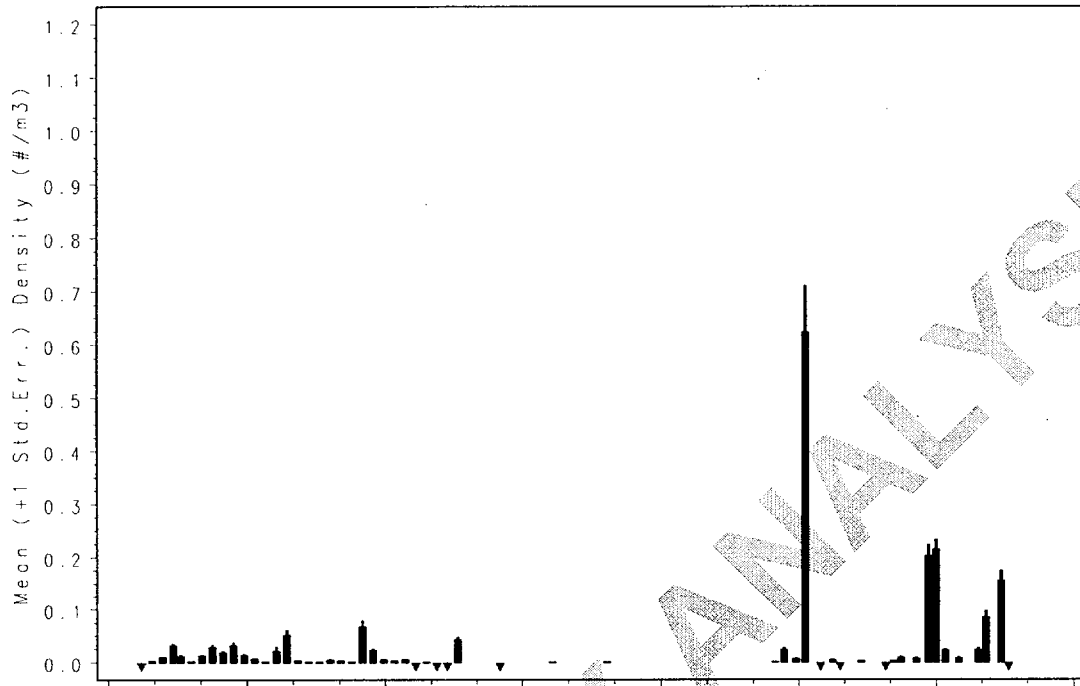


B-10) northern lampfish (*Stenobranchius leucopsarus*)

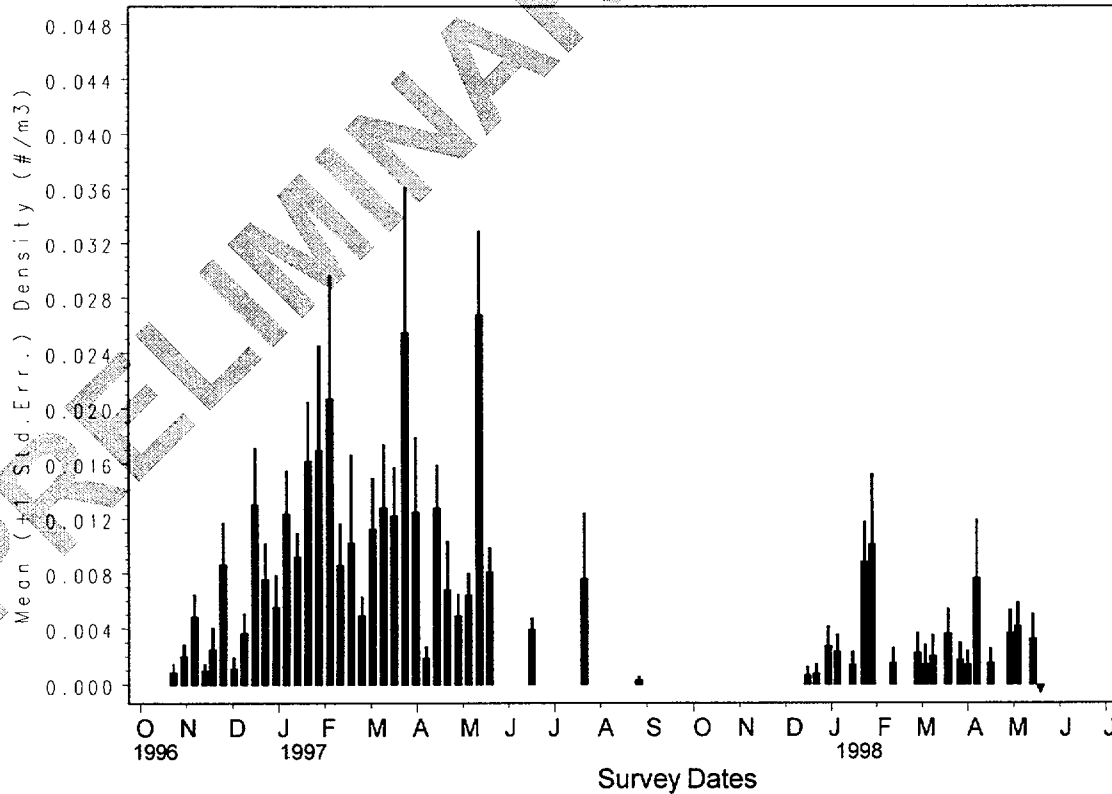


▼ - designates survey with density = 0

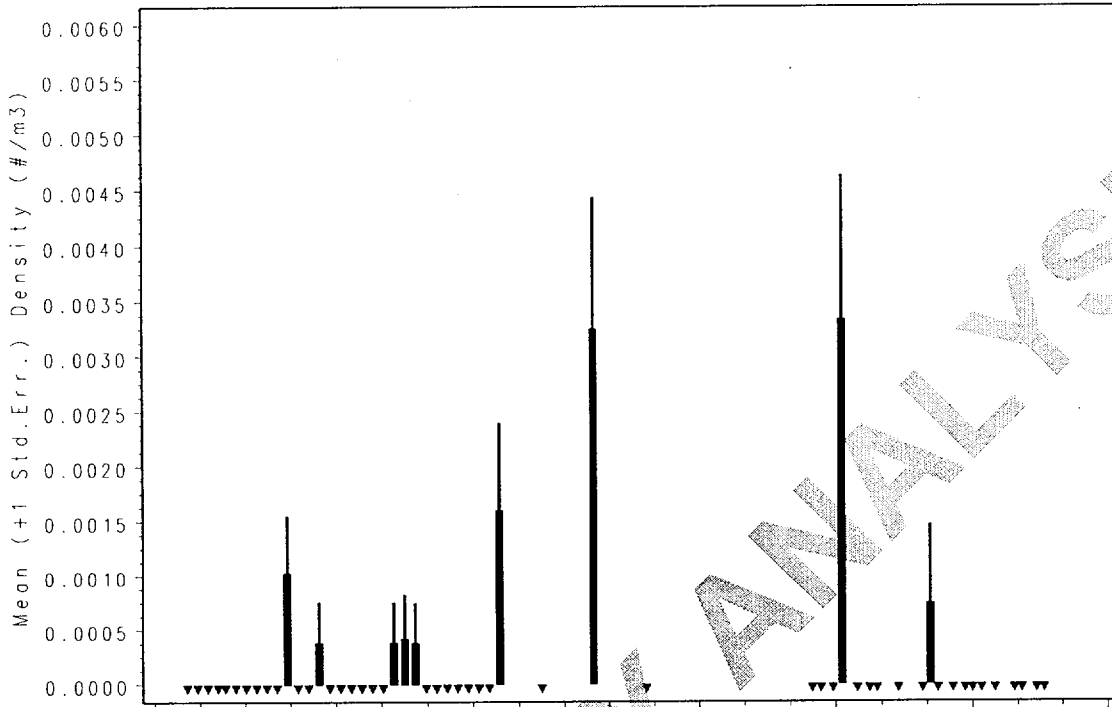
B-11) northern anchovy (*Engraulis mordax*)



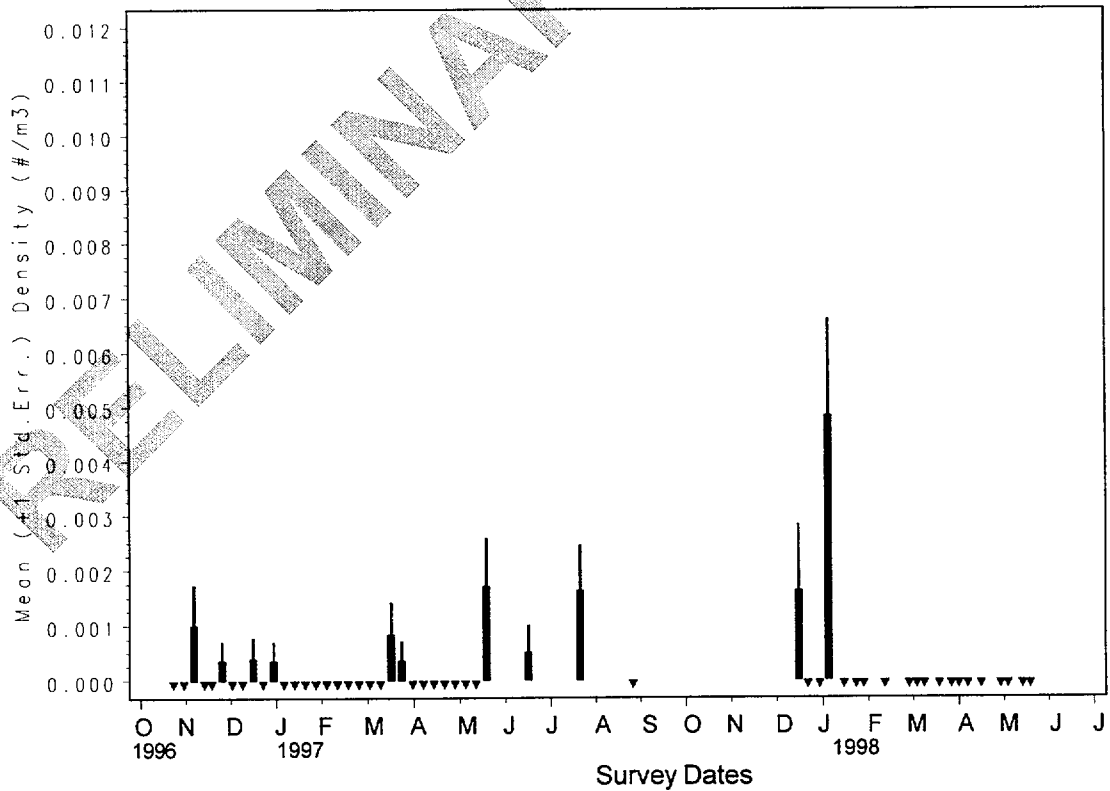
B-12) painted greenling (*Oxylebius pictus*)



B-15) speckled sanddab (*Citharichthys stigmaeus*)



B-16) Pacific sanddab (*Citharichthys sordidus*)



▼ - designates survey with density = 0

APPENDIX C

Mean Densities of the Ten Most Abundant Fish Taxa, July and August 1997

APPENDIX C

Mean density (#/m³) and standard deviation of the ten most abundant fish taxa collected in the study grid and entrainment samples. Shaded boxes are for those taxa that were densest in both paired surveys, '—' indicates that this taxon did not occur in the survey: C-1) July 21-24, 1997 study grid and July 21-22, 1997 entrainment; C-2) August 25-28, 1997 study grid and August 26-27, 1997 entrainment. NOTE: Data are preliminary and not intended for use in any context other than this report.

C-1)

Taxon	Common name	Study grid July 21-24, 1997			Entrainment Survey July 21-22, 1997		
		Mean Density (#/m ³)	Standard Deviation	Rank	Mean Density (#/m ³)	Standard Deviation	Rank
<i>Artedius lateralis</i>	smoothhead sculpin	0.020	0.053	6	0.019	0.054	6
<i>Cebidichthys violaceus</i>	monkeyface eel	0.008	0.021	12	0.025	0.049	5
<i>Citharichthys stigmaeus</i>	speckled sanddab	0.009	0.022	10	0.003	0.007	19
<i>Citharichthys</i> spp.	sanddabs	0.008	0.024	11	0.007	0.012	12
<i>Clinocottus analis</i>	wooly sculpin	0.005	0.017	15	0.011	0.028	8
<i>Coryphopterus nicholsi</i>	blackeye goby	0.033	0.053	3	0.089	0.291	2
<i>Gibbonsia</i> spp.	clinid kelpfishes	0.034	0.170	2	0.110	0.150	1
<i>Liparis</i> spp.	snailfishes	0.020	0.039	7	0.008	0.012	11
<i>Orthonopias triacis</i>	snubnose sculpin	0.051	0.171	1	0.086	0.196	3
<i>Oxylebius pictus</i>	painted greenling	0.006	0.017	13	0.008	0.028	10
<i>Radulinus</i> spp.	sculpins	0.002	0.009	26	0.006	0.015	13
<i>Typhlogobius californiensis</i>	blind goby	0.027	0.050	5	0.003	0.007	18

C-2)

Taxon	Common name	Study grid August 25-28, 1997			Entrainment Survey August 26-27, 1997		
		Mean Density (#/m ³)	Standard Deviation	Rank	Mean Density (#/m ³)	Standard Deviation	Rank
<i>Artedius lateralis</i>	smoothhead sculpin	0.003	0.008	9	0.007	0.012	6
<i>Artedius</i> spp.	sculpins	—	—	—	0.002	0.009	10
<i>Citharichthys sordidus</i>	Pacific sanddab	0.001	0.004	13	—	—	—
<i>Clevelandia ios</i>	arrow goby	—	—	—	0.002	0.005	12
<i>Coryphopterus nicholsi</i>	blackeye goby	0.026	0.045	1	0.141	0.295	1
<i>Engraulis mordax</i>	northern anchovy	0.007	0.014	3	<0.001	0.002	21
<i>Gibbonsia</i> spp.	clinid kelpfishes	0.004	0.030	7	0.090	0.096	2
<i>Gobiesox</i> spp.	clingfishes	—	—	—	0.006	0.007	8
<i>Lepidogobius lepidus</i>	bay goby	—	—	—	0.017	0.044	4
<i>Liparis</i> spp.	snailfishes	0.007	0.024	2	0.006	0.011	7
<i>Lythrypnus</i> spp.	gobies	0.002	0.010	10	—	—	—
<i>Orthonopias triacis</i>	snubnose sculpin	0.005	0.016	4	0.009	0.013	5
<i>Triphoturus mexicanus</i>	Mexican lampfish	<0.001	0.004	21	0.002	0.005	11
<i>Typhlogobius californiensis</i>	blind goby	0.005	0.018	5	—	—	—

APPENDIX D

Delta Method for Calculating Variance

APPENDIX D

Variance for PE_i

Using the delta method (Seber, 1984), variance of PE_i can be effectively approximated by

$$\begin{aligned} Var(PE_i) &= Var\left(\frac{\hat{N}}{(1+\hat{f})\hat{A}_i}\right) \\ &= Var(\hat{N}_i)\left(\frac{1}{(1+f_i)A_i}\right)^2 + Var(\hat{f}_i)\left(\frac{-N_i}{A_i(1+f_i)^2}\right)^2 \\ &\quad + Var(A_i)\left(\frac{-N_i}{(1+f)A_i^2}\right)^2 \\ &= \left(\frac{-N_i}{(1+f_i)A_i}\right)^2 \left[\frac{Var(\hat{N}_i)}{N_i^2} + \frac{Var(\hat{f}_i)}{(1+f_i)^2} + \frac{Var(\hat{A}_i)}{A_i^2} \right] \\ &= PE_i^2 [CV(\hat{N}_i)^2 + CV(1+\hat{f})^2 + CV(\hat{A}_i)^2] . \end{aligned}$$

Variance for S_A

can be estimated from

$$\hat{S}_A = \frac{2}{\hat{F} \cdot \hat{R} \cdot \hat{S}_E \cdot \hat{S}_L}$$

where:

\hat{F} = average egg mass per female per year;

\hat{R} = reproduction longevity, average number of years of reproduction for a female;

\hat{S}_E = egg survival rate;

\hat{S}_L = survival of larvae from hatching to time of entrainment.

The variance of \hat{S}_A based on the delta method is then estimated by the approximate formula

$$Var(\hat{S}_A) = S_A^2 \left[\frac{Var(\hat{F})}{\hat{F}^2} + \frac{Var(\hat{R})}{\hat{R}^2} + \frac{Var(\hat{S}_E)}{\hat{S}_E^2} + \frac{Var(\hat{S}_L)}{\hat{S}_L^2} \right] .$$

For the example of monkeyface eel, the variance of \hat{S}_A is estimated as

$$\begin{aligned} \text{Var}(\hat{S}_A) &= (0.0001388)^2 \left[\frac{(4,667)^2}{(32,000)^2} + \frac{(2.08)^2}{(11.75)^2} + \frac{(0.0373)^2}{(0.4240)^2} + \frac{(0.0314)^2}{(0.0904)^2} \right] \\ &= 0.0000000035 \end{aligned}$$

or

$$\hat{SE}(\hat{S}_A) = 0.00005905 .$$

Variance for $A\hat{E}L$

The estimator of adult equivalent loss is

$$A\hat{E}L = \hat{E}_T \cdot \hat{S}_A$$

with exact variance

$$\text{Var}(A\hat{E}L) = \text{Var}(\hat{E}_T) \cdot S_A^2 + \text{Var}(\hat{S}_A)^2 \cdot E_T^2 + \text{Var}(\hat{E}_T)^2 \cdot \text{Var}(\hat{S}_A) .$$

Using the variance formula in conjunction with the monkeyface eel data results in an estimated variance of

$$\begin{aligned} \hat{V}ar(A\hat{E}L) &= (197,677,101)^2 (0.0001388)^2 + (0.00005905)^2 (160,544,555)^2 + (192,677,101)^2 (0.00005905) \\ &= 934,541,905.8 \end{aligned}$$

or

$$\hat{SE}(A\hat{E}L) = 30,570.3 .$$

Variance for $\hat{F}H$

The estimator of hindcast fecundity lost is

$$\hat{F}H = \frac{\hat{E}_T}{\hat{S}_E \cdot \hat{S}_L \cdot \hat{F}_T}$$

where

\hat{E}_T = estimated total entrainment of larvae;

\hat{S}_E = survival probability for eggs;

\hat{S}_L = survival of larvae from hatching to time of entrainment;

\hat{F}_T = estimated average total lifetime fecundity = $\hat{F} \cdot \hat{R}$.

Using the Delta method, an approximate variance estimator is

$$\hat{V}ar(\hat{F}H) = FH^2 \left[\frac{\hat{V}ar(\hat{E}_T)}{\hat{E}_T^2} + \frac{\hat{V}ar(\hat{S}_E)}{\hat{S}_E^2} + \frac{\hat{V}ar(\hat{S}_L)}{\hat{S}_L^2} + \frac{\hat{V}ar(\hat{F})}{\hat{F}^2} + \frac{\hat{V}ar(\hat{R})}{\hat{R}^2} \right] .$$

For the example of monkeyface eel, the variance of \hat{FH} is calculated to be

$$\begin{aligned} \hat{V}ar(\hat{FH}) &= (11,140)^2 \left[\frac{(192,677,101)^2}{(160,544,555)^2} + \frac{(0.0373)^2}{(0.4240)^2} + \frac{(0.0314)^2}{(0.0904)^2} + \frac{(4,667)^2}{(32,000)^2} + \frac{(2.08)^2}{(11.75)^2} \right] \\ &= 201,208,630 \end{aligned}$$

or

$$\hat{S}E(\hat{FH}) = 14,184.8 .$$

APPENDIX E

***PE* Estimates from Sequentially Varying Study Grid Shape and Size**

APPENDIX E

E1

Preliminary estimates from sequential expansion of the study grid offshore from the intake of measured and expected proportional entrainment (PE) and its standard error (SE; $\pm 2SE = 95\%$ confidence interval) in percentages for eight examples of taxa entrained at DCP (sequence of $n=2, 4, 12, 16, 30, 36, 56, 64$; see Figure 2-5a). NOTE: Data are preliminary and not intended for use in any context other than this report.

July 1997

Taxa	n=2	n=4	n=12	n=16	n=30	n=36	n=56	n=64
	PE (%)	2 SE (%)	PE (%)	2 SE (%)	PE (%)	2 SE (%)	PE (%)	2 SE (%)
<i>Arctidius lateralis</i>	18	19	3	2	3	1	1	1
<i>Cebidichthys violaceus</i>	48	71	8	5	4	2	3	2
<i>Citharichthys</i> spp.	51	100	12	20	4	1	1	<1
<i>Coryphopterus nitobolus</i>	620	1,400	40	45	16	14	4	2
<i>Githbonisa</i> spp.	48	97	47	48	19	21	6	5
<i>Liparis</i> spp.	12	24	2	1	<1	<1	<1	<1
<i>Orthompius triacis</i>	52	82	9	8	3	2	2	1
<i>Oxyechinus pictus</i>	-	-	8	13	5	8	2	2
Expected PE (%)	40	-	15	-	5	-	2	-

August 1997

Taxa	n=2	n=4	n=12	n=16	n=36	n=56	n=64
	PE (%)	2 SE (%)	PE (%)	2 SE (%)	PE (%)	2 SE (%)	2 SE (%)
<i>Arctidius lateralis</i>	-	-	10	10	7	7	3
<i>Cebidichthys violaceus</i>	-	-	-	-	-	-	-
<i>Citharichthys</i> spp.	-	1	1	2	1	1	<1
<i>Coryphopterus nitobolus</i>	-	87	180	20	17	16	8
<i>Githbonisa</i> spp.	380	750	180	250	180	250	75
<i>Liparis</i> spp.	-	10	21	5	6	4	2
<i>Orthompius triacis</i>	-	27	54	9	7	4	3
<i>Oxyechinus pictus</i>	-	-	1	3	1	3	1
Expected PE	40	15	5	3	2	1	1

“-“ indicates taxon not collected in the survey

E2

Preliminary estimates from offshore expansion of the study grid by row of measured and expected proportional entrainment (PE) and its standard error (SE, $\pm 2 SE = 95\%$ confidence interval) in percentages for eight examples of taxa entrained at DCP (sequence of $n=8, 16, 24, 32, 40, 48, 56, 64$; see Figure 2-5b). NOTE: Data are preliminary and not intended for use in any context other than this report.

July 1997

Taxa	n=8	n=16	n=24	n=32	n=40	n=48	n=56	n=64
	PE (%)	2 SE (%)	PE (%)	2 SE (%)	PE (%)	2 SE (%)	PE (%)	2 SE (%)
<i>Atracinus lateralis</i>	16	17	2	1	1	1	1	1
<i>Cebidichthys violaceus</i>	48	71	10	7	4	2	3	2
<i>Citharichthys</i> spp.	7	9	3	3	1	1	1	<1
<i>Coryphopterus nicholsi</i>	87	130	22	26	10	8	4	3
<i>Gilbousia</i> spp.	12	13	7	7	6	5	5	5
<i>Liparis</i> spp.	5	5	2	1	1	<1	<1	<1
<i>Orthomopius tricus</i>	42	55	5	4	2	2	2	1
<i>Oxylechis plicatus</i>	9	13	4	6	3	2	2	1
Expected PE	12		5	3	3	2	1	1

August 1997

Taxa	n=8	n=16	n=24	n=32	n=40	n=48	n=56	n=64
	PE (%)	2 SE (%)	PE (%)	2 SE (%)	PE (%)	2 SE (%)	PE (%)	2 SE (%)
<i>Atracinus lateralis</i>	28	16	17	16	10	7	7	3
<i>Cebidichthys violaceus</i>	-	-	-	-	-	-	-	-
<i>Citharichthys</i> spp.	-	1	1	2	1	1	1	<1
<i>Coryphopterus nicholsi</i>	420	870	64	100	15	12	7	7
<i>Gilbousia</i> spp.	380	750	59	100	50	75	44	59
<i>Liparis</i> spp.	41	82	2	2	2	1	1	1
<i>Orthomopius tricus</i>	-	11	15	4	4	3	2	2
<i>Oxylechis plicatus</i>	-	-	-	1	1	3	1	3
Expected PE	12		5	3	3	2	1	1

“-” indicates taxon not collected in the survey

APPENDIX F

Impingement

Diablo Canyon Power Plant 316(b) Study

Impingement

November 23, 1998

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1.0 INTRODUCTION TO DCPD IMPINGEMENT STUDY

The purpose of this report is to determine if additional impingement monitoring at the Diablo Canyon Power Plant (DCPP) is necessary based on a review of the 1985-1986 316(b) impingement study (PG&E, 1988). This report also reviews modifications made to the traveling screen assemblies since 1987 and the potential effects of those changes on impingement.

The DCPD cooling water system entrains and impinges larval, juvenile and adult fishes and invertebrates. Impingement occurs when organisms too large to pass through the 3/8-in. mesh of the traveling screens are held against the screens by the velocity of the water pumped into the plant. Entrainment occurs when organisms smaller than the traveling screen mesh pass through the screens and enter the cooling water system. Although some fraction of entrained and impinged organisms were expected to survive after returning to the ocean, the DCPD assessment assumed a zero chance of survival (PG&E, 1988). Estimated impingement mortality losses will be used in the Adult Equivalent Loss (AEL) and the Fecundity Hindcast (FH) modelling approaches described in the Phase 3 report.

1.1 Description of the DCPD Intake Structure

The intake for DCPD Units 1 and 2 is a shoreline structure housing bar racks, vertical traveling screens, auxiliary cooling water systems, and main circulating water pumps (Figure 1-1). On the ocean side of the

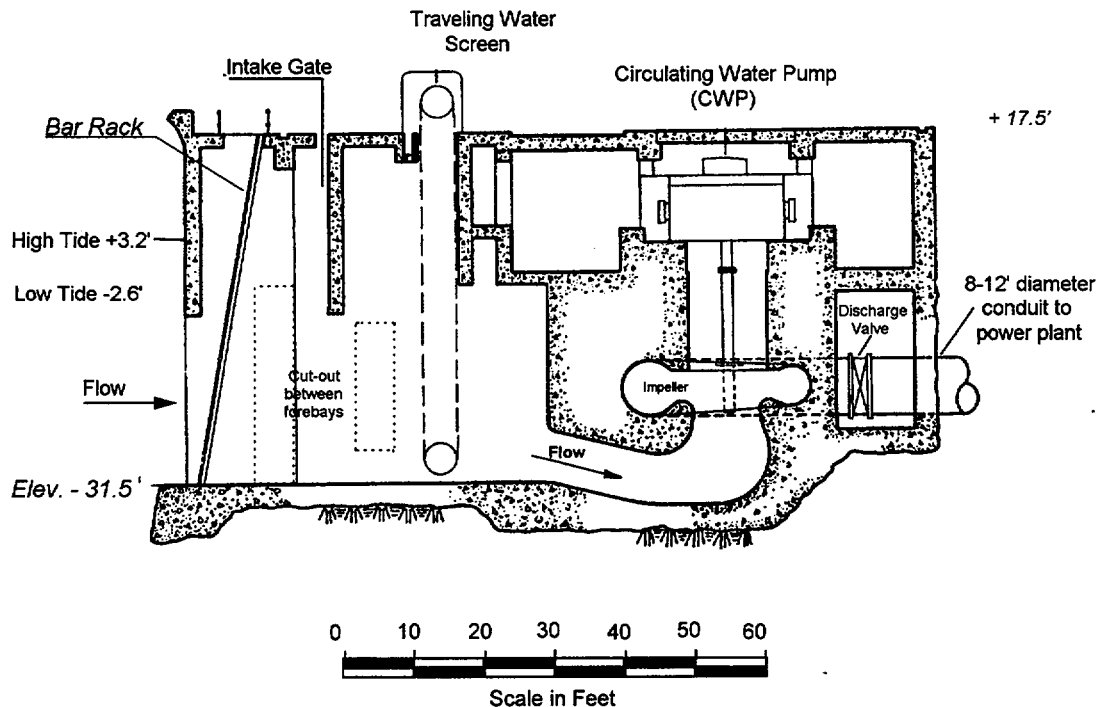


Figure 1-1. Cross-section diagram of DCPD intake structure showing waterflow path. Elevations are based on mean sea level (modified from PG&E 1988).

intake structure, a concrete curtain wall extends 7.75 feet below mean sea level (MSL) to prevent floating debris from entering the structure. Seawater entering the intake structure passes through 16 sets of bar racks designed to exclude large debris from the forebays. The bar racks are 5 or 10 ft wide vertical rows of 3-in. x 3/8-in. flat steel bars 3 inches apart. There are seven vertical traveling screens per unit that are used to remove debris that pass through the bar racks. The screens extend from the upper deck of the intake structure to the bottom at a depth of about 32 ft below (MSL). The six wider traveling screens filter seawater to the unit's two main circulating water pumps (CWP), and one narrower traveling screen filters seawater to the two auxiliary seawater (ASW) pumps. Each CWP traveling screen is composed of 57 baskets that are 10 ft wide by 2 ft tall. The ASW traveling screen also has 57 baskets that are 5 ft wide by 2 ft tall. The interior of each basket is covered with 3/8-in. mesh designed to prevent material from entering the conduits and clogging the 1-in. diameter condenser tubes. Objects small enough to pass through the bar racks and larger than the 3/8-in. mesh of the traveling screens may be impinged.

Each CWP has a manufacturer's estimated average pumping flow rate of 433,500 gallons per minute (PG&E, 1998). The calculated DCPD total daily intake volume is 2.50 billion gallons (9.45 million m³) when all four CWPs (2 per unit) are operating. The flow rates of the ASW pumps are 11,000 gallons per minute (0.067 million m³/day/pump). The daily volume of cooling water can vary daily due to a variety of factors that include changes in tidal and swell height, as well as resistance caused by occlusion of condenser tubes.

The traveling screen assemblies are equipped with a high-pressure seawater wash system that sprays the screens as they rotate. The impinged debris, fishes and invertebrates are rinsed from the screens into a sloping trough that enters a central refuse sump area (Figure 1-2). All material in the sump is then pumped back into the ocean at the foot of the west breakwater. Screen rotation occurs either automatically or manually. Automatic operation of the screens occurs in one of two ways: by timed cycles or by hydrostatic pressure. Timers are typically set to initiate a 40-minute screen wash once every four hours. The screens also rotate automatically when an 8-inch water height differential across the screen surface is detected. Manual operation of the traveling screens occurs when heavy accumulations of kelp threaten the operation of the intake system. During these times continuous screen washing may be necessary.

1.2 DCPD Impingement Study, 1985-86

Impingement studies were conducted at DCPD to fulfill the Federal Clean Water Act Section 316(b) requirement. Results of these and other studies were reported in *DCPD Cooling Water Intake Structure 316(b) Demonstration* (PG&E, 1988). The impingement studies began February 5, 1985 during the start-up and testing phases of power plant operations and continued through March 26, 1986. Unit 1 began commercial operation in May 1985 and Unit 2 began commercial operation in March 1986. The purpose of the impingement study was to provide the quantitative information necessary to determine:

- taxonomic composition and abundance of impinged organisms;
- size of impinged fishes and selected macroinvertebrates;
- diel and seasonal patterns of impinged organisms; and
- sex ratio and degree of gonadal maturity of selected impinged species.

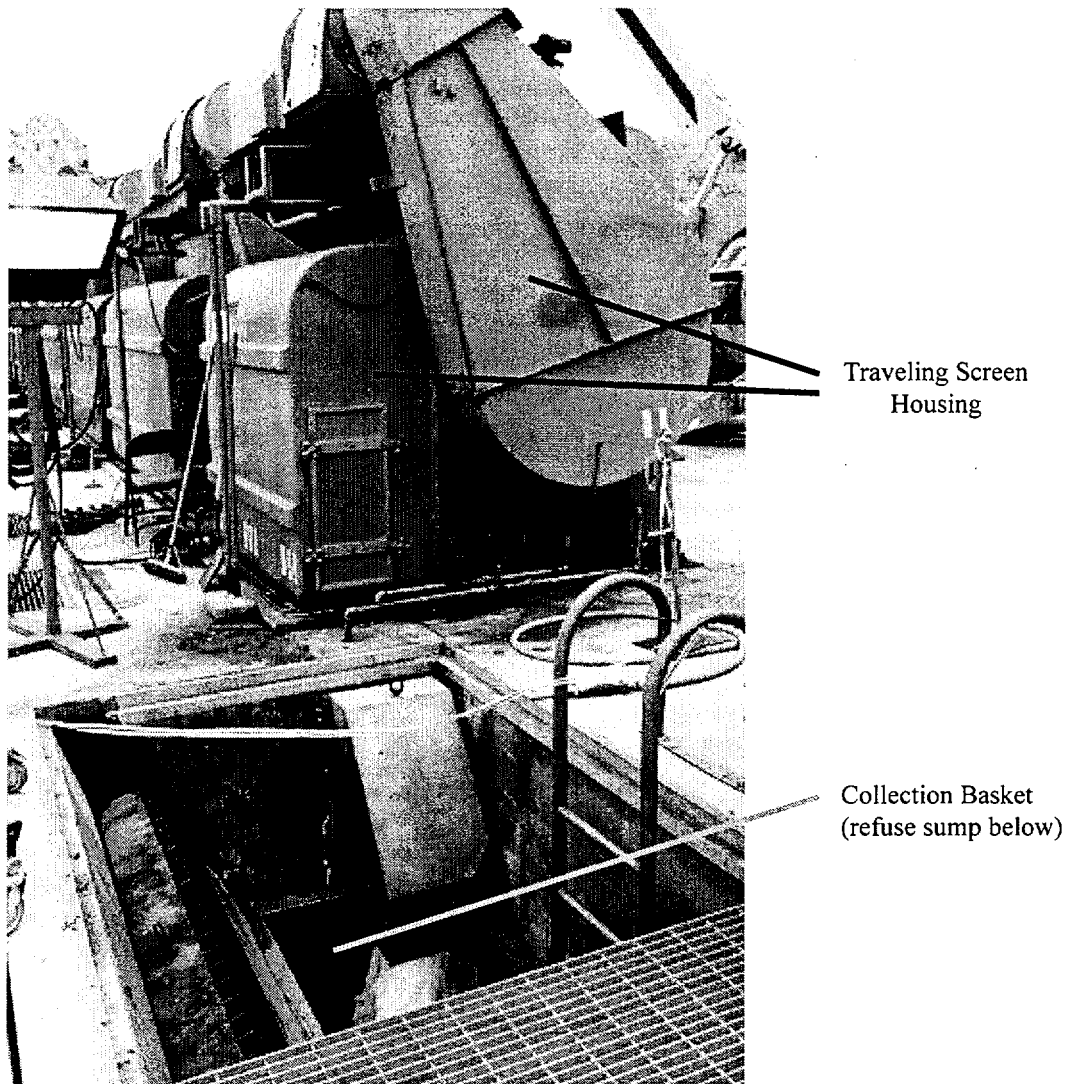


Figure 1-2. Unit 1 traveling screen assemblies photographed in 1985 during an impingement collection.

1.3 Methods

Traveling screens were rotated and rinsed before each collection to ensure all screens were clean before the sampling began. Troughs were cleaned of any accumulated debris and organisms. The screens remained stationary for approximately 3-3/4 hours and then were rotated and rinsed for 15 minutes. The material on the screens was rinsed into the troughs and collected in a metal basket made of 1/4 in. steel mesh. All of the impinged material was removed from the collection basket after each of these 4-hour samples (cycles) except during times of heavy kelp accumulation when the screens ran continuously. During continuous screen rotation the screen wash was stopped, when possible, for 15 minutes per cycle to allow for the removal of the sample from the basket. The impinged material collected from each unit

was kept separate. All organisms were removed from the impinged material and returned to the laboratory for processing. A quality control program was implemented and a percentage of samples were resorted to verify that all organisms had been removed during the sorting process.

All fishes and selected invertebrates were identified, measured and weighed. A quality assurance program verified the identifications, counts, weights and measurements of organisms for a randomly selected percentage of samples. Invertebrates that were measured and weighed included caridean shrimp, decapod and pelagic red crabs, cephalopod molluscs, rock scallops, and sea urchins. All other invertebrates were recorded as either individual counts or as present, and were not measured or weighed.

1.3.1 Sampling Criteria

Impingement samples were collected once per week for a continuous 24-hour period. A requirement for sampling was that at least one of the two CWPs per unit be in service for the entire 24 hours. There were times when collection was postponed because of equipment testing or maintenance that may have prevented the collection of a 24-hour sample. If possible, sampling was re-scheduled later the same week. Samples could not be collected when kelp accumulation caused the collection baskets to overflow potentially leading to the loss of organisms and inaccurate estimates of impingement rates.

2.0 RESULTS AND DISCUSSION

Unit 2 was in the final stages of construction and testing during the DCP 316(b) impingement study, limiting the number of days when operational pumps and traveling screens were sampled (Figure 2-1). Equipment repairs on Unit 1 also resulted in periods when pumps or traveling screens were not in full operation. Although sampling was scheduled to occur on the same day each week, it was adjusted several times due to operations at the intake. A total of 51 days were sampled for Unit 1 and 24 days were sampled for Unit 2. Unit 2 began operating on a more regular basis by October 1985. A total of 8 days were sampled when both Units 1 and 2 were fully operational for 24 hours (Figure 2-1).

A total of 66 taxa representing 29 families of bony fishes, sharks, rays, and eels was identified from impinged material collected during the 1985-86 DCP study (Table 2-1). The table lists the number of individuals, total weight, and rate of biomass impingement (grams/million m³) for each taxon identified from the samples for two periods. Some taxa, such as thornback rays, were collected in higher numbers and biomass at Unit 2 despite more frequent sampling at Unit 1. The densities of impinged fishes for Units 1 and 2 were compared during a ten-day period when pump and traveling screen operations between units were similar (PG&E, 1988). The densities of impinged skates and rays were greater on the Unit 2 screens than at Unit 1 (PG&E, 1988). Impingement rates for both units were similar for rockfishes and total bony fishes (PG&E, 1988).

Many fishes live within the intake forebays without becoming impinged. Diver observations and underwater video of the DCP traveling screens during pre-operation (Behrens and Larsson, 1979) and operation (PG&E, 1988) have recorded both large and small fishes freely swimming throughout the forebays in front of the traveling screens. During the impingement study, divers in the Intake Cove on August 21, 1985, observed over 100 juvenile yellowtail/olive rockfishes in front of the Unit 1 bar racks (PG&E, 1988), yet only one rockfish was collected during the two August impingement surveys.

The number of fishes, their combined weight and the amount of debris collected during each of the 24-hour surveys were compared for samples collected at Units 1 and 2 (Figure 2-2). There does not appear to be a relationship between the number of fishes or their weight and the amount of debris collected by Unit 1. The largest number of fishes were collected from Unit 1 during late June when the amount of debris collected was low. The total weight of the fishes was low because most of the individuals were young-of-the-year rockfishes ca. 60-80 mm in length. At Unit 2, the largest number and most weight of fishes impinged did not consistently occur when the amount of debris was heaviest. The largest amount of debris was collected during late December. During that period, the weight of the fishes in the collection was high but the number of individuals was low.

Several changes have been made to the traveling screens since the 1985-86 impingement study. These changes were made to improve system reliability and decrease maintenance. The original traveling screens had a steel frame around the 3/8-in. wire mesh. These frames were replaced with lighter, thicker fiberglass frames. Metal kelp rakes were also added across the width of some of the traveling screen baskets to increase the efficiency of debris removal from the forebays. These modifications have been completed on all of the CWP traveling screen assemblies and both auxiliary saltwater system (ASW) screens. The modifications to the traveling screen frames have decreased the open surface area through which water flows to each CWP. This has caused an increase in through-screen water velocities of about 20% (Anastasio, 1996). The modifications to the traveling screens have not caused any changes to water velocities through the bar racks and into the large intake forebays.

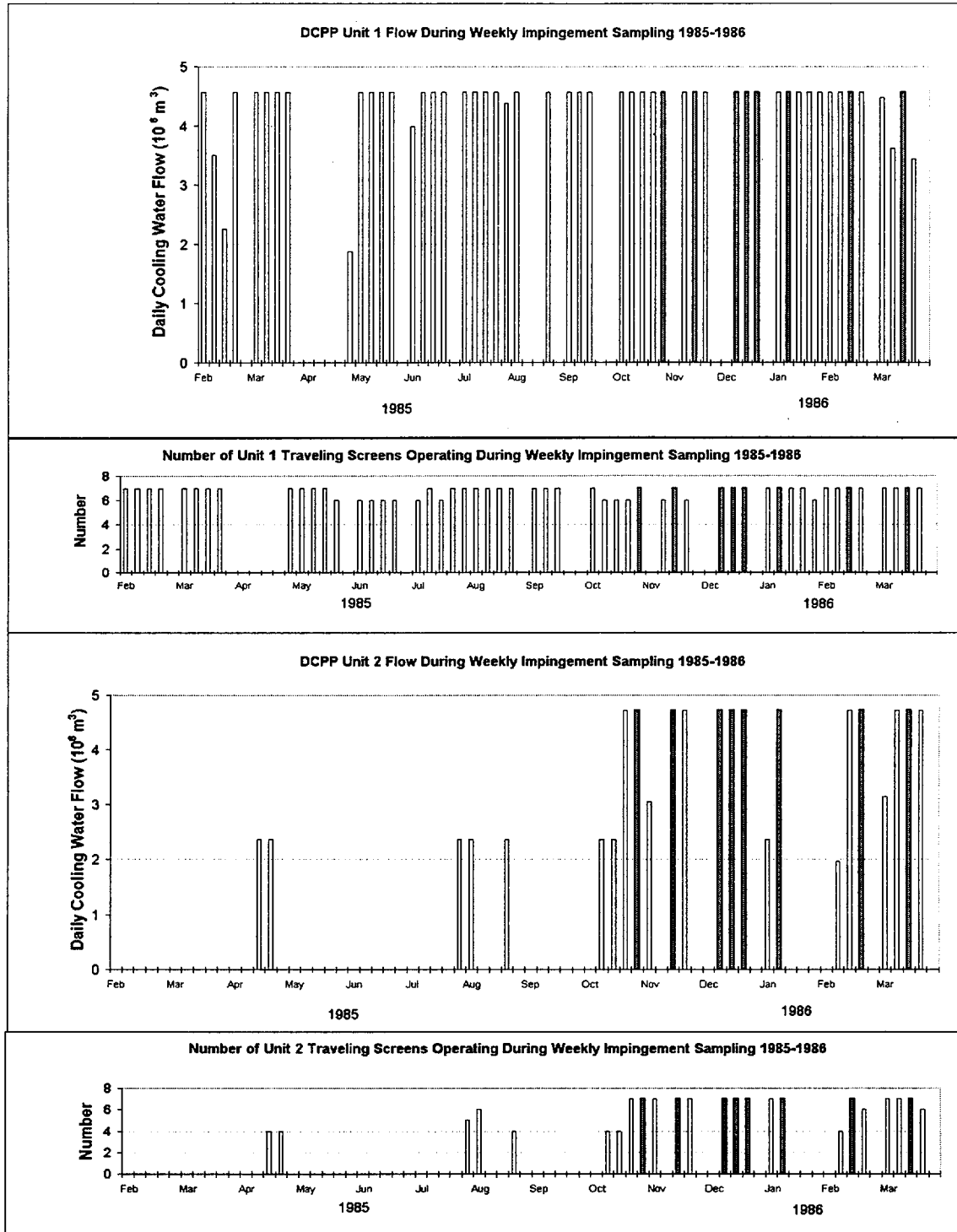
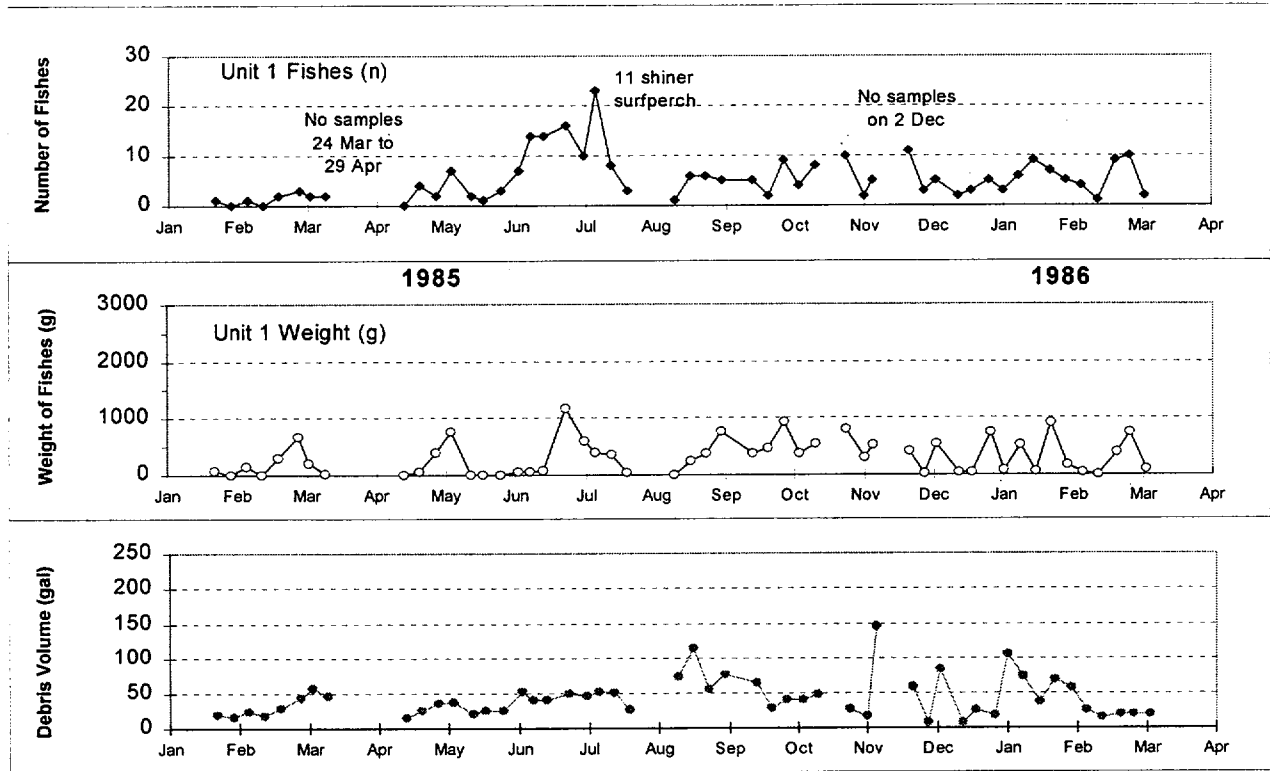


Figure 2-1. Diablo Canyon Power Plant intake operational status. Bars indicate each unit's cooling water pump (CWP) daily water flow and number of traveling screens operating on impingement sampling days. **Bold bars** indicate days when all pumps and traveling screens operated concurrently. Each unit pulls water through seven traveling screens (six for the cooling water pumps and one for the auxiliary seawater system).

Table 2-1. Total abundance and weight (grams) and average biomass (grams/million m³ flow) of impinged fishes at Diablo Canyon Power Plant (DCPP) during 1985-86. Abundance and weight are totals for the sampling periods; biomass is number of grams per million m³ of water flow during the collection periods.

Taxon	Scientific Name	Common Name	02/05/85 - 03/31/85			Unit 1		04/01/85 - 03/31/86		Unit 1		Unit 2	
			Abun.	Weight	Bio.	Abundance	Weight	Abundance	Weight	Abundance	Weight	Biomass	Biomass
Total All Fishes:			11	1421	6.49	262	140	14441.3	12746.2	65.64	148.21		
BONY FISHES (Osteichthyes)													
Engraulidae	<i>Engraulis mordax</i>	northern anchovy					1		24.0			0.28	
Batrachoididae	<i>Porichthys notatus</i>	plainfin midshipman				11	8	1056.6	658.2	4.80	7.65		
Ophidiidae	<i>Chilara taylori</i>	spotted cusk-eel	1	23.8	0.11								
Gobiesocidae	<i>Gobiosox maeandricus</i>	northern clingfish				2	1	2.6	7.7	0.01	0.09		
Atherinidae	<i>Atherinops affinis</i>	topsmelt				1	2	11.0	55.5	0.05	0.65		
Gasterosteidae	<i>Aulorhynchus flavidus</i>	tubesnout				7	6	14.5	23.2	0.07	0.27		
Syngnathidae	<i>Syngnathus californiensis</i>	kelp pipefish	1	4.8	0.02	8	4	143.5	40.2	0.65	0.47		
	<i>Syngnathus</i> spp.	unidentified pipefish				2	1	6.9	5.3	0.03	0.06		
	Syngnathidae unid.	unidentified pipefish				1		0.7		<0.01			
Scorpaenidae	<i>Sebastes atrovirens</i>	kelp rockfish				6	3	509.2	21.9	2.31	0.25		
	<i>Sebastes carnatus</i>	gopher rockfish				2	1	8.4	2.0	0.04	0.02		
	<i>Sebastes flavidus</i>	yellowtail rockfish				34	14	207.3	144.5	0.94	1.68		
	<i>Sebastes jordani</i>	shortbelly rockfish				1		1.6		0.01			
	<i>Sebastes melanops</i>	black rockfish				1	1	3.9	3.4	0.02	0.04		
	<i>Sebastes mystinus</i>	blue rockfish				5	3	326.4	152.1	1.48	1.77		
	<i>Sebastes paucispinis</i>	boccaccio				2		7.8		0.04			
	<i>Sebastes rastrelliger</i>	grass rockfish	1	70.2	0.32								
	<i>Sebastes serranoides</i>	olive rockfish				19	9	484.7	543.4	2.20	6.32		
	<i>Sebastes serranoides/flavidus</i>	olive/yellowtail rockfish				7	3	46.3	16.2	0.21	0.19		
	<i>Sebastes</i> spp.	unidentified rockfish				6	2	21.4	6.5	0.10	0.05		
Hexagrammidae	<i>Hexagrammos decagrammus</i>	kelp greenling	1	143.1	0.65	1		5.9		0.03			
	<i>Oxylebius pictus</i>	painter greenling				1		29.3		0.13			
	<i>Zaniolepis latipinnis</i>	longspine combfish					1		29.0		0.34		
Cottidae	<i>Artedius creaseri</i>	roughcheek sculpin				1		2.4		0.01			
	<i>Artedius corallinus</i>	coralline sculpin				8	2	74.4	6.2	0.34	0.07		
	<i>Artedius lateralis</i>	smoothead sculpin	1	5.8	0.03	7	3	37.7	12.8	0.17	0.15		
	<i>Artedius notospilotus</i>	bonyhead sculpin				1		2.3		0.01			
	Cottidae	unidentified sculpin				1		3.5		0.02			
	<i>Oligocottus maculosus</i>	tidepool sculpin				1		3.1		0.01			
	<i>Oligocottus rubellio</i>	rosy sculpin				2		9.2		0.04			
	<i>Orithopias triacis</i>	snubnose sculpin				5	4	29.2	22.7	0.13	0.26		
	<i>Scorpaenichthys marmoratus</i>	cabezon				1		4.9		0.02			
Agonidae	<i>Agonopsis sterletus</i>	southern poacher					1		7.8		0.09		
Cyclopteridae	<i>Liparis mucosus</i>	slimy snailfish				1		3.0		0.01			
Carangidae	<i>Trachurus symmetricus</i>	jack mackerel	1	273.4	1.24	1	3	329.4	386.8	1.50	4.50		
Sciaenidae	<i>Seriphus politus</i>	queenfish				2	7	8.2	40.5	0.04	0.47		
Embiotocidae	<i>Amphistichus argenteus</i>	barred surfperch				2		10.0		0.05			
	<i>Brachystichus frenatus</i>	kelp surfperch				6	3	79.8	29.1	0.36	0.34		
	<i>Cymatogaster aggregata</i>	shiner surfperch				17		212.3		0.97			
	<i>Embiotoca jacksoni</i>	black surfperch	1	296.3	1.35	2		517.4		2.35			
	<i>Embiotoca lateralis</i>	striped surfperch			0.03	3		190.7		0.87			
	Embiotocidae	unidentified surfperch	1	6.4	0.03	3		45.3		0.21			
	<i>Hyperprosopon argenteum</i>	walleye surfperch				2	3	23.0	103.8	0.10	1.21		
	<i>Micrometrus minimus</i>	dwarf surfperch				1	1	7.7	4.1	0.04	0.05		
	<i>Phaeoerodon furcatus</i>	white surfperch				1		3.6		0.02			
Labridae	<i>Oxyjulis californica</i>	senorita					1		16.0		0.19		
Pomacentridae	<i>Chromis punctipinnis</i>	blacksmith				1	2	109.5	66.7	0.50	0.78		
Clinidae	<i>Gibbonsia erythra</i>	scarlet kelpfish					2		12.8		0.15		
	<i>Gibbonsia metzi</i>	striped kelpfish				8	1	145.0	4.7	0.66	0.05		
	<i>Gibbonsia montereyensis</i>	crevice kelpfish				4		16.4		0.07			
	<i>Gibbonsia</i> spp.	unidentified kelpfish					2		55.5		0.65		
Stichaeidae	<i>Anoplarchus purpurascens</i>	high cockscomb				2	2	26.5	23.4	0.12	0.27		
Pholidae	<i>Ulvicola sanctaerosae</i>	kelp gunnel				1		3.3		0.02			
	<i>Xeropes ficorum</i>	rockweed gunnel				1	1	8.5	4.9	0.04	0.06		
Scombridae	<i>Scomber japonicus</i>	Pacific mackerel				2	2	801.7	733.4	3.64	8.53		
Cynoglossidae	<i>Symphurus atricauda</i>	California tonguefish				2		6.8		0.03			
Paralichthyidae	<i>Citharichthys stigmaeus</i>	speckled sanddab	1	20.7	0.09	4		4.7		0.02			
	<i>Xystreurys fioletis</i>	fantail sole				9		869.2		3.95			
Pleuronectidae	Pleuronectidae unid.	unidentified turbot or sole				1		1.7		0.01			
	<i>Microstomus pacificus</i>	dover sole				1		32.8		0.15			
	<i>Pleuronichthys coenosus</i>	C-O turbot				1		74.8		0.34			
Total Fishes:			9	844.5	3.87	223	100	6586.0	3261.8	29.94	37.93		
Sharks and Rays (Chondrichthyes)													
Rajidae	<i>Raja binoculata</i>	big skate				3	2	86.0	73.6	0.39	0.86		
Torpedinidae	<i>Torpedo californica</i>	Pacific electric ray	1	374.4	1.70	10	4	1830.2	693.2	8.32	8.06		
Platyrrhinidae	<i>Platyrrhinoidis triseriata</i>	thornback ray	1	202.1	0.92	23	32	4687.4	7475.9	21.31	86.93		
Dasyatididae	<i>Urolophus halleri</i>	round stingray					1		407.9		4.74		
Chimeridae	<i>Hydrolagus collei</i>	spotted ratfish				3	1	1251.7	833.8	5.69	9.70		
Total Sharks and Rays:			2	576.5	2.62	39	40	7855.3	9484.4	35.71	110.28		

UNIT 1



UNIT 2

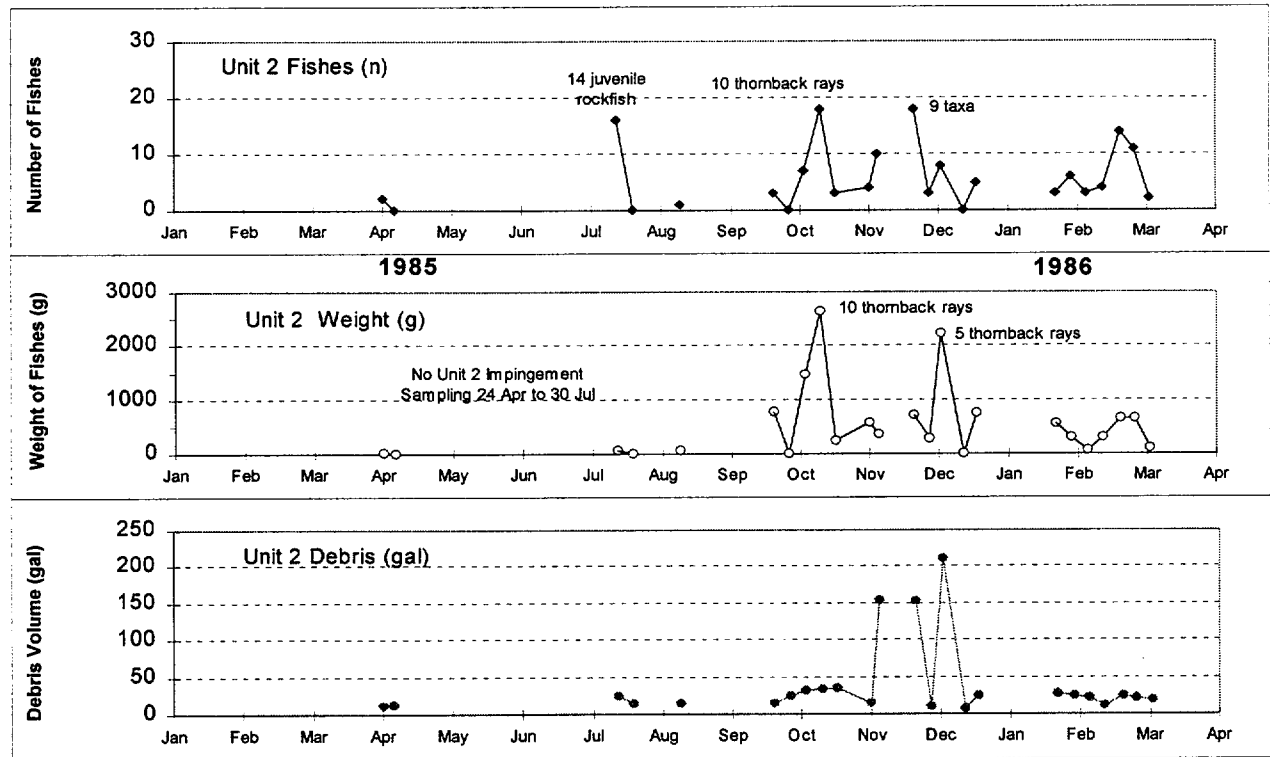


Figure 2-2. Comparison of fish abundance (n) and weight (g), and seaweed debris volume (gallons) collected in DCP Unit 1 and 2 impingement samples.

The motors that rotate the screens were also replaced with larger motors and high-speed controllers. These modifications allowed the screens to rotate at higher speeds. During the 1985-86 impingement studies, traveling screens were operated at 5 ft/min (fpm) under normal conditions and 10 fpm during periods of high kelp debris buildup. Since December 1995, traveling screen speeds have been increased to 10 fpm (normal) and 20 fpm (debris buildup). The higher rotation speeds increase the efficiency of the system to remove debris from the forebays. The ASW screen system has not been upgraded with larger motors and continues to operate at the slower speeds.

Fishes and invertebrates have been observed freely moving within the intake's forebays despite the modifications to the intake system. A video tape recording of one of the screens following the modifications showed an *Oxylebius pictus* (painted greenling) about 15 cm in length swimming in front of the screens. Weekly bar rack inspections conducted since the late 1980s have documented low numbers of fishes in front of the intake. Divers have observed young-of-the-year rockfishes, surfperches, señoritas, blackeye gobies, and other small fishes swimming in front of the bar racks. Diver observations and underwater videos show that many fishes live throughout the forebays and do not appear to be susceptible to impingement on the traveling screens. Many of these fishes were too large to swim back through the bar rack openings and, based on their size, had probably been living and growing in this environment for at least a few years.

Measurements taken during the DCPD 1985-86 impingement study estimated cooling water velocity at the bar racks to be about 0.8 ft/sec (fps), while the velocity through the traveling screens was estimated to have been about 1.75 fps (PG&E, 1988; Table 2-2). Measurements taken at the bar racks during 1986 (Wyman, 1987) found that water velocity at Unit 1 was slower (0.78-0.82 fps) than at Unit 2 (0.95-1.05 fps). This report did not include estimates of velocities through the traveling screens. It did note that during earlier performance testing of the plant's circulating water pumps, the flow through Unit 2 was approximately 4% higher than Unit 1 (Wyman, 1987). Anastasio in 1998 (pers. comm.) stated that the flow volume through both units is quite similar, despite the small differences in flow rates.

Table 2-2. Estimates of approach velocities (fps) measured at the bar racks and traveling screens and estimates of through-screen velocities at Diablo Canyon Power Plant (DCPD), San Onofre Nuclear Generating Station (SONGS), Moss Landing Power Plant (MLPP), and Morro Bay Power Plant (MBPP). The 1996 estimated flow velocities for DCPD were calculated after traveling screen modifications were completed.

Facility (year, units)	Flow velocities (fps)		
	Bar Rack	Traveling Screen Approach	Through-Screen
DCPD (1985, Units 1&2)	0.8	1.1	1.75
DCPD (1996, Units 1&2) ¹	1.0	1.0	2.26
SONGS (1990, Units 2-3)	1.7 ²	2.0	3.0
MLPP (1980, Units 1-5)	0.7	1.0	2.4
MLPP (1980, Units 6-7)	0.8	0.8	1.5
MBPP (1978, Units 3-4)	0.5	0.6	1.4

¹ Based on calculations for new equipment and modifications (Anastasio, 1996)

² SONGS velocity measured at entrance of offshore velocity cap.

The measured flow velocities are within the range of reported continuous swimming speeds of selected fishes that occur in the vicinity of the DCPD intake (Table 2-3 from Dorn et al., 1979; Webb, 1980). In some cases burst speeds for these fishes are reported to be over 2 to 4 times faster than the DCPD estimated intake water velocities. Dorn et al. (1979) and Webb (1980) did not give any details as to the length of time that these fishes could maintain their burst speeds. Recent modifications to the traveling screens have increased velocity through the screen mesh to an estimated 2.26 fps (Anastasio, 1996). The through-screen velocity is faster than the highest reported continuous swimming speeds for these fishes (Dorn et al., 1979; Table 2-3). The burst speeds for all of the species tested by Dorn et al. (1979) and Webb (1980) exceed the water velocities through the modified traveling screens.

Table 2-3. Swimming performance of California inshore fishes found in the DCPD area. Continuous speeds are those maintained by the fish for more than 60 minutes. Burst speeds were measured for about one (1) second.

Species	Common Name	Continuous swimming speed (fps)	Burst speed (fps)
<i>Chromis punctipinnis</i> ¹	blacksmith	1.67	3.08
<i>Citharichthys stigmaeus</i> ²	speckled sanddab	nr	1.93-2.70
<i>Cymatogaster aggregata</i> ¹	shiner surfperch	1.51	3.54
<i>Embiotoca jacksoni</i> ¹	black surfperch	1.71	3.67
<i>Genyonemus lineatus</i> ¹	white croaker	2.00	4.49
<i>Hyperprosopon agrentum</i> ¹	walleye surfperch	1.38	nr
<i>Hypsurus caryi</i> ¹	rainbow surfperch	1.38	nr
<i>Sebastes mystinus</i> ¹	blue rockfish	1.80	3.48
<i>Sebastes serranoides</i> ¹	olive rockfish	1.73	nr

nr = data not reported

¹ data from Dorn et al. (1979)

² data from Webb (1980)

Dr. Gregor Cailliet (Moss Landing Marine Laboratories; pers. comm.) noted that *Oxyjulis californica* (señorita) are weak swimmers because they mainly use their pectoral fins for locomotion. This species is regularly observed in the vicinity of DCPD during quarterly subtidal fish observations (Tenera, Inc., 1997) and has been seen on occasion in the Intake Cove. Despite its poor swimming ability and relative abundance in the area only one was impinged during the 1985-86 DCPD study (Table 2-1).

Annual impingement data at four coastal California power plants were compared to assist in addressing the question of possible variation in annual impingement rates. The annual biomass of impinged fishes (grams/million m³ of cooling water) at DCPD, San Onofre Nuclear Power Station (SONGS), Moss Landing Power Plant (MLPP) and Morro Bay Power Plant (MBPP) is presented in Table 2-4. The data in the table were collected during the following periods:

- DCPD data collected from April 1985 through March 1986 (PG&E, 1988);
- SONGS annual averages for the period 1984-1995 (Southern California Edison Company, Annual Reports, 1985-1996; Appendix B);
- MLPP annual values for the period of March 1979 through March 1980 (Ecological Analysts, 1983); and
- MBPP data collected from January 1978 through December 1978 (PG&E, 1982).

Table 2-4. Annual biomass (grams/million m³ flow) of impinged fishes at Diablo Canyon Power Plant, San Onofre Nuclear Generating Station (SONGS), Moss Landing Power Plant, and Morro Bay Power Plant. SONGS data also include fishes collected during heat treatments.

Family and Scientific Name	Common Name	Diablo Canyon Power Plant		San Onofre Nuclear Generating Station		Moss Landing Power Plant		Morro Bay Power Plant
		1 Apr 1985 - 31 Mar 1986	Unit 1	Unit 2	1984-1995 Annual Average	Unit 2	Unit 3	29 Mar 1979 - 17 Mar 1980
Total Biomass (grams/million m³) All Fishes:		65.64	148.21	5557.52	9910.30	3925.90	1722.96	4907.46
Clupeidae	sardines & herring	-	-	61.58	765.50	329.21	24.32	0.58
Engraulidae	anchovies	-	0.28	536.04	840.42	743.04	1010.19	467.83
Batrachoididae	midshipman	4.80	7.65	36.47	57.32	197.86	40.92	1622.84
Atherinidae	jacksmelt & grunion	0.05	0.65	887.74	1922.14	189.71	133.53	1123.15
Scorpaenidae	rockfishes	7.35	10.32	1.93	4.22	116.30	81.41	187.62
Cottidae	sculpins	0.76	0.48	24.34	46.63	216.92	128.12	48.24
Pristipomatidae	salema & sargo	-	-	263.88	275.57	-	-	-
Sciaenidae	croakers & white sea bass	0.04	0.47	2812.69	4535.55	52.99	10.91	19.79
Kyphosidae	zebraperch	-	-	75.65	79.88	0.17	0.32	-
Embiotocidae	surfperches	4.95	1.59	92.56	119.36	754.62	47.22	683.63
Serranidae	kelp bass and sand bass	-	-	83.43	62.95	0.61	-	0.18
Clinidae	kelpfishes & fringeheads	0.73	0.85	18.03	15.44	2.31	1.22	6.64
Scombridae	mackerel & bonito	3.64	8.53	75.96	216.64	0.61	-	<0.01
Stromateidae	butterfish	-	-	48.37	170.29	26.06	1.67	14.49
Pleuronectidae	flatfishes	4.50	-	13.27	15.03	269.55	73.46	32.17
Molidae	mola	-	-	-	-	288.53	9.88	-
Other Osteichthyes	other bony fishes	3.11	7.10	77.50	148.59	109.88	44.20	111.37
Chondrichthyes	sharks and rays	35.71	110.28	448.08	634.77	627.53	115.59	588.93

The first two months of 1985 DCPD data were not used so that a comparison of a continuous 12-month period of impingement data could be made for each plant. The months used for this comparison varied among the four plants because the only available data had been summarized into the reporting periods listed above. At Moss Landing and Morro Bay power plants, the impingement sampling took place over a period of 15 and 18 months, respectively. The data reported for MLPP were already summarized into 3- and 12-month periods and the data for MBPP were summarized into 6- and 12-month periods. Monthly impingement data were not available for analysis for MLPP and MBPP. For comparison among facilities, the annual rate of fish impingement was normalized to weight (grams) per one million m³ of cooling water. The data listed by individual taxa are found in Appendices A and B. A complete listing of all 14 months of DCPD fish impingement data is found in Table 2-1.

The 1984 to 1995 average annual fish biomass (g/million m³) impinged by SONGS Unit 3 was about 150 times more than that impinged by DCPD Unit 1 during April 1985 through March 1986 (Table 2-4). The total DCPD Unit 1 impinged biomass for all fishes, sharks and rays was about 66 g/million m³, or about 0.7 pounds/day with both pumps in operation. The biomass of impinged fishes, sharks and rays at DCPD Unit 2 (148 g/million m³) was about 1.6 pounds/day. In comparison, the 1984 to 1995 average impinged biomass of fishes, sharks and rays at SONGS Units 2 and 3 (5,557 and 9,910 g/million m³) was 52.8 and 98.8 pounds/day/unit, respectively. At MLPP, the total biomass of impinged fishes, sharks and rays (3,926 and 1,723 g/million m³) was 17.9 and 12.4 pounds/day for Units 1-5 and 6-7, respectively. Total biomass of fishes, sharks and rays at MBPP (4,907 g/million m³) was 17.8 pounds/day for Units 3-4.

The taxonomic composition of fishes impinged at the four plants was also different (Table 2-4). The groups (anchovy, croaker, etc.) with the highest biomass at SONGS, MBPP and MLPP were collected at DCPD in low numbers. Rockfishes represented the group of bony fishes with the highest annual impingement rate for Unit 1 at DCPD (7.35 g/million m³ flow). The rate of rockfish impingement was lower at SONGS, but higher at both MBPP and MLPP.

Differences in intake structure, design and location may explain the substantially higher impingement rates and differences in species composition at SONGS, Moss Landing and Morro Bay power plants. Although Moss Landing and Morro Bay power plants have shoreline intake structures similar to DCPD, the structures are located in embayments that are parts of larger estuaries. SONGS Units 2 and 3 intakes are located about 3,200 feet offshore above a sandy seafloor. The intake velocities at the four plants are presented in Table 2-2. The intake velocity at SONGS is almost two times the velocity at the DCPD bar racks.

Annual variation of fish impingement at SONGS Unit 2 and Unit 3 was much higher than at DCPD (Figure 2-3). The variation at SONGS was caused by fluctuations in the number of individuals from the following taxonomic groups: croakers; jacksmelt (grouped with 'other fishes' for this figure); and the anchovy and sardine group. None of these groups were abundant in the DCPD impingement study. Queenfish were the most abundant croaker at SONGS, followed by white croaker and yellowfin croaker. Only three queenfish and no white or yellowfin croakers were impinged at DCPD. During subtidal fish surveys in the DCPD area over the last 20 years only a few queenfish and neither of the croakers have been observed. Jacksmelt also contributed to the high interannual variability of impingement estimates at SONGS. These were impinged in high numbers during one year at Unit 2 and two years at Unit 3. Jacksmelt were only rarely observed in the vicinity of DCPD during subtidal fish observations (Tenera, Inc., 1997) and none were impinged during the 1985-1986 study at DCPD. In general, the composition of fish taxa impinged at DCPD reveal few species that form large schools. The absence of schooling anchovies, sardines, smelt, and croakers contribute to the low impingement of fishes at DCPD compared to the three other facilities.

A comparison of percent composition data between impingement and observations from the Thermal Effects Monitoring Program (TEMP) South Control subtidal fish transect study was done after discussion with the Entrainment Technical Work Group. The purpose of the comparison was to determine if other data from DCPD could be used to estimate interannual variation of fish susceptible to impingement (Figure 2-4). The dominant fish groups impinged were rockfishes and sharks and rays, while the dominant fishes seen at South Control during the same period were topsmelt and señoritas. Señoritas have been seen on numerous occasions swimming in the Intake Cove. At the TEMP fish transect stations there was high interannual variability in juvenile rockfishes (Tenera, Inc., 1997). Even if there were substantially higher numbers of these fishes impinged, the total weight would be low due to their small size.

The South Control area used in the comparison is about 1 km down coast of the intake structure and its habitat is quite different from the Intake Cove. The Intake Cove has a sandy-muddy bottom and the South Control area is dominated by rocky substrate. It is possible that at least some of the differences in species composition of fishes are due to the different habitats. Due to the lack of similarity between these areas, a comparison of the annual variability of the TEMP fish observation data would not be useful for determining interannual variation of impinged fishes at DCPD.

Low numbers of fishes have consistently been observed by divers conducting weekly bar rack inspections since the late 1980's. At times, young-of-the-year rockfishes and schools of señoritas have been seen in the water near the bar racks. These fishes did not appear to be at risk to impingement and the low numbers collected during the 1985-86 study support these observations.

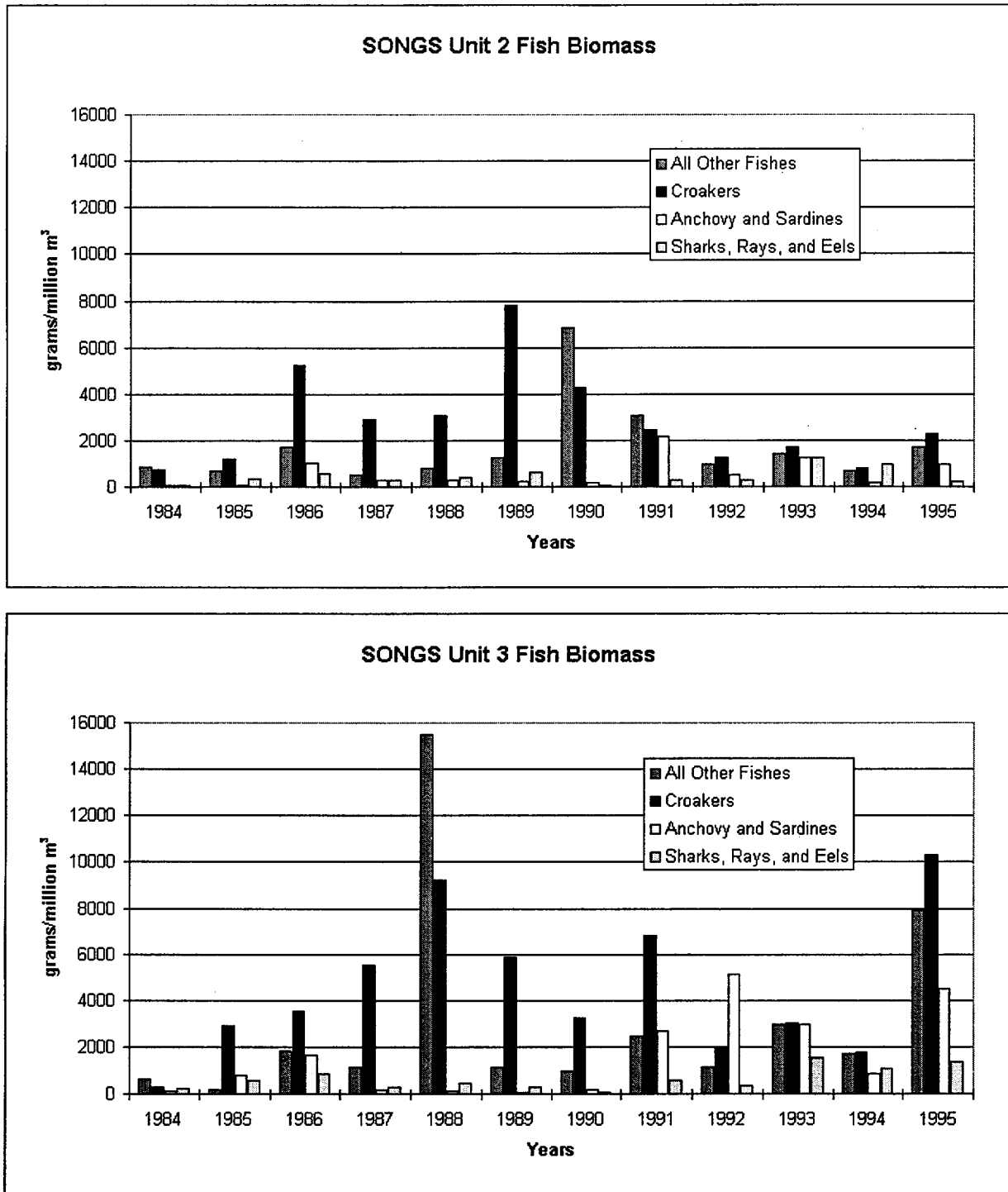


Figure 2-3. Biomass (grams/million m³ flow) of combined fish taxa impinged at San Onofre Nuclear Generating Station (SONGS) Units 2 and 3.

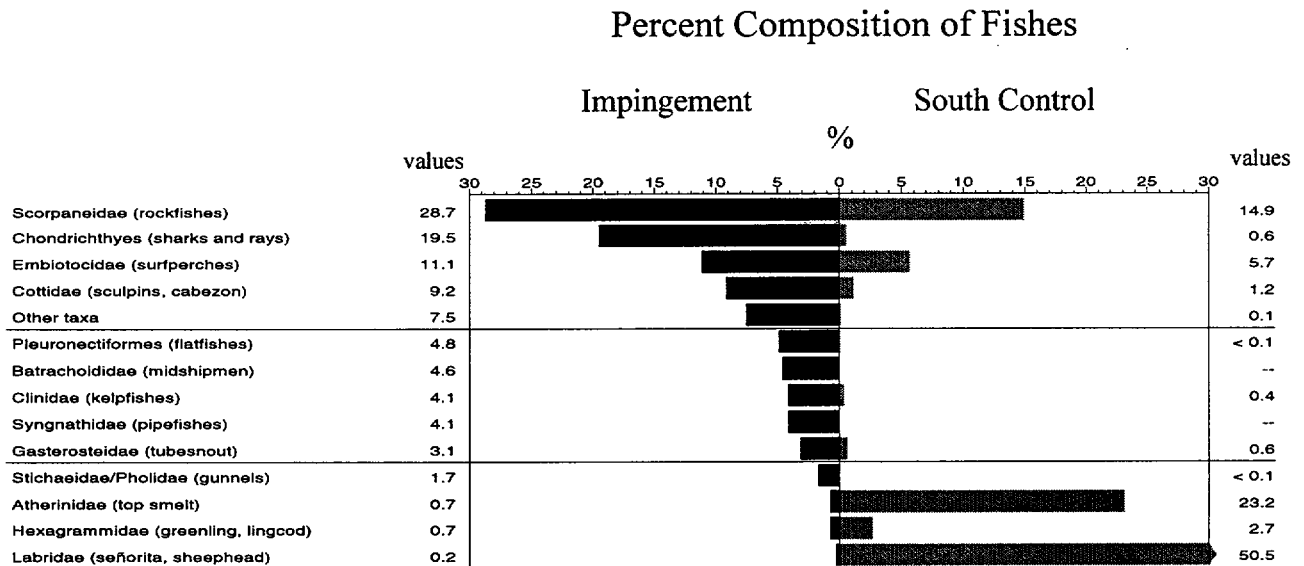


Figure 2-4. Percent composition of fishes impinged at DCPD compared to percent composition of fishes observed on midwater and benthic subtidal transect swims in the Thermal Effects Monitoring Program's (TEMP) South Control area from February 1985 through March 1986 (TEMP data from Tenera, Inc., 1997).

The low numbers of impinged fishes during 1985-86 are consistent with the findings of an earlier impingement study performed during 1975-77 at DCP (Behrens and Larsson, 1979). That impingement study was conducted before commercial operation during testing of the circulating water pumps. The sampling periods were December 1975 through February 1976 and January to June 1977. Monthly impingement densities ranged from 0.09 to 1.0 fish/million m³, while biomass ranged from 6.3 to 131 grams/million m³. The most commonly impinged species, comprising 33% of the total fishes, were blue rockfish, kelp surfperch and striped surfperch. Similar to the 1985-86 study, only a few schooling fishes were impinged during this earlier study. The 1975-77 impingement data corroborate the low rates of impingement seen in the winter and spring of 1985-86 at DCP.

A total of 1,314 *Cancer antennarius* was impinged at DCP. The 1,272 individuals categorized as juveniles had an average weight of about 3 grams and were small in size. Table 2-5 presents the biomass (g/million m³) of *Cancer* crab species impinged at DCP, Moss Landing and Morro Bay power plants. Impingement data for *Cancer* and other invertebrates were not collected at SONGS. Among the various species of *Cancer* crabs, *C. antennarius* are impinged at the highest rate at all three plants. Impingement of *C. antennarius* at DCP Unit 1 was about 50% less than at Moss Landing Units 6-7 and almost 95% less than at MLPP Units 1-5 and MBPP.

Table 2-5. Impinged *Cancer* spp. crab biomass (grams/million m³ flow) at DCP, Moss Landing (MLPP) and Morro Bay (MBPP) power plants.

Species	DCP		MLPP	MLPP	MBPP
	Unit 1 (4-85 to 3-86)	Unit 2 (4-85 to 3-86)	Units 1-5 (3-79 to 3-80)	Units 6-7 (3-79 to 3-80)	Units 3-4 (1978)
<i>Cancer antennarius</i>	27.43	21.69	485.37	50.82	396.34
<i>Cancer anthonyi</i>	0.02	0.88	32.43	11.50	352.61
<i>Cancer productus</i>	0.47	1.97	13.62	9.12	196.00
<i>Cancer jordani</i>	0.42	0.27	0.87	0.25	0.80
<i>Cancer magister</i>	0.01	-	1.67	2.21	16.18
<i>Cancer</i> spp.	0.03	0.01	0.01	0.01	1.52
<i>Cancer gracilis</i>	0.29	-	5.01	3.52	5.03
<i>Cancer oregonensis</i>	-	-	<0.01	-	-
TOTAL	28.67	24.82	538.98	77.43	968.47

3.0 CONCLUSIONS

The estimated weight of fishes impinged by the DCPD cooling water system is about 0.7 to 1.6 pounds per day per unit. The low rate of impingement at DCPD is believed to reflect the low intake approach velocities and the absence of large numbers of fishes, particularly numbers of schooling species, in the Intake Cove. The impingement rate at DCPD is low compared to rates reported at three other California coastal power plants.

Structural modifications to the intake system that were completed after the 1985-86 study resulted in a 20% increase in water velocity through the traveling screens although approach velocity to the bar racks remained the same. Despite these changes, fishes and invertebrates were observed freely moving within the intake structure forebays, and directly in front of the traveling screens. Water flow in all areas of the intake structure between the bar racks and through the traveling screens is below the burst swimming speeds of most species and appears to be slow enough to allow healthy fishes to swim freely away from the traveling screens.

Impingement data were collected at the DCPD intake for one year at Unit 1 and part of a year at Unit 2. The majority of the DCPD impingement data are from Unit 1. It is reasonable to conclude that the 1985-86 Unit 1 impingement data were representative of impingement for both units, since flow rates are similar between units. Intake field observations, low intake velocities, and relatively minor impingement rates compared to other power plants, support the conclusion that additional impingement monitoring is not necessary.

An estimate of the total annual abundance and biomass of fishes and invertebrates impinged will be determined based on the results of all available data collected during the DCPD 1985-1986 weekly impingement surveys. These values will be used, as applicable, in the calculation of AEL and FH to evaluate the intake effects of the DCPD cooling water system.

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APPENDIX A

Annual biomass (grams/million m³) of fish taxa collected during impingement at four power plants.

Annual biomass (grams/million m³) of fish taxa collected during impingement sampling at Diablo Canyon Power Plant (DCPP; 1985-1986), San Onofre Nuclear Generating Station (SONGS; 1984-1995), Moss Landing Power Plant (MLPP; 1979-1980) and Morro Bay Power Plant (MBPP; 1978). SONGS data included fishes killed during heat treatments. NOTE: Data are preliminary and not intended for use in any context other than this report.

Appendix A: Fish Biomass Impinged Annually at Four Power Plants

Appendix A.

Family and Scientific Name	Common Name	Diablo Canyon Power Plant 1 Apr 1985 - 31 Mar 1986		San Onofre Nuclear Generating Station 1984-1995 Annual Average		Moss Landing Power Plant 29 Mar 1979 - 17 Mar 1980		Morro Bay Power Plant 4 Jan 1978 - 19 Dec 1978
		Unit 1	Unit 2	Unit 2	Unit 3	Units 1-5	Units 6-7	Units 3-4
Total Biomass (grams/million m³ flow) All Fishes:		65.64	148.21	5557.52	9910.30	3925.90	1722.96	4907.46
BONY FISHES (Osteichthyes)								
Clupeidae								
<i>Alosa sapidissima</i>	American shad	-	-	-	-	0.08	0.04	-
<i>Clupea harengus</i>	Pacific herring	-	-	-	-	328.61	24.19	0.58
<i>Dorosoma petenense</i>	threadfin shad	-	-	<0.01	-	0.52	0.09	<0.01
<i>Etrumeus teres</i>	round herring	-	-	<0.01	0.01	-	-	<0.01
<i>Opisthonema medirastre</i>	middling thread herring	-	-	0.14	0.29	-	-	-
<i>Sardinops sagax</i>	Pacific sardine	-	-	61.44	765.20	-	-	-
Engraulididae								
<i>Anchoa compressa</i>	deepbody anchovy	-	-	42.55	51.78	-	-	-
<i>Anchoa delicatissima</i>	slough anchovy	-	-	10.87	65.19	-	-	-
<i>Engraulis mordax</i>	northern anchovy	-	0.28	482.62	723.45	743.04	1010.19	467.83
Salmonidae								
<i>Oncorhynchus kisutch</i>	silver salmon	-	-	-	1.21	-	-	-
<i>Oncorhynchus tshawytscha</i>	king salmon	-	-	-	-	0.02	-	-
Salmonidae	unidentified salmon	-	-	-	-	0.01	-	-
Osmeridae								
<i>Hypomesus pretiosus</i>	surf smelt	-	-	-	-	0.92	0.35	-
<i>Spirinchus starksi</i>	night smelt	-	-	-	-	23.49	2.39	-
<i>Spirinchus thaleichthys</i>	longfin smelt	-	-	-	-	0.01	-	-
Myctophidae								
<i>Stenobrachius leucopsarus</i>	northern lampfish	-	-	-	-	0.01	-	-
Synodontidae								
<i>Synodus lucioceps</i>	California lizardfish	-	-	5.42	16.94	0.14	0.01	0.18
Batrachoididae								
<i>Porichthys myriaster</i>	specklefin midshipman	-	-	16.35	18.01	-	-	-
<i>Porichthys notatus</i>	plainfin midshipman	4.80	7.65	20.12	39.31	197.86	40.92	1622.84
Ophidiidae								
<i>Chilara taylori</i>	spotted cusk-eel	-	-	1.01	1.25	1.13	2.99	26.54
<i>Otophidium scrippsi</i>	basketweave cusk-eel	-	-	4.74	3.02	-	-	-
Gobiesocidae								
<i>Gobiesox maeandricus</i>	northern clingfish	0.01	0.09	-	-	-	-	0.05
<i>Gobiesox rhessodon</i>	California clingfish	-	-	<0.01	<0.01	-	-	-
Merlucciidae								
<i>Merluccius productus</i>	Pacific hake	-	-	-	-	17.48	-	0.57
Gadidae								
<i>Microgadus proximus</i>	Pacific tomcod	-	-	-	-	1.96	0.44	-
Belonidae								
<i>Strongylura exilis</i>	California needlefish	-	-	-	0.04	-	-	-
Atherinidae								
Atherinidae unid.	unidentified Atherinid	-	-	-	-	-	0.12	-
<i>Atherinops affinis</i>	topsmelt	0.05	0.65	20.05	19.04	154.16	116.43	813.99
<i>Atherinopsis californiensis</i>	jacksmelt	-	-	861.85	1895.43	35.51	16.97	308.68
<i>Leuresthes tenuis</i>	California grunion	-	-	5.84	7.67	0.05	0.02	0.47
Trachipteridae								
<i>Trachipterus altivelis</i>	king-of-the-salmon	-	-	-	-	-	-	0.02
Gasterosteidae								
<i>Aulorhynchus flavidus</i>	tubesnout	0.07	0.27	-	-	0.01	0.01	1.50
<i>Gasterosteus aculeatus</i>	threespine stickleback	-	-	-	-	0.03	0.02	-
Syngnathidae								
Syngnathidae unid.	unidentified pipefish	<0.01	-	-	-	0.88	0.56	-
<i>Syngnathus californiensis</i>	kelp pipefish	0.65	0.47	0.04	0.08	-	-	-
<i>Syngnathus leptorhynchus</i>	bay pipefish	-	-	-	-	-	-	3.42
<i>Syngnathus</i> spp.	unidentified pipefish	0.03	0.06	2.75	1.91	-	-	-
Scorpaenidae								
Scorpaenidae	unidentified rockfish	-	-	-	-	2.43	1.12	2.53
<i>Sebastes atrovirens</i>	kelp rockfish	2.31	0.25	0.12	-	0.14	0.06	6.39
<i>Sebastes auriculatus</i>	brown rockfish	-	-	0.18	1.47	11.38	11.15	13.60
<i>Sebastes carnatus</i>	gopher rockfish	0.04	0.02	-	-	-	-	0.71
<i>Sebastes caurinus</i>	copper rockfish	-	-	-	-	0.20	0.09	3.76

(Table continued)

Appendix A: Fish Biomass Impinged Annually at Four Power Plants

Appendix A (continued).

Family and Scientific Name	Common Name	Diablo Canyon Power Plant 1 Apr 1985 - 31 Mar 1986		San Onofre Nuclear Generating Station 1984-1995 Annual Average		Moss Landing Power Plant 29 Mar 1979 - 17 Mar 1980		Morro Bay Power Plant 4 Jan 1978 - 19 Dec 1978
		Unit 1	Unit 2	Unit 2	Unit 3	Units 1-5	Units 6-7	Units 3-4
BONY FISHES (continued)								
Scorpaenidae (continued)								
<i>Sebastes chrysomelas</i>	black and yellow rockfish	-	-	-	-	-	-	0.05
<i>Sebastes crameri</i>	darkblotched rockfish	-	-	-	-	0.02	0.02	-
<i>Sebastes dallii</i>	calico rockfish	-	-	<0.01	-	-	-	-
<i>Sebastes entomelas</i>	widow rockfish	-	-	-	-	-	-	0.27
<i>Sebastes flavidus</i>	yellowtail rockfish	0.94	1.68	0.01	-	1.49	0.68	-
<i>Sebastes goodei</i>	chilipepper	-	-	-	-	0.12	0.02	-
<i>Sebastes jordani</i>	shortbelly rockfish	0.01	-	-	-	0.02	<0.01	-
<i>Sebastes levis</i>	cowcod	-	-	-	-	0.01	-	-
<i>Sebastes melanops</i>	black rockfish	0.02	0.04	-	-	0.04	0.03	-
<i>Sebastes miniatus</i>	vermillion rockfish	-	-	-	-	-	0.02	-
<i>Sebastes mystinus</i>	blue rockfish	1.48	1.77	-	<0.01	4.10	0.78	1.54
<i>Sebastes paucispinis</i>	boccacio	0.04	-	0.86	0.04	82.05	61.68	136.51
<i>Sebastes rastrelliger</i>	grass rockfish	-	-	0.65	2.69	8.03	3.22	17.46
<i>Sebastes saxicola</i>	stripetail rockfish	-	-	-	-	0.14	0.18	-
<i>Sebastes serranoides</i>	olive rockfish	2.20	6.32	<0.01	0.01	6.13	2.37	3.42
<i>Sebastes serranoides/flavidus</i>	olive/yellowtail rockfish	0.21	0.19	-	-	-	-	0.02
<i>Sebastes serripes</i>	treefish	-	-	0.10	0.01	-	-	-
<i>Sebastes</i> spp.	unidentified rockfish	0.10	0.05	0.01	<0.01	-	-	1.35
Anoplopomatidae								
<i>Anoplopoma fimbria</i>	sablefish	-	-	-	-	-	-	13.66
Hexagrammidae								
Hexagrammidae unid.								
<i>Hexagrammos decagrammus</i>	kelp greenling	0.03	-	<0.01	-	0.79	0.30	-
<i>Ophiodon elongatus</i>	lingcod	-	-	-	-	2.79	1.11	8.00
<i>Oxylebius pictus</i>	painted greenling	0.13	-	-	0.01	0.02	-	-
<i>Zaniolepis latipinnis</i>	longspine combfish	-	0.34	-	-	-	-	-
Cottidae								
<i>Artedius creaseri</i>	roughcheek sculpin	0.01	-	<0.01	<0.01	-	-	0.05
<i>Artedius corallinus</i>	coralline sculpin	0.34	0.07	<0.01	<0.01	-	-	0.50
<i>Artedius harringtoni</i>	scalyhead sculpin	-	-	-	-	0.12	-	-
<i>Artedius lateralis</i>	smoothhead sculpin	0.17	0.15	-	-	-	-	1.79
<i>Artedius notosplitotus</i>	bonyhead sculpin	0.01	-	-	-	0.75	0.45	-
<i>Artedius</i> spp.	unidentified sculpin	-	-	-	<0.01	-	-	-
Cottidae								
<i>Leptocottus armatus</i>	staghorn sculpin	-	-	0.42	<0.01	-	-	-
<i>Oligocottus armatus</i>	staghorn sculpin	-	-	0.72	0.57	189.90	109.25	22.99
<i>Oligocottus maculosus</i>	tidepool sculpin	0.01	-	-	-	-	-	-
<i>Oligocottus rubellio</i>	rosy sculpin	0.04	-	-	-	-	-	-
<i>Orhonomias triellio</i>	snubnose sculpin	0.13	0.26	-	-	-	-	0.02
<i>Scorpaena guttata</i>	sculpin	-	-	22.54	45.06	-	-	-
<i>Scorpaenichthys marmoratus</i>	cabezon	0.02	-	0.65	1.00	26.15	18.42	22.88
Agonidae								
<i>Agonopsis sterletus</i>	southern poacher	-	0.09	<0.01	-	-	-	-
<i>Odontopyxis trispinosa</i>	pygmy poacher	-	-	<0.01	-	<0.01	0.01	-
<i>Stellerina xyosterna</i>	pricklebreast poacher	-	-	-	-	0.07	<0.01	0.04
Cyclopteridae								
<i>Liparis fucensis</i>	slipskin snailfish	-	-	-	-	0.01	-	-
<i>Liparis mucosus</i>	slimy snailfish	0.01	-	-	-	<0.01	0.01	-
Carangidae								
<i>Seriola dorsalis</i>	yellowtail	-	-	-	0.13	-	-	-
<i>Trachurus symmetricus</i>	jack mackerel	1.50	4.50	9.36	9.82	0.78	1.12	5.20
Pristipomatidae								
<i>Anisotremus davidsonii</i>	sargo	-	-	177.59	198.31	-	-	-
<i>Xenistius californiensis</i>	salema	-	-	86.28	77.26	-	-	-
Sciaenidae								
<i>Atractoscion nobilis</i>	white sea bass	-	-	2.70	5.41	-	-	-
<i>Cheilotrema saturnum</i>	black croaker	-	-	2.27	2.09	-	-	-
<i>Genyonemus lineatus</i>	white croaker	-	-	108.18	192.77	52.99	10.90	18.80
<i>Menticirrhus undulatus</i>	California corbina	-	-	6.34	3.81	-	-	-
<i>Roncador stearnsi</i>	spotfin croaker	-	-	44.14	6.71	-	-	-
<i>Seriphus politus</i>	queenfish	0.04	0.47	2377.09	3838.43	-	0.01	0.99
<i>Umbrina roncador</i>	yellowfin croaker	-	-	271.96	486.33	-	-	-

(Table continued)

Appendix A: Fish Biomass Impinged Annually at Four Power Plants

Appendix A (continued).

Family and Scientific Name	Common Name	Diablo Canyon Power Plant 1 Apr 1985 - 31 Mar 1986		San Onofre Nuclear Generating Station 1984-1995 Annual Average		Moss Landing Power Plant 29 Mar 1979 - 17 Mar 1980		Morro Bay Power Plant 4 Jan 1978 - 19 Dec 1978
		Unit 1	Unit 2	Unit 2	Unit 3	Units 1-5	Units 6-7	Units 3-4
BONY FISHES (continued)								
Kyphosidae								
<i>Girella nigricans</i>	opaleye	-	-	6.04	3.27	-	0.32	-
<i>Hermosilla azurrae</i>	zebraperch	-	-	67.58	75.39	-	-	-
<i>Medialuna californiensis</i>	halfmoon	-	-	2.04	1.23	0.17	-	-
Embiotocidae								
<i>Amphistichus argenteus</i>	barred surfperch	0.05	-	0.62	0.77	0.02	0.03	-
<i>Amphistichus koelzi</i>	calico surfperch	-	-	0.01	-	-	-	-
<i>Brachyistius frenatus</i>	kelp surfperch	0.36	0.34	8.13	25.06	0.13	0.01	1.99
<i>Cymatogaster aggregata</i>	shiner surfperch	0.97	-	5.78	4.00	489.43	26.89	329.79
<i>Damalichthys vacca</i>	pile surfperch	-	-	1.90	2.61	20.11	0.57	40.95
<i>Embiotoca jacksoni</i>	black surfperch	2.35	-	6.97	3.53	9.04	0.33	98.99
<i>Embiotoca lateralis</i>	striped surfperch	0.87	-	-	<0.01	2.13	-	41.69
Embiotocidae								
<i>Hyperprosopon anale</i>	spotfin surfperch	-	-	0.03	-	0.27	0.02	-
<i>Hyperprosopon argenteum</i>	walleye surfperch	0.10	1.21	34.75	26.36	116.08	6.66	8.88
<i>Hyperprosopon ellipticum</i>	silver surfperch	-	-	-	-	0.06	0.02	1.35
<i>Hypsurus caryi</i>	rainbow surfperch	-	-	0.01	0.01	0.54	0.02	0.05
<i>Micrometrus aurora</i>	reef surfperch	-	-	-	<0.01	-	-	-
<i>Micrometrus minimus</i>	dwarf surfperch	0.04	0.05	0.04	0.07	3.49	0.47	0.31
<i>Phanerodon furcatus</i>	white surfperch	0.02	-	32.40	56.69	111.29	11.90	55.92
<i>Rachochilus toxotes</i>	rubberlip surfperch	-	-	1.92	0.26	2.01	0.27	97.99
Labridae								
<i>Halichoeres semicinctus</i>	rock wrasse	-	-	6.60	44.95	-	-	-
<i>Oxyjulis californica</i>	senorita	-	0.19	1.21	1.11	0.24	0.12	-
<i>Semicossyphus pulchur</i>	California sheephead	-	-	4.93	1.53	-	-	-
Serranidae								
<i>Morone saxatilis</i>	striped bass	-	-	-	-	0.61	-	-
<i>Paralabrax clathratus</i>	kelp bass	-	-	35.61	26.79	-	-	0.18
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	-	-	0.36	0.18	-	-	-
<i>Paralabrax nebulifer</i>	barred sand bass	-	-	46.50	35.69	-	-	-
<i>Sterolepis gigas</i>	giant sea bass	-	-	0.96	0.29	-	-	-
Branchiostegidae								
<i>Caulolatilus princeps</i>	ocean whitefish	-	-	<0.01	-	-	-	-
Pomacentridae								
<i>Chronis punctipinnis</i>	blacksmith	0.50	0.78	2.00	8.33	-	-	-
<i>Hypsopops rubicundus</i>	garibaldi	-	-	3.48	0.49	-	-	-
Sphyaeniidae								
<i>Sphyaena argenta</i>	barracuda	-	-	7.29	14.25	-	-	-
Bathymasteridae								
<i>Rathbunella hypoplecta</i>	smooth ronquill	-	-	-	<0.01	-	-	0.17
Anarhichadidae								
<i>Anarrhichthys ocellatus</i>	wolf-eel	-	-	-	-	1.36	0.51	-
Blenniidae								
<i>Hypsoblennius gentilis</i>	bay blenny	-	-	0.02	0.01	-	-	-
<i>Hypsoblennius gilberti</i>	rockpool blenny	-	-	0.31	0.24	-	-	-
<i>Hypsoblennius jenkinsi</i>	mussel blenny	-	-	0.01	0.01	-	-	-
<i>Hypsoblennius</i> spp.	unidentified blenny	-	-	0.31	0.69	-	-	-
<i>Paraclinus integripinnis</i>	reef finspot	-	-	<0.01	<0.01	-	-	-
Clinidae								
<i>Gibbonsia elegans</i>	spotted kelpfish	-	-	0.43	0.54	-	-	0.24
<i>Gibbonsia erythra</i>	scarlet kelpfish	-	0.15	-	<0.01	-	-	-
<i>Gibbonsia metzi</i>	striped kelpfish	0.66	0.05	0.12	0.01	0.39	0.52	3.92
<i>Gibbonsia montereyensis</i>	crevice kelpfish	0.07	-	<0.01	<0.01	-	-	-
<i>Gibbonsia</i> spp.	unidentified kelpfish	-	0.65	0.10	0.01	-	-	-
<i>Heterostichus rostratus</i>	giant kelpfish	-	-	17.37	14.88	0.12	-	1.06
<i>Neoclinus blanchardi</i>	sarcastic fringehead	-	-	-	<0.01	0.25	0.02	0.37
<i>Neoclinus uninotatus</i>	onespot fringehead	-	-	0.01	-	1.55	0.67	1.06
Stichaeidae								
<i>Anoplarchus purpurescens</i>	high cockscomb	0.12	0.27	-	-	-	-	0.47
<i>Cebidichthys violaceus</i>	monkeyface-eel	-	-	-	-	1.75	1.85	3.35
<i>Stichaeopsis</i> sp.	masked prickleback	-	-	-	-	-	-	1.04

(Table continued)

Appendix A: Fish Biomass Impinged Annually at Four Power Plants

Appendix A (continued).

Family and Scientific Name	Common Name	Diablo Canyon Power Plant 1 Apr 1985 - 31 Mar 1986		San Onofre Nuclear Generating Station 1984-1995 Annual Average		Moss Landing Power Plant 29 Mar 1979 - 17 Mar 1980		Morro Bay Power Plant 4 Jan 1978 - 19 Dec 1978
		Unit 1	Unit 2	Unit 2	Unit 3	Units 1-5	Units 6-7	Units 3-4
BONY FISHES (continued)								
Pholidae								
<i>Apodichthys flavidus</i>	penpoint gunnel	-	-	-	-	0.06	0.30	1.27
<i>Ulvicola sanctaerosae</i>	kelp gunnel	0.02	-	-	-	-	-	-
<i>Xeropes fucorum</i>	rockweed gunnel	0.04	0.06	-	-	0.01	-	0.02
Ammodytidae								
<i>Ammodytes hexapterus</i>	Pacific sandlance	-	-	-	-	0.02	0.02	0.02
Icosteidae								
<i>Icosteus aenigmaticus</i>	ragfish	-	-	-	-	0.64	-	-
Gobiidae								
<i>Acanthogobius flavimanus</i>	yellowfin goby	-	-	0.11	0.08	3.14	2.66	-
<i>Coryphopterus nicholsi</i>	blackeye goby	-	-	<0.01	<0.01	0.17	0.22	-
<i>Gillichthys mirabilis</i>	longjaw mudsucker	-	-	-	-	0.17	0.45	-
<i>Lepidogobius lepidus</i>	bay goby	-	-	-	-	6.04	5.87	0.78
Gobiidae unid.	unidentified goby	-	-	-	<0.01	-	0.01	-
Trichiuridae								
<i>Trichiurus nitens</i>	Pacific cutlassfish	-	-	0.26	0.02	-	-	-
Scombridae								
<i>Sarda chiliensis</i>	Pacific bonito	-	-	0.08	-	-	-	-
<i>Scomber japonicus</i>	Pacific mackerel	3.64	8.53	75.87	216.64	0.61	-	-
Stromateidae								
<i>Ichthyosoma lockingtoni</i>	medusafish	-	-	-	-	0.63	0.49	0.45
<i>Peprilus simillimus</i>	Pacific butterfish	-	-	48.37	170.29	25.42	1.18	14.04
Cynoglossidae								
<i>Symphurus atricauda</i>	California toungefish	0.03	-	0.05	0.02	10.13	11.67	20.30
Paralichthyidae								
<i>Citharichthys sordidus</i>	Pacific sanddab	-	-	0.01	0.03	0.08	0.10	-
<i>Citharichthys stigmaeus</i>	speckled sanddab	0.02	-	1.71	1.90	11.68	9.61	4.80
<i>Citharichthys xanthostigma</i>	longfin sanddab	-	-	<0.01	0.11	-	-	-
<i>Paralichthys californicus</i>	California halibut	-	-	23.53	34.58	22.54	1.48	1.93
<i>Xystreurys liolepis</i>	fantail sole	3.95	-	0.91	1.81	-	-	-
Pleuronectidae								
<i>Eopsetta exilis</i>	slender sole	-	-	0.01	-	0.03	-	-
<i>Errex zachirus</i>	rex sole	-	-	-	-	-	0.01	-
<i>Hippoglossina stomata</i>	bigmouth sole	-	-	<0.01	-	-	-	-
<i>Hypsosetta guttulata</i>	diamond turbot	-	-	3.92	3.23	37.23	9.37	12.78
<i>Microstomus pacificus</i>	dover sole	0.15	-	-	<0.01	-	-	-
<i>Platichthys stellatus</i>	starry flounder	-	-	-	-	191.42	48.78	1.08
<i>Pleuronectes vetulus</i>	english sole	-	-	<0.01	<0.01	31.07	11.79	16.08
Pleuronectidae unid.	unidentified turbot or sole	0.01	-	-	-	-	-	0.18
<i>Pleuronichthys coenosus</i>	C-O turbot	0.34	-	0.43	0.18	-	-	1.13
<i>Pleuronichthys decurrens</i>	curlfin turbot	-	-	-	0.06	2.59	1.24	0.91
<i>Pleuronichthys ritteri</i>	spotted turbot	-	-	7.57	11.37	-	-	-
<i>Pleuronichthys verticalis</i>	hornyhead turbot	-	-	1.34	0.19	-	-	-
<i>Psettichthys melanostictus</i>	sand sole	-	-	-	-	7.21	2.27	-
Balistidae								
<i>Balistes polylepis</i>	finescale triggerfish	-	-	1.44	4.03	1.29	-	-
Molidae								
<i>Mola mola</i>	common mola	-	-	-	-	288.53	9.88	-
Unidentified fish	unidentified fish	-	-	-	-	<0.01	0.02	18.04
Fish Biomass Total:		29.94	37.93	5109.46	9275.58	3298.40	1607.39	4318.52

(Table continued)

Appendix A: Fish Biomass Impinged Annually at Four Power Plants

Appendix A (continued).

Family and Scientific Name	Common Name	Diablo Canyon Power Plant 1 Apr 1985 - 31 Mar 1986		San Onofre Nuclear Generating Station 1984-1995 Annual Average		Moss Landing Power Plant 29 Mar 1979 - 17 Mar 1980		Morro Bay Power Plant 4 Jan 1978 - 19 Dec 1978
		Unit 1	Unit 2	Unit 2	Unit 3	Units 1-5	Units 6-7	Units 3-4
Sharks, Rays, and Eels (Chondrichthyes)								
Petromyzonidae								
<i>Lampetra tirdentata</i>	Pacific lamprey	-	-	-	0.27	-	-	-
Heterodontidae								
<i>Heterodontus francisci</i>	horn shark	-	-	2.34	6.45	-	-	-
Squalidae								
<i>Squalus acanthias</i>	spiny dogfish	-	-	41.39	101.22	3.06	0.11	3.77
Squatinae								
<i>Squatina californica</i>	Pacific angel shark	-	-	-	3.43	-	-	-
Alopiidae								
<i>Alopias vulpinus</i>	common thresher	-	-	-	-	-	2.70	-
Scyliorhinidae								
<i>Apristurus brunneus</i>	brown cat shark	-	-	-	-	0.46	-	-
<i>Cephaloscyllium ventriosum</i>	swell shark	-	-	-	-	-	-	16.15
<i>Parmaturus xanthurus</i>	filetail cat shark	-	-	-	-	-	-	10.91
Carcharhinidae								
<i>Mustelus henlei</i>	brown smoothhound	-	-	1.59	2.45	24.75	1.05	-
<i>Mustelus californicus</i>	gray smoothhound	-	-	4.57	4.52	45.77	0.40	-
<i>Mustelus</i> spp.	smoothhound	-	-	-	0.02	-	-	-
<i>Triakis semifasciata</i>	leopard shark	-	-	0.40	0.76	220.49	0.61	0.47
Rajidae								
<i>Raja binoculata</i>	big skate	0.39	0.86	-	0.28	38.16	3.62	-
<i>Raja inornata</i>	California skate	-	-	0.26	0.50	-	-	-
Torpedinidae								
<i>Torpedo californica</i>	Pacific electric ray	8.32	8.06	269.31	353.95	101.25	100.79	48.77
Platyrrhinidae								
<i>Platyrrhinoidis triseriata</i>	thornback ray	21.31	86.93	51.65	30.12	42.34	1.52	196.61
Rhinobatidae								
<i>Rhinobatos productus</i>	shovelnose guitarfish	-	-	17.05	30.56	17.57	0.31	-
Myliobatidae								
<i>Myliobatis californica</i>	bat ray	-	-	11.47	44.55	125.50	3.60	284.72
Dasyatidae								
<i>Urolophus halleri</i>	round stingray	-	4.74	27.76	28.71	8.16	-	22.29
Gymnuridae								
<i>Gymnura marmorata</i>	California butterfly ray	-	-	19.66	25.92	-	-	-
Chimeridae								
<i>Hydrolagus collei</i>	spotted ratfish	5.69	9.70	-	0.06	-	0.89	5.22
Muraenidae								
<i>Gymnothorax mordax</i>	California moray	-	-	0.02	0.18	-	-	-
Ophichthidae								
<i>Ophichthus triseriatis</i>	Pacific snake eel	-	-	0.44	0.28	-	-	-
<i>Ophichthus zophochir</i>	yellow snake eel	-	-	0.15	0.53	-	-	-
Sh, Rays and Eels Biomass Totals:		35.71	110.28	448.08	634.77	627.53	115.59	588.93

APPENDIX B

Biomass (grams/million m³) of fish taxa impinged at San Onofre Nuclear Generating Station.

Biomass (grams/million m³ flow) of fishes impinged by San Onofre Nuclear Generating Station (SONGS) Units 2 (B1) and 3 (B2) during the period 1984 through 1995. The data combines fishes impinged during normal operations and heat treatments. NOTE: Data are preliminary and not intended for use in any context other than this report.

Appendix B1.

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Yearly cooling water volume (million m ³):		1160	1304	1326	1276	1689	1285	1622	1249	1659	1482	1684	1366
Total Biomass (grams/million m ³ flow) All fishes:		1738	2287	8517	4027	4516	9846	11361	7950	3046	5596	2628	5178
BONY FISHES (Osteichthyes)													
Clupeidae													
<i>Alosa sapidissima</i>	American shad	-	-	-	-	-	-	-	-	-	-	-	-
<i>Clupea harengus</i>	Pacific herring	-	-	-	-	-	-	-	-	-	-	-	-
<i>Dorosoma petenense</i>	threadfin shad	0.04	-	-	-	-	-	-	-	-	-	-	-
<i>Etrumeus teres</i>	round herring	-	-	-	-	-	-	-	-	-	0.01	-	-
<i>Opishonema medirastre</i>	middling thread herring	-	-	-	-	-	-	-	-	1.65	0.06	-	-
<i>Sardinops sagax</i>	Pacific sardine	11.21	0.77	0.75	0.01	0.59	0.78	91.86	1.35	112.46	314.74	49.73	152.97
Engraulidae													
<i>Anchoa compressa</i>	deepbody anchovy	13.79	16.87	74.66	212.38	17.76	2.33	19.11	2.95	4.24	62.79	13.02	70.66
<i>Anchoa delicatissima</i>	slough anchovy	7.76	8.44	30.17	27.43	2.96	0.12	0.46	0.05	2.75	25.85	4.01	20.50
<i>Engraulis mordax</i>	northern anchovy	43.97	52.91	906.49	40.75	242.75	196.11	85.70	2155.51	408.68	827.73	88.66	742.21
Salmonidae													
<i>Oncorhynchus kisutch</i>	silver salmon	-	-	-	-	-	-	-	-	-	-	-	-
<i>Oncorhynchus tshawytscha</i>	king slamon	-	-	-	-	-	-	-	-	-	-	-	-
Salmonidae													
	unidentified salmon	-	-	-	-	-	-	-	-	-	-	-	-
Osmeridae													
<i>Hypomesus pretiosus</i>	surf smelt	-	-	-	-	-	-	-	-	-	-	-	-
<i>Spirinchus starksi</i>	night smelt	-	-	-	-	-	-	-	-	-	-	-	-
<i>Spirinchus thaleichthys</i>	longfin smelt	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae													
<i>Stenobranchius leucopsarus</i>	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-
Synodontidae													
<i>Synodus lucioceps</i>	California lizardfish	-	2.30	2.26	-	22.50	32.68	0.62	-	1.38	2.31	-	0.94
Batrachoididae													
<i>Porichthys myriaster</i>	specklefin midshipman	2.59	29.91	47.51	18.81	31.38	31.13	5.55	0.15	3.68	9.10	12.38	3.99
<i>Porichthys notatus</i>	plainfin midshipman	6.90	9.20	4.52	24.29	68.09	49.03	10.48	7.96	11.82	21.30	17.77	10.07
Ophidiidae													
<i>Chilara taylori</i>	spotted cusk-eel	0.04	-	0.75	0.78	-	0.54	-	-	-	5.42	4.55	-
<i>Otophidium scrippi</i>	basketweave cusk-eel	0.04	1.53	15.08	1.57	1.78	15.56	0.62	3.45	0.17	13.36	0.70	2.95
Gobiesocidae													
<i>Gobiesox maeandricus</i>	northern clingfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gobiesox rhesodon</i>	California clingfish	-	-	-	-	-	-	0.03	-	-	<0.01	-	-
Merlucciidae													
<i>Merluccius productus</i>	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-
Gadidae													
<i>Microgadus proximus</i>	Pacific tomcod	-	-	-	-	-	-	-	-	-	-	-	-
Belonidae													
<i>Strongylura exilis</i>	California needlefish	-	-	-	-	-	-	-	-	-	-	-	-
Atherinidae													
Atherinidae unid.	unidentified Atherinid	-	-	-	-	-	-	-	-	-	-	-	-
<i>Atherinops affinis</i>	topsmelt	1.72	3.07	1.51	26.65	5.33	10.12	36.99	1.27	7.90	55.01	28.28	62.76
<i>Atherinopsis californiensis</i>	jacksmelt	13.79	98.93	628.96	11.76	110.72	46.69	6062.89	2490.75	29.83	405.51	23.00	419.34
<i>Leuresthes tenuis</i>	California grunion	0.04	1.53	2.26	3.92	1.78	0.01	11.71	0.58	2.54	34.99	1.70	9.02
Trachipteridae													
<i>Trachipterus altivelis</i>	king-of-the-salmon	-	-	-	-	-	-	-	-	-	-	-	-
Gasterosteidae													
<i>Auloryhynchus flavidus</i>	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gasterosteus aculeatus</i>	threespine stickleback	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathidae													
Syngnathidae unid.	unidentified pipefish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Syngnathus californiensis</i>	kelp pipefish	-	-	-	-	-	-	-	-	-	-	0.53	-
<i>Syngnathus leptorhynchus</i>	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Syngnathus</i> spp.	unidentified pipefish	0.04	0.31	9.80	0.47	1.78	10.89	3.70	1.40	0.79	2.77	0.34	0.65
Scorpaenidae													
Scorpaenidae	unidentified rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes atrovirens</i>	kelp rockfish	-	-	-	-	-	-	-	-	-	1.15	0.30	-
<i>Sebastes auriculatus</i>	brown rockfish	0.04	0.08	0.38	0.78	0.12	-	0.03	0.16	0.55	-	-	-
<i>Sebastes carnatus</i>	gopher rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes caurinus</i>	copper rockfish	-	-	-	-	-	-	-	-	-	-	-	-

(Table continued)

Appendix B1 (continued).

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
BONY FISHES (continued)													
Scorpaenidae (continued)													
<i>Sebastes chrysomelas</i>	black and yellow rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes crameri</i>	darkblotched rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes dallii</i>	calico rockfish	-	-	-	-	-	-	-	0.02	-	-	-	-
<i>Sebastes entomelas</i>	widow rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes flavidus</i>	yellowtail rockfish	-	-	-	-	0.18	-	-	-	-	-	-	-
<i>Sebastes goodei</i>	chilipepper	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes jordani</i>	shortbelly rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes levis</i>	cowcod	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes melanops</i>	black rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes miniatus</i>	vermillion rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes mystinus</i>	blue rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes paucispinis</i>	boccacio	0.04	0.08	-	-	10.07	-	-	0.14	-	-	-	0.01
<i>Sebastes rastrelliger</i>	grass rockfish	0.86	0.08	-	2.35	2.37	0.23	0.03	0.12	0.24	0.79	0.70	-
<i>Sebastes saxicola</i>	stripetail rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes serranoides</i>	olive rockfish	-	-	-	-	-	-	-	-	-	-	-	0.01
<i>Sebastes serranoides/flavidus</i>	olive/yellowtail rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes serriceps</i>	treefish	-	-	-	0.78	-	-	-	0.33	-	-	-	0.05
<i>Sebastes</i> spp.	unidentified rockfish	0.04	-	-	-	-	-	-	0.04	0.01	-	0.06	-
Anoplopomatidae													
<i>Anoplopoma fimbria</i>	sablefish	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae													
Hexagrammidae unid.													
<i>Hexagrammos decagrammus</i>	kelp greenling	-	-	-	-	0.06	-	-	-	-	-	-	-
<i>Ophiodon elongatus</i>	lingcod	-	-	-	-	-	-	-	-	-	-	-	-
<i>Oxylebiscus pictus</i>	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-
<i>Zaniolepis latipinnis</i>	longspine combfish	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae													
<i>Artedius creaseri</i>	roughcheek sculpin	-	-	-	-	-	-	-	-	-	0.00	-	-
<i>Artedius corallinus</i>	coralline sculpin	-	-	-	0.05	-	-	-	-	-	-	-	2.9
<i>Artedius harringtoni</i>	scalyhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Artedius lateralis</i>	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Artedius notosplitus</i>	bonyhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Artedius</i> spp.	unidentified sculpin	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae													
<i>Leptocottus armatus</i>	staghorn sculpin	-	0.77	0.75	0.78	0.59	0.78	-	0.36	0.68	1.63	0.20	2.12
<i>Oligocottus maculosus</i>	tidepool sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Oligocottus rubellio</i>	rosy sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Orithonopias triacis</i>	snubnose sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scorpaena guttata</i>	sculpin	1.72	4.60	33.18	32.13	16.58	67.70	6.78	13.92	7.85	23.80	37.47	24.72
<i>Scorpaenichthys marmoratus</i>	cabezon	0.04	0.08	1.51	0.78	0.27	0.78	1.85	0.68	1.79	0.02	0.02	0.03
Agonidae													
<i>Agonopsis sterletus</i>	southern poacher	-	-	-	-	-	-	-	-	-	-	0.02	-
<i>Odontopyxis trispinosa</i>	pygmy poacher	-	-	-	-	0.06	-	-	-	-	-	-	-
<i>Stellerina xyosterna</i>	pricklebreast poacher	-	-	-	-	-	-	-	-	-	-	-	-
Cyclopteridae													
<i>Liparis fucensis</i>	slipskin snailfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Liparis mucosus</i>	slimy snailfish	-	-	-	-	-	-	-	-	-	-	-	-
Carangidae													
<i>Seriola dorsalis</i>	yellowtail	-	-	-	-	-	-	-	-	-	-	-	-
<i>Trachurus symmetricus</i>	jack mackerel	0.04	4.60	12.82	3.13	-	3.89	0.62	0.06	1.49	1.82	57.65	26.24
Pristipomatidae													
<i>Anisotremus davidsonii</i>	sargo	363.79	266.10	134.99	121.47	129.66	156.42	182.49	153.31	202.30	106.94	136.33	177.27
<i>Xenistius californiensis</i>	salema	37.07	25.31	24.13	18.81	3.55	14.01	50.55	18.87	58.21	41.65	111.26	631.99
Sciaenidae													
<i>Atractoscion nobilis</i>	white sea bass	2.59	2.30	9.05	0.78	4.14	3.89	3.70	1.09	0.37	1.58	1.61	1.35
<i>Cheilotrema saturnum</i>	black croaker	7.76	2.30	3.02	0.39	0.59	3.89	0.62	0.55	1.38	3.27	2.15	1.35
<i>Genyonemus lineatus</i>	white croaker	6.03	85.12	61.09	5.49	278.86	257.59	100.49	263.52	14.33	128.17	29.12	68.37
<i>Menticirrhus undulatus</i>	California corbina	0.86	2.30	30.92	2.35	20.13	12.45	1.85	-	0.51	0.29	0.20	4.25
<i>Rovincador stearnsi</i>	spotfin croaker	250.00	9.97	160.63	3.13	5.92	16.34	7.40	55.46	-	18.25	1.76	0.83
<i>Seriphys politus</i>	queenfish	137.93	828.22	4768.48	1703.76	2664.30	6987.55	4074.60	2102.97	1082.81	1542.27	730.46	1901.75
<i>Umbriina roncadore</i>	yellowfin croaker	326.72	251.53	231.52	1206.90	81.11	509.73	98.64	22.03	147.79	14.95	48.14	324.42

(Table continued)

Appendix B1 (continued).

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
BONY FISHES (continued)													
Kyphosidae													
<i>Girella nigricans</i>	opaleye	12.07	0.77	9.05	1.57	4.74	10.12	1.23	12.73	18.62	1.23	0.31	-
<i>Hermosilla azurea</i>	zebraperch	295.69	128.83	66.37	26.65	77.56	92.61	63.50	27.38	2.33	1.34	27.97	0.72
<i>Medialuna californiensis</i>	halfmoon	0.04	0.23	6.79	7.05	0.59	1.56	1.23	4.84	0.58	0.11	0.42	1.03
Embiotocidae													
<i>Amphistichus argenteus</i>	barred surfperch	-	0.77	-	-	-	4.67	-	1.95	-	-	-	-
<i>Amphistichus koelzi</i>	calico surfperch	-	-	-	-	-	-	-	-	-	-	-	0.10
<i>Brachyistius frenatus</i>	kelp surfperch	0.04	-	0.75	0.78	29.01	4.67	32.68	19.46	3.58	5.88	0.36	0.30
<i>Cymatogaster aggregata</i>	shiner surfperch	0.04	0.77	9.05	0.39	0.59	33.46	6.17	2.30	3.83	3.25	2.95	6.62
<i>Damalichthys vacca</i>	pile surfperch	0.04	0.01	0.75	1.57	0.59	6.23	2.47	9.04	1.86	0.19	-	0.09
<i>Embiotoca jacksoni</i>	black surfperch	0.86	0.77	14.33	5.49	4.14	18.68	8.01	6.81	6.02	4.84	4.24	9.46
<i>Embiotoca lateralis</i>	striped surfperch	-	-	-	-	-	-	-	-	-	-	-	-
Embiotocidae													
<i>Hyperprosopon anale</i>	spotfin surfperch	-	0.31	-	-	-	-	-	-	-	-	-	-
<i>Hyperprosopon argenteum</i>	walleye surfperch	0.86	6.90	12.82	4.70	14.80	203.11	43.77	31.65	7.73	39.94	9.10	41.64
<i>Hyperprosopon ellipticum</i>	silver surfperch	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hypsurus caryi</i>	rainbow surfperch	-	-	-	-	-	-	-	-	-	0.06	0.10	-
<i>Micrometrus aurora</i>	reef surfperch	-	-	-	-	-	-	-	-	-	-	-	-
<i>Micrometrus minimus</i>	dwarf surfperch	-	-	-	-	0.36	-	-	-	-	0.16	-	-
<i>Phanerodon furcatus</i>	white surfperch	2.59	3.07	12.82	18.03	50.33	120.62	49.94	56.91	7.81	42.21	13.02	11.46
<i>Rachochilus toxotes</i>	rubberlip surfperch	0.86	0.08	7.54	-	4.74	6.23	0.62	0.48	2.16	-	0.26	0.04
Labridae													
<i>Halichoeres semicinctus</i>	rock wrasse	1.72	5.37	16.59	19.59	10.07	7.78	1.23	6.43	3.13	4.03	1.83	1.41
<i>Oxyjulis californica</i>	senorita	-	0.12	0.38	0.78	2.96	0.47	1.85	3.51	0.54	1.82	1.83	0.26
<i>Semicossyphus pulchur</i>	California sheephead	0.86	1.53	29.41	17.24	2.96	0.47	0.62	2.06	3.05	0.43	0.58	-
Serranidae													
<i>Morone saxatilis</i>	striped bass	-	-	-	-	-	-	-	-	-	-	-	-
<i>Paralabrax clathratus</i>	kelp bass	44.83	4.60	147.81	27.43	10.07	27.24	12.33	64.28	42.71	15.34	11.81	18.82
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	0.04	0.35	0.53	0.71	-	-	-	0.23	1.89	0.12	0.44	-
<i>Paralabrax nebulifer</i>	barred sand bass	28.45	26.07	169.68	48.59	51.51	42.80	14.80	33.51	49.89	36.94	16.31	39.49
<i>Sterolepis gigas</i>	giant sea bass	-	-	-	0.78	-	-	1.85	2.00	-	-	0.04	6.88
Branchiostegidae													
<i>Canolatilus princeps</i>	ocean whitefish	-	-	-	-	-	-	-	-	-	0.01	-	2.38
Pomacentridae													
<i>Chromis punctipinnis</i>	blacksmith	1.72	2.30	2.26	0.78	5.33	2.33	1.23	2.77	1.71	0.65	1.14	1.74
<i>Hypsopops rubicundus</i>	garibaldi	5.17	0.77	18.85	8.62	3.55	1.56	0.62	1.24	0.89	0.40	-	0.12
Sphyrnaeidae													
<i>Sphyrna argenta</i>	barracuda	0.86	5.37	9.05	0.78	4.14	3.89	26.51	18.45	10.80	2.23	0.83	4.60
Bathymasteridae													
<i>Rathbunella hypoplecta</i>	smooth ronquil	-	-	-	-	-	-	-	-	-	-	-	-
Anarhichadidae													
<i>Anarhichthys ocellatus</i>	wolf-eel	-	-	-	-	-	-	-	-	-	-	-	-
Blenniidae													
<i>Hypsoblennius gentilis</i>	bay blenny	-	-	-	-	-	0.08	0.03	0.02	-	0.06	-	-
<i>Hypsoblennius gilberti</i>	rockpool blenny	0.04	-	-	0.24	0.15	0.23	0.03	0.06	0.14	1.84	0.63	0.37
<i>Hypsoblennius jenkinsi</i>	mussel blenny	-	-	-	-	-	-	0.03	0.02	0.03	-	0.01	-
<i>Hypsoblennius spp.</i>	unidentified blenny	1.72	0.77	0.75	0.16	0.12	0.08	0.03	0.04	0.01	-	0.02	-
<i>Paraclinus integripinnis</i>	reef finspot	-	-	-	-	-	-	0.03	-	-	-	-	-
Clinidae													
<i>Gibbonsia elegans</i>	spotted kelpfish	0.04	-	0.38	0.01	1.18	0.78	0.62	0.29	0.14	0.26	1.40	0.12
<i>Gibbonsia erythra</i>	scarlet kelpfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gibbonsia metzi</i>	striped kelpfish	-	0.08	0.75	0.08	0.12	0.23	0.03	0.10	-	-	-	-
<i>Gibbonsia montereyensis</i>	crevice kelpfish	0.04	-	-	-	-	-	-	-	-	-	-	-
<i>Gibbonsia spp.</i>	unidentified kelpfish	0.04	0.08	0.53	0.16	0.36	-	-	-	-	-	-	-
<i>Heterostichus rostratus</i>	giant kelpfish	0.86	6.90	14.33	6.27	33.16	35.80	66.58	11.87	9.66	7.20	2.62	13.15
<i>Neoclinus blanchardi</i>	sarcastic fringehead	-	-	-	-	-	-	-	-	-	-	-	-
<i>Neoclinus unnotatus</i>	onespot fringehead	-	-	0.15	-	-	-	-	-	-	-	-	-
Stichaeidae													
<i>Anoplarchus purpureus</i>	high cockscomb	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cebidichthys violaceus</i>	monkeyface-eel	-	-	-	-	-	-	-	-	-	-	-	-
<i>Stichaeopsis sp.</i>	masked prickleback	-	-	-	-	-	-	-	-	-	-	-	-

(Table continued)

Appendix B1 (continued).

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
BONY FISHES (continued)													
Pholidae													
<i>Apodichthys flavidus</i>	penpoint gunnel	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ulvicola sanctaerosae</i>	kelp gunnel	-	-	-	-	-	-	-	-	-	-	-	-
<i>Xeropes fucorum</i>	rockweed gunnel	-	-	-	-	-	-	-	-	-	-	-	-
Ammodytidae													
<i>Ammodytes hexapterus</i>	Pacific sandlance	-	-	-	-	-	-	-	-	-	-	-	-
Loosteidae													
<i>Icosteus aenigmaticus</i>	ragfish	-	-	-	-	-	-	-	-	-	-	-	-
Gobiidae													
<i>Acanthogobius flavimanus</i>	yellowfin goby	-	-	0.38	-	-	-	-	0.26	-	0.57	0.12	-
<i>Coryphopterus nicholsi</i>	blackeye goby	-	-	-	-	0.01	-	-	-	-	-	-	-
<i>Gillichthys mirabilis</i>	longjaw mudsucker	-	-	-	-	-	-	-	-	-	-	-	-
<i>Lepidogobius lepidus</i>	bay goby	-	-	-	-	-	-	-	-	-	-	-	-
Gobiidae unid.	unidentified goby	-	-	-	-	-	-	-	-	-	-	-	-
Trichiuridae													
<i>Trichiurus nitens</i>	Pacific cutlassfish	-	-	-	-	-	-	-	-	-	3.18	-	-
Scombridae													
<i>Sarda chiliensis</i>	Pacific bonito	-	-	-	-	-	-	-	0.97	-	-	-	-
<i>Scomber japonicus</i>	Pacific mackerel	3.45	5.37	19.61	18.81	2.37	12.45	16.65	11.22	457.36	183.72	104.39	75.11
Stromateidae													
<i>Ichthyophis lockingtoni</i>	medusafish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Peprilus simillimus</i>	Pacific butterfish	7.76	6.90	144.04	10.19	24.87	104.28	85.08	28.83	7.18	115.78	17.71	27.80
Cynoglossidae													
<i>Symphurus atricauda</i>	California tonguefish	-	-	0.60	-	-	-	-	-	-	-	-	-
Paralichthyidae													
<i>Citharichthys sordidus</i>	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	0.07
<i>Citharichthys stigmaeus</i>	speckled sanddab	-	0.15	1.51	0.24	2.37	2.33	0.03	0.34	0.14	12.64	0.48	0.26
<i>Citharichthys xanthostigma</i>	longfin sanddab	-	-	-	-	-	-	-	-	-	0.03	-	-
<i>Paralichthys californicus</i>	California halibut	3.45	9.20	33.94	10.19	13.03	43.58	4.32	3.10	11.11	119.61	2.24	28.65
<i>Xystreurys hiolepis</i>	fantail sole	-	0.77	0.68	3.92	1.78	2.33	-	0.13	0.83	0.36	0.15	-
Pleuronectidae													
<i>Eopsetta exilis</i>	slender sole	-	-	-	-	-	-	-	-	-	-	-	0.11
<i>Errex zachirus</i>	rex sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hippoglossina stomata</i>	bigmouth sole	-	-	-	-	-	-	-	-	-	-	0.01	-
<i>Hypsosetta guttulata</i>	diamond turbot	0.04	-	11.31	0.78	1.78	-	0.62	1.44	-	29.57	1.32	0.23
<i>Microstomus pacificus</i>	dover sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Platichthys stellatus</i>	starry flounder	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronectes bilineatus</i>	rock sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronectes vetulus</i>	english sole	-	-	-	-	-	-	-	-	-	-	0.02	-
Pleuronectidae unid.	unidentified turbot or sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronichthys coenosus</i>	C-O turbot	0.86	-	-	0.08	-	0.78	-	-	1.84	0.01	1.57	-
<i>Pleuronichthys decurrens</i>	curlfin turbot	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronichthys ritteri</i>	spotted turbot	0.86	0.77	12.07	0.78	4.14	8.56	1.85	3.91	1.40	42.69	5.29	8.54
<i>Pleuronichthys verticalis</i>	hornyhead turbot	-	-	1.51	-	-	0.16	0.03	-	-	14.36	-	-
<i>Psettichthys melanostictus</i>	sand sole	-	-	-	-	-	-	-	-	-	-	-	-
Balistidae													
<i>Balistes polylepis</i>	finest triggerfish	0.86	-	-	9.40	-	-	-	-	-	-	3.55	3.51
Molidae													
<i>Mola mola</i>	common mola	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified fish	unidentified fish	-	-	-	-	-	-	-	-	-	-	-	-
Fish Biomass Total:		1654.31	1929.15	7974.74	3725.53	4089.41	9231.41	11306	7669.66	2767.16	4360.57	1637.14	4968.47

(Table continued)

Appendix B1 (continued).

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Sharks, Rays, and Eels (Chondrichthyes)													
Petromyzonidae													
<i>Lampetra tirdentata</i>	Pacific lamprey	-	-	-	-	-	-	-	-	-	-	-	-
Heterodontidae													
<i>Heterodontus francisci</i>	horn shark	-	4.60	15.08	0.24	-	-	-	-	1.00	-	7.19	-
Squalidae													
<i>Squalus acanthias</i>	spiny dogfish	-	-	50.53	39.18	56.84	34.24	-	4.22	11.59	295.86	4.18	-
Squatinae													
<i>Squatina californica</i>	Pacific angel shark	-	-	-	-	-	-	-	-	-	-	-	-
Alopiidae													
<i>Alopias vulpinus</i>	common thresher	-	-	-	-	-	-	-	-	-	-	-	-
Scyliorhinidae													
<i>Apristurus brunneus</i>	brown cat shark	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cephaloscyllium ventriosum</i>	swell shark	-	-	-	-	-	-	-	-	-	-	-	-
<i>Parmaturus xamiurus</i>	filetail cat shark	-	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae													
<i>Mustelus henlei</i>	brown smoothhound	-	0.27	0.38	-	1.78	-	-	3.70	9.36	-	3.65	-
<i>Mustelus californicus</i>	gray smoothhound	-	3.07	3.02	12.54	21.31	11.67	0.62	0.46	-	2.17	-	-
<i>Mustelus</i> spp.	smoothhound	-	-	-	-	-	-	-	-	-	-	-	-
<i>Triakis semifasciata</i>	leopard shark	-	1.53	-	-	0.59	1.56	-	1.12	-	-	-	-
Rajidae													
<i>Raja binoculata</i>	big skate	-	-	-	-	-	-	-	-	-	-	-	-
<i>Raja inornata</i>	California skate	-	-	-	-	-	3.11	-	-	-	-	-	-
Torpedinidae													
<i>Torpedo californica</i>	Pacific electric ray	46.55	250.00	254.15	90.13	246.89	317.51	33.29	101.28	239.42	573.43	948.26	130.86
Platyrrhinidae													
<i>Platyrrhinoidis triseriata</i>	thornback ray	6.03	16.10	105.58	44.67	31.97	40.47	12.95	99.18	4.73	233.29	9.71	15.16
Rhinobatidae													
<i>Rhinobatos productus</i>	shovelnose guitarfish	2.59	60.58	30.92	54.08	4.74	28.02	6.78	-	7.45	6.48	-	3.00
Myliobatidae													
<i>Myliobatis californica</i>	bat ray	-	9.97	40.72	3.13	-	7.78	-	12.70	0.68	21.27	2.42	38.95
Dasyatidae													
<i>Urolophus halleri</i>	round stingray	28.45	6.13	33.94	36.83	49.14	59.92	1.23	21.31	4.14	66.38	15.54	10.14
Gymnuridae													
<i>Gymnura marmorata</i>	California butterfly ray	-	5.37	7.54	19.59	7.70	110.51	-	35.94	0.86	36.84	-	11.60
Chimeridae													
<i>Hydrolagus collei</i>	spotted ratfish	-	-	-	-	-	-	-	-	-	-	-	-
Muraenidae													
<i>Gymnothorax mordax</i>	California moray	-	-	-	-	-	-	-	-	-	-	0.26	-
Ophichthidae													
<i>Ophichthus triserialis</i>	Pacific snake eel	-	-	-	-	5.33	-	-	-	-	-	-	-
<i>Ophichthus zophochir</i>	yellow snake eel	-	0.08	-	1.57	-	-	-	-	-	0.12	-	-
Sharks, Rays and Eels Biomass Totals:		83.62	357.71	541.86	301.96	426.29	614.79	54.87	279.90	279.22	1235.86	991.22	209.71

Appendix B2.

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Yearly cooling water volume (million m ³):		1160	1304	1326	1276	1689	1285	1622	1249	1659	1482	1684	1366
Total Biomass (grams/million m ³ flow) All fishes:		1302	4444	7840	7083	25323	7328	4462	12541	8593	10490	5438	24079
BONY FISHES (Osteichthyes)													
Clupeidae													
<i>Alosa sapidissima</i>	American shad	-	-	-	-	-	-	-	-	-	-	-	-
<i>Clupea harengus</i>	Pacific herring	-	-	-	-	-	-	-	-	-	-	-	-
<i>Dorosoma petenense</i>	threadfin shad	-	-	-	-	-	-	-	-	-	-	-	-
<i>Etrumeus teres</i>	round herring	-	0.04	0.03	-	-	-	-	-	-	0.01	-	-
<i>Opisthonema medirastre</i>	middling thread herring	-	-	-	-	-	-	-	-	3.50	-	-	-
<i>Sardinops sagax</i>	Pacific sardine	0.79	-	0.03	0.04	0.04	0.59	183.36	36.17	2893.63	2035.86	534.64	3497.29
Engraulidae													
<i>Anchoa compressa</i>	deepbody anchovy	73.90	138.98	109.63	74.47	46.06	0.59	3.68	1.81	4.90	125.52	14.09	27.78
<i>Anchoa delicatissima</i>	slough anchovy	17.30	610.17	33.22	29.79	8.17	-	1.47	0.01	2.10	26.21	7.78	46.07
<i>Engraulis mordax</i>	northern anchovy	42.45	43.22	1520.93	65.96	61.66	74.23	1.47	2648.58	2243.53	751.03	291.98	936.31
Salmonidae													
<i>Oncorhynchus kisutch</i>	silver salmon	-	-	-	-	-	-	-	14.47	-	-	-	-
<i>Oncorhynchus tshawytscha</i>	king slamon	-	-	-	-	-	-	-	-	-	-	-	-
Salmonidae													
unidentified salmon													
Osmeridae													
<i>Hypomesus pretiosus</i>	surf smelt	-	-	-	-	-	-	-	-	-	-	-	-
<i>Spirinchus starksi</i>	night smelt	-	-	-	-	-	-	-	-	-	-	-	-
<i>Spirinchus thaleichthys</i>	longfin smelt	-	-	-	-	-	-	-	-	-	-	-	-
Mycetophidae													
<i>Stenobranchius leucopsarus</i>	northern lampfish	-	0.85	1.99	0.04	131.50	45.72	0.74	0.60	17.49	1.38	0.26	2.71
Synodontidae													
<i>Synodus lucioceps</i>	California lizardfish	-	-	-	-	-	-	-	-	-	-	-	-
Batrachoididae													
<i>Porichthys myriaster</i>	specklefin midshipman	-	15.25	63.12	37.59	28.23	30.29	0.74	10.71	8.40	8.97	10.08	2.71
<i>Porichthys notatus</i>	plainfin midshipman	10.22	31.36	25.25	29.79	26.00	40.38	0.74	144.06	26.59	32.41	28.38	76.56
Ophidiidae													
<i>Chilara taylori</i>	spotted cusk-eel	-	-	1.33	0.04	0.04	1.78	3.68	-	0.02	1.38	6.69	-
<i>Otophidium scrippsi</i>	basketweave cusk-eel	0.04	0.85	3.32	1.42	2.97	9.50	1.47	5.42	0.01	6.90	2.98	1.36
Gobiesocidae													
<i>Gobiesox maeandricus</i>	northern clingfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gobiesox rhessodon</i>	California clingfish	-	-	-	-	-	-	0.04	-	-	-	-	-
Merlucciidae													
<i>Merluccius productus</i>	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-
Gadidae													
<i>Microgadus proximus</i>	Pacific tomcod	-	-	-	-	-	-	-	-	-	-	-	-
Belonidae													
<i>Strongylura exilis</i>	California needlefish	-	-	-	-	-	-	-	-	-	0.01	0.52	-
Atherinidae													
unidentified Atherinid													
<i>Atherinops affinis</i>	topsmelt	3.14	0.85	0.66	2.84	3.71	1.19	8.10	2.41	14.00	40.69	46.56	104.34
<i>Atherinopsis californiensis</i>	jacksmelt	3.14	5.93	718.94	29.79	13509.66	36.22	244.48	1260.40	10.50	1455.86	50.92	5419.38
<i>Leuresthes tenuis</i>	California grunion	0.04	0.04	7.31	2.84	1.49	1.78	8.84	4.22	2.10	53.79	0.77	8.81
Trachipteridae													
<i>Trachipterus altivelis</i>	king-of-the-salmon	-	-	-	-	-	-	-	-	-	-	-	-
Gasterosteidae													
<i>Aulorhynchus flavidus</i>	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gasterosteus aculeatus</i>	threespine stickleback	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathidae													
unidentified pipefish													
<i>Syngnathus californiensis</i>	kelp pipefish	-	-	-	-	-	-	-	-	-	-	0.95	0.01
<i>Syngnathus leptorhynchus</i>	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Syngnathus spp.</i>	unidentified pipefish	0.04	0.85	0.66	0.71	2.23	3.56	5.15	4.82	0.07	3.45	0.04	1.36
Scorpaenidae													
unidentified rockfish													
<i>Sebastes atrovirens</i>	kelp rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes auriculatus</i>	brown rockfish	-	2.54	5.32	-	7.43	-	0.74	0.09	0.70	0.69	0.14	-
<i>Sebastes carnatus</i>	gopher rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes caurinus</i>	copper rockfish	-	-	-	-	-	-	-	-	-	-	-	-

(Table continued)

Appendix B2 (continued).

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
BONY FISHES (continued)													
Scorpaenidae (continued)													
<i>Sebastes chrysomelas</i>	black and yellow rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes crameri</i>	darkblotched rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes dallii</i>	calico rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes entomelas</i>	widow rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes flavidus</i>	yellowtail rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes goodei</i>	chilipepper	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes jordani</i>	shortbelly rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes levis</i>	cowcod	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes melanops</i>	black rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes miniatus</i>	vermillion rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes mystinus</i>	blue rockfish	-	-	-	-	-	-	-	0.01	-	-	-	-
<i>Sebastes paucispinis</i>	boccacio	0.04	0.04	0.03	-	0.04	-	0.04	0.12	-	-	0.01	0.14
<i>Sebastes rastrelliger</i>	grass rockfish	0.04	-	-	-	28.97	0.03	0.74	0.24	0.70	1.38	0.23	-
<i>Sebastes saxicola</i>	stripetail rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes serranoides</i>	olive rockfish	-	-	-	0.04	-	-	-	0.06	-	-	-	-
<i>Sebastes serranoides/flavidus</i>	olive/yellowtail rockfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes serriceps</i>	treefish	-	0.04	-	-	-	-	0.04	-	-	-	-	-
<i>Sebastes</i> spp.	unidentified rockfish	-	-	-	-	-	-	-	-	0.01	-	-	-
Anoplopomatidae													
<i>Anoplopoma fimbria</i>	sablefish	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae													
Hexagrammidae unid.													
<i>Hexagrammos decagrammus</i>	kelp greenling	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ophiodon elongatus</i>	lingcod	-	-	-	-	-	-	-	-	-	-	-	-
<i>Oxylebius pictus</i>	painted greenling	-	-	-	-	0.04	0.03	-	-	-	-	-	-
<i>Zaniolepis latipinnis</i>	longspine combfish	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae													
<i>Artedius creaseri</i>	roughcheek sculpin	-	-	-	0.04	-	-	-	-	-	-	-	-
<i>Artedius corallinus</i>	coralline sculpin	-	-	-	-	-	0.03	-	-	-	-	-	0.01
<i>Artedius harringtoni</i>	scalyhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Artedius lateralis</i>	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Artedius notosplitotus</i>	bonyhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Artedius</i> spp.	unidentified sculpin	-	-	-	-	-	0.03	-	-	-	-	-	-
Cottidae													
<i>Leptocottus armatus</i>	staghorn sculpin	0.04	0.04	1.33	0.04	1.49	1.78	0.04	0.18	0.14	0.28	0.19	1.36
<i>Oligocottus maculosus</i>	tidepool sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Oligocottus rubellio</i>	rosy sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Orthonopias triacis</i>	snubnose sculpin	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scorpaena guttata</i>	sculpin	4.72	1.69	7.97	14.18	250.37	72.45	26.51	27.73	16.79	40.00	64.72	13.55
<i>Scorpaenichthys marmoratus</i>	cabezon	0.04	0.04	1.99	2.13	0.04	1.19	2.21	1.21	1.40	0.69	0.34	0.68
Agonidae													
<i>Agonopsis sterletus</i>	southern poacher	-	-	-	-	-	-	-	-	-	-	-	-
<i>Odontopyxis trispinosa</i>	pygmy poacher	-	-	-	-	-	-	-	-	-	-	-	-
<i>Stellerina xyosterna</i>	pricklebreast poacher	-	-	-	-	-	-	-	-	-	-	-	-
Cyclopteridae													
<i>Liparis fucensis</i>	slipskin snailfish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Liparis mucosus</i>	slimy snailfish	-	-	-	-	-	-	-	-	-	-	-	-
Carangidae													
<i>Seriola dorsalis</i>	yellowtail	1.57	-	-	-	-	-	-	-	-	-	-	-
<i>Trachurus symmetricus</i>	jack mackerel	1.57	0.85	4.65	0.71	0.04	17.81	0.74	0.01	2.10	3.45	63.51	22.36
Pristipomatidae													
<i>Anisotremus davidsonii</i>	sargo	375.79	49.15	168.77	606.38	58.69	317.10	109.72	143.46	114.77	189.66	191.99	54.20
<i>Xenistius californiensis</i>	salema	9.43	5.08	30.56	44.68	66.12	38.60	50.81	61.48	24.49	110.34	96.00	389.57
Sciaenidae													
<i>Atractoscion nobilis</i>	white sea bass	2.36	0.85	1.99	7.80	4.46	5.34	6.63	1.21	2.80	11.03	9.58	10.84
<i>Cheilotrema saturnum</i>	black croaker	7.86	0.04	1.99	0.71	0.74	5.34	0.04	2.41	0.70	2.07	1.79	1.36
<i>Genyonemus lineatus</i>	white croaker	2.36	513.56	90.37	4.26	792.72	149.64	27.25	291.14	33.59	205.52	37.55	165.31
<i>Menticirrhus undulatus</i>	California corbina	0.79	0.04	7.97	9.22	0.04	14.85	1.47	9.04	0.70	0.21	0.07	1.36
<i>Roncador stearnsi</i>	spotfin croaker	14.15	0.04	3.32	21.28	1.49	9.50	1.47	11.45	2.80	9.66	-	5.42
<i>Seriphus politus</i>	queenfish	187.11	1076.27	3033.22	3121.99	8424.22	4678.15	3158.32	6300.78	1768.37	2734.48	1620.20	9957.99
<i>Umbrina roncador</i>	yellowfin croaker	75.47	1333.90	364.12	2347.52	26.00	982.78	50.07	200.12	146.96	52.41	117.69	138.89

(Table continued)

Appendix B2 (continued).

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
BONY FISHES (continued)													
Kyphosidae													
<i>Girella nigricans</i>	opaleye	14.15	0.85	1.33	-	2.97	1.19	0.74	7.23	7.00	-	1.03	2.71
<i>Hermosilla azuræ</i>	zebraperch	61.32	-	476.41	146.81	14.12	96.79	77.32	8.44	8.40	0.69	14.35	-
<i>Medialuna californiensis</i>	halfmoon	0.04	-	0.66	2.84	-	2.38	1.47	0.60	4.90	0.07	0.39	1.36
Embiotocidae													
<i>Amphistichus argenteus</i>	barred surfperch	0.04	-	-	0.04	-	1.19	0.04	7.84	-	0.07	-	-
<i>Amphistichus koelzi</i>	calico surfperch	-	-	-	-	-	-	-	-	-	-	-	-
<i>Brachyistius frenatus</i>	kelp surfperch	0.04	-	0.03	0.04	195.39	4.16	39.03	47.62	2.80	10.34	0.53	0.68
<i>Cymatogaster aggregata</i>	shiner surfperch	0.04	1.69	1.33	0.71	8.92	8.31	4.42	6.03	2.80	2.07	4.26	7.45
<i>Damalichthys vacca</i>	pile surfperch	1.57	-	3.99	3.55	3.71	8.91	3.68	2.41	0.28	2.76	0.03	0.41
<i>Embiotoca jacksoni</i>	black surfperch	0.79	0.04	0.66	4.96	0.74	5.94	8.84	7.23	0.70	6.21	2.83	3.39
<i>Embiotoca lateralis</i>	striped surfperch	-	-	-	-	-	0.03	-	-	-	-	-	-
Embiotocidae													
<i>Hyperprosopon anale</i>	spotfin surfperch	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hyperprosopon argenteum</i>	walleye surfperch	0.79	0.85	2.66	4.96	52.01	43.35	33.87	96.44	4.20	53.79	12.61	10.84
<i>Hyperprosopon ellipticum</i>	silver surfperch	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hypsurus caryi</i>	rainbow surfperch	-	-	-	-	-	-	-	0.06	-	0.01	-	0.07
<i>Micrometrus aurora</i>	reef surfperch	-	-	-	-	-	0.03	-	-	-	-	-	-
<i>Micrometrus minimus</i>	dwarf surfperch	-	-	-	0.04	0.74	-	-	0.01	-	0.02	-	-
<i>Phanerodon furcatus</i>	white surfperch	0.79	6.78	3.99	15.60	299.41	70.07	21.35	151.30	13.30	73.79	11.03	12.87
<i>Rachochilus toxotes</i>	rubberlip surfperch	-	-	-	0.04	0.74	0.59	0.04	0.06	0.70	0.69	0.03	0.27
Labridae													
<i>Halichoeres semicinctus</i>	rock wrasse	0.04	0.85	2.66	17.02	500.74	2.97	5.15	6.63	1.40	0.69	1.08	0.14
<i>Oxyjulis californica</i>	senorita	-	0.04	-	0.04	1.49	0.59	0.04	3.01	-	6.21	1.84	0.07
<i>Semicossyphus pulchur</i>	California sheephead	2.36	-	5.98	3.55	1.49	0.59	0.04	3.01	-	0.69	0.67	-
Serranidae													
<i>Morone saxatilis</i>	striped bass	-	-	-	-	-	-	-	-	-	-	-	-
<i>Paralabrax clathratus</i>	kelp bass	29.87	10.17	46.51	27.66	22.29	30.29	22.83	49.43	18.89	21.38	21.20	21.00
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	0.04	-	0.03	-	-	1.19	0.04	0.18	-	0.69	-	-
<i>Paralabrax nebulifer</i>	barred sand bass	68.40	9.32	97.67	41.13	34.18	35.04	13.25	27.12	34.99	20.69	13.30	33.20
<i>Sterolepis gigas</i>	giant sea bass	-	-	-	-	-	-	-	-	0.03	-	3.40	-
Branchiostegidae													
<i>Caulolatilus princeps</i>	ocean whitefish	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae													
<i>Chromis punctipinnis</i>	blacksmith	2.36	0.85	1.33	0.71	80.98	1.78	1.47	4.82	0.70	2.76	1.57	0.68
<i>Hypsopops rubicundus</i>	garibaldi	0.79	-	1.99	2.13	0.74	0.03	-	0.18	-	0.07	-	-
Sphyraeniidae													
<i>Sphyraena argenta</i>	barracuda	2.36	3.39	5.98	4.96	10.40	11.88	65.54	15.07	20.29	13.79	1.78	15.58
Bathymasteridae													
<i>Rathbunella hypoplecta</i>	smooth ronquil	-	-	-	-	-	0.03	-	-	-	-	-	-
Anarhichadidae													
<i>Anarhichthys ocellatus</i>	wolf-eel	-	-	-	-	-	-	-	-	-	-	-	-
Blenniidae													
<i>Hypsobleinnius gentilis</i>	bay blenny	-	-	-	-	-	-	-	0.06	-	-	-	-
<i>Hypsobleinnius gilberti</i>	rockpool blenny	-	-	0.03	0.04	0.04	0.03	0.04	0.36	0.14	0.69	0.84	0.68
<i>Hypsobleinnius jenkinsi</i>	mussel blenny	-	-	-	-	-	0.03	0.04	-	0.07	-	-	-
<i>Hypsobleinnius spp.</i>	unidentified blenny	3.14	4.24	0.66	0.04	0.04	0.03	0.04	0.06	-	0.07	-	-
<i>Paraclymus integripinnis</i>	reef finspot	-	-	-	-	-	-	0.04	-	-	-	-	-
Clinidae													
<i>Gibbonsia elegans</i>	spotted kelpfish	0.04	0.04	0.03	-	1.49	0.59	0.74	3.01	0.14	0.14	0.23	0.07
<i>Gibbonsia erythra</i>	scarlet kelpfish	-	-	-	0.04	-	-	-	-	-	-	-	-
<i>Gibbonsia metzi</i>	striped kelpfish	0.04	-	0.03	-	-	0.03	-	0.01	-	-	-	-
<i>Gibbonsia montereyensis</i>	crevice kelpfish	0.04	-	-	-	-	-	-	-	-	-	-	-
<i>Gibbonsia spp.</i>	unidentified kelpfish	0.04	0.04	-	0.04	-	-	-	-	-	-	-	-
<i>Heterostichus rostratus</i>	giant kelpfish	5.50	3.39	3.99	6.38	18.57	32.07	54.49	25.92	4.90	10.34	2.12	10.84
<i>Neoclinus blanchardi</i>	sarcastic fringehead	0.04	-	-	-	-	-	-	-	-	-	-	-
<i>Neoclinus uminotatus</i>	onespot fringehead	-	-	-	-	-	-	-	-	-	-	-	-
Stichaeidae													
<i>Anoplarchus purpurascens</i>	high cockscomb	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cebidichthys violaceus</i>	monkeyface-eel	-	-	-	-	-	-	-	-	-	-	-	-
<i>Stichaeopsis sp.</i>	masked prickleback	-	-	-	-	-	-	-	-	-	-	-	-

(Table continued)

Appendix B2 (continued).

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
BONY FISHES (continued)													
Pholidae													
<i>Apodichthys flavidus</i>	penpoint gunnel	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ulvicola sanctaerosae</i>	kelp gunnel	-	-	-	-	-	-	-	-	-	-	-	-
<i>Xerapes fucorum</i>	rockweed gunnel	-	-	-	-	-	-	-	-	-	-	-	-
Ammodytidae													
<i>Ammodytes hexapterus</i>	Pacific sandlance	-	-	-	-	-	-	-	-	-	-	-	-
Icosteidae													
<i>Icosteus aenigmaticus</i>	ragfish	-	-	-	-	-	-	-	-	-	-	-	-
Gobiidae													
<i>Acanthogobius flavimamus</i>	yellowfin goby	-	-	-	-	-	-	-	-	-	0.69	0.23	-
<i>Coryphopterus nicholsi</i>	blackeye goby	-	-	-	-	0.04	-	-	-	-	-	-	-
<i>Gillichthys mirabilis</i>	longjaw mudsucker	-	-	-	-	-	-	-	-	-	-	-	-
<i>Lepidogobius lepidus</i>	bay goby	-	-	-	-	-	-	-	-	-	-	-	-
Gobiidae unid.	unidentified goby	0.04	-	-	-	-	-	-	-	-	-	-	-
Trichiuridae													
<i>Trichiurus nitens</i>	Pacific cutlassfish	-	-	-	-	-	-	-	-	-	0.21	-	-
Scombridae													
<i>Sarda chiliensis</i>	Pacific bonito	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scomber japonicus</i>	Pacific mackerel	1.57	3.39	56.48	30.50	12.63	46.91	14.73	37.97	760.67	96.55	990.23	548.10
Stromateidae													
<i>Icichthys lockingtoni</i>	medusafish	-	-	-	-	-	-	-	-	-	-	-	-
<i>Peprilus simillimus</i>	Pacific butterfish	13.36	2.54	49.17	29.08	64.64	80.17	104.57	189.87	11.90	378.62	27.42	1092.14
Cynoglossidae													
<i>Symphurus atricauda</i>	California tonguefish	-	0.04	-	-	-	-	-	-	-	0.01	0.20	-
Paralichthyidae													
<i>Citharichthys sordidus</i>	Pacific sanddab	-	-	0.03	-	-	-	-	-	-	-	-	0.34
<i>Citharichthys stigmaeus</i>	speckled sanddab	-	0.04	0.03	-	5.94	1.78	0.04	3.01	0.03	11.03	0.57	0.34
<i>Citharichthys xanthostigma</i>	longfin sanddab	-	-	-	-	-	-	-	-	0.70	-	-	0.68
<i>Paralichthys californicus</i>	California halibut	6.29	4.24	30.56	14.18	13.37	15.44	5.89	59.67	2.80	212.41	18.21	31.84
<i>Xystreurus liolepis</i>	fantail sole	-	2.54	1.99	1.42	-	4.75	-	1.81	0.70	8.28	0.19	-
Pleuronectidae													
<i>Eopsetta exilis</i>	slender sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Errex zachirus</i>	rex sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hippoglossina stomata</i>	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hypsosetta guttulata</i>	diamond turbot	0.04	-	1.33	2.13	4.46	-	-	2.41	-	25.52	2.87	-
<i>Microstomus pacificus</i>	dover sole	-	0.04	-	-	-	-	-	-	-	-	-	-
<i>Platichthys stellatus</i>	starry flounder	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronectes bilineatus</i>	rock sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronectes vetulus</i>	english sole	-	-	-	-	-	0.03	-	-	-	-	-	-
Pleuronectidae unid.	unidentified turbot or sole	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronichthys coenosus</i>	C-O turbot	1.57	-	-	-	0.04	0.59	-	-	-	-	-	-
<i>Pleuronichthys decurrens</i>	curlfin turbot	-	-	-	0.71	-	0.03	-	-	-	-	-	-
<i>Pleuronichthys ritteri</i>	spotted turbot	2.36	1.69	4.65	0.71	5.20	12.47	1.47	22.30	0.28	51.03	6.47	27.78
<i>Pleuronichthys verticalis</i>	hornyhead turbot	0.04	-	-	0.71	0.74	0.03	-	-	-	0.69	0.09	-
<i>Psettichthys melanostictus</i>	sand sole	-	-	-	-	-	-	-	-	-	-	-	-
Balistidae													
<i>Balistes polylepis</i>	finescale triggerfish	3.14	-	-	-	6.69	-	-	-	-	8.97	21.43	8.13
Molidae													
<i>Mola mola</i>	common mola	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified fish	unidentified fish	-	-	-	-	-	-	-	-	-	-	-	-
Fish Biomass Total:		1057.43	3889.66	7012.29	6818.97	24849.59	7062.83	4382.00	11975.64	8247.54	8928.07	4363.65	22719.32

(Table continued)

Appendix B2 (continued).

Family and Scientific Name	Common Name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Sharks, Rays, and Eels (Chondrichthyes)													
Petromyzonidae													
<i>Lampetra tirdentata</i>	Pacific lamprey	-	-	-	1.42	-	-	-	1.81	-	-	-	-
Heterodontidae													
<i>Heterodontus francisci</i>	horn shark	2.36	2.54	1.33	0.71	12.63	-	-	1.21	-	43.45	2.33	10.84
Squalidae													
<i>Squalus acanthias</i>	spiny dogfish	-	0.85	-	-	24.52	4.16	-	29.54	-	325.52	86.15	743.90
Squatinae													
<i>Squatina californica</i>	Pacific angel shark	-	-	41.20	-	-	-	-	-	-	-	-	-
Alopiidae													
<i>Alopias vulpinus</i>	common thresher	-	-	-	-	-	-	-	-	-	-	-	-
Scyliorhinidae													
<i>Apristurus brumeus</i>	brown cat shark	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cephaloscyllium ventriosum</i>	swell shark	-	-	-	-	-	-	-	-	-	-	-	-
<i>Parmaturus xanthurus</i>	filetail cat shark	-	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae													
<i>Mustelus henlei</i>	brown smoothhound	-	9.32	4.65	-	-	-	0.74	8.44	0.70	5.52	-	-
<i>Mustelus californicus</i>	gray smoothhound	4.72	5.08	5.32	19.86	0.74	4.75	-	4.22	-	6.21	-	3.39
<i>Mustelus spp.</i>	smoothhound	-	-	-	-	-	-	-	0.12	0.10	-	-	-
<i>Triakis semifasciata</i>	leopard shark	-	-	4.65	0.71	-	-	-	3.01	-	0.69	0.06	0.01
Rajidae													
<i>Raja binoculata</i>	big skate	-	-	3.32	-	-	-	-	-	-	-	-	-
<i>Raja inornata</i>	California skate	-	-	-	-	5.94	-	-	-	-	-	-	-
Torpedinidae													
<i>Torpedo californica</i>	Pacific electric ray	191.04	507.63	272.43	51.06	316.49	154.39	39.76	185.65	326.80	837.24	843.20	521.68
Platyrrhinidae													
<i>Platyrrhinoidis triseriata</i>	thornback ray	6.29	11.02	28.57	21.99	10.40	18.41	38.29	29.54	8.40	153.79	9.67	25.07
Rhinobatidae													
<i>Rhinobatos productus</i>	shovelnose guitarfish	21.23	3.39	62.46	48.23	13.37	33.25	-	160.34	0.70	22.07	0.34	1.36
Myliobatidae													
<i>Myliobatis californica</i>	bat ray	-	4.24	319.60	41.84	7.43	27.91	-	24.11	4.20	35.86	19.96	49.46
Dasyatidae													
<i>Urolophus halleri</i>	round stingray	14.15	4.24	61.79	14.89	63.89	20.78	-	51.24	0.70	106.21	3.97	2.71
Gymnuridae													
<i>Gymnura marmorata</i>	California butterfly ray	3.14	2.54	20.60	63.12	17.09	1.78	1.47	63.89	4.20	24.14	109.11	-
Chimeridae													
<i>Hydrolagus collei</i>	spotted ratfish	-	-	-	-	-	-	-	-	-	0.69	-	-
Muraenidae													
<i>Gymnothorax mordax</i>	California moray	1.57	-	-	-	-	0.03	-	0.60	-	-	-	-
Ophichthidae													
<i>Ophichthus triserialis</i>	Pacific snake eel	-	3.39	-	-	-	-	-	-	-	-	-	-
<i>Ophichthus zophochir</i>	yellow snake eel	-	-	1.99	-	0.74	-	-	1.81	-	0.48	-	1.36
Sharks, Rays and Eels Biomass Totals:		244.50	554.24	827.91	263.83	473.25	265.47	80.27	565.52	345.80	1561.86	1074.79	1359.77

Appendix D

DCPP 316(b) Entrainment Study, Field and Laboratory Procedures.

PROCEDURE FOR BONGO NET PLANKTON SAMPLING

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1. PURPOSE

- 1.1 The purpose of this procedure is to define the steps required to collect plankton with a bongo net in front of the intake structure and in the nearshore vicinity of Diablo Canyon Power Plant.

2. RESPONSIBILITIES

- 2.1 The Entrainment and Survey Grid Sampling Field Supervisors are responsible for assuring that plankton samples are collected in accordance with written procedures.
- 2.2 Investigating biologists are responsible for sample collection in accordance with written procedures.

3. INSTRUCTIONS

3.1 Field Sampling Preparation

- 3.1.1 Ensure there are enough jars, labels, and preservative for the sample collection effort. Checkout the required number of field data sheets from the Data Coordinator.
- 3.1.2 Inspect the frame, nets and codends for any damage. If damaged, repairs must be made before sampling begins. Ensure the flowmeters have been calibrated and they are operational. Attach a flowmeter to the mouth of each net.
- 3.1.3 Ensure that the remaining equipment (Attachment 5.1) is in good operating condition. Make repairs if necessary.

3.2 Flowmeter Calibration

- 3.2.1 Disconnect the flowmeter from the net. Record the serial number of the flowmeter on the calibration data sheet. Connect the flowmeter to a rod. Measure and mark a distance of at least 20-30 feet on the dock.
- 3.2.2 Record the initial number of spins from the readout on the flowmeter totalizer. Lower the flowmeter into the water slowly so that the propeller does not spin. Walk along the dock towing the flowmeter at a speed of

between 1 to 1.5 feet per second for the marked distance checking to make sure that the propeller is spinning. When the flowmeter has been towed over the measured distance, carefully raise it out of the water. Record the end number of spins from the flowmeter totalizer.

3.2.3 Repeat this procedure at least 10 times for each flowmeter. Subtract the initial reading from the end reading and record the total number of spins per trial on the data sheet. The total spins for each of the ten trials are summed and divided by the number of trials. The resulting mean is the calculated calibration value.

3.2.4 Calibrate each flowmeter at least once every 3 months.

3.3 Entrainment Sample Collection

3.3.1 Determine the order of station sampling. The order is randomly chosen prior to each sampling period. The information is posted on the Random Order of Mooring Sampling Form (Attachment 5.2) posted on the boat.

3.3.2 Attach the winch line to the bongo net frame and ensure that a codend is attached to each net. The winch line is marked at known distances so that the sampling personnel know how much line is being deployed.

3.3.3 Secure the boat to both the stern and bow mooring lines at the predetermined station. The boat should be positioned so that the nets will enter the water about 20-30 feet in front of the intake structure's curtain wall.

3.3.4 Determine the water depth with the fathometer or other depth measuring device. Record the water depth on the field data sheet (Attachment 5.3). (The recording of the water depth began in May 1997.)

3.3.5 Record each flowmeter's serial number and number of spins from the unit's totalizer on the field data sheet. Make sure that the propeller does not spin while lowering the bongo frame and nets into the water.

3.3.6 Record the start time (Pacific Standard Time) on the field data sheet.

3.3.7 Lower the nets until the frame is at the water's surface and the nets are underwater. Use a boat hook to turn the frame over so that the nets start filtering water from the surface. When the proper amount of line is deployed, reverse the winch and raise the nets. When the frame reaches the surface, use the boat hook to turn the frame over and lower the nets. The nets are turned as close to the surface as possible. This procedure is repeated until the net has made a total of eight hauls.

3.3.8 If the nets become clogged with material during the hauls, they must be rinsed before all eight hauls are completed. Stabilize the flowmeters to prevent spinning. Rinse the material in the nets into the codends. Attach a closing device above the codend of each net to ensure the collected

material will not be lost during the subsequent hauls. Continue the net hauls until a total of eight are completed.

- 3.3.9 Pull the frame out of the water and record the flowmeter readings on the field data sheet.
- 3.3.10 Record the end time and total time of the collection on the field data sheet.
- 3.3.11 Beginning at the top of the net, rinse the sample down into the codend. Since the wash water is not filtered and may contain plankton, rinse the net from the outside ensuring that unfiltered water does not contaminate the sample. Inspect the net to ensure that it has been thoroughly rinsed.
- 3.3.12 Prepare sample labels containing the following information: serial number, station number, date, cycle number, start time, and sample number.
- 3.3.13 The samples collected at the first station of each three-hour cycle will be preserved with 70-80% ethanol. After the net is rinsed, detach the codend from one net and pour the sample into a funnel which has 335 μm mesh attached to the bottom. Rinse and inspect the codend before reattaching to the net. Repeat this step for the second codend. Rinse the sample from the funnel into the sample jar using a squirt bottle containing 70-80% ethanol. Larval fish preserved in ethanol can be used if future otolith studies are required. The remaining six samples per cycle are transferred from the codends into sample jars and preserved by adding enough buffered formaldehyde to end up with a concentration with about 5% formaldehyde. Sample preservation is completed soon after collection.
- 3.3.14 The following is an explanation of the coding for the entrainment field data sheet sequence numbers and jar labels.
 - a. Each serial number used on the data sheet for sample identification consists of a series of 5 letters followed by 4 numbers (EADCM####). The first two letters are "EA" which signifies ENTRAINMENT ABUNDANCE. The third and fourth letters are "DC" for DIABLO CANYON. The fifth letter ("M") signifies collection off the MOORED BOAT. Each sampling period is given a single four digit number beginning with 0001. For each subsequent sampling period this number will increase from the previous number by one (1). In most cases the sampling is for a consecutive 24-hour period.
 - b. The date recorded on the field data sheet is the actual date the cycle was collected. Each 24-hour sample collection period generally consists of samples collected on two consecutive calendar days. At the start of a new day (midnight), use a new field data sheet.
 - c. The station designation is three letters, followed by one number (IMA#). The "I" designates an INTAKE sample, the "M" designates a MOORED BOAT sample, and the third letter designates the

MOORING BUOY sampled, either an "A", "B", "C", or "D". The buoys are located in front of the intake structure and each is oriented in front of an individual circulating water pump; "A" buoy with pump 1-1, "B" with pump 1-2, "C" with pump 2-1 and "D" with pump 2-2. The last number of the station designation is the bongo net number, either "1" or "2".

- d. There are a total of 8 three-hour cycles during each 24-hour sampling period. The cycle time blocks are presented in Attachment 5.4. The first sampled time block of each 24-hour sampling period is Cycle 1.

- 3.3.15 Ensure that the sample jar contains an inner label and a jar-top label. A sample inner label is presented in Attachment 5.2.
- 3.3.16 Deliver the samples to the laboratory at the completion of the sampling effort.
- 3.3.17 After at least 2 days, the samples preserved in formalin are transferred to a solution of 70-80% ethanol.

3.4 Survey Grid Sample Collection

- 3.4.1 The survey grid sampling effort currently collects 256 sub-samples within 64 grid cells (Attachment 5.5) over approximately a 72-hour period. The order and station location of grid cell sampling is randomly chosen before each survey. Currently, two stations within each grid cell are sampled per survey. During this sampling, the net is only lowered and raised one time at each station.
- 3.4.2 Locate the station using latitude/longitude coordinates. Determine the water depth with the fathometer or other depth measuring device. Record the water depth on the field data sheet.
- 3.4.3 Ensure that the winch line is attached to the bongo net frame, and a weight is attached to the center of the frame. Also ensure that a codend is attached to each net.
- 3.4.4 Record each flowmeter's serial number on the field data sheet (Attachment 5.3). Record the initial number of spins from each of the flowmeter's on the field data sheet. Record the start time (Pacific Standard Time) on the field data sheet.
- 3.4.5 Using the measured marks on the winch cable, lower the nets and frame through the water column until the frame is approximately 10 feet from the bottom. When the appropriate depth is reached, the boat is motored forward and the cable is retrieved trying to maintain a 45 degree tow angle. When the frame reaches the surface, carefully return it to the side of the boat.
- 3.4.6 Record the end time (Pacific Standard Time) on the field data sheet.

- 3.4.7 Record the end number of spins from each of the flowmeter's on the field data sheet. Subtract the initial number of spins from the end number and record the total on the field data sheet. If the integrity of either or both flowmeter readings is questionable (e.g., seaweed wrapped around the propellers), discard both samples. Detach the codends. Rinse the nets and reattach the codends. Record the circumstance on the data sheet. Repeat the sample collection.
- 3.4.8 Beginning at the top of the net, rinse the collected material down into the codend. Since the wash water is not filtered and may contain plankton, rinse the net from the outside ensuring that unfiltered water does not contaminate the sample. Inspect the net to ensure that it has been thoroughly rinsed.
- 3.4.9 Detach the codend from net #1 and pour the sample into a funnel which has 335 μm mesh attached to the bottom. Rinse the sample from the funnel into a sample jar using a squirt bottle containing ethanol. Fill the sample jar with at least enough ethanol to cover the sample. Rinse and inspect the codend of net #1 before reattaching to the net. Rinse the contents of net #2 into a sample jar with filtered seawater. Fill the sample jar with enough buffered formaldehyde to cover the sample and to end up with about a 5% solution of formaldehyde. Rinse and inspect the codend of net #2 before reattaching to the net. Sample preservation will be completed soon after collection.
- 3.4.10 Ensure that the sample jar contains an inner label and a jar-top label. A sample inner label is presented in Attachment 5.2.
- 3.4.11 The following is an explanation of the coding for the study grid field data sheet sequence numbers and jar labels.
- a. Each serial number on the data sheet for sample identification consists of a series of 5 letters followed by 4 numbers (NSDCG####). The first two letters are "NS" designates a NEARSHORE SAMPLE. The third and fourth letters are "DC" for DIABLO CANYON. The fifth letter ("G") designates collection within the GRID CELLS. Each sampling period is assigned a four digit number beginning with 0001. For each subsequent sampling period this number increases by one (1). In most cases the sampling will be for a consecutive 72-hour period.
 - b. The station designation consists of a letter-number-letter-number combination. The first letter/number combination designates the grid cell sampled. The first letter designates columns A through H of the grid cell, and the first number designates rows 1 through 8 of the grid cell. The second letter designates the station within the grid cell, and is an "A" for the first station sampled and a "B" for the second station sampled. The second number designates the net number,

either "1" or "2." For example, B3A1 means that the sample was collected from grid column B, row 3, station A, net 1.

- c. The date of sampling will correspond to the actual date of each sampling effort. At the start of a new day (midnight), use a new field data sheet.
- d. The cycle number is used for the study grid samples to maintain consistency with the entrainment sampling database.

3.4.12 Deliver the samples to the laboratory at the completion of the sampling effort.

3.5 Sample Voiding in the Field

3.5.1 Samples should be voided if any of the following occurs: 1) possible flowmeter obstruction due to kelp or other debris on the propeller, 2) obviously malfunctioning or damaged flowmeters; 3) damaged (torn) nets found after a sample is collected; 4) gear failure which prevents completion of any tows/hauls; 5) an incident or situation which may prevent reliable data collection; 6) an incident or situation which may jeopardize the safety of sampling personnel.

3.5.2 If a hole or tear is found in the net mesh, mark the damaged area and either repair or replace the net. Discard both samples. Record the circumstance on the data sheet. Repeat the sample collection.

3.5.3 Starting with Entrainment Survey 65, the number of flowmeter spins from the paired bongo nets was checked in the field to confirm that the measured volumes were similar.

4. RECORDS

- 4.1 The Task Leader should review, initial, and code all data sheets.
- 4.2 Submit the data to the Data Coordinator for logging, computer entry, and storage.
- 4.3 Original data sheets are permanently stored.

5. ATTACHMENTS

- 5.1 Equipment List
- 5.2 Random Order of Mooring Sampling Form
- 5.3 Field Data Sheet
- 5.4 Cycle Time Blocks for Entrainment Sampling
- 5.5 Survey Grid

ATTACHMENT 5.1

TITLE: EQUIPMENT LIST

1. Bongo net frame, attached 335 mesh nets, codends, and calibrated flowmeters
2. Winch line
3. Winch for net deployment and retrieval
4. Stock 70-80% ethanol (denatured)
5. Stock buffered formaldehyde solution (approximately 37-40% solution from the manufacturer)
6. Squeeze bottle
7. Labeled jars for sample storage
8. Data sheets, pencils and labels
9. Wash-down pump
10. Canning funnel with attached mesh
11. Watch
12. Boat hook
13. Flashlight
14. Fathometer or other water depth measuring device
15. Metal or wooden rod for calibration
16. Two codend closing devices for entrainment sampling
17. GPS for nearshore sampling

ATTACHMENT 5.2

TITLE: Example of Random Order of Mooring Sampling Form

Random Order of Mooring Sampling

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<u>Cycle #</u>	<u>Order of Station Sampling</u>
1	D-C-B-A (D samples in alcohol)
2	A-C-B-D (A samples in alcohol)
3	A-D-C-B (A samples in alcohol)
4	C-D-A-B (C samples in alcohol)
5	A-D-B-C (A samples in alcohol)
6	B-C-D-A (B samples in alcohol)
7	B-D-A-C (B samples in alcohol)
8	C-B-A-D (C samples in alcohol)

LABELS SHOULD HAVE THE FOLLOWING INFORMATION

Serial # _____	Date _____
Station _____	Cycle # _____
Sample # _____	Start Time _____

(Example of entrainment sample label.)

EADCM0002	10/17/96
IMB2	Cycle # 5
Sample # 1	2135

ATTACHMENT 5.4

TITLE: CYCLE TIME BLOCKS FOR ENTRAINMENT SAMPLING

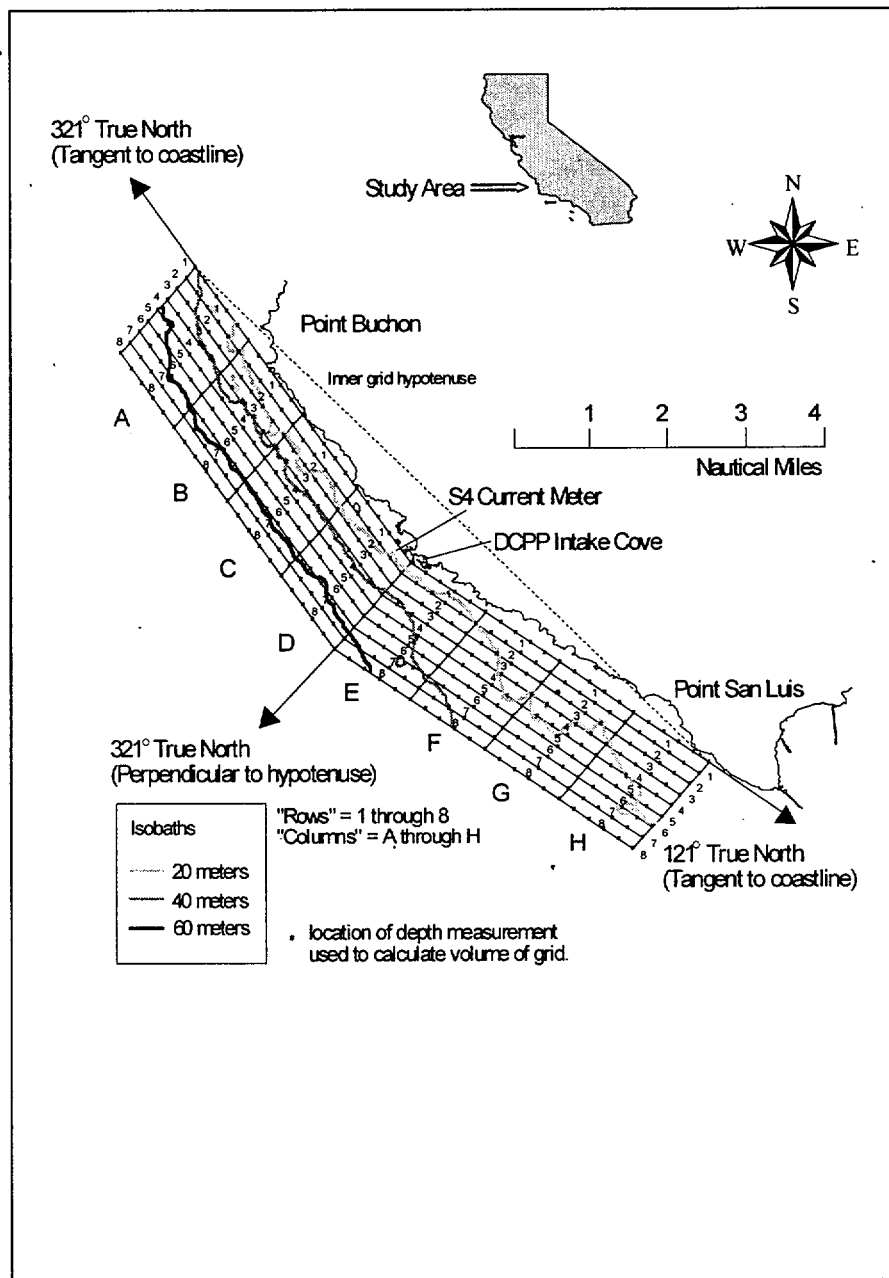
Time Blocks (Pacific Standard Time)

0000-0300
0301-0600
0601-0900
0901-1200
1201-1500
1501-1800
1801-2100
2101-2400

Cycle 1 is the first time block sampled during a 24-hour sampling period.

ATTACHMENT 5.5

TITLE: SURVEY GRID



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PROCEDURE FOR SORTING PLANKTON SAMPLES IN THE LABORATORY

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1. PURPOSE

- 1.1 The purpose of this procedure is to define the steps for sorting target organisms from plankton samples collected at Diablo Canyon Power Plant, and to describe the Quality Control Program (QC) used to monitor the sorting accuracy of individual sorters.

2. RESPONSIBILITIES

- 2.1 The Laboratory Supervisor is responsible for assuring that plankton sample sorting is in accordance with written procedures.
- 2.2 The Quality Control Supervisor is responsible for implementing the Quality Control Program which monitors sorting accuracy in accordance with written procedures.
- 2.3 Investigating biologists are responsible for sorting samples in accordance with written procedures.

3. INSTRUCTIONS

3.1 Sorting Procedures

3.1.1 Sample Processing

- a. Ensure that the proper equipment necessary for sample processing is available (Attachment 5.1).
- b. Transfer the samples to be sorted to the laboratory trailer.
- c. Samples that were originally fixed in formaldehyde after collection, must be transferred to 70-80% ethanol before laboratory processing. This is done outside to lessen the exposure to formaldehyde fumes.

1. A funnel with the appropriate mesh size attached to its bottom opening is placed into a jar or can. The mesh must not be larger than that used during sample collection. Place the jar and funnel in a tray so the sample can be retrieved if spillage occurs.
2. Pour the sample carefully into the canning funnel. The sample jar and jar lid are rinsed with water, directing the water and

- organisms into the funnel. Rinse the sample with water to flush the formaldehyde from the sample.
3. Rinse the sample into a labeled jar with 70-80% ethanol from a squeeze bottle. Make certain that the jar has both an inner label and a jar top label. Additional ethanol is added to the sample jar to cover the sample.
 4. The waste formaldehyde and rinse water is then discarded into the appropriate hazardous waste container.
- d. Consult the sorting schedule posted in the processing laboratory to determine sorting priorities.
 - e. Sign out the sample on the Laboratory Sample Tracking Sheet (Attachment 5.2) by writing your initials under the 'sorter' column. Transcribe information from the sample label into the Sorter's Log Book (Attachment 5.3) and into the sorter's notebook (each sorter has separate log sheets and a notebook for this purpose).
 - f. Take two clean canning funnels with attached mesh netting, one labeled 'sorted' and the other labeled 'unsorted'. The mesh size should be no larger than that used to collect the samples.
 - g. Place the 'unsorted' canning funnel on a clean jar. Next, place the jar and funnel in a dish so samples can be retrieved if spillage occurs. Pour a sample into the funnel. The funnel will contain the material to be sorted, while the ethanol will drain into the jar.
 - h. Place the 'unsorted' funnel on a second jar or can. Using fresh water in a squeeze bottle, rinse any remaining sample from the sample jar, the jar lid and inner sample label into the funnel containing the unsorted sample.
 - i. Pour the ethanol that was filtered through the canning funnel into the original sample jar. Keep the original ethanol-filled sample jar with the sample. Dispose of the alcohol waste-water from the second jar into the appropriate waste container.
 - j. Place the 'unsorted' funnel containing the sample and the empty 'sorted' funnel into individual glass bowls in a tray. Do not let the sample dehydrate during processing.
 - k. Transfer a small amount of the sample from the 'unsorted' funnel to the sorting tray. Add enough water to cover the sample. Distribute the sample in the sorting tray.
 - l. Place the sorting tray on the base of the dissecting microscope. Adjust the magnification so that the field of view is slightly larger than the width of an individual marked grid.
 - m. Arrange the light source to provide adequate illumination.

- n. Carefully scan the entire sorting tray using the grids for orientation. Remove the target organism with forceps and place them either into a shell vial containing 70-80% ethanol or into a small dish containing water.
- o. Log the number of organisms removed from the sample in the sorter notebook.
- p. Scan the tray a second time. If target organisms are found on the second pass, repeat a third time. Continue this process until a scan does not produce any additional target organisms.
- q. Once sorted, pour the sorted sample into the 'sorted' funnel and rinse with a small amount of water. Take a second aliquot from the 'unsorted' funnel as described above. Repeat the above steps until the entire sample has been sorted.
- r. When the sorting has been completed, the sorted organisms should be placed into a shell vial containing ethanol. Place cotton into the top end of the vial to keep the organisms inside. Place the vial into a labeled jar containing ethanol.
- s. Add enough 70-80% ethanol to at least cover the shell vials and label each jar lid with a colored dot label. (The jar lid color coding system is posted in the lab.) Prepare a waterproof inner label for the jar containing the shell vial. Both labels should contain the following information:
 - 1. Serial number
 - 2. Date the sample was collected
 - 3. Station, cycle and sample number
 - 4. Collection start time
 - 5. Jar number (if more than one jar)
 - 6. Sorter's initials
 - 7. Number of organisms in shell vial
- t. The total number of sorted organisms and the total time required to process the sample is recorded in the sorter's notebook.
- u. Put the sorted sample back into the original sample jar containing the ethanol. Rinse any remaining sample from the funnel into the jar using a squirt bottle containing ethanol. Make sure the inner waterproof label is in the sample jar. Thoroughly clean the funnels of all the remaining sample.
- v. For samples that do not contain any larval fish, an empty jar is labeled with the above information with zero (0) organisms

indicated, and placed in the appropriate storage location. No vial or jars are prepared for samples not containing any *Cancer* spp. megalops, zoea or sea urchin larvae.

w. If a sample must be stored before completion:

1. Put the sorted portion of the sample back into the original sample jar. Rinse any remaining material from the funnel into the jar using a squirt bottle containing ethanol. Make sure that the sample is adequately covered with ethanol.
2. Put the unsorted sample into a second jar. Rinse any sample from the 'unsorted' funnel into the jar using a squirt bottle containing ethanol. Using a dot label, label the jar lid with the sample identification information, sorter's initials, and the word "unsorted". Make an additional inner label with the sample identification information and marked 'unsorted'. Place the label inside the jar with the 'unsorted' sample. Make certain that the 'unsorted' sample is adequately covered with ethanol.
3. The sorted and unsorted portion of the sample should be stored in a flammable materials storage cabinet until sorting can continue.

3.1.2 Once the sample is completed, place an appropriately colored dot label on the jar top with the sorter's initials and date of sorting. Return the jar to the box from which it was originally removed.

- a. Transcribe the information recorded in the sorter's notebook to the Laboratory Sample Tracking Sheet (Attachment 5.2), and to the Sorter's Log (Attachment 5.3).

3.2 Sample Splitting Procedure

3.2.1 For large volume samples or samples that contain large numbers of *Cancer* spp. zoea or sea urchins, the following splitting technique should be used.

3.2.2 Drain the alcohol from the sample to be split. Wash the sample with water into a plankton splitter. With water, increase the volume of the mixture to the level indicated on the plankton splitter. Rotate the splitter wheel quickly, depositing the mixture into two individual receptacles labeled "A" and "B". Wash the sample from "B" into a separate jar. Wash sample from "A" back into the plankton splitter. Repeat the process, splitting the sample from "A" into four aliquots. Wash the sample from "B" into the plankton splitter and repeat the process, splitting "B" into four aliquots.

3.2.3 Randomly select one aliquot from both "A" and "B". Split each aliquot an additional time, so that there are two aliquots from both "A" and "B". Randomly select one aliquot from "A" and "B" and combine them into a single jar. This is the material to be sorted.

- 3.2.4 After a sample is split, all remaining aliquots that will not be sorted will be recombined into the original sample jar. The sample jar will be labeled as an incomplete sample containing seven eighths of the original sample. The sample to be sorted will be labeled as an incomplete sample containing one eighth of the original sample.
- 3.2.5 It is possible that the sample might not be split for one group of organisms and split for another.

3.3 Sorting Quality Control Program

3.3.1 QC Sorting Criteria

- a. The first ten samples that are sorted by an individual are completely resorted by a designated QC sorter. A sorter is allowed to miss one target organism when the original sorted count is 1-19. For original counts above 20 a sorter must maintain a sorting accuracy of 90%.
- b. After the sorter has passed 10 consecutive sorts, the program is switched to a '1 sample in 10' QC program for that sorter. After the sorter has completed another 10 samples, one sample is randomly selected by the designated QC sorter for a QC resort.
- c. If the sorter maintains the 90% accuracy sorting rate for this sample, then the sorter continues in the '1 sample in 10' QC mode.
- d. If a sample does not meet the 90% accuracy rate their subsequent samples will be resorted until 10 consecutive samples meet the criteria.

3.3.2 QC Resorting

- a. Sorting procedures used during the QC resort are the same as the sorting procedures described in Section 3.1.
- b. All fish and selected invertebrate larvae that were missed by the sorter are removed during the QC resort.
- c. For the QC process, a larval fish is defined as having a head plus at least 50% of the body. Any parts without a head and/or less than 50% of the body will be considered a fragments and will not be counted against the original sorter as a missed fish. However, it is important for each sorter to remove all fish and fragments from each sample that is sorted and correctly record them as # fish / # fragments in the sorter's notebook and on the tracking sheet.
- d. Any vials of fish larvae or selected invertebrate larvae generated from the resort are labeled with an orange dot label, and labeled as described in the sorting procedures with the addition of "QC" added to the label.

- e. An orange dot label should also be placed on the top of the jar of the sample that was resorted and labeled with the QCer's initials, survey number, sample number, and date the resort was completed.
- f. The vials are stored in the appropriate location.

3.4 Waste Disposal

- 3.4.1 No ethanol or formaldehyde or water contaminated with either ethanol or formaldehyde should be disposed of into the sewage system. Dispose of any water contaminated with these chemicals in the designated waste water container.

4. RECORDS

- 4.1 All data sheets are later reviewed, initialed, and coded by the Task Leader or his designate, and submitted to the Data Coordinator for logging, computer entry, and storage.
- 4.2 Original data sheets are permanently stored.

5. ATTACHMENTS

- 5.1 Equipment List
- 5.2 Laboratory Sample Tracking Sheet
- 5.3 Sorter's Log Book Sheet

ATTACHMENT 5.1

TITLE: EQUIPMENT LIST

1. Tray or dish
2. Bowls
3. Sample jars
4. Two canning funnels with attached plankton mesh netting, labeled with mesh size, and labeled 'sorted' and 'unsorted'
5. Squeeze bottle containing 70-80 percent ethanol (denatured)
6. Squeeze bottle containing fresh water
7. Sorting tray or petri dish marked with a sorting grid
8. Dissecting microscope with light source
9. Dissecting microscope with camera attachment connected to computer equipped with Optimas 6.2
10. Glass shell vials and cotton
11. Jar/vials with lids
12. Forceps
13. Waterproof labels
14. Dot labels
15. Sorter's notebook
16. Plankton splitter
17. Micrometer

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PROCEDURES FOR THE IDENTIFICATION OF LARVAL FISHES, *CANCER* SPP. AND SEA URCHINS

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1. PURPOSE

- 1.1 The purpose of these procedures is to define the steps for identifying planktonic organisms, and to describe the Quality Control (QC) Program used to monitor the accuracy of each individual's identification performance.

2. RESPONSIBILITIES

- 2.1 The Lead Taxonomist is responsible for assuring that plankton identifications are performed in accordance with written procedures and for implementing the Quality Control Program.
- 2.2 Investigating biologists are responsible for plankton identifications and for monitoring accuracy in accordance with written procedures.

3. INSTRUCTIONS

- 3.1 Identification procedures for larval fishes, *Cancer* spp. crab and metamorphosing or recently metamorphosed sea urchin.
- 3.1.1 Ensure that the proper equipment necessary for the identification of target organisms is available (Attachment 5.1).
- 3.1.2 The fish, crab and sea urchins from each sample are kept in separate containers and processed following this procedure in essentially the same manner.
- 3.1.3 Sign out the sample to be identified by placing your initials in the "ID'er" column on the Laboratory Sample Tracking Sheet (Attachment 5.2).
- 3.1.4 The container of target organisms to be identified is carefully emptied into a dish. The dish is placed on the microscope stage and the lighting adjusted to provide adequate illumination.
- 3.1.5 Each target organism is identified to the lowest taxonomic classification possible. The total number of each taxon is recorded on the Entrainment Abundance/Nearshore Plankton Tow Lab Data Sheet (Attachment 5.3).

- 3.1.6 All individuals of each identified taxon of larvae from a sample should be put into a shell vial containing 70-80% ethanol. Each vial should contain a label with the taxon name and sample number. Cotton should be pushed into the upper end of the vial to keep the label and organisms enclosed.
- 3.1.7 Mutilated larvae (partial organisms that are missing body parts and are unable to be identified) are placed in a separate labeled vial. Whole larvae that are unidentified, are placed in a separate labeled vial.
- 3.1.8 All vials containing target organisms from an individual sample should be put into a labeled jar containing enough 70-80% ethanol to cover the vials. The jar should contain both an inside label and a label attached to the outside of the lid denoting the sample number, date and time collected, and identifier's initials. Tighten the jar lid to prevent evaporation of the preservative. Samples with many different fish taxa may require more than one labeled jar.
- 3.1.9 On the Laboratory Sample Tracking Sheet, record the identifier's initials and date sample was logged in. The identifier's log will contain the total number of larvae identified and the date identified. If more than one day was needed to complete the identification, record the date the sample identification was completed.
- 3.1.10 Place the jar into the appropriate box containing identified samples.
- 3.1.11 Dispose of any liquids containing ethanol into the appropriate waste container.

3.2 Identification Quality Control (QC) Program

3.2.1 Fishes

- a. The first ten samples of larval fishes that are identified by an individual identifying biologist will be completely re-identified by a designated identification QC biologist. A total of at least 50 individuals from at least 5 taxa (50/5 criteria) must be present in these first ten samples. If the first 10 consecutive samples do not pass the 50/5 criteria, additional samples must be re-identified until this criteria is met.
- b. The identifying biologist must maintain a 95% identification accuracy level in these first 10 samples. For all samples, if a sample contains between 1-19 larvae, one larvae can be mis-identified and the sample will not fail the QC check.
- c. If the identifying biologist identifies a larval fish to a certain family or genus and subsequently the identification QC biologist is able to refine the identification to a lower taxonomic level, this will not be considered a mis-identification pertaining to the 95% identification accuracy level. A mis-identification will be one in which the identifying biologist identifies the fish as belonging to a certain

family, genus or species, and then the identification QC biologist determines that the initial identification was incorrect and changes the identification to a different family, genus or species or changes it to a higher taxonomic group.

- d. After the identifying biologist has passed 10 consecutive samples, the program is switched to a "1 sample in 10" QC program. After the identifying biologist has completed another 10 samples, one sample is randomly selected by the designated identification QC biologist for a QC review.
- e. If this sample maintains the 95% accuracy level as determined by the identification QC biologist, then the identifying biologist continues in the "1 sample in 10" QC mode. If a sample does not meet the 95% accuracy level, their subsequent samples will be re-identified until 10 consecutive samples meet this level of accuracy.
- f. Any mis-identified fish found by the identification QC biologist, will be placed into the appropriate labeled vial for that sample. This information will be recorded on the Fish Identification Data Sheet.
- g. Approximately five (5) percent of the identified larval fish samples will be randomly chosen and sent to offsite experts for identification verification.

3.2.2 *Cancer* spp.

- a. The first ten samples identified by an individual identifying biologist will be completely re-identified by a designated identification QC biologist. These first ten samples must have a total of at least 50 individual *Cancer* spp. larvae. If the first 10 consecutive samples do not have at least 50 *Cancer* spp. larvae or sea urchins, then additional consecutive identified samples from the same identifying biologist must be re-identified until this number is reached.
- b. The identifying biologist must maintain a 95% accuracy level in these first 10 samples. For all samples, if a sample contains between 1-19 *Cancer* larvae, one larvae can be mis-identified and the sample will not fail the QC check.
- c. After the identifying biologist has passed 10 consecutive samples, containing at least 50 organisms, the program is switched to a "1 sample in 10" QC program. After the identifying biologist has completed another 10 samples, one sample is randomly selected by the designated identification QC biologist for a QC review.
- d. A mis-identification of a *Cancer* spp. larvae will occur when a crab other than a *Cancer* spp. is labeled as *Cancer* spp., or a *Cancer* spp. larvae being mis-identified to the wrong stage of development or wrong species.

- e. If this sample maintains the 95 % accuracy level as determined by the identification QC biologist, then the identifying biologist continues in the "1 sample in 10" QC mode.
- f. If an identifier's sample does not meet the 95 % accuracy level, their subsequent samples will be re-identified until 10 consecutive samples meet this level.
- g. Any mis-identified *Cancer* spp. found by the identification QC biologist, will be placed into the appropriate labeled vial for that sample and recorded on the appropriate laboratory identification data sheet.
- h. Approximately five (5) percent of the identified larval *Cancer* spp. samples will be randomly chosen and sent to offsite experts for identification verification.

3.2.3 Sea urchins

- a. Currently QC identifications of the urchins is completed by an offsite larval urchin expert.
- b. The first ten samples identified by an individual identifying biologist will be completely re-identified by a designated identification QC expert. These first ten samples must have a total of at least 50 individual sea urchins. If the first 10 consecutive samples do not have at least 50 sea urchins, then additional consecutive identified samples from the same identifying biologist must be re-identified until this number is reached.
- c. The identifying biologist must maintain a 95 % accuracy level in these first 10 samples. For all samples, if a sample contains between 1-19 urchin larvae, one larvae can be mis-identified and the sample will not fail the QC check.
- d. After the identifying biologist has passed 10 consecutive samples, containing at least 50 organisms, one (1) sample from each entrainment survey (8 samples/survey) and six (6) samples from each grid survey (currently a total of 64/grid survey) are sent for QC identification.
- e. The mis-identification of an urchin is generally one that is mis-identified at the species level.
- f. If this sample maintains the 95 % accuracy level as determined by the identification QC biologist, then the identifying biologist continues to send the same number of samples to the QC identification expert.
- g. If an identifier's sample does not meet the 95 % accuracy level, their subsequent samples will be re-identified until 10 consecutive samples meet this level.

- h. Any mis-identified urchins found by the identification QC biologist, will be placed into the appropriate labeled vial for that sample and recorded on the appropriate laboratory identification data sheet.

3.3 Larval Fish Measuring

3.3.1 Larval Fish Measuring Procedure

- a. Turn on the computer, camera, and light source at the measuring station.
- b. Consult posted notices near the measuring station to determine measuring priorities and retrieve the binder containing the appropriate data sheets.
- c. Locate the box containing the fish to be measured and place it in a easily accessible area close to the measuring station.
- d. Open the Optimas Image Analysis software by clicking with the mouse on the Optimas icon.
- e. Open the Larval Fish Measuring macro in Optimas, and follow the macro's directions.
- f. Select the jar of fish to be measured and consult the jar label. Compare data on the jar label with the inner label and the data sheet for this sample. Consult an identifier regarding discrepancies between labels.
- g. Enter the data queried for by the macro including the last five digits of the serial number, the measurer's initials, the data sheet sequence number and the species code.
- h. Open the jar and remove the vials for the target taxa to be measured as per the posted list. Place the vials in a rack designed to allow the vials to maintain an upright posture so as to reduce spillage.
- i. Select the first vial to be measured. Remove the cotton and the label. Compare the label with the data sheet for confirmation.
- j. Empty the vial into a shallow dish. Remove any fish that have adhered to the vial, cotton, the label, or any tools used in the transferring process and place the fish in the dish. Add alcohol to the dish if necessary to prevent desiccation.
- k. If the number of larval fish in the vial exceeds fifty or what can be reasonably measured on a single image capture, transfer some of the fish to another glass dish and immerse them in alcohol.
- l. Place the dish on the stage of the microscope. Arrange the fish so that all fish appear on the screen. Adjust the zoom, focus, and lighting for the best possible image. If this is the first group of larval fish being measured, or if the magnification has been changed, it is

necessary to re-calibrate. Place the micrometer on the stage of the microscope and re-calibrate by drawing a line from one of the micrometers millimeter marks to another, noting the distance between the two marks, and entering that value when queried. Replace the dish containing the larval fish to be measured.

- m. Measure larval fish by drawing a line from the pre-maxillary to the end of the notochord, being careful to follow the contours of the fish. If the fish is too damaged to find either the pre-maxillary or to estimate the path taken by the notochord, do not measure, and proceed to the next larval fish. If the line does not adequately approximate the larval fish's length it must be re-measured.
- n. Note the program's display of the measurement, check that it seems reasonable. If it does not seem reasonable, it may be necessary to re-calibrate and re-measure. If the problem persists, contact an identifier. Make note of any problems in measuring and post near the measuring station.
- o. The macro will store the measurement in at least two separate data files along with the necessary sample information.
- p. Repeat the above steps for all fish in the dish.
- q. When all larval fish in the dish have been measured, fill the vial that originally contained the fish with alcohol and transfer the measured fish to the vial.
- r. If the larval fish from this vial have been segregated into two or more groups, place another group into the dish, being careful to submerge them in alcohol, and measure as above. Do not measure more than fifty larval fish of any one taxon from each sample.
- s. *Cancer* spp. larvae and sea urchins are not measured.

4. RECORDS

- 4.1 All data sheets are later reviewed, initialed, and coded by the Task Leader or his designate, and submitted to the Data Coordinator for logging, computer entry, and storage.
- 4.2 Original data sheets are permanently stored.

5. ATTACHMENTS

- 5.1 Equipment List
- 5.2 Laboratory Sample Tracking Sheet
- 5.3 Entrainment Abundance/ Nearshore Plankton Tow Lab Data Sheet
- 5.4 Larval Fish Length Data Sheet (not needed for measurements completed with a computer-based measuring system.)

ATTACHMENT 5.1

TITLE: EQUIPMENT LIST

1. Dissecting microscope with light source and calibrated ocular micrometer
2. Sorting tray or petri dish
3. Squeeze bottle containing 70-80% ethanol (denatured)
4. Glass shell vials
5. Holder for shell vials
6. Jar containing target organisms to be identified
7. Cotton
8. Forceps
9. Waterproof labels
10. Dot labels
11. Data sheets
12. Identifier's log sheet
13. Taxonomic references

PROCEDURE FOR SAMPLING PLANKTON FROM THE DCPD INTAKE HEADER PIPE

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1. PURPOSE

- 1.1 The purpose of this procedure is to define the steps required to collect plankton samples from the Diablo Canyon Power Plant's intake header pipe system.

2. RESPONSIBILITIES

- 2.1 The Entrainment Field Supervisor is responsible for assuring that the header pipe sampling is completed in accordance with written procedures.
- 2.2 Investigating biologists are responsible for collecting header pipe samples in accordance with written procedures.

3. INSTRUCTIONS

3.1 Field Sampling Preparation

- 3.1.1 Ensure there are enough jars, labels, and preservative for the sample collection effort. Checkout the required number of the field data sheets (Attachment 5.1) from the Data Coordinator.
- 3.1.2 Inspect the nets and codends for any damage. If damaged, repairs must be made before sampling begins. Ensure the flowmeters have been calibrated and they are operational.
- 3.1.3 Take all required materials (Attachment 5.2) to the header pipe sampling location.

3.2 Field Sampling

- 3.2.1 Sample collection will correspond to the times of collection from the boat moored in front of the Intake Structure. The first time block of each 24-hour sampling period will be considered Cycle 1 for the sampling from the boat. There will be a total of 8 cycles during each 24-hour sampling period. If for example, it only takes two hours to collect the samples from the boat (from 0900-1100), then the header pipe samples will only be collected during that 2-hour period. During each cycle, the boat sampling crew will let the header pipe sampler know when they begin their first

sample and end their last sample. This will allow for sample time coordination.

- 3.2.2 Determine which circulating water pumps are contributing to the header pipe water supply both before and after each 24-hour field sampling effort. This information is used to determine the code number used as part of the station number (see 3.3.3 below and Attachment 5.3).
- 3.2.3 Adjust the valving inside the intake trailer so the appropriate volume of water is flowing through the pipe that directs water into the outside collection tank. Before sampling, let the water run into the tank for at least 2 minutes to flush out any accumulated material in the pipe.
- 3.2.4 Ensure the flowmeter is operating.
- 3.2.5 At the desired time, turn off the water flow into the tank and suspend a plankton net with attached codend in the collection tank.
- 3.2.6 Zero the totalizer on the flowmeter.
- 3.2.7 Start the flow of water and record the start time and totalizer value on the field data sheet.
- 3.2.8 Stop the water after 15 minutes of sampling and remove the net. Put a clean net into the tank and restart the flow of water. To lessen the impact of abrasion and to prevent predation, the net is removed after 15 minutes. All sample material collected during two 15-minute sub-samples is combined into a single sample jar.
- 3.2.9 Record the end time and the total number of gallons filtered for the total collection period onto the data sheet.
- 3.2.10 Prepare sample labels containing the following information: serial number; station number; date; cycle number; start time; and, sample number.
- 3.2.11 To rinse the net, begin at the top of the net and rinse the sample down into the codend. Since the wash water is not filtered and may contain plankton, rinse the net from the outside ensuring that unfiltered water does not contaminate the sample. Inspect the net to ensure that it is thoroughly rinsed.
- 3.2.12 Position a tray or tub under the codend before detaching it from the net. This will allow retrieval of any spilled sample. Detach the codend from the net and pour the sample into a canning funnel which has the appropriate size mesh attached to the bottom. Rinse the codend with filtered seawater and inspect to ensure that it is clean. Reattach the codend to the net.
- 3.2.13 Repeat the above steps for the collection of the second 15-minute sub-sample. Rinse all collected material into the codend with filtered seawater, and combine this material with that collected during the first 15 minutes.

- 3.2.14 Fill the jar with enough 5% buffered formalin to cover the sample. Sample preservation is completed soon after collection to avoid possible losses of target organisms by predation. After at least 2 days, these samples are transferred to a solution of 70-80% ethanol.
 - 3.2.15 Continue steps 3.2.3 - 3.2.12 for the required number of samples.
 - 3.2.16 If during the sample collection a hole or tear is found in the net mesh, mark the damaged area and either repair or replace the net. Continue sampling with the other net. Note the time on the data sheet when the damage was discovered. The net must be repaired before it can be reused.
- 3.3 Data Sheet Sequence Numbers and Jar Labeling
- 3.3.1 Each serial number will consist of a series of 5 letters followed by 4 numbers. (EADCH ####). The first two letters should be "EA" which will signify ENTRAINMENT ABUNDANCE. The third and fourth letters should be "DC" for DIABLO CANYON. The fifth letter will be a "H" for HEADER PIPE. Each 24-hour sampling period will be given a single four digit number beginning with 0001. This number will increase from the previous number by one (1) for each subsequent 24-hour sampling period.
 - 3.3.2 The date of sampling will correspond to the actual date each cycle was collected. Each 24-hour sample collection period will generally consist of samples collected on two consecutive calendar days.
 - 3.3.3 The station designation will be IH##. The "I" will refer to an INTAKE sample, and the "H" will refer to the HEADER PIPE location. The ## will be a two digit code number designating the source of the header pipe water. The code numbers are listed in Attachment 5.3.
4. RECORDS
- 4.1 All data sheets are later reviewed, initialed, and coded by the Task Leader or his designate, and submitted to the Data Coordinator for logging, computer entry, and storage.
 - 4.2 Original data sheets are permanently stored.
5. ATTACHMENTS
- 5.1 Equipment List
 - 5.2 Field Data Sheet
 - 5.3 Code Numbers for Source of Header Pipe Water

ATTACHMENT 5.1

TITLE: EQUIPMENT LIST

1. 2 - 335 μ m mesh plankton nets and codends
2. Stock buffered formalin solution
3. Squeeze bottles
4. Labeled sample jars
5. Data sheets and pencil
6. Portable VHF radio
7. Canning funnel with 335 μ m mesh for filtering seawater
8. Watch
9. Plastic tray/pan
10. Lights
11. Waterproof labels

1. ATTACHMENT 5.3

TITLE: CODE NUMBERS FOR SOURCE OF HEADER PIPE WATER

= Source of header pipe water; must be one of the following combinations:

<u>Water only from</u>	<u>Code #</u>
1-1	01
1-2	02
2-1	03
2-2	04
1-1 + 1-2	05
1-1 + 2-1	06
1-1 + 2-2	07
1-2 + 2-1	08
1-2 + 2-2	09
2-1 + 2-2	10
1-1 + 1-2 + 2-1	11
1-1 + 1-2 + 2-2	12
1-1 + 2-1 + 2-2	13
1-2 + 2-1 + 2-2	14
1-1 + 1-2 + 2-1 + 2-2	15

PROCEDURE FOR TOWED PLANKTON NET SAMPLING

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1. PURPOSE

- 1.1 The purpose of this procedure is to define the steps required to collect plankton with a towed net in the vicinity of Diablo Canyon Power Plant.

2. RESPONSIBILITIES

- 2.1 The Field Supervisor is responsible for assuring that plankton samples are collected in accordance with written procedures.
- 2.2 Investigating biologists are responsible for sample collection in accordance with written procedures.

3. INSTRUCTIONS

3.1 Field Sampling Preparation

- 3.1.1 Ensure there are enough jars, labels, and preservative for the sample collection effort. Checkout the required number of field data sheets from the Data Coordinator.
- 3.1.2 Inspect the net and codend for any damage. If damaged, repairs must be made before sampling begins. Ensure the flowmeters have been calibrated and they are operational. Attach a flowmeter to the mouth of each net.
- 3.1.3 Ensure that the remaining equipment (Attachment 5.1) is in good operating condition. Make repairs if necessary.

3.2 Flowmeter Calibration

- 3.2.1 Disconnect the flowmeter from the net. Record the serial number of the flowmeter on the calibration data sheet. Connect the flowmeter to a rod. Measure and mark a distance of at least 20-30 feet on the dock.
- 3.2.2 Record the initial number of spins from the readout on the flowmeter totalizer. Lower the flowmeter into the water slowly so that the propeller does not spin. Walk along the dock towing the flowmeter at a speed of between 1 to 1.5 feet per second for the marked distance checking to make sure that the propeller is spinning. When the flowmeter has been towed

over the measured distance, carefully raise it out of the water. Record the end number of spins from the flowmeter totalizer.

3.2.3 Repeat this procedure at least 10 times for each flowmeter. Subtract the initial reading from the end reading and record the total number of spins per trial on the data sheet. The total spins for each of the ten trials are summed and divided by the number of trials. The resulting mean is the calculated calibration value.

3.2.4 Calibrate each flowmeter at least once every 3 months.

3.3 Intake Cove Sample Collection

3.3.1 This sampling is undertaken at daybreak.

3.3.2 Attach towing bridle to the boat. Attach the tow line to the center of the plankton net bridle and the first tow line clip to the towing bridle. This clip is approximately 20 yards from the end that was just attached to the net.

3.3.3 Attach a codend to the net.

3.3.4 Record the flowmeter's serial number and number of spins from the unit's totalizer on the field data sheet. Make sure that the propeller does not spin before lowering the net into the water.

3.3.5 Position the boat near the east of the intake structure. With the boat moving forward at a slow rate lower the net into the water and deploy the line. This is recorded as the start time (Pacific Standard Time) on the field data sheet.

3.3.6 The transect line over which the net is towed proceeds across the front of about ½ of the intake structure and then out between the breakwaters to a position about even with the outer end of the west breakwater.

3.3.7 The boat should maintain a speed so that the net remains just below the surface and that the total tow time is approximately 3 minutes. If the sea conditions are rough (swell coming over the breakwater) the length of the tow can be shortened.

3.3.8 At the end of the transect, the boat is slowed, the net is pulled aboard and flowmeter's totalizer reading is recorded on the field data sheet. Also record the end time and total time of the collection (to the nearest minute) on the field data sheet.

3.3.9 Beginning at the top of the net, rinse the sample down into the codend. Since the wash water is not filtered and may contain plankton, rinse the net from the outside ensuring that unfiltered water does not contaminate the sample. Inspect the net to ensure that it has been thoroughly rinsed.

3.3.10 Prepare sample labels containing the following information: survey and sample number and the collection date.

- 3.3.11 The samples are preserved after all samples are collected. They are preserved by adding enough buffered formaldehyde to end up with a concentration of about 5% formaldehyde.
- 3.3.12 The following is an explanation of the coding for the entrainment field data sheet survey numbers.
 - a. Each serial number used on the data sheet for sample identification consists of a series of 5 letters followed by 4 numbers (NSLFB####). The first two letters are "NS" which signifies NEARSHORE. The third and fourth letters are "LF" for LARVAL FISHES. The fifth letter ("B") signifies collection near the BREAKWATER. Each sampling period is given a consecutive single four digit number. For each subsequent sampling period or area this number will increase from the previous number by one (1).
 - b. The individual samples are numbered starting at 1. Generally a total of three (3) samples are collected on each sampling day. After the number is the letter "S" which designates that these samples were collected mainly near the surface.
- 3.3.13 Ensure that the sample jar contains an inner label.
- 3.3.14 Deliver the samples to the laboratory at the completion of the sampling effort.
- 3.3.15 After at least 2 days, the samples preserved in formalin are transferred to a solution of 70-80% ethanol.
- 3.4 Nearshore Sample Collection
 - 3.4.1 This sampling is undertaken at a location approximately ½ mile from the DCPD breakwater. Currently these samples are being collected but not laboratory processed.
 - 3.4.2 Attach towing bridle to the boat. Attach the tow line to center of the plankton net bridle and the second tow line clip to the towing bridle. This clip is approximately 25 yards from the end that was attached to the net.
 - 3.4.3 Attach a codend to the net.
 - 3.4.4 Record the flowmeter's serial number and number of spins from the unit's totalizer on the field data sheet. Make sure that the propeller does not spin before lowering the net into the water.
 - 3.4.5 Stop the boat near the start of the transect. Lower the net into the water until the tow line is completely deployed and the net is about 25 yards below the surface. The time (to the nearest minute) is recorded on the field data sheet as the tow start time (Pacific Standard Time) when the boat begins to motor slowly forward. The net is towed at this speed for a period of two (2) minutes. At that time the boat speed is increased slightly which will cause the net to move closer to the surface. After this second two (2)

minute period the boat is again increased in speed so that the net is being towed just slightly below the surface for another two (2) minute period.

Total tow time is six (6) minutes.

- 3.4.6 The transect line over which the net is towed proceeds from the start location directly toward Point Buchon.
- 3.4.7 At the end of the transect, the boat is slowed, the net is pulled aboard and flowmeter's totalizer reading is recorded on the field data sheet.. The end time and total time of the collection (to the nearest minute) is recorded on the field data sheet.
- 3.4.8 Beginning at the top of the net, rinse the sample down into the codend. Since the wash water is not filtered and may contain plankton, rinse the net from the outside ensuring that unfiltered water does not contaminate the sample. Inspect the net to ensure that it has been thoroughly rinsed.
- 3.4.9 Prepare sample labels containing the following information: survey and sample number and the collection date.
- 3.4.10 The samples are preserved after all samples are collected. They are preserved by adding enough buffered formaldehyde to end up with a concentration of about 5% formaldehyde.
- 3.4.11 The following is an explanation of the coding for the entrainment field data sheet sequence numbers.
 - a. Each serial number used on the data sheet for sample identification consists of a series of 5 letters followed by 4 numbers (NSLFP####). The first two letters are "NS" which signifies NEARSHORE. The third and fourth letters are "LF" for LARVAL FISHES. The fifth letter ("P") signifies collection near the PELAGIC. Each sampling period is given a consecutive single four digit number. For each subsequent sampling period this number will increase from the previous number by one (1).
 - b. The individual samples are numbered starting at one (1). Generally a total of three (3) samples are collected on each sampling day. No letter follows the sample number.
- 3.4.12 Ensure that the sample jar contains an inner label.
- 3.4.13 Deliver the samples to the laboratory at the completion of the sampling effort.
- 3.4.14 After at least 2 days, the samples preserved in formalin are transferred to a solution of 70-80% ethanol.

4. RECORDS

- 4.1 The Task Leader should review, initial, and code all data sheets.
- 4.2 Submit the data to the Data Coordinator for logging, computer entry, and storage.

4.3 Original data sheets are permanently stored.

5. ATTACHMENTS

5.1 Equipment List

5.2 Field Data Sheet

ATTACHMENT 5.1

TITLE: EQUIPMENT LIST

1. Plankton net with attached 335 mesh nets, codends, and calibrated flowmeters
2. Tow line and bridle
3. Stock 70-80% ethanol (denatured)
4. Stock buffered formaldehyde solution (approximately 37-40% solution from the manufacturer)
5. Labeled jars for sample storage
6. Data sheets, pencils and labels
7. Wash-down pump
8. Watch
9. Metal or wooden rod for calibration
10. GPS for nearshore sampling

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Appendix E

DCPP 316(b) Study: Comparison of Entrainment
Larval Density in Paired Samples: One-vs. Two-nets.

Diablo Canyon Power Plant
316 (b) Study

**Comparison of Entrainment Larval
Density in Paired Samples: One-
vs. Two-Nets**

October 5, 1998

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DCPP 316(b) STUDY

COMPARISON OF ENTRAINMENT LARVAL DENSITY IN PAIRED SUB-SAMPLES: ONE- VS. TWO-NETS

Introduction

The purpose of this report is to provide the statistical basis for processing and analyzing one instead of both of the two-net entrainment samples for estimating larval fish densities at the Diablo Canyon Power Plant (DCPP). Weekly samples for the DCPP 316(b) entrainment studies are collected from a moored boat at four stations located directly in front of the DCPP intake structure. A survey consists of a 24-hour sampling period that is divided into eight 3-hour cycles, with each station being sampled once per cycle. At each station oblique tows are used to collect a sample volume of approximately 40-50 m³ in each of two 335 µm mesh nets suspended on a 0.71 m diameter bongo net frame. All 64 sub-samples are preserved following collection and later processed in the laboratory for larval fishes, *Cancer* spp. crabs and sea urchins. Further details of the intake entrainment sampling are presented in the Phase 1 - Entrainment Study Design I. Sampling Location (Tenera Inc., 1997a) and Phase 1 - Entrainment Study Design II. Selection of Target Organisms, Methods and Gear Testing (Tenera Inc., 1997b) reports previously submitted to the Entrainment Technical Workgroup (ETWG).

For the comparisons in this report, the 64 sub-samples (2 nets per station per cycle) collected during each of 16 surveys were processed in the laboratory separately. Entrainment densities for each survey were then estimated in two ways: 1) by using the data from one net per station per cycle (32 samples); and 2) by summing the sample volumes and taxa abundances from the two nets also resulting in 32 samples. This report compares the one- versus two-net estimates of entrainment density.

Methods

The entrainment data from 16 surveys collected from December 1996 through March 1997 were analyzed for the 10 most abundant taxa during the period. Analyses were also run on total fish density for each survey. These surveys were selected because all 64 paired-net sub-samples had been processed in the laboratory for larval fishes and data entry and verification had been completed. These pairs of sub-samples were combined into 32 samples for each of these surveys. For the comparisons using only a single net (i.e., one sample per station per cycle), data were generated by randomly selecting one of the two nets from each station during each sampling cycle. Some of the pairs of sub-samples were excluded from

the randomization process because the difference between the two sample volumes was greater than 20%. The random selection process for the single net samples was performed for 100 iterations to obtain estimates of the mean and 1,000 iterations to obtain estimates of the variance. More iterations are usually required to obtain accurate estimates of the variance (Efron and Tibshirani, 1993).

The data collected during each entrainment survey were analyzed using a stratified random design to calculate estimates of daily entrainment density. The design utilizes the fact that the variability within strata will likely be less than the variability over the entire survey, thereby giving more precise estimates. For the entrainment study, each 3-hour cycle within a day was treated as a block or stratum and the four stations were treated as random samples within the block. Mean larval density within a cycle was estimated as

$$\bar{x}_h = \frac{\sum_{i=1}^{n_h} x_{hi}}{n_h} ,$$

where $n_h = 4$, and the variance within each cycle was calculated by

$$\hat{S}_{x_{hi}}^2 = \frac{\sum_{i=1}^{n_h} (x_{hi} - \bar{x}_h)^2}{n_h - 1} .$$

Daily mean entrainment density for the survey was estimated by

$$\bar{x}_s = \sum_{h=1}^8 \bar{x}_h \frac{n_h}{N} ,$$

where $N = 32$ and the associated variance estimator for the survey was

$$\hat{Var}(\bar{X}_s | X_s) = \frac{1}{64} \sum_{h=1}^8 \frac{\hat{S}_{x_{hi}}^2}{n_h} .$$

Where i = the individual sample within a cycle h , n_h is the number of stations sampled within a cycle, and N is the total number of samples for the survey, s . The means for a day drawn from 100 iterations of the one-net samples were plotted against the daily mean for the two-net samples for each survey. If sampling is unbiased, the mean from a set of random samples drawn from a population of samples should

quickly converge on the population mean (Efron and Tibshirani, 1993). A total of 1,000 iterations was run to obtain estimates of the variance and standard errors for the one-net samples. The mean from these 1,000 iterations was used to obtain a final estimate of the variance and standard error for the one-net samples used for comparison with the two-net estimates. The estimates of the standard error for the two-net mean density were compared with the mean standard error of the estimates of the one-net standard error from 1,000 random iterations. The percentage difference between the two estimates was then calculated. This value represents the average increase in the confidence interval around the mean that could be expected using only one net per sample.

The individual estimates of entrainment for each survey using both one- and two-net samples were also combined into monthly entrainment estimates. Final entrainment estimates will be calculated over periods of time that represent peak larval abundances, oceanic seasons or specific sampling events such as a survey in the study grid for proportional entrainment. This process will involve combining several surveys and then calculating an entrainment estimate for all those surveys. Estimates over a single month that combined four surveys were calculated for this comparison study, since this time period may be used in combination with monthly study grid sampling to estimate proportional entrainment. Estimates of the combined monthly entrainment sample variance were computed using the formula

$$\hat{var}\langle \bar{X}_T | X_T \rangle = \sum_{i=1}^4 \left[D_i^2 \cdot \hat{var}\langle \bar{X}_i | X_i \rangle \right] ,$$

where D is the number of days within each sampling period, i .

Although this variance will underestimate the true variance because it does not account for day-to-day variation in entrainment, it is only being used in this report to calculate differences between the one-net and two-net estimates. The differences between the two estimates should not be affected by using this variance estimator.

The potential differences in taxonomic composition between the one- and two-net samples were also examined. The cumulative number of unique taxa for a survey was calculated from randomly selected net samples. Before calculating the cumulative numbers of taxa in the two sets of samples, the 32 samples within each survey were randomized. Rather than accumulating samples during the analysis one cycle at a time, this random selection helped eliminate any diurnal pattern in species accumulation.

Results & Discussion

All of the one-net mean densities were within the 95% confidence interval around the two-net mean density except in a few instances (Figure 1). For the ten taxa examined, the percent difference between the two estimates of the mean was usually 1% or less (Table 1). The largest difference (16%) occurred in *Cebidichthys violaceus* (monkeyface eel) for the January 6, 1997 survey. The distribution of the one-net sample means around the two-net sample mean indicates that the sampling generates an unbiased estimate of the population mean. Overall, the results show that, on average, estimates of the mean for one-net are very close to the estimates using two nets.

Comparisons of the estimates of the standard error for the two-net mean density were compared with the mean standard error of the estimates of the one-net standard error from 1,000 random iterations (Table 1). The percentage difference between the two estimates ranged from 0 to 168%, but for most surveys was 25% or less. Greater differences occurred when larval fish densities were low and there were a large number of samples with only a few fishes (Figure 2). When densities were higher the differences in standard error were generally less than 25%. Differences between the standard errors for the category of total fishes, that combines counts from all taxa, were all less than 20%.

The percentage differences for monthly estimates of the standard errors were generally less than 25% (Table 2). The largest differences occurred for months when the density of a taxon was extremely low in one or more surveys. The large differences for the northern lampfish, *Stenobranchius leucopsarus*, were an exception. This taxon is mesopelagic and its density is expected to be highly variable in entrainment samples. Individual survey differences between standard error estimates for this species were as high as 136%.

Cumulative species curves showed variable results among surveys (Figure 3). Despite this variability most surveys showed only small differences in total species for the one- and two-net results. The smallest differences generally occurred for December and January surveys when overall species richness for the surveys was lower. Ten more taxa occurred in the two-net versus the one-net samples in March surveys, a time when species richness was highest. The two cumulative species curves for each survey generally track one another becoming asymptotic at similar sample sizes. This would seem to indicate that both sets of samples were tracking changes in species composition, and the one-net samples tend to miss the rarer species more often than the two-net samples. When these less frequent species were more numerous, differences between the two methods decrease. This interpretation is supported by the estimates

of total density for the two sets of samples shown in Table 1. The differences between the one- and two-net sample estimated means and standard errors for total fish density were generally very small.

Conclusions

These results show that estimates of mean sample densities using one net results in an unbiased estimate of the true sample mean. The estimate of the mean using one net will on average be similar to the estimate using two nets. The results also show that using the volume of one net does decrease the accuracy of the entrainment estimates for key species. Of the 176 individual survey estimates examined in this report, approximately 5% resulted in increases to the confidence interval around the sample estimates of greater than 40%. A small number of large increases would be expected based on chance alone. The results also show that almost 80% of the estimates resulted in increases of 25% or less. Many of the surveys with large differences resulted from samples with low larval fish densities. The chances of large differences occurring between the two nets increases when densities for an individual taxon are low. The combined monthly estimates showed that when entrainment is estimated over longer time periods, the overall differences in the error from analyzing the larval density from one net are less. Finally, analysis of species accumulation curves show that the smaller sample volumes track the larger sample volumes and produce similar estimates of species richness. Although overall species richness is reduced with the smaller sample volume, this does not result in lower overall estimates of fish density because species not included in the smaller volume samples are likely to be rare and low in density.

Based on these results we propose to process and analyze one of the net sub-samples at each station. Using the current sampling protocol, the other sub-sample will be archived for future processing if required.

Literature Cited

- Efron B. and R.J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall. New York. 436 p.
- Tenera Inc. 1997a. Diablo Canyon Power Plant Phase 1 - Entrainment study design. I. Sampling location. Doc. No. E6-202.7. San Francisco, California.
- Tenera Inc. 1997b. Diablo Canyon Power Plant Phase 1 - Entrainment study design. II. Selection of target organisms, methods and gear testing. Doc. No. E7-203.7. San Francisco, California.

Table 1. Mean survey densities, confidence intervals and standard error estimates for one-net and two-net samples, and percentage difference between standard errors. These data are of a preliminary nature and are not intended for use in any other context except this draft report.

Taxa	Survey Date	Densities		Mean Abs. Diff.	Mean % Abs. Diff.	Upper 95% CLM-Both Nets	Lower 95% CLM-Both Nets	Std. Error Two Nets	Std. Error One Net	Std. Error Diff.	% Diff.
		Two Nets	One Net								
<i>Artedius lateralis</i>											
	12/09/96	0.00075	0.00076	0.0000063	1%	0.00184	-0.00034	0.00053	0.00065	0.0001167	22%
	12/16/96	0.00188	0.00192	0.0000441	2%	0.00443	-0.00068	0.00124	0.00141	0.0001719	14%
	12/23/96	0.00147	0.00149	0.0000197	1%	0.00328	-0.00033	0.00087	0.00113	0.0002589	30%
	12/30/96	0.00475	0.00472	0.0000246	1%	0.00784	0.00165	0.00150	0.00182	0.0003259	22%
	01/06/97	0.00610	0.00614	0.0000419	1%	0.00919	0.00301	0.00150	0.00209	0.0005882	39%
	01/13/97	0.00262	0.00253	0.0000918	4%	0.00472	0.00053	0.00102	0.00141	0.0003924	39%
	01/20/97	0.00231	0.00231	0.0000099	0%	0.00434	0.00027	0.00099	0.00135	0.0003599	37%
	01/27/97	0.00782	0.00782	0.0000024	0%	0.01457	0.00107	0.00327	0.00348	0.0002110	6%
	02/03/97	0.01040	0.01037	0.0000289	0%	0.01496	0.00583	0.00221	0.00266	0.0004483	20%
	02/10/97	0.00731	0.00720	0.0001030	1%	0.01079	0.00382	0.00169	0.00215	0.0004576	27%
	02/17/97	0.01922	0.01952	0.0003069	2%	0.02912	0.00931	0.00480	0.00522	0.0004209	9%
	02/24/97	0.00629	0.00640	0.0001068	2%	0.01039	0.00219	0.00199	0.00230	0.0003158	16%
	03/03/97	0.01970	0.01977	0.0000691	0%	0.03153	0.00787	0.00573	0.00612	0.0003891	7%
	03/10/97	0.04813	0.04827	0.0001403	0%	0.06028	0.03597	0.00589	0.00803	0.0021399	36%
	03/17/97	0.04309	0.04320	0.0001142	0%	0.06118	0.02499	0.00877	0.00987	0.0011060	13%
	03/24/97	0.03597	0.03572	0.0002425	1%	0.05437	0.01756	0.00892	0.00994	0.0010191	11%
<i>Cebidichthys violaceus</i>											
	12/09/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/16/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/23/96	0.00182	0.00181	0.0000151	1%	0.00327	0.00038	0.00070	0.00103	0.0003314	47%
	12/30/96	0.00929	0.00936	0.0000697	1%	0.01625	0.00232	0.00337	0.00398	0.0006082	18%
	01/06/97	0.00129	0.00121	0.0000738	6%	0.00290	-0.00032	0.00078	0.00093	0.0001490	19%
	01/13/97	0.00776	0.00782	0.0000666	1%	0.01634	-0.00083	0.00416	0.00437	0.0002069	5%
	01/20/97	0.01152	0.01169	0.0001694	1%	0.01975	0.00328	0.00399	0.00440	0.0004080	10%
	01/27/97	0.02046	0.02043	0.0000283	0%	0.03545	0.00547	0.00726	0.00745	0.0001842	3%
	02/03/97	0.06578	0.06584	0.0000637	0%	0.17238	-0.04082	0.05165	0.05174	0.0000846	0%
	02/10/97	0.05000	0.05099	0.0009870	2%	0.10629	-0.00629	0.02727	0.02850	0.0012245	4%
	02/17/97	0.14687	0.14877	0.0019060	1%	0.39147	-0.09774	0.11852	0.11804	-0.0004735	0%
	02/24/97	0.06226	0.06337	0.0011094	2%	0.09587	0.02865	0.01629	0.01667	0.0003831	2%
	03/03/97	0.02872	0.02893	0.0002072	1%	0.04612	0.01132	0.00843	0.00927	0.0008427	10%
	03/10/97	0.07750	0.07751	0.0000066	0%	0.11394	0.04106	0.01766	0.01811	0.0004566	3%
	03/17/97	0.25430	0.25475	0.0004409	0%	0.36753	0.14108	0.05486	0.05596	0.0011023	2%
	03/24/97	0.04974	0.04983	0.0000857	0%	0.07556	0.02393	0.01251	0.01301	0.0004987	4%
<i>Cottidae unid.</i>											
	12/09/96	0.00076	0.00075	0.0000121	2%	0.00187	-0.00035	0.00054	0.00063	0.0000968	18%
	12/16/96	0.00147	0.00149	0.0000162	1%	0.00333	-0.00039	0.00090	0.00103	0.0001338	15%
	12/23/96	0.02203	0.02213	0.0001012	0%	0.02825	0.01580	0.00302	0.00423	0.0012162	40%
	12/30/96	0.00311	0.00312	0.0000076	0%	0.00542	0.00080	0.00112	0.00144	0.0003272	29%
	01/06/97	0.03054	0.03067	0.0001323	0%	0.03832	0.02276	0.00377	0.00483	0.0010555	28%
	01/13/97	0.01327	0.01333	0.0000582	0%	0.01847	0.00806	0.00252	0.00310	0.0005738	23%
	01/20/97	0.00072	0.00070	0.0000160	2%	0.00177	-0.00033	0.00051	0.00060	0.0000947	19%
	01/27/97	0.02040	0.02036	0.0000415	0%	0.02702	0.01378	0.00321	0.00398	0.0007727	24%
	02/03/97	0.00902	0.00894	0.0000877	1%	0.01758	0.00046	0.00415	0.00427	0.0001254	3%
	02/10/97	0.01329	0.01338	0.0000837	1%	0.02468	0.00191	0.00551	0.00573	0.0002122	4%
	02/17/97	0.00210	0.00205	0.0000527	3%	0.00388	0.00033	0.00086	0.00129	0.0004339	50%
	02/24/97	0.08704	0.08778	0.0007427	1%	0.11095	0.06313	0.01159	0.01339	0.0018013	16%
	03/03/97	0.02618	0.02625	0.0000706	0%	0.03647	0.01589	0.00499	0.00594	0.0009567	19%
	03/10/97	0.01915	0.01919	0.0000403	0%	0.02655	0.01175	0.00358	0.00467	0.0010846	30%
	03/17/97	0.13291	0.13318	0.0002707	0%	0.19014	0.07569	0.02773	0.02869	0.0009590	3%
	03/24/97	0.05955	0.05915	0.0004008	1%	0.07386	0.04525	0.00693	0.00845	0.0015217	22%

Table 1.(continued) Mean survey densities, confidence intervals and standard error estimates for one-net and two-net samples, and percentage difference between standard errors. These data are of a preliminary nature and are not intended for use in any other context except this draft report.

Taxa	Survey Date	Densities		Mean Abs. Diff.	Mean % Abs. Diff.	Upper 95% CLM-Both Nets	Lower 95% CLM-Both Nets	Std. Error Two Nets	Std. Error One Net	Std. Error Diff.	% Diff.
		Two Nets	One Net								
<i>Engraulis mordax</i>											
	12/09/96	0.02817	0.02833	0.0001604	1%	0.03872	0.01762	0.00511	0.00627	0.0011568	23%
	12/16/96	0.01821	0.01825	0.0000334	0%	0.02621	0.01022	0.00387	0.00406	0.0001817	5%
	12/23/96	0.03061	0.03055	0.0000553	0%	0.04369	0.01752	0.00634	0.00697	0.0006259	10%
	12/30/96	0.01283	0.01266	0.0001741	1%	0.01863	0.00704	0.00281	0.00356	0.0007533	27%
	01/06/97	0.00640	0.00641	0.0000173	0%	0.00975	0.00304	0.00162	0.00185	0.0002270	14%
	01/13/97	0.00132	0.00132	0.0000039	0%	0.00268	-0.00005	0.00066	0.00088	0.0002143	32%
	01/20/97	0.02041	0.02032	0.0000812	0%	0.03909	0.00172	0.00905	0.00912	0.0000677	1%
	01/27/97	0.04892	0.04894	0.0000182	0%	0.07189	0.02596	0.01113	0.01147	0.0003381	3%
	02/03/97	0.00237	0.00237	0.0000002	0%	0.00467	0.00007	0.00112	0.00126	0.0001396	13%
	02/10/97	0.00035	0.00033	0.0000155	4%	0.00107	-0.00037	0.00035	0.00033	-0.0000155	-4%
	02/17/97	0.00092	0.00093	0.0000114	1%	0.00232	-0.00047	0.00067	0.00074	0.0000621	9%
	02/24/97	0.00461	0.00476	0.0001458	3%	0.00736	0.00186	0.00133	0.00182	0.0004907	37%
	03/03/97	0.00292	0.00303	0.0001046	4%	0.00594	-0.00009	0.00146	0.00190	0.0004417	30%
	03/10/97	0.00106	0.00106	0.0000023	0%	0.00219	-0.00007	0.00055	0.00076	0.0002111	39%
	03/17/97	0.06744	0.06728	0.0001591	0%	0.09127	0.04361	0.01155	0.01237	0.0008272	7%
	03/24/97	0.02259	0.02260	0.0000107	0%	0.02894	0.01624	0.00308	0.00401	0.0009346	30%
<i>Genyonemus lineatus</i>											
	12/09/96	0.01520	0.01528	0.0000791	1%	0.02348	0.00691	0.00401	0.00439	0.0003747	9%
	12/16/96	0.06111	0.06148	0.0003666	1%	0.08159	0.04063	0.00992	0.01072	0.0007966	8%
	12/23/96	0.02086	0.02095	0.0000878	0%	0.02932	0.01239	0.00410	0.00468	0.0005744	14%
	12/30/96	0.02867	0.02852	0.0001475	1%	0.03736	0.01998	0.00421	0.00533	0.0011230	27%
	01/06/97	0.01508	0.01493	0.0001487	1%	0.02103	0.00912	0.00288	0.00360	0.0007177	25%
	01/13/97	0.00345	0.00346	0.0000181	1%	0.00545	0.00145	0.00097	0.00136	0.0003939	41%
	01/20/97	0.06255	0.06248	0.0000714	0%	0.07577	0.04933	0.00640	0.00735	0.0009424	15%
	01/27/97	0.12248	0.12246	0.0000189	0%	0.14681	0.09815	0.01179	0.01424	0.0024498	21%
	02/03/97	0.00813	0.00809	0.0000332	0%	0.01230	0.00395	0.00202	0.00234	0.0003175	16%
	02/10/97	0.00390	0.00409	0.0001886	5%	0.00724	0.00056	0.00162	0.00236	0.0007432	46%
	02/17/97	0.05187	0.05204	0.0001672	0%	0.06456	0.03919	0.00615	0.00725	0.0011013	18%
	02/24/97	0.08948	0.09079	0.0013103	1%	0.10908	0.06987	0.00950	0.01305	0.0035527	37%
	03/03/97	0.00138	0.00140	0.0000153	1%	0.00312	-0.00036	0.00084	0.00107	0.0002307	27%
	03/10/97	0.00741	0.00732	0.0000911	1%	0.01157	0.00325	0.00202	0.00261	0.0005878	29%
	03/17/97	0.34792	0.34767	0.0002530	0%	0.41009	0.28576	0.03012	0.03642	0.0062977	21%
	03/24/97	0.02008	0.02009	0.0000152	0%	0.02686	0.01330	0.00329	0.00442	0.0011328	34%
<i>Gibbonsia</i> spp.											
	12/09/96	0.06316	0.06349	0.0003226	1%	0.07782	0.04851	0.00710	0.00858	0.0014769	21%
	12/16/96	0.01759	0.01751	0.0000788	0%	0.02294	0.01224	0.00259	0.00314	0.0005482	21%
	12/23/96	0.05914	0.05908	0.0000636	0%	0.07739	0.04089	0.00884	0.01028	0.0014323	16%
	12/30/96	0.09233	0.09240	0.0000671	0%	0.11418	0.07048	0.01059	0.01197	0.0013829	13%
	01/06/97	0.06565	0.06556	0.0000929	0%	0.08868	0.04262	0.01116	0.01260	0.0014384	13%
	01/13/97	0.03327	0.03323	0.0000424	0%	0.04469	0.02186	0.00553	0.00698	0.0014530	26%
	01/20/97	0.06972	0.06961	0.0001083	0%	0.08641	0.05303	0.00809	0.00914	0.0010523	13%
	01/27/97	0.01669	0.01666	0.0000365	0%	0.02444	0.00895	0.00375	0.00478	0.0010254	27%
	02/03/97	0.10462	0.10454	0.0000783	0%	0.13017	0.07906	0.01238	0.01459	0.0022080	18%
	02/10/97	0.04855	0.04868	0.0001342	0%	0.06236	0.03474	0.00669	0.00770	0.0010112	15%
	02/17/97	0.02740	0.02765	0.0002551	1%	0.03774	0.01706	0.00501	0.00591	0.0008976	18%
	02/24/97	0.11853	0.11264	0.0058904	5%	0.15953	0.07752	0.01987	0.02021	0.0003444	2%
	03/03/97	0.02661	0.02667	0.0000674	0%	0.03546	0.01775	0.00429	0.00529	0.0009978	23%
	03/10/97	0.02674	0.02668	0.0000503	0%	0.03450	0.01897	0.00376	0.00549	0.0017324	46%
	03/17/97	0.02397	0.02397	0.0000010	0%	0.03197	0.01597	0.00388	0.00458	0.0007004	18%
	03/24/97	0.02587	0.02580	0.0000683	0%	0.03712	0.01461	0.00545	0.00631	0.0008625	16%

Table 1.(continued) Mean survey densities, confidence intervals and standard error estimates for one-net and two-net samples, and percentage difference between standard errors. These data are of a preliminary nature and are not intended for use in any other context except this draft report.

Taxa	Survey Date	Densities		Mean Abs. Diff.	Mean % Abs. Diff.	Upper 95% CLM-Both Nets	Lower 95% CLM-Both Nets	Std. Error Two Nets	Std. Error One Net	Std. Error Diff.	% Diff.
		Two Nets	One Net								
<i>Scorpaenichthys marmoratus</i>											
	12/09/96	0.01918	0.01902	0.0001557	1%	0.02617	0.01218	0.00339	0.00544	0.0020501	60%
	12/16/96	0.07482	0.07499	0.0001689	0%	0.11903	0.03061	0.02142	0.02182	0.0003954	2%
	12/23/96	0.02551	0.02551	0.0000051	0%	0.04515	0.00586	0.00952	0.00962	0.0001051	1%
	12/30/96	0.03759	0.03765	0.0000642	0%	0.05075	0.02442	0.00638	0.00675	0.0003740	6%
	01/06/97	0.07483	0.07494	0.0001112	0%	0.09670	0.05295	0.01060	0.01152	0.0009213	9%
	01/13/97	0.02393	0.02386	0.0000684	0%	0.04820	-0.00034	0.01176	0.01195	0.0001946	2%
	01/20/97	0.04961	0.04945	0.0001633	0%	0.08054	0.01869	0.01498	0.01530	0.0003210	2%
	01/27/97	0.02090	0.02088	0.0000252	0%	0.03235	0.00945	0.00555	0.00618	0.0006347	11%
	02/03/97	0.01744	0.01743	0.0000094	0%	0.02977	0.00510	0.00597	0.00635	0.0003718	6%
	02/10/97	0.02223	0.02146	0.0007764	3%	0.03831	0.00616	0.00779	0.00957	0.0017862	23%
	02/17/97	0.00891	0.00907	0.0001622	2%	0.01530	0.00252	0.00310	0.00327	0.0001727	6%
	02/24/97	0.00550	0.00552	0.0000198	0%	0.01066	0.00033	0.00250	0.00275	0.0002474	10%
	03/03/97	0.00480	0.00487	0.0000633	1%	0.01044	-0.00083	0.00273	0.00290	0.0001714	6%
	03/10/97	0.00486	0.00488	0.0000195	0%	0.00758	0.00214	0.00132	0.00180	0.0004808	36%
	03/17/97	0.01234	0.01233	0.0000076	0%	0.02388	0.00080	0.00559	0.00589	0.0003000	5%
	03/24/97	0.01595	0.01579	0.0001582	1%	0.02499	0.00690	0.00438	0.00542	0.0010428	24%
<i>Stenobranchius leucopsarus</i>											
	12/09/96	0.00083	0.00087	0.0000440	5%	0.00204	-0.00038	0.00059	0.00075	0.0001604	27%
	12/16/96	0.00036	0.00035	0.0000095	3%	0.00110	-0.00038	0.00036	0.00035	-0.0000095	-3%
	12/23/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/30/96	0.00043	0.00043	0.0000024	1%	0.00132	-0.00046	0.00043	0.00043	0.0000024	1%
	01/06/97	0.00243	0.00246	0.0000331	1%	0.00508	-0.00022	0.00128	0.00148	0.0001954	15%
	01/13/97	0.00181	0.00179	0.0000193	1%	0.00349	0.00013	0.00081	0.00109	0.0002767	34%
	01/20/97	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	01/27/97	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	02/03/97	0.00552	0.00548	0.0000396	1%	0.00846	0.00259	0.00142	0.00197	0.0005426	38%
	02/10/97	0.00448	0.00453	0.0000547	1%	0.00768	0.00128	0.00155	0.00182	0.0002656	17%
	02/17/97	0.04128	0.04099	0.0002898	1%	0.05015	0.03241	0.00430	0.00583	0.0015360	36%
	02/24/97	0.11656	0.11665	0.0000967	0%	0.14105	0.09207	0.01186	0.01334	0.0014775	12%
	03/03/97	0.00240	0.00241	0.0000031	0%	0.00513	-0.00033	0.00132	0.00146	0.0001351	10%
	03/10/97	0.03342	0.03337	0.0000558	0%	0.03917	0.02768	0.00278	0.00386	0.0010775	39%
	03/17/97	0.03708	0.03726	0.0001786	0%	0.04213	0.03203	0.00245	0.00577	0.0033181	136%
	03/24/97	0.03020	0.03000	0.0001932	1%	0.04162	0.01878	0.00553	0.00684	0.0013111	24%
<i>Sebastes spp. V</i>											
	12/09/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/16/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/23/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/30/96	0.00066	0.00066	0.0000027	0%	0.00162	-0.00030	0.00047	0.00056	0.0000961	21%
	01/06/97	0.01099	0.01089	0.0000950	1%	0.01502	0.00695	0.00195	0.00270	0.0007405	38%
	01/13/97	0.01041	0.01038	0.0000311	0%	0.01429	0.00652	0.00188	0.00316	0.0012736	68%
	01/20/97	0.01630	0.01649	0.0001885	1%	0.02500	0.00760	0.00422	0.00463	0.0004160	10%
	01/27/97	0.10377	0.10419	0.0004218	0%	0.12743	0.08011	0.01146	0.01575	0.0042902	37%
	02/03/97	0.09238	0.09236	0.0000208	0%	0.16881	0.01596	0.03703	0.03701	-0.0000214	0%
	02/10/97	0.17228	0.17265	0.0003675	0%	0.32143	0.02314	0.07226	0.07290	0.0006360	1%
	02/17/97	0.13345	0.13520	0.0017541	1%	0.27839	-0.01149	0.07023	0.07031	0.0000857	0%
	02/24/97	0.01893	0.01918	0.0002481	1%	0.03485	0.00301	0.00771	0.00788	0.0001696	2%
	03/03/97	0.06141	0.06152	0.0001043	0%	0.14828	-0.02545	0.04209	0.04219	0.0001036	0%
	03/10/97	0.02882	0.02876	0.0000546	0%	0.04685	0.01079	0.00874	0.00944	0.0007047	8%
	03/17/97	0.00632	0.00624	0.0000810	1%	0.01082	0.00182	0.00218	0.00243	0.0002505	11%
	03/24/97	0.01530	0.01542	0.0001282	1%	0.02603	0.00456	0.00520	0.00628	0.0010766	21%

Table 1.(continued) Mean survey densities, confidence intervals and standard error estimates for one-net and two-net samples, and percentage difference between standard errors. These data are of a preliminary nature and are not intended for use in any other context except this draft report.

Taxa	Survey Date	Densities		Mean Abs. Diff.	Mean % Abs. Diff.	Upper 95% CLM-Both Nets	Lower 95% CLM-Both Nets	Std. Error Two Nets	Std. Error One Net	Std. Error Diff.	% Diff.
		Two Nets	One Net								
<i>Sebastes</i> spp. V_De											
	12/09/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/16/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/23/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	12/30/96	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	01/06/97	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	01/13/97	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	01/20/97	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	01/27/97	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	02/03/97	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	02/10/97	0.00658	0.00653	0.0000429	1%	0.01619	-0.00304	0.00466	0.00479	0.0001285	3%
	02/17/97	0.00112	0.00072	0.0003949	5%	0.00287	-0.00063	0.00085	0.00062	-0.0002326	-27%
	02/24/97	0.00000	0.00000	0.0000000	0%	0.00000	0.00000	0.00000	0.00000	0.0000000	0%
	03/03/97	0.00037	0.00037	0.0000008	0%	0.00114	-0.00039	0.00037	0.00037	-0.0000008	0%
	03/10/97	0.01848	0.01853	0.0000504	0%	0.03504	0.00192	0.00802	0.00833	0.0003029	4%
	03/17/97	0.14682	0.14627	0.0005487	0%	0.26498	0.02866	0.05725	0.05881	0.0015541	3%
	03/24/97	0.26132	0.26160	0.0002779	0%	0.65725	-0.13460	0.19183	0.19201	0.0001736	0%
Total Fishes											
	12/09/96	0.15952	0.15995	0.0004311	0%	0.18884	0.13020	0.01421	0.01696	0.0027477	19%
	12/16/96	0.28887	0.28934	0.0004695	0%	0.34802	0.22971	0.02866	0.03010	0.0014357	5%
	12/23/96	0.21704	0.21699	0.0000455	0%	0.26053	0.17354	0.02107	0.02328	0.0022021	10%
	12/30/96	0.28314	0.28229	0.0008587	0%	0.32699	0.23930	0.02124	0.02406	0.0028196	13%
	01/06/97	0.25887	0.25918	0.0003112	0%	0.29800	0.21974	0.01896	0.02081	0.0018513	10%
	01/13/97	0.11620	0.11619	0.0000128	0%	0.15187	0.08053	0.01728	0.01892	0.0016369	9%
	01/20/97	0.38298	0.38272	0.0002642	0%	0.43806	0.32791	0.02669	0.02874	0.0020570	8%
	01/27/97	0.48761	0.48825	0.0006424	0%	0.57376	0.40145	0.04174	0.04426	0.0025208	6%
	02/03/97	0.40095	0.40046	0.0004914	0%	0.54829	0.25361	0.07139	0.07237	0.0009836	1%
	02/10/97	0.39615	0.39742	0.0012764	0%	0.59635	0.19595	0.09700	0.09914	0.0021388	2%
	02/17/97	0.57009	0.57132	0.0012270	0%	0.88645	0.25374	0.15328	0.15431	0.0010245	1%
	02/24/97	0.67120	0.66939	0.0018114	0%	0.77290	0.56950	0.04928	0.05142	0.0021458	4%
	03/03/97	0.29276	0.29320	0.0004419	0%	0.42060	0.16492	0.06194	0.06260	0.0006584	1%
	03/10/97	0.55440	0.55414	0.0002647	0%	0.65623	0.45257	0.04934	0.05120	0.0018653	4%
	03/17/97	1.77230	1.77306	0.0007578	0%	2.08957	1.45503	0.15372	0.16315	0.0094273	6%
	03/24/97	0.69370	0.69368	0.0000114	0%	1.08389	0.30350	0.18906	0.18980	0.0007398	0%

Table 2. Monthly estimates of variance and standard error for one-net and two-net sample density estimates, and percentage difference between standard errors. These data are of a preliminary nature and are not intended for use in any other context except this draft report.

Taxa	Month	Variance Two Nets	Variance One Net	Std. Error Two Nets	Std. Error One Net	% Difference
<i>Artedius lateralis</i>						
	Dec. '96	0.0002	0.0004	0.01537	0.0196	27%
	Jan. '97	0.0007	0.0010	0.02706	0.0322	19%
	Feb. '97	0.0017	0.0022	0.04125	0.0469	14%
	Mar. '97	0.0110	0.0149	0.10475	0.1222	17%
<i>Cebidichthys violaceus</i>						
	Dec. '96	0.0006	0.0009	0.02411	0.0294	22%
	Jan. '97	0.0042	0.0047	0.06514	0.0689	6%
	Feb. '97	0.8684	0.8838	0.93189	0.9401	1%
	Mar. '97	0.1739	0.1831	0.41701	0.4279	3%
Cottidae unid.						
	Dec. '96	0.0002	0.0004	0.01395	0.0190	36%
	Jan. '97	0.0006	0.0010	0.02458	0.0316	29%
	Feb. '97	0.0089	0.0115	0.09451	0.1071	13%
	Mar. '97	0.0419	0.0472	0.20462	0.2173	6%
<i>Engraulis mordax</i>						
	Dec. '96	0.0044	0.0059	0.06612	0.0769	16%
	Jan. '97	0.0102	0.0108	0.10102	0.1038	3%
	Feb. '97	0.0002	0.0003	0.01327	0.0168	27%
	Mar. '97	0.0071	0.0087	0.08436	0.0935	11%
<i>Genyonemus lineatus</i>						
	Dec. '96	0.0073	0.0092	0.08543	0.0962	13%
	Jan. '97	0.0088	0.0128	0.09373	0.1130	21%
	Feb. '97	0.0066	0.0115	0.08125	0.1073	32%
	Mar. '97	0.0452	0.0675	0.21264	0.2598	22%
<i>Gibbonsia</i> spp.						
	Dec. '96	0.0121	0.0163	0.10997	0.1275	16%
	Jan. '97	0.0136	0.0168	0.11669	0.1296	11%
	Feb. '97	0.0303	0.0354	0.17402	0.1881	8%
	Mar. '97	0.0038	0.0059	0.06155	0.0769	25%
<i>Scorpaenichthys marmoratus</i>						
	Dec. '96	0.0295	0.0319	0.17183	0.1786	4%
	Jan. '97	0.0248	0.0275	0.15734	0.1659	5%
	Feb. '97	0.0090	0.0101	0.09503	0.1004	6%
	Mar. '97	0.0029	0.0039	0.05406	0.0621	15%
<i>Stenobranchius leucopsarus</i>						
	Dec. '96	0.0000	0.0000	0.00567	0.0081	43%
	Jan. '97	0.0001	0.0002	0.01064	0.0132	24%
	Feb. '97	0.0080	0.0109	0.08953	0.1042	16%
	Mar. '97	0.0023	0.0048	0.04752	0.0696	46%

Table 2.(continued) Monthly estimates of variance and standard error for one-net & two-net sample density estimates, and percentage difference between standard errors. These data are of a preliminary nature and are not intended for use in any other context except this draft report.

Taxa	Month	Variance Two Nets	Variance One Net	Std. Error Two Nets	Std. Error One Net	% Difference
<i>Sebastes</i> spp. V						
	Dec. '96	0.0000	0.0000	0.00327	0.0045	36%
	Jan. '97	0.0119	0.0147	0.10885	0.1213	11%
	Feb. '97	0.5676	0.5788	0.75341	0.7608	1%
	Mar. '97	0.0921	0.0947	0.30348	0.3077	1%
<i>Sebastes</i> spp. V_De						
	Dec. '96	0.0000	0.0000	0.00000	0.0000	--
	Jan. '97	0.0000	0.0000	0.00000	0.0000	--
	Feb. '97	0.0011	0.0012	0.03314	0.0344	4%
	Mar. '97	1.9670	1.9821	1.40249	1.4079	0%
Total Fishes						
	Dec. '96	0.0942	0.1147	0.30698	0.3387	10%
	Jan. '97	0.1553	0.1776	0.39406	0.4215	7%
	Feb. '97	1.9840	2.0591	1.40854	1.4350	2%
	Mar. '97	3.2225	3.3991	1.79514	1.8437	3%

Note:

Sebastes spp. V is a pigment grouping of rockfish larvae with a short ventral series and no dorsal or pectoral pigment which consists of 16 possible species (*Sebastes aleutianus*, *S. alutus*, *S. brevispinus*, *S. crameri*, *S. diploproa*, *S. elongatus*, *S. macdonaldi*, *S. miniatus*, *S. nigrocinctus*, *S. proriger*, *S. rosaceus*, *S. ruberrimus*, *S. serriceps*, *S. umbrosus*, *S. wilsoni*, and *S. zacentrus*).

Sebastes spp. V_De is a pigment grouping of rockfish larvae with a long ventral series and an elongating dorsal series which consists of as many as 10 possible species (*S. atrovirens*, *S. auriculatus*, *S. carnatus*, *S. caurinus*, *S. chrysomelas*, *S. dalli*, *S. maliger*, *S. nebulosus*, *S. rastrelliger*, and *S. semicinctus*).

Appendix F

Estimating Total Entrainment Mortality Using the Delta Method.

The variance of \widehat{P}_M for the *ETM* calculations can be approximated by the Delta method as follows:

$$\begin{aligned}
 \widehat{Var}(\widehat{P}_M) &= \widehat{Var}\left(1 - \sum_{i=1}^{12} \hat{f}_i (1 - \widehat{PE}_i \widehat{P}_S)^{d_i}\right) \\
 &= \widehat{Var}\left(\sum_{i=1}^{12} \hat{f}_i (1 - \widehat{PE}_i \widehat{P}_S)^{d_i}\right) \\
 &= \sum_{i=1}^{12} \left[\widehat{Var}(\hat{f}_i) (1 - \widehat{PE}_i \widehat{P}_S)^{2d_i} \right. \\
 &\quad \left. + \sum_{i=1}^{12} \left[\widehat{Var}(\widehat{PE}_i) \left(\hat{f}_i d_i \widehat{P}_S (1 - \widehat{PE}_i \widehat{P}_S)^{d_i-1} \right)^2 \right] \right. \\
 &\quad \left. + \widehat{Var}(\widehat{P}_S) \left[\sum_{i=1}^{12} \left(\hat{f}_i d_i \widehat{PE}_i (1 - \widehat{PE}_i \widehat{P}_S)^{d_i-1} \right)^2 \right] \right. \\
 &\quad \left. + 2 \sum_{i \neq j} \left[\widehat{Cov}(\hat{f}_i, \hat{f}_j) (1 - \widehat{PE}_i \widehat{P}_S)^{d_i} (1 - \widehat{PE}_j \widehat{P}_S)^{d_j} \right] \right].
 \end{aligned}$$

In the formula above, define

$$\hat{f}_i = \frac{\widehat{E}_i}{\left(\widehat{E}_i + \sum_{j \neq i} \widehat{E}_j \right)}$$

where \widehat{E}_i = estimated total entrainment for the *i*th survey period.

Then, based on the Delta method,

$$\begin{aligned}
 \widehat{Var}(\hat{f}_i) &= \widehat{Var}\left(\frac{\widehat{E}_i}{\left(\widehat{E}_i + \sum_{j \neq i} \widehat{E}_j \right)} \right) \\
 \widehat{Var}(\hat{f}_i) &\doteq \hat{f}_i^2 (1 - \hat{f}_i)^2 \left[\frac{\widehat{Var}(\widehat{E}_i)}{\widehat{E}_i^2} + \frac{\widehat{Var}\left(\sum_{j \neq i} \widehat{E}_j\right)}{\left(\sum_{j \neq i} \widehat{E}_j\right)^2} \right].
 \end{aligned}$$

Now, for convenience, \hat{f}_i and \hat{f}_j will be expressed as

$$\hat{f}_i = \frac{\widehat{E}_i}{\widehat{E}_i + \widehat{E}_j + \sum_{\substack{g \neq i \\ g \neq j}} \widehat{E}_g}$$

and

$$\hat{f}_j = \frac{\widehat{E}_j}{\widehat{E}_j + \widehat{E}_i + \sum_{\substack{g \neq i \\ g \neq j}} \widehat{E}_g}$$

Then the covariance of \hat{f}_i and \hat{f}_j can be estimated from the Delta method as follows:

$$\widehat{Cov}(\hat{f}_i, \hat{f}_j) = \frac{\hat{f}_i \hat{f}_j \widehat{Var}\left(\sum_{\substack{g \neq i \\ g \neq j}} \widehat{E}_g\right)}{\left(\sum_{i=1}^{12} \widehat{E}_i\right)^2} - \frac{\hat{f}_j(1-\hat{f}_i) \widehat{Var}(\widehat{E}_i)}{\left(\sum_{i=1}^{12} \widehat{E}_i\right)^2} - \frac{\hat{f}_i(1-\hat{f}_j) \widehat{Var}(\widehat{E}_j)}{\left(\sum_{i=1}^{12} \widehat{E}_i\right)^2}$$

Appendix G

Number of Samples Collected and Laboratory
Processed.

Table G-1. Entrainment survey collection dates, number of subsamples collected and sorted, and raw numbers of larvae identified for fishes, *Cancer* spp. megalops and zoea, and sea urchins.

Survey Number	Collection Date	# of subsamples collected	Fish		<i>Cancer</i> spp. (megalops)		<i>Cancer</i> spp. (zoea) & sea urchins		
			# of subsamples analyzed	# of fish larvae	# of subsamples analyzed	# of megalops	# of subsamples analyzed	# of zoea	# of sea urchins
1 ^a	10/16/96	8	8	14*	0	-	-	-	-
2 ^a	10/17/96	34	34	83*	0	-	-	-	-
3 ^a	10/23/96	64 ^h	63	139	63	9	-	-	-
4 ^a	10/30/96	64	64	118	64	54	-	-	-
5 ^a	11/06/96	64	64	377	64	151	-	-	-
6 ^a	11/13/96	64	64	516	64	49	-	-	-
7 ^a	11/18/96	64	64	266	64	27	-	-	-
8 ^a	11/25/96	64	64	282	64	20	-	-	-
9 ^a	12/02/96	64	64	237	64	29	-	-	-
10 ^b	12/03/96	128	128	553	128	31	8	313	14
11 ^c	12/09/96	64	64	429	64	28	8	416	5
12	12/16/96	64	64	761	64	153	8	1,588	3
13	12/23/96	64	64	593	64	12	8	482	5
14	12/30/96	64	64	764	64	56	8	950	10
15	01/06/97	64 ^j	64	809	64	104	8	2,610	2
16	01/13/97	64	64	319	64	15	8	1,689	10
17	01/20/97	64	64	1,174	64	70	8	1,858	19
18	01/27/97	64	64	1,522	64	111	8	2,468	10
19	02/03/97	64	64	1,172	64	40	8	1,911	13
20	02/10/97	64	64	1,155	64	16	8	1,437	23
21	02/17/97	64 ⁱ	63	1,599	63	20	8	939	107
22	02/24/97	64 ⁱ	63	1,754	63	9	8	3,666	199
23	03/03/97	64	64	857	64	56	8	146	12
24	03/10/97	64	64	1,484	64	42	8	6,354	37
25	03/17/97	64	64	4,496	64	93	8	7,524	120
26	03/24/97	64	64	1,814	64	151	8	1,195	127
27	03/31/97	64 ^j	64	1,757	64	1,061	8	813	262
28	04/07/97	64	64	3,460	64	627	8	2,098	264
29	04/14/97	64	64	5,290	64	110	8	1,664	573
30	04/21/97	64	32	1,297	32	10	8	1,824	176
31	04/28/97	64	64	1,366	64	114	8	343	655
32	05/05/97	64	64	2,851	64	29	8	306	88
33	05/12/97	64	32	1,560	32	23	8	1,051	512
34	05/19/97	64 ^j	64	3,288	64	68	8	801	202
35	05/27/97	64	32	2,596	32	89	8	423	465
36	06/02/97	64	64	2,619	64	41	8	253	260
37	06/09/97	64	32	1,188	32	11	8	849	353
38	06/16/97	64 ^{k,j}	63	2,655	63	120	8	1,129	389
39	06/23/97	64	32	728	32	34	8	1,073	103
40	06/30/97	64	64	1,529	64	70	8	107	47
41	07/07/97	64	32	440	32	4	8	313	252
42	07/14/97	64	32	655	32	4	8	250	141
43	07/21/97	64	63	1,462	63	2	8	308	47
44	07/28/97	64	32	554	32	4	8	87	7
45	08/04/97	64 ^l	31	740	31	1	8	314	6
46	08/11/97	64	32	513	32	12	8	67	2
47	08/18/97	64	32	236	32	0	8	433	2
48	08/26/97	64	64	894	64	1	8	271	0
49	09/02/97	64	32	395	32	6	8	461	0
50	09/08/97	64	32	295	32	0	8	334	9
51	09/15/97	64	32	410	32	2	8	491	9
52	09/22/97	64	32	218	32	3	8	541	1
53	09/30/97	64	32	232	32	0	8	516	0
54	10/06/97	64	32	137	32	9	8	91	0
55	10/13/97	64	32	88	32	5	8	454	0
56	10/21/97	64	32	186	32	24	8	708	0
57	10/27/97	64	32	128	32	5	8	582	0
58	11/04/97	64	32	117	32	4	8	1,147	0

(continued)

Table G-1 (continued). Entrainment survey collection dates, number of subsamples collected and sorted, and raw numbers of larvae identified for fishes, *Cancer* spp. megalops and zoea, and sea urchins.

Survey Number	Collection Date	# of subsamples collected	Fish		<i>Cancer</i> spp. (megalops)		<i>Cancer</i> spp. (zoea) & sea urchins		
			# of subsamples analyzed	# of fish larvae	# of subsamples analyzed	# of megalops	# of subsamples analyzed	# of zoea	# of sea urchins
59	11/10/97	64	32	110	32	2	8	317	0
60	11/18/97	64	32	127	32	2	8	1,496	0
61	11/24/97	64	32	88	32	4	8	406	0
62	12/02/97	64	32	97	32	0	8	1,071	0
63	12/11/97	64	32	80	32	0	8	1,528	0
64	12/16/97	64	32	58	32	1	8	2,058	3
65	12/22/97	64 ^j	32	79	32	0	7	179	0
66	12/30/97	64	32	202	32	4	8	2,056	0
67	01/05/98	64	32	1,180	32	1	8	1,947	2
68	01/15/98	64	32	121	32	0	8	197	0
69	01/23/98	64	32	159	32	0	8	1,722	2
70	01/28/98	48 ^d	24	109	24	0	6	865	0
71	02/02/98	0 ^c	NS	NS	NS	NS	NS	NS	NS
72	02/11/98	64	32	146	32	1	8	599	0
73	02/16/98	0 ^c	NS	NS	NS	NS	NS	NS	NS
74	02/27/98	64	32	85	32	0	8	527	0
75	03/04/98	64	32	348	32	0	8	4,088	3
76	03/09/98	64	32	264	32	1	8	1,545	5
77	03/19/98	64	32	483	32	0	8	1,347	16
78	03/27/98	64	32	1,070	32	0	8	2,523	107
79	04/01/98	64	32	822	32	5	8	1,134	75
80	04/07/98	64	32	373	32	5	8	192	12
81	04/16/98	64 ^k	32	1,255	32	7	8	795	12
82	04/24/98	0 ^f	NS	NS	NS	NS	NS	NS	NS
83	04/29/98	64 ⁱ	32	2,564	32	18	8	1,866	74
84	05/04/98	64	32	3,198	32	5	8	4,127	18
85	05/14/98	64	32	2,568	32	102	8	3,730	33
86	05/19/98	64	32	1,378	32	44	8	377	1
87	05/26/98	64	32	2,029	32	29	8	612	14
88	06/01/98	64	32	1,701	32	102	8	772	0
89	06/09/98	58 ^e	29	1,528	29	28	7	790	3
90	06/15/98	64	32	1,149	32	34	8	787	24
91	06/22/98	64 ⁱ	31	1,332	31	212	8	643	7
92	06/29/98	64	32	1,702	32	33	8	351	14
93	07/06/98	64	32	718	32	17	Zoea and sea urchin sorting and identification discontinued per agreement with ETWG		
94	07/13/98	64	32	436	32	82			
95	07/21/98	64	32	189	32	11			
96	07/27/98	64	31	349	31	10			
97	08/03/98	64	32	131	32	6			
98	08/10/98	64	32	277	32	19			
99	08/18/98	64	32	193	32	2			
100	08/26/98	64	30	287	30	6			
101	08/31/98	64	32	369	32	4			
102	09/08/98	64	32	132	32	2			
103	09/16/98	64	32	115	32	5			
104	09/21/98	64	32	140	32	7			
105	09/28/98	64	32	285	32	3			
106	10/06/98	64	32	130	32	11			
107	10/12/98	64 ^m	NS	NS	32	8			
108	10/20/98	64 ^m	NS	NS	32	43			
109	10/27/98	64 ^m	NS	NS	32	12			
110	11/03/98	64 ^m	NS	NS	31	1			
111	11/11/98	64	32	130	32	3			
112	11/17/98	64 ^m	NS	NS	32	22			
113	11/23/98	64 ^m	NS	NS	32	5			
114	12/01/98	0 ^c	NS	NS	NS	NS			
115	12/09/98	64	32	153	32	4			
116	12/16/98	64 ^m	NS	NS	27	0			

(continued)

Table G-1 (continued). Entrainment survey collection dates, number of subsamples collected and sorted, and raw numbers of larvae identified for fishes, *Cancer* spp. megalops and zoea, and sea urchins.

Survey Number	Collection Date	# of subsamples collected	Fish		<i>Cancer</i> spp. (megalops)		<i>Cancer</i> spp. (zoea) & sea urchins		
			# of subsamples analyzed	# of fish larvae	# of subsamples analyzed	# of megalops	# of subsamples analyzed	# of zoea	# of sea urchins
117	12/21/98	64 ^m	NS	NS	32	2	Zoea and sea urchin sorting and identification discontinued per agreement with ETWG		
118	12/28/98	64 ^m	NS	NS	32	1			
119	01/04/99	64 ^m	NS	NS	32	1			
120	01/12/99	64	32	321	32	3			
121	01/20/99	64 ^m	NS	NS	32	3			
122	01/25/99	64 ^m	NS	NS	32	1			
123	02/03/99	64	32	619	32	0			
124	02/11/99	64 ^m	NS	NS	32	5			
125	02/15/99	64 ^m	NS	NS	32	0			
126	02/26/99	64 ^m	NS	NS	32	0			
127	03/05/99	64 ^m	NS	NS	32	1			
128	03/10/99	64 ^m	NS	NS	32	2			
129	03/17/99	64	32	858	32	4			
130	03/24/99	40 ^{d, m}	NS	NS	20	7			
131	03/29/99	64 ^m	NS	NS	31	1			
132	04/07/99	64 ^m	NS	NS	32	8			
133	04/14/99	64	32	1,204	32	5			
134	04/20/99	64 ^m	NS	NS	32	10			
135	04/27/99	64 ^m	NS	NS	32	0			
136	05/05/99	64 ^m	NS	NS	32	8			
137	05/12/99	64 ^m	NS	NS	32	4			
138	05/21/99	64 ^m	NS	NS	32	11			
139	05/24/99	64 ^l	32	1,318	32	8			
140	06/01/99	56 ^{d, m}	NS	NS	28	20			
141	06/09/99	64 ^m	NS	NS	32	2			
142	06/07/99	0 ^l	NS	NS	NS	NS			
143	06/23/99	64	32	760	32	17			
144	06/29/99	64 ^m	NS	NS	32	1			
Total		8,804	4,693	98,690	5,524	4,887	636	96,295	5,966

* – Data from surveys 1 and 2 not used for final analysis of larval fish entrainment.

NS – indicates sample not sorted for one or more taxa according to ETWG agreement or canceled survey.

PLANKTON NET MESH CHANGES

^a – Surveys 1-9 samples collected with 505 μ m mesh nets.

^b – Survey 10: 64 samples collected with 505 μ m and 64 with 335 μ m mesh nets.

^c – Surveys 11-144 collected with 335 μ m mesh nets.

PARTIAL AND CANCELED SURVEYS

^d – Survey not completed due to a change in the sea and weather conditions during collection period.

^e – No samples collected due to rough sea conditions making sample collection unsafe all week.

^f – No samples collected due to high concentrations of phytoplankton that clogged the nets.

^g – Winch malfunction; only 2 subsamples collected during cycle 4 (1800-2100 hours).

^l – No samples collected due to high concentrations of salps that clogged the nets.

VOIDED SUBSAMPLES

^h – Subsample lost while transferring from formalin to ethanol: Survey 3, subsample 42.

ⁱ – Subsamples cannot be sorted due to improper preservation:

Survey 21, subsample 13; Survey 22, subsample 12; Survey 38, subsample 18; Survey 45, subsamples 37, 38; Survey 83, subsample 41; Survey 91, subsamples 15, 16, 21, 34; Survey 139, subsample 33.

^j – Subsamples spilled after sorting for larval fish and *Cancer* spp. megalops; unable to sort subsamples for *Cancer* spp. zoea or sea urchins:

Survey 15, subsample 12; Survey 27, subsample 38; Survey 34, subsample 37; Survey 38, subsamples 5, 39; Survey 65, subsample 31.

^k – Some fishes were lost during identification of Survey 81 subsample 30.

^m – Survey sorted for megalops only according to ETWG agreement.

Table G-2. Study Grid survey collection dates, number of subsamples collected, sorted and raw numbers of larvae identified for fishes, *Cancer* spp. megalops and zoea, and sea urchins.

Survey Number	Collection Date	# of subsamples collected	Fish		<i>Cancer</i> spp. (megalops)		<i>Cancer</i> spp. (zoea) & sea urchins		
			# of subsamples analyzed	# of fish larvae	# of subsamples analyzed	# of megalops	# of subsamples analyzed	# of zoea	# of sea urchins
Prelim.	06/25/97	22	NS	NS	NS	NS			
1	07/14/97	102	102	1,373	102	52			
2	07/21/97	253 ^a	128	1,485	128	105			
3	08/25/97	256	128	310	128	5			
4	09/29/97	256	128	699	128	19			
5	10/20/97	256	128	194	128	12			
6	11/17/97	256	128	296	128	31			
7	12/10/98	256	128	563	128	3			
8	01/22/98	256	128	904	128	3			
9	02/26/98	256	128	814	128	14			
10	03/18/98	256	127	7,769	127	8	64	16,155	438
11	04/15/98	256	128	4,947	128	99	64	11,115	326
12	05/18/98	256 ^{b,c}	122	6,892	127	4,337			
13	06/08/98	256	128	1,484	128	816			
14	07/20/98	256	127	1,184	127	138			
15	08/17/98	36	NS	NS	NS	NS			
16	08/25/98	256	128	1,080	128	116			
17	09/15/98	256	128	874	128	85			
18	10/05/98	256	128	410	128	56			
19	11/10/98	256	128	220	128	54			
20	12/08/98	256	128	447	128	37			
21	01/11/99	256	128	1,672	128	12			
22	02/02/99	256	128	3,090	128	42			
23	03/17/99	256	126	1,946	126	125			
24	04/14/99	256	128	2,158	128	44			
25	05/23/99	256	128	2,891	128	142			
26	06/22/99	256	127	1,456	127	296			
	Total	6,301	3,163	43,785	3,168	6,599	128	27,270	764

NS – indicates sample not sorted for one or more taxa according to ETWG agreement or canceled survey.

VOIDED SUBSAMPLES

^a – Survey 2, subsample 75: sample lost on deck of boat; subsamples 220 and 224 voided in field due to jellyfish in the net.

^b – Survey 12, subsamples 117, 119, 157, 159, 163, 175, 177, 179, 181, and 187: portions of these samples were not properly preserved in ethanol. Survey 12, subsample 152: sample lost on deck of boat.

^c – Some megalops were lost during laboratory processing Survey 12, subsample 164. Data from this subsample not used in the analysis of megalops.

^d – Fishes from Survey 12, subsamples 184 and 240 mixed together during identification. Data from these subsamples not used in the analysis of the fishes.

Table G-3 (continued). Intake Cove surface plankton tow survey collection dates, number of samples collected and sorted, and number of fish larvae: 1990 - 1998.

1993			1994			1995		
Collection Date	# of samples collected & processed	# of fish larvae	Collection Date	# of samples collected & processed	# of fish larvae	Collection Date	# of samples collected & processed	# of fish larvae
01/08/93	3	24	01/07/94	3	140	01/06/95	3	1
01/15/93	3	19	01/14/94	3	35	01/13/95	3	37
01/22/93	3	17	01/21/94	3	1,354	01/20/95	3	100
01/29/93	3	42	01/28/94	3	22	01/27/95	3	50
02/05/93	3	16	02/04/94	3	67	02/03/95	3	8
02/12/93	3	14	02/11/94	3	100	02/10/95	3	27
02/19/93	3	29	02/18/94	3	19	02/17/95	3	91
02/26/93	3	54	02/25/94	3	130	02/24/95	3	114
03/05/93	3	25	03/04/94	3	431	03/03/95	3	71
03/12/93	3	42	03/11/94	3	273	03/10/95	0 ^e	NS
03/19/93	3	37	03/18/94	3/2 ^b	35	03/17/95	3	60
03/26/93	3	37	03/25/94	3	26	03/24/95	3	2
						03/31/95	3	99
04/02/93	3	10	04/01/94	3	39			
04/09/93	3	207	04/08/94	3	35	04/07/95	3	252
04/16/93	3	18	04/15/94	3	77	04/14/95	3	59
04/23/93	3	32	04/22/94	3	42	04/19/95	3	6
04/30/93	3	25	04/29/94	3	73	04/28/95	3	153
05/07/93	3	78	05/06/94	3/2 ⁱ	208	05/05/95	3	192
05/14/93	3	530	05/13/94	3	427	05/12/95	3/2 ^b	55
05/21/93	3	36	05/20/94	3	193	05/19/95	3	43
05/28/93	3	135	05/27/94	3	215	05/26/95	3	149
06/04/93	3	71	06/03/94	3	125	06/02/95	3	35
06/11/93	3	30	06/10/94	3	184	06/09/95	3	242
06/18/93	3	59	06/17/94	3	209	06/16/95	0 ^f	NS
06/25/93	3	56	06/24/94	3/2 ^b	78	06/23/95	0 ^f	NS
						06/30/95	3	19
07/02/93	3	30						
07/09/93	3	15						
07/15/93	3	5						
07/23/93	3	22						
07/28/93	3	27						
08/06/93	3	130						
08/13/93	3	22						
08/20/93	3	119						
08/27/93	3	82						
09/03/93	0 ^d	NS	Samples collected during July - November not sorted per agreement with ETWG			Samples collected during July - November not sorted per agreement with ETWG		
09/10/93	3	174						
09/17/93	3	165						
09/24/93	3	59						
10/01/93	3	151						
10/08/93	3	70						
10/15/93	3/2 ^b	489						
10/22/93	3	96						
10/29/93	3/2 ^{a, i}	17						
11/05/93	3/2 ^b	2						
11/12/93	3	17						
11/19/93	3	35						
11/24/93	3	32						
12/03/93	3	26	12/02/94	3	54	12/01/95	3	34
12/10/93	3	9	12/09/94	3	25	12/08/95	3	207
12/17/93	3	23	12/16/94	3	13	12/15/95	3	9
12/22/93	3/2 ^c	55	12/23/94	3	0	12/22/95	0 ^f	NS
12/30/93	3	13	12/30/94	3	42	12/29/95	3	55
Total	153/149	3,258		90/87	4,671		81/80	2,170

(continued)

Table G-3 (continued). Intake Cove surface plankton tow survey collection dates, number of samples collected and sorted, and number of fish larvae: 1990 - 1998.

1996			1997			1998		
Collection Date	# of samples collected & processed	# of fish larvae	Collection Date	# of samples collected & processed	# of fish larvae	Collection Date	# of samples collected & processed	# of fish larvae
01/05/95	3	73	01/03/97	3	13	01/02/98	3	29
01/12/95	3	262	01/10/97	3	19	01/09/98	3	20
01/19/95	3	91	01/17/97	3	10	01/16/98	3	2
01/26/95	3	202	01/24/97	3	55	01/23/98	3	10
			01/31/97	3	34	01/30/98	0 ^c	NS
02/02/95	3	635	02/07/97	3	69	02/06/98	0 ^c	NS
02/09/95	3	37	02/14/97	3	37	02/13/98	3	11
02/16/95	3	422	02/21/97	3	51	02/20/98	3	2
02/23/95	3	45	02/28/97	3	15	02/27/98	3	2
03/01/95	3	34						
03/08/95	3	176	03/07/97	3	26	03/06/98	3	18
03/15/95	3	24	03/14/97	3	310	03/13/98	3	23
03/22/95	3	31	03/21/97	3	187	03/20/98	3	20
03/29/95	3	83	03/28/97	3	117	03/27/98	3	46
04/05/96	3	90	04/04/97	3	109	04/03/98	3	47
04/12/96	3	214	04/11/97	3	76	04/10/98	3	57
04/19/96	3	87	04/18/97	3	256	04/17/98	3	55
04/26/96	3/0 ^b	NS	04/25/97	3	37	04/24/98	3	223
05/03/96	3	221	05/02/97	3	39	05/01/98	3	189
05/10/96	0 ^f	NS	05/09/97	3	217	05/08/98	3	309
05/17/96	3	272	05/16/97	3	184	05/15/98	3	85
05/24/96	3	49	05/23/97	3	161	05/22/98	3	108
05/31/96	3	41	05/30/97	3	66	05/29/98	3	344
06/07/96	3	94	06/06/97	3	69	06/05/98	3	138
06/14/96	3	34	06/13/97	3	199	06/12/98	3	30
06/21/96	3	51	06/20/97	3	78	06/19/98	3	26
06/28/96	3	52	06/27/97	3	39	06/26/98	3	104
12/06/96	3	1	12/05/97	3	4	12/04/98	3/0 ^j	NS
12/13/96	3	22	12/10/97	3	1	12/11/98	3/0 ^j	NS
12/20/96	3	38	12/19/97	3	1	12/18/98	3/0 ^j	NS
12/27/96	3	19	12/24/97	1 ^h	3	12/23/98	3/0 ^j	NS
						12/31/98	3/0 ^j	NS
Total	87/84	3,400		88	2,482		87/72	1,898

NS – indicates sample not sorted according to ETWG agreement, canceled survey, or lost sample.
 #/# – Number collected / Number sorted

VOIDED SUBSAMPLES AND PARTIAL AND CANCELED SURVEYS

- ^a – subsamples voided after collection due to incorrect collection technique.
- ^b – subsamples lost before processing.
- ^c – subsamples could not be sorted or identified due to insufficient preservation.
- ^d – no samples were collected because wash down pump out of service.
- ^e – survey canceled due to rough sea conditions making collection unsafe.
- ^f – no samples were collected.
- ^g – no samples were collected because boat out of service.
- ^h – plankton net lost during survey.
- ⁱ – larval fishes lost after subsample was sorted.
- ^j – subsamples not sorted no fish identified.

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Appendix H

Estimated Mean Density of Larvae Collected at DCPP.

Table H-2. Density of larval fishes (#/m³) collected in the study grid subsamples at DCP. (NS = no samples collected)

		Survey	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21	G22	G23	G24	G25	G26
		Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335
		Number of sub-samples sorted	128	128	128	128	128	128	128	128	128	128	128	128	128	NS	128	128	128	128	128	128	128	128	128	128	128
		Start Date	07/21	08/25	09/29	10/20	11/17	12/10	01/22	02/26	03/18	04/15	05/18	06/08	07/20		08/25	09/15	10/05	11/10	12/08	01/01	02/02	03/16	04/13	05/23	06/22
		Total # of Individuals per Taxa	1999																								
		Study Grid Totals	1998																								
		1997	1999																								
Taxa / Common Name																											
<i>Sebastes</i> spp. V_De	rockfishes	22,930	5,354	<.001	-	-	-	<.001	0.004	0.005	0.012	0.067	0.294	0.056	0.001	-	-	-	-	-	-	0.007	0.009	0.028	0.092	0.282	0.048
<i>Engraulis mordax</i>	northern anchovy	11,909	8,464	0.004	0.005	0.040	0.019	0.021	0.047	0.012	0.034	0.443	0.095	0.371	0.048	0.027	0.046	0.012	-	0.003	0.007	0.005	<.001	<.001	<.001	0.004	0.004
<i>Gibbonsia</i> spp.	climid kelpfishes	9,828	467	0.033	0.003	0.003	0.002	0.004	0.004	0.013	0.010	0.005	<.001	0.001	0.002	<.001	<.001	0.003	0.002	0.002	0.013	0.020	0.005	<.001	<.001	<.001	<.001
<i>Coryphopterus nicholsi</i>	blackeye goby	8,913	1,255	0.032	0.019	0.010	<.001	<.001	<.001	0.001	-	<.001	0.004	0.009	0.013	0.048	0.010	0.002	0.028	0.023	0.011	<.001	<.001	<.001	<.001	0.010	0.025
<i>Cebidichthys violaceus</i>	monkeyface eel	7,994	904	0.007	-	-	-	-	-	<.001	0.004	0.009	0.013	0.048	0.010	0.002	-	-	-	-	-	-	0.005	0.018	0.041	0.038	0.010
<i>Sardinops sagax</i>	Pacific sardine	7,313	5,122	-	-	-	-	-	-	<.001	0.330	0.235	0.049	0.011	<.001	-	-	-	-	-	-	<.001	-	-	0.044	<.001	<.001
<i>Stenobrachius leucopsarus</i>	northern lampfish	6,349	4,023	<.001	-	-	<.001	<.001	-	0.006	0.010	0.102	0.054	0.043	0.024	<.001	<.001	-	-	<.001	0.005	0.020	0.140	0.015	0.091	0.010	0.003
<i>Arctidius lateralis</i>	smoothhead sculpin	6,274	676	0.020	0.002	-	-	-	<.001	<.001	0.012	0.010	0.015	0.015	0.004	<.001	<.001	-	-	<.001	-	0.002	0.006	0.015	0.012	0.018	0.007
<i>Genyonemus lineatus</i>	white croaker	6,010	1,710	<.001	-	<.001	-	0.007	0.004	0.015	0.202	0.014	0.019	<.001	-	-	-	-	<.001	0.003	0.063	0.006	0.003	-	<.001	-	-
<i>Sebastes</i> spp. V	rockfishes	5,693	2,962	0.006	0.002	0.012	0.005	0.002	0.001	0.027	0.004	0.005	0.010	0.024	0.008	0.007	<.001	<.001	0.002	0.004	0.003	0.047	0.119	0.004	0.014	0.019	0.026
<i>Orthonopias triacis</i>	snubnose sculpin	4,980	447	0.049	0.004	-	-	0.001	-	0.003	<.001	-	0.007	0.014	0.012	0.003	<.001	0.002	<.001	<.001	<.001	<.001	0.002	0.002	0.004	0.006	0.002
Cottidae unid.	sculpins	4,029	403	0.018	0.003	<.001	<.001	<.001	<.001	<.001	0.001	0.003	0.014	0.007	0.004	0.001	<.001	<.001	<.001	-	-	<.001	<.001	<.001	0.003	0.006	0.007
Gobiidae unid.	gobies	3,799	269	<.001	0.001	<.001	<.001	<.001	<.001	-	0.001	0.003	0.018	0.013	0.005	<.001	-	<.001	0.011	-	0.002	-	<.001	<.001	<.001	0.005	<.001
Stichaeidae unid.	pricklebacks	3,004	230	<.001	-	-	-	-	<.001	<.001	0.001	0.017	0.013	0.002	-	-	-	-	-	-	-	-	0.002	0.007	0.003	0.002	-
Bathymasteridae unid.	ronquils	2,992	1,656	0.030	<.001	-	-	<.001	-	<.001	0.003	0.057	0.052	0.005	0.004	-	-	-	-	-	-	<.001	0.016	0.056	0.021	0.013	0.011
<i>Scorpaenichthys marmoratus</i>	cabezon	2,813	875	-	-	<.001	<.001	0.004	0.009	0.037	0.012	0.018	<.001	-	-	-	-	-	0.003	0.003	0.016	0.021	0.013	0.006	<.001	<.001	-
<i>Oligocottus</i> spp.	sculpins	1,739	31	<.001	-	-	-	<.001	-	<.001	<.001	<.001	<.001	<.001	<.001	-	-	-	<.001	<.001	<.001	<.001	0.001	0.001	0.001	0.001	-
<i>Oxylebius pictus</i>	painted greenling	1,505	372	0.006	<.001	-	<.001	<.001	<.001	0.001	<.001	<.001	0.002	0.005	0.004	0.001	-	-	<.001	<.001	<.001	0.004	0.004	0.008	0.003	0.009	0.009
<i>Liparis</i> spp.	snailfishes	1,330	430	0.019	0.006	<.001	<.001	-	-	-	-	-	0.002	0.002	<.001	-	0.002	<.001	<.001	<.001	<.001	<.001	<.001	0.004	0.004	0.016	0.017
<i>Hypsoblennius</i> spp.	blennies	1,179	893	-	-	<.001	<.001	0.004	0.003	0.005	<.001	<.001	<.001	0.006	0.039	0.020	0.021	0.012	0.003	0.002	<.001	0.001	0.001	<.001	<.001	<.001	0.006
<i>Oligocottus maculosus</i>	tidepool sculpin	1,051	16	-	-	-	-	-	-	-	<.001	<.001	<.001	<.001	<.001	-	-	-	-	<.001	-	-	<.001	<.001	<.001	<.001	<.001
larval fish fragment		1,036	189	<.001	<.001	<.001	-	<.001	<.001	-	<.001	0.005	0.001	0.002	<.001	0.001	<.001	<.001	<.001	<.001	<.001	0.002	0.004	0.002	0.001	0.001	0.001
<i>Ruscarius creaseri</i>	roughcheek sculpin	949	316	0.003	-	-	-	-	-	<.001	0.002	0.003	0.005	0.002	<.001	-	-	-	-	-	-	<.001	<.001	0.008	0.008	0.010	0.010
Chaenopsidae unid.	tube blennies	846	29	-	<.001	-	-	-	-	-	-	0.001	<.001	<.001	-	-	0.001	<.001	<.001	-	-	-	<.001	<.001	<.001	<.001	-
<i>Sebastes</i> spp. V_D	rockfishes	844	188	-	-	-	-	-	-	<.001	<.001	0.002	0.018	0.001	-	-	<.001	<.001	<.001	-	-	-	-	0.002	0.003	0.002	<.001
<i>Triphoturus mexicanus</i>	Mexican lampfish	844	523	0.006	<.001	<.001	<.001	<.001	-	-	-	-	-	<.001	0.003	0.042	0.018	0.005	<.001	<.001	<.001	<.001	-	-	-	-	<.001
<i>Clinocottus analis</i>	wooly sculpin	830	147	0.005	<.001	-	<.001	<.001	<.001	<.001	<.001	0.003	0.002	0.001	<.001	-	-	-	<.001	<.001	<.001	-	-	0.003	0.001	0.008	0.004
Pleuronectidae unid.	righteye flounders	799	101	0.008	0.001	<.001	-	-	-	-	<.001	0.002	<.001	<.001	-	-	-	-	-	-	-	-	<.001	0.003	<.001	-	<.001
<i>Bathylagus ochotensis</i>	pokey blacksmelt	744	247	-	-	-	-	-	<.001	0.004	0.002	0.014	0.005	0.004	-	-	-	-	-	-	<.001	<.001	<.001	<.001	0.001	<.001	-
<i>Parophrys vetulus</i>	English sole	728	367	<.001	-	-	-	-	-	-	0.002	0.009	0.032	<.001	-	-	-	-	-	-	-	<.001	0.003	<.001	-	<.001	<.001
<i>Sebastes</i> spp. VD	rockfishes	724	663	-	-	-	-	-	<.001	0.002	0.002	0.002	0.001	-	-	-	-	-	<.001	0.001	0.012	0.033	0.016	0.003	0.001	<.001	<.001
<i>Arctidius</i> spp.	sculpins	709	86	<.001	-	-	-	-	-	-	0.003	0.004	-	<.001	-	-	<.001	<.001	-	-	-	-	0.002	0.001	0.004	0.002	0.002
<i>Sebastes</i> spp.	rockfishes	666	309	-	<.001	-	<.001	-	<.001	<.001	<.001	0.002	0.018	<.001	<.001	<.001	<.001	-	-	<.001	0.002	0.002	0.002	0.002	0.009	<.001	<.001
<i>Paralichthys californicus</i>	California halibut	629	251	0.005	<.001	0.002	-	<.001	<.001	<.001	-	0.002	0.010	0.004	-	0.011	<.001	<.001	<.001	-	-	<.001	-	0.003	-	-	-
<i>Lepidogobius lepidus</i>	bay goby	571	30	<.001	-	<.001	-	<.001	-	<.001	<.001	<.001	<.001	<.001	<.001	-	-	-	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
<i>Typhlogobius californiensis</i>	blind goby	550	349	0.026	0.003	0.002	-	-	-	-	<.001	0.002	0.009	0.010	0.006	0.002	0.005	0.002	<.001	-	-	-	<.001	<.001	<.001	0.003	0.003
<i>Tarletonbeania crenularis</i>	blue lanternfish	438	236	<.001	-	-	-	-	-	-	-	<.001	<.001	-	-	-	-	<.001	<.001	<.001	0.005	0.004	<.001	0.013	<.001	0.004	-
Pleuronectiformes unid.	flatfishes	397	108	0.004	-	<.001	-	<.001	<.001	<.001	<.001	<.001	-	<.001	-	0.002	0.003	<.001	-	<.001	<.001	0.001	0.003	-	-	<.001	<.001
<i>Neoclinus</i> spp.	fringeheads	386	34	<.001	-	<.001	-	-	-	-	-	0.002	<.001	-	-	-	-	-	-	<.001	-	-	-	0.001	0.002	-	-
Osmeridae unid.	smelts	369	13	-	-	-	-	-	<.001	<.001	<.001	-	-	-	-	-	-	-	-	-	<.001	-	-	<.001	-	<.001	<.001
larval/post-larval fish, unid.		348	81	0.001	-	-	<.001	-	<.001	<.001	0.002	-	-	-	<.001	-	-	-	<.001	<.001	-	<.001	<.001	0.002	<.001	<.001	<.001
Pholididae unid.	gunnels	344	21	-	-	-	-	-	-	<.001	-	<.001	0.003	<.001	-	-	-	-	-	-	-	-	-	-	<.001	<.001	-
<i>Brosomphycis marginata</i>	red brotula	330	73	0.003	<.001	-	-	-	-	-	-	0.002	0.002	0.002	<.001	-	<.001	<.001	-	-	-	-	-	-	<.001	<.001	0.003
Sciaenidae unid.	croakers	326	34	0.002	-	-	-	-	<.001	0.001	<.001	-	-	-	0.001	-	-	-	-	-	-	<.001	-	<.001	-	-	-
<i>Nannobrachium</i> spp.	lanternfishes	322	225	<.001	-	-	<.001	<.001	0.003	<.001	0.009	0.004	<.001	<.001	<.001	-	0.002	<.001	<.001	<.001	<.001	-	0.002	-	0.003	-	<.001
<i>Merluccius productus</i>	Pacific hake	317	1																								

Table H-3. Density of *Cancer* spp. megalops (#/m³) collected in the entrainment and study grid subsamples at DCP. (NS = no samples collected)

Entrainment			Survey	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30																											
			Mesh Size (mm)	0.505	0.505	0.505	0.505	0.505	0.505	0.505	*	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335																												
			Number of sub-samples sorted	63	64	64	64	64	64	64	128	64	64	64	64	64	64	64	64	64	64	63	63	64	64	64	64	64	64	64	32																											
			Start Date	10/23	10/30	11/06	11/13	11/18	11/25	12/02	12/03	12/09	12/16	12/23	12/30	01/06	01/13	01/20	01/27	02/03	02/10	02/17	02/24	03/03	03/10	03/17	03/24	03/31	04/07	04/14	04/21																											
Taxa / Common Name	Total # of Indiv. per Taxa	Entrainment Totals	1996																												1997																											
<i>Cancer antennarius</i> (megalops)	brown rock crab	7,480	3,282	<.001	0.001	0.012	0.003	0.001	-	0.003	0.002	0.004	0.025	0.001	0.005	0.015	0.002	0.009	0.012	0.008	0.001	<.001	<.001	<.001	0.004	0.021	0.054	0.358	0.179	0.033	0.009																											
<i>Cancer gracilis</i> (megalops)	slender crab	2,200	1,144	<.001	0.007	0.004	0.006	0.005	0.007	0.006	0.004	0.005	0.033	0.002	0.016	0.018	0.004	0.016	0.025	0.005	0.003	0.006	0.002	0.019	0.011	0.014	0.006	0.019	0.031	0.006	-																											
<i>Cancer anthonyi</i> (megalops)	yellow rock crab	1,012	271	0.001	0.009	0.031	0.008	0.002	-	0.001	<.001	0.001	<.001	<.001	-	-	-	<.001	-	-	-	<.001	-	-	-	<.001	-	-	-	-	-																											
<i>Cancer productus</i> (megalops)	red rock crab	338	117	-	-	-	-	<.001	<.001	-	-	-	-	<.001	-	-	-	-	-	0.001	<.001	-	<.001	<.001	-	<.001	<.001	0.001	<.001	-	-																											
<i>Cancer</i> sp. A (megalops)	cancer crabs	264	51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																											
<i>C. antennarius</i> / <i>C. gracilis</i> (megalops)	rock crabs	115	12	-	<.001	<.001	<.001	<.001	-	-	-	<.001	<.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																											
<i>Cancer</i> spp. (megalops)	cancer crabs	40	9	-	-	-	-	-	-	-	-	-	<.001	-	-	-	-	-	-	-	-	-	-	-	-	<.001	-	-	-	-	-																											
<i>Cancer magister</i> (megalops)	dungeness crab	27	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																											
<i>Cancer</i> sp. B (megalops)	cancer crabs	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																											
Total	11,486	4,887	0.003	0.018	0.048	0.017	0.009	0.008	0.010	0.006	0.011	0.061	0.005	0.022	0.033	0.006	0.025	0.038	0.013	0.006	0.007	0.004	0.020	0.015	0.036	0.060	0.378	0.210	0.038	0.009																												

Entrainment			Survey	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
			Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335
			Number of sub-samples sorted	64	64	32	64	32	64	32	63	32	64	32	32	64	32	31	32	32	64	32	32	32	32	32	32	32	32	32	32
			Start Date	04/28	05/05	05/12	05/19	05/27	06/02	06/09	06/16	06/23	06/30	07/07	07/14	07/21	07/28	08/04	08/11	08/18	08/26	09/02	09/08	09/15	09/22	09/30	10/06	10/13	10/21	10/27	11/04
Taxa / Common Name	Total # of Indiv. per Taxa	Entrainment Totals	1997																												
<i>Cancer antennarius</i> (megalops)	brown rock crab	7,480	3,282	0.042	0.011	0.010	0.030	0.067	0.011	0.003	0.034	0.015	0.016	0.001	-	-	<.001	-	0.002	-	-	-	-	-	-	-	<.001	0.001	0.002	0.002	-
<i>Cancer gracilis</i> (megalops)	slender crab	2,200	1,144	<.001	<.001	0.006	0.002	<.001	0.004	0.003	0.009	0.008	0.008	<.001	0.001	-	0.002	<.001	0.003	-	<.001	0.002	-	<.001	-	-	0.005	<.001	0.004	0.001	0.002
<i>Cancer anthonyi</i> (megalops)	yellow rock crab	1,012	271	-	-	0.003	0.003	-	-	-	0.004	-	-	-	0.001	<.001	<.001	-	<.001	-	-	<.001	-	<.001	0.002	-	-	0.001	0.008	-	-
<i>Cancer productus</i> (megalops)	red rock crab	338	117	-	-	-	-	<.001	-	<.001	<.001	<.001	<.001	<.001	-	<.001	-	-	0.003	-	-	<.001	-	-	-	-	-	-	-	-	-
<i>Cancer</i> sp. A (megalops)	cancer crabs	264	51	-	-	<.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>C. antennarius</i> / <i>C. gracilis</i> (megalops)	cancer crabs	115	12	-	-	-	-	-	-	-	<.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cancer</i> spp. (megalops)	cancer crabs	40	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cancer magister</i> (megalops)	dungeness crab	27	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cancer</i> sp. B (megalops)	cancer crabs	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	11,486	4,887	0.043	0.012	0.020	0.036	0.069	0.016	0.007	0.049	0.024	0.025	0.002	0.003	<.001	0.003	<.001	0.008	-	<.001	0.003	-	0.001	0.002	-	0.005	0.003	0.014	0.003	0.002	

Entrainment			Survey	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
			Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	
			Number of sub-samples sorted	32	32	32	32	32	32	32	32	32	32	32	32	24	NS	32	NS	32	32	32	32	32	32	32	32	NS	32	32	32	32
			Start Date	11/10	11/18	11/24	12/02	12/11	12/16	12/22	12/30	01/05	01/15	01/23	01/28		02/11		02/27	03/04	03/09	03/19	03/27	04/01	04/07	04/16		04/29	05/04	05/14	05/19	
Taxa / Common Name	Total # of Indiv. per Taxa	Entrainment Totals	1997													1998																
<i>Cancer antennarius</i> (megalops)	brown rock crab	7,480	3,282	-	<.001	-	-	-	<.001	-	-	<.001	-	-	-	<.001	-	-	-	-	-	-	-	-	0.003	0.002	0.003		0.009	0.004	0.060	0.024
<i>Cancer gracilis</i> (megalops)	slender crab	2,200	1,144	0.001	<.001	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.001	-	-	-	0.001	0.001		0.005	-	0.005	0.002	
<i>Cancer anthonyi</i> (megalops)	yellow rock crab	1,012	271	-	-	-	-	-	-	-	-	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.001	-	-	<.001	-	
<i>Cancer productus</i> (megalops)	red rock crab	338	117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Cancer</i> sp. A (megalops)	cancer crabs	264	51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>C. antennarius</i> / <i>C. gracilis</i> (megalops)	cancer crabs	115	12	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Cancer</i> spp. (megalops)	cancer crabs	40	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Cancer magister</i> (megalops)	dungeness crab	27	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Cancer</i> sp. B (megalops)	cancer crabs	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	11,486	4,887	0.001	0.001	0.003	-	-	<.001	-	0.002	<.001	-	-	-	-	<.001	-	-	-	<.001	-	-	-	0.003	0.003	0.005		0.014	0.004	0.065	0.026	

* 0.505 and 0.335 mm net mesh data combined for Survey 10.

Table H-3 (continued). Density of *Cancer* spp. megalops (#/m³) collected in the entrainment and study grid subsamples at DCP. (NS = no samples collected)

Entrainment			Survey	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	
			Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335
			Number of sub-samples sorted	32	32	29	32	31	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	NS	32
			Start Date	05/26	06/01	06/09	06/15	06/22	06/29	07/06	07/13	07/21	07/27	08/03	08/10	08/18	08/26	08/31	09/08	09/16	09/21	09/28	10/06	10/12	10/20	10/27	11/03	11/11	11/17	11/23		12/09	
				1998																													
Taxa / Common Name	Total # of Indiv. per Taxa	Entrainment Totals																															
<i>Cancer antennarius</i> (megalops)	brown rock crab	7,480	3,282	0.012	0.047	0.014	0.018	0.129	0.017	0.010	0.038	<.001	<.001	<.001	0.001	-	-	-	<.001	-	-	-	<.001	-	0.001	0.001	-	<.001	-	-	-	0.001	
<i>Cancer gracilis</i> (megalops)	slender crab	2,200	1,144	0.004	0.012	0.001	0.003	0.006	0.002	<.001	0.001	-	0.003	-	0.004	0.001	<.001	-	<.001	0.001	<.001	<.001	0.003	0.003	0.024	0.007	<.001	<.001	0.014	0.003	-	0.001	
<i>Cancer anthonyi</i> (megalops)	yellow rock crab	1,012	271	-	0.001	0.001	-	0.003	-	<.001	0.009	0.003	<.001	<.001	0.002	-	0.001	-	-	<.001	<.001	<.001	0.002	0.001	0.002	-	-	-	-	-	-		
<i>Cancer productus</i> (megalops)	red rock crab	338	117	0.002	0.001	<.001	<.001	0.011	0.001	-	0.003	0.001	0.001	0.002	0.004	-	0.003	<.001	-	<.001	0.002	<.001	-	<.001	<.001	-	-	-	-	-	-		
<i>Cancer</i> sp. A (megalops)	cancer crabs	264	51	<.001	<.001	<.001	-	-	-	<.001	0.006	0.002	0.001	<.001	0.001	-	<.001	<.001	-	0.001	-	-	0.001	<.001	0.001	-	-	<.001	<.001	-	-		
<i>C. antennarius</i> / <i>C. gracilis</i> (megalops)	cancer crabs	115	12	-	-	-	<.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Cancer</i> spp. (megalops)	cancer crabs	40	9	-	-	-	-	-	-	-	<.001	<.001	-	-	-	-	-	-	-	-	-	0.001	-	-	-	-	-	-	-	-	-		
<i>Cancer magister</i> (megalops)	dungeness crab	27	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Cancer</i> sp. B (megalops)	cancer crabs	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total		11,486	4,887	0.018	0.062	0.018	0.022	0.149	0.020	0.012	0.058	0.008	0.006	0.005	0.012	0.001	0.004	0.003	0.001	0.003	0.005	0.002	0.007	0.006	0.030	0.009	<.001	0.002	0.015	0.003	0.003		

Entrainment			Survey	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	
			Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	
			Number of sub-samples sorted	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	NS	32	32
			Start Date	12/16	12/21	12/28	01/04	01/12	01/20	01/25	02/03	02/11	02/15	02/23	03/04	03/10	03/17	03/24	03/29	04/07	04/14	04/20	04/26	05/05	05/12	05/21	05/24	06/01	06/09		06/23	06/29	
				1999																													
Taxa / Common Name	Total # of Indiv. per Taxa	Entrainment Totals																															
<i>Cancer antennarius</i> (megalops)	brown rock crab	7,480	3,282	-	-	-	<.001	-	<.001	-	-	-	-	-	-	-	-	-	-	-	0.001	-	-	-	-	-	0.005	-	0.008	-	0.003	<.001	
<i>Cancer gracilis</i> (megalops)	slender crab	2,200	1,144	-	0.002	<.001	-	<.001	0.001	<.001	-	<.001	-	-	<.001	-	0.001	0.004	-	0.003	-	0.007	-	0.003	0.003	<.001	0.002	0.003	<.001	-	0.002	-	
<i>Cancer anthonyi</i> (megalops)	yellow rock crab	1,012	271	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.002	-	-	-	0.002	-	
<i>Cancer productus</i> (megalops)	red rock crab	338	117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.001	0.002	<.001	0.002	<.001	-	0.002	-	0.001	0.002	0.006	<.001	0.003	-		
<i>Cancer</i> sp. A (megalops)	cancer crabs	264	51	-	-	-	-	0.001	-	-	-	0.003	-	-	-	<.001	<.001	0.002	-	-	0.002	<.001	-	<.001	-	-	<.001	<.001	-	0.001	-		
<i>C. antennarius</i> / <i>C. gracilis</i> (megalops)	cancer crabs	115	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Cancer</i> spp. (megalops)	cancer crabs	40	9	-	-	-	-	-	-	-	-	-	-	-	-	<.001	-	-	-	-	0.001	-	-	-	-	-	-	-	-	-	-		
<i>Cancer magister</i> (megalops)	dungeness crab	27	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Cancer</i> sp. B (megalops)	cancer crabs	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total		11,486	4,887	-	0.002	<.001	<.001	0.002	0.002	<.001	-	0.004	-	-	<.001	0.001	0.003	0.009	<.001	0.006	0.004	0.008	-	0.006	0.003	0.007	0.006	0.017	0.001	0.011	<.001		

Study Grid			Survey	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21	G22	G23	G24	G25	G26					
			Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335				
			Number of sub-samples sorted	128	128	128	128	128	128	128	128	128	128	128	128	128	NS	128	128	128	128	128	128	128	128	128	128	128	128				
			Start Date	07/21	08/25	09/29	10/20	11/17	12/10	01/22	02/26	03/18	04/15	05/18	06/08	07/20		08/25	09/15	10/05	11/10	12/08	01/01	02/02	03/16	04/13	05/23	06/22					
				1997											1998														1999				
Taxa / Common Name	Total # of Indiv. per Taxa	Study Grid Totals																															
<i>Cancer antennarius</i> (megalops)	brown rock crab	7,480	4,198	0.002	<.001	0.001	<.001	<.001	-	<.001	<.001	<.001	0.005	0.380	0.070	0.004	-	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	-	0.005	0.016				
<i>Cancer gracilis</i> (megalops)	slender crab	2,200	1,056	0.017	-	<.001	<.001	0.002	<.001	-	0.001	<.001	0.006	0.034	0.033	0.002	-	0.015	0.013	0.005	0.005	0.002	<.001	0.003	0.018	0.003	0.010	0.005					
<i>Cancer anthonyi</i> (megalops)	yellow rock crab	1,012	741	0.002	<.001	<.001	0.002	0.003	<.001	<.001	-	-	<.001	0.080	0.003	0.005	-	<.001	<.001	0.003	<.001	<.001	<.001	<.001	-	-	-	<.001	0.007				
<i>Cancer productus</i> (megalops)	red rock crab	338	221	0.003	<.001	<.001	<.001	-	-	-	-	-	-	0.005	0.004	0.002	-	0.005	0.006	<.001	<.001	<.001	-	-	0.005	<.001	0.002	0.006					
<i>Cancer</i> sp. A (megalops)	cancer crabs	264	213	-	-	-	-	-	-	-	-	-	-	<.001	0.001	0.001	0.008	-	<.001	<.001	<.001	0.002	0.001	<.001	0.003	0.003	<.001	<.001	0.005				
<i>C. antennarius</i> / <i>C. gracilis</i> (megalops)	cancer crabs	115	103	-	-	<.001	-	-	-	-	<.001	-	-	0.009	<.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
<i>Cancer</i> spp. (megalops)	cancer crabs	40	31	-	-	-	-	-	-	-	-	-	-	-	<.001	-	<.001	-	<.001	<.001	-	<.001	<.001	-	<.001	<.001	-	<.001	<.001				
<i>Cancer magister</i> (megalops)	dungeness crab	27	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.001	0.004	<.001				
<i>Cancer</i> sp. B (megalops)	cancer crabs	10	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.001	-	-	-	-	<.001	-	-	<.001	<.001	<.001	-	-			
Total		11,486	6,599	0.024	<.001	0.003	0.004	0.005	<.001	<.001	0.002	0.001	0.012	0.510	0.112	0.021	-	0.022	0.021	0.010	0.008	0.004	0.002	0.006	0.027	0.006	0.022	0.041					

Table H-4 (continued). Density of *Cancer* spp. zoea (#/m3) in the entrainment and study grid subsamples at DCPD for surveys sorted for this group. Totals represent estimates calculated from split fractions of subsamples.

Entrainment			Survey	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92		
			Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335	NS	0.335	NS	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	NS	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335			
			Number of sub-samples sorted	8	8	8	8	6	NS	8	NS	8	8	8	8	8	8	8	8	NS	8	8	8	8	8	8	7	8	8	8		
			Start Date	12/30	01/05	01/15	01/23	01/28		02/11		02/27	03/04	03/09	03/19	03/27	04/01	04/07	04/16		04/29	05/04	05/14	05/19	05/26	06/01	06/09	06/15	06/22	06/29		
Taxa / Common Name	Total # of Individuals per Taxa	Entrainment Totals																														
<i>Cancer anten. / C. anth. / C. grac.</i> (zoea I) cancer crabs	223,267	191,623	5.793	4.611	4.190	6.454	3.742		2.669		3.621	11.271	13.145	23.896	10.632	5.975	1.006	8.048														
<i>Cancer antennarius</i> (zoea II) brown rock crab	44,035	40,139	-	0.059	-	-	-	-	-	-	-	-	-	0.022	0.008	0.027	0.041	0.105														
<i>Cancer antennarius</i> (zoea III) brown rock crab	36,971	34,079	-	-	-	-	-	-	-	-	-	-	-	-	-	0.010	0.023	0.004														
<i>Cancer</i> sp. A (zoea I) cancer crabs	17,112	16,162	1.346	0.483	0.266	0.150	0.428		0.064		0.253	0.682	0.546	1.144	0.429	0.156	0.462	0.669														
<i>Cancer antennarius</i> (zoea IV) brown rock crab	8,001	7,232	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.124	9.564	0.064	0.146	-	1.480	-	-	0.116	-	
<i>Cancer</i> spp. (zoea I) cancer crabs	2,034	1,829	0.060	0.022	-	0.047	0.007		0.028		0.021	0.057	0.107	-	0.221	0.005	0.070	-			0.066	0.129	0.358	0.065	0.012	0.063	0.034	0.037	0.786	0.003		
<i>Cancer</i> sp. B (zoea I) cancer crabs	1,678	1,401	0.012	0.046	0.020	0.005	0.007		-		-	0.014	0.006	-	0.003	0.056	0.003	-			0.023	0.020	-	-	0.050	0.042	0.047	0.042	2.599	0.081		
<i>Cancer</i> spp. (zoea III) cancer crabs	1,416	1,327	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.468	0.063	0.018	-	0.085	-	-	-	-		
<i>Cancer productus</i> (zoea I) red rock crab	1,211	893	0.002	0.003	-	-	-	-	-	-	-	-	-	-	0.032	-	-	0.071			-	-	0.041	0.019	0.088	-	0.060	0.007	1.240	0.010		
<i>Cancer</i> spp. (zoea II) red rock crab	1,151	1,051	-	0.046	-	-	-	-	-	-	-	-	-	-	-	0.002	-	-			0.191	0.930	0.735	0.035	-	-	-	-	0.039	-		
<i>Cancer gracilis</i> (zoea II) slender crab	825	735	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.265	0.224	0.315	-	-	0.272	0.023	0.002	0.199	-		
<i>Cancer antennarius</i> (zoea V) brown rock crab	679	620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.278	-	0.089	-	0.284	-	-	-	-		
<i>Cancer gracilis</i> (zoea III) slender crab	272	183	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.154	0.118	-	-	0.065	-	-	0.023	-		
<i>Cancer</i> spp. (zoea IV) cancer crabs	205	193	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.191	-	-	-	-	-	-	-	-		
<i>Cancer</i> sp. B (zoea II) cancer crabs	64	64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.185	-		
<i>Cancer</i> sp. A (zoea II) cancer crabs	46	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.046	-		
<i>Cancer</i> spp. (zoea V) cancer crabs	39	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.044	-	-	-	-	-	-	-	-		
<i>Cancer</i> spp. (pre-zoea) cancer crabs	38	38	-	-	-	-	-	-	-	-	-	-	-	-	0.022	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Cancer gracilis</i> (zoea IV) slender crab	27	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Cancer productus</i> (zoea II) red rock crab	18	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.023	-		
<i>Cancer</i> sp. A (zoea III) cancer crabs	16	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Cancer gracilis</i> (zoea V) slender crab	6	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Cancer anthonyi</i> (zoea III) yellow rock crab	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total	339,112	297,672	7.213	5.275	4.476	6.657	4.184		2.761		3.895	12.024	13.805	25.062	11.346	6.231	1.605	8.898			43.052	91.836	60.392	4.217	2.812	12.512	8.456	3.529	30.194	2.480		

Study Grid			Survey	G10	G11
			Mesh Size (mm)	0.335	0.335
			Number of sub-samples sorted	64	64
			Start Date	03/18	04/15
Taxa / Common Name	Total # of Individuals per Taxa	Study Grid Totals			
<i>Cancer anten. / C. anth. / C. grac.</i> (zoea I) cancer crabs	223,267	31,644	8.570	4.469	
<i>Cancer antennarius</i> (zoea II) brown rock crab	44,035	3,896	0.491	0.834	
<i>Cancer antennarius</i> (zoea III) brown rock crab	36,971	2,892	0.246	0.589	
<i>Cancer</i> sp. A (zoea I) cancer crabs	17,112	950	0.165	0.170	
<i>Cancer antennarius</i> (zoea IV) brown rock crab	8,001	769	0.002	0.175	
<i>Cancer</i> spp. (zoea I) cancer crabs	2,034	205	0.042	0.035	
<i>Cancer</i> sp. B (zoea I) cancer crabs	1,678	277	0.019	0.067	
<i>Cancer</i> spp. (zoea III) cancer crabs	1,416	89	<.001	0.020	
<i>Cancer productus</i> (zoea I) red rock crab	1,211	318	0.025	0.059	
<i>Cancer</i> spp. (zoea II) red rock crab	1,151	100	0.004	0.025	
<i>Cancer gracilis</i> (zoea II) slender crab	825	90	0.003	0.023	
<i>Cancer antennarius</i> (zoea V) brown rock crab	679	59	<.001	0.012	
<i>Cancer gracilis</i> (zoea III) slender crab	272	89	-	0.028	
<i>Cancer</i> spp. (zoea IV) cancer crabs	205	12	<.001	0.003	
<i>Cancer</i> sp. B (zoea II) cancer crabs	64	0	-	-	
<i>Cancer</i> sp. A (zoea II) cancer crabs	46	22	0.004	<.001	
<i>Cancer</i> spp. (zoea V) cancer crabs	39	1	-	<.001	
<i>Cancer</i> spp. (pre-zoea) cancer crabs	38	0	-	-	
<i>Cancer gracilis</i> (zoea IV) slender crab	27	13	-	0.003	
<i>Cancer productus</i> (zoea II) red rock crab	18	8	-	0.001	
<i>Cancer</i> sp. A (zoea III) cancer crabs	16	0	-	-	
<i>Cancer gracilis</i> (zoea V) slender crab	6	6	<.001	<.001	
<i>Cancer anthonyi</i> (zoea III) yellow rock crab	1	0	-	-	
Total	339,112	41,440	9.573	6.514	

Table H-5. Density of sea urchins (#/m3) in the entrainment and study grid subsamples at DCP for surveys sorted for this group. Totals represent estimates calculated from split fractions of subsamples.

Entrainment			Survey	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	
			Mesh Size (mm)	*	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335		
			Number of sub-samples sorted	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
			Start Date	12/03	12/09	12/16	12/23	12/30	01/06	01/13	01/20	01/27	02/03	02/10	02/17	02/24	03/03	03/10	03/17	03/24	03/31	04/07	04/14	04/21	04/28	05/05	05/12	05/19	05/27	06/02	06/09	
Taxa / Common Name		Total # of Individuals per Taxa	Entrainment Totals	1996					1997																							
<i>Strongylocentrotus purpuratus</i>	purple sea urchin	16,405	15,589	0.039	0.014	0.009	0.068	0.025	0.005	0.024	0.046	0.026	0.041	0.061	0.912	0.546	0.272	0.109	2.252	1.125	0.788	2.480	4.099	0.577	2.122	0.276	1.868	0.879	3.778	0.774	7.512	
<i>Strongylocentrotus franciscanus</i>	red sea urchin	1,319	982	0.003	-	-	-	0.003	-	0.003	-	-	-	-	0.003	0.034	-	-	0.625	0.077	0.057	0.078	0.097	0.009	0.014	0.019	0.008	0.061	0.208	0.009	0.106	
Echinoidea unid.	unid. sea urchins	98	88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.107	0.014	0.006	-	0.012	-	0.006	-	-	-	-	-	0.025	
Echinoidea unid (damaged juv.)	unid. sea urchins	53	34	-	-	-	-	-	-	-	0.003	-	-	-	0.003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.025	
Total		17,875	16,693	0.042	0.014	0.009	0.068	0.028	0.005	0.028	0.049	0.026	0.041	0.061	0.918	0.581	0.272	0.109	2.983	1.216	0.851	2.558	4.208	0.586	2.143	0.295	1.876	0.940	3.987	0.783	7.667	

Entrainment			Survey	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	
			Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	
			Number of sub-samples sorted	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
			Start Date	06/16	06/23	06/30	07/07	07/14	07/21	07/28	08/04	08/11	08/18	08/26	09/02	09/08	09/15	09/22	09/30	10/06	10/13	10/21	10/27	11/04	11/10	11/18	11/24	12/02	12/11	12/16	12/22	
Taxa / Common Name		Total # of Individuals per Taxa	Entrainment Totals																													
<i>Strongylocentrotus purpuratus</i>	purple sea urchin	16,405	15,589	6.558	0.451	1.102	0.625	2.619	0.510	0.065	0.052	0.038	0.005	-	-	0.012	-	0.002	-	-	-	-	-	-	-	-	-	-	-	0.002	-	
<i>Strongylocentrotus franciscanus</i>	red sea urchin	1,319	982	0.163	0.128	0.104	0.096	0.308	0.009	0.024	-	-	-	-	-	0.009	0.021	-	-	-	-	-	-	-	-	-	-	-	-	0.005	-	
Echinoidea unid.	unid. sea urchins	98	88	-	-	-	-	0.081	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Echinoidea unid (damaged juv.)	unid. sea urchins	53	34	-	-	-	0.003	0.025	-	-	-	-	-	-	-	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total		17,875	16,693	6.722	0.579	1.205	0.724	3.035	0.519	0.089	0.052	0.038	0.005	-	-	0.023	0.021	0.002	-	-	-	-	-	-	-	-	-	-	0.007	-		

Entrainment			Survey	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	
			Mesh Size (mm)	0.335	0.335	0.335	0.335	0.335		0.335		0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335		0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	
			Number of sub-samples sorted	8	8	8	8	8	NS	8	NS	8	8	8	8	8	8	8	8	NS	8	8	8	8	8	8	8	8	8	8	8
			Start Date	12/30	01/05	01/15	01/23	01/28		02/11		02/27	03/04	03/09	03/19	03/27	04/01	04/07	04/16		04/29	05/04	05/14	05/19	05/26	06/01	06/09	06/15	06/22	06/29	
Taxa / Common Name		Total # of Individuals per Taxa	Entrainment Totals																												
<i>Strongylocentrotus purpuratus</i>	purple sea urchin	16,405	15,589	-	-	-	-	-	-	-	-	-	0.009	0.015	0.225	0.412	0.351	0.106	0.169		0.238	0.272	0.170	0.002	0.091	-	0.003	0.063	0.246	0.035	
<i>Strongylocentrotus franciscanus</i>	red sea urchin	1,319	982	-	0.005	-	0.008	-	-	-	-	-	-	-	0.025	0.016	0.006	0.035		0.050	0.111	0.114	-	0.059	-	0.006	0.015	0.039	-	-	
Echinoidea unid.	unid. sea urchins	98	88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Echinoidea unid (damaged juv.)	unid. sea urchins	53	34	-	-	-	-	-	-	-	-	-	-	-	-	0.031	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		17,875	16,693	-	0.005	-	0.008	-	-	-	-	-	0.009	0.015	0.225	0.468	0.367	0.111	0.204		0.287	0.383	0.285	0.002	0.150	-	0.009	0.078	0.285	0.035	

Study Grid			Survey	G10	G11
			Mesh Size (mm)	0.335	0.335
			Number of sub-samples sorted	64	64
			Start Date	03/18	04/15
Taxa / Common Name		Total # of Individuals per Taxa	Study Grid Totals		
<i>Strongylocentrotus purpuratus</i>	purple sea urchin	16,405	816	0.193	0.115
<i>Strongylocentrotus franciscanus</i>	red sea urchin	1,319	337	0.019	0.073
Echinoidea unid.	unid. sea urchins	98	10	0.003	<.001
Echinoidea unid (damaged juv.)	unid. sea urchins	53	19	0.003	0.001
Total		17,875	1,182	0.217	0.189

* 0.505 and 0.335 data combined for Survey 10.

Table H-6. 1990: Density of larval fishes (#/m³) collected in Intake Cove surface plankton tows at DCP.

1990	Survey	B201	B202	B204	B206	B208	B210	B212	B214	B216	B218	B220	B222	B224	B226	B228	B230	B231	B232	B233	
	Number of samples sorted	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
	Date	02/23	02/27	03/06	03/14	03/20	03/27	04/03	04/10	04/17	04/24	05/03	05/10	05/18	05/25	06/01	06/08	06/15	06/20	06/29	
Taxa / Common Name	Total # of Individuals per Taxa																				
<i>Sebastes</i> spp. V_De	rockfishes	152	0.058	-	0.022	0.012	0.023	0.041	-	0.063	0.041	0.021	0.242	0.611	0.296	-	-	-	0.076	0.010	-
<i>Gibbonsia</i> spp.	clinid kelpfishes	133	0.023	0.090	-	0.041	0.012	0.010	-	0.063	0.010	0.054	0.039	0.037	0.020	0.077	0.193	0.040	0.174	0.320	0.236
Gobiidae unid.	gobies	114	0.012	-	-	0.111	0.012	-	-	-	-	-	-	0.275	0.058	0.042	0.049	0.043	-	0.631	
<i>Orthonopias triacis</i>	snubnose sculpin	108	-	-	-	0.018	-	0.031	-	0.119	0.010	0.011	0.026	0.009	0.040	0.183	0.022	-	0.682	-	
Stichaeidae unid.	pricklebacks	88	0.011	0.015	-	0.029	-	0.185	-	0.209	0.103	0.032	0.125	0.054	0.010	-	0.113	0.010	0.022	0.011	0.012
<i>Cebidichthys violaceus</i>	monkeyface eel	77	-	-	-	-	-	-	-	0.011	-	0.023	-	-	-	0.019	0.021	-	0.612	0.132	0.011
<i>Oligocottus</i> spp.	sculpins	76	0.069	0.060	0.022	0.018	-	-	0.049	0.011	0.186	-	0.077	0.009	-	-	0.140	-	0.185	0.041	-
<i>Sebastes</i> spp. V	rockfishes	70	0.410	0.090	-	0.117	-	0.092	-	-	0.010	-	0.026	0.037	0.020	-	0.011	-	-	-	0.011
<i>Coryphopterus nicholsi</i>	blackeye goby	58	-	-	-	-	0.031	-	-	-	0.010	0.262	0.038	0.074	0.027	0.048	0.011	-	0.022	-	0.089
<i>Sebastes jordani</i>	shortbelly rockfish	38	0.419	-	-	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ariedius lateralis</i>	smoothhead sculpin	37	-	-	0.011	0.012	-	0.010	-	-	0.010	0.011	-	-	0.010	0.107	0.022	0.010	0.127	0.031	0.023
Cottidae unid.	sculpins	36	0.011	-	0.022	-	-	0.021	-	0.011	0.010	0.022	-	0.009	-	0.020	0.010	-	0.216	-	0.033
<i>Ophiodon elongatus</i>	lingcod	28	0.011	-	-	0.012	-	0.267	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scorpaenichthys marmoratus</i>	cabezon	27	0.011	0.015	-	0.029	0.012	0.226	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Stenobranchius leucopsarus</i>	northern lampfish	20	0.034	-	-	0.018	0.023	0.072	-	-	-	0.021	0.026	0.019	-	-	-	-	0.011	-	-
<i>Ariedius</i> spp.	sculpins	15	-	-	-	-	-	-	-	-	-	0.011	-	-	-	-	-	-	0.154	-	-
Pholididae unid.	gunnels	15	-	-	0.022	0.018	0.023	0.010	0.025	-	0.072	-	-	-	-	-	-	-	-	-	-
<i>Sebastes</i> spp.	rockfishes	14	0.011	-	0.011	-	-	0.072	-	0.010	-	0.011	-	-	-	-	0.021	-	-	0.011	-
Chaenopsidae unid.	tube blennies	13	-	-	-	-	-	-	-	0.093	-	0.011	0.013	0.009	-	-	-	-	0.011	-	-
<i>Lepidogobius lepidus</i>	bay goby	13	-	-	-	0.111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.067
<i>Diaphus theta</i>	California headlight fish	12	-	-	-	-	0.124	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes</i> spp. V_D	rockfishes	12	-	-	-	-	-	-	-	-	0.011	0.013	0.027	0.054	-	-	-	-	0.011	-	-
<i>Oligocottus maculosus</i>	tidepool sculpin	11	-	-	-	-	-	-	-	-	-	-	-	-	0.019	0.032	-	0.054	0.011	-	-
<i>Liparis</i> spp.	snailfishes	10	-	-	-	-	-	-	-	-	-	-	-	0.010	0.019	0.011	0.019	0.033	-	0.011	-
Clinidae unid.	clinid kelpfishes	7	-	-	-	-	0.010	-	-	-	-	-	-	-	-	-	0.057	-	-	-	-
<i>Neoclinus</i> spp.	fringeheads	7	0.011	0.015	-	-	0.041	-	-	-	-	-	-	-	-	-	-	0.011	-	-	-
<i>Bathylagus ochotensis</i>	popeye blacksmelt	6	-	-	-	-	0.052	-	-	-	-	-	-	-	0.010	-	-	-	-	-	-
Bathymasteridae unid.	ronquils	4	-	-	-	0.018	0.020	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-
<i>Chirolophis nugator</i>	mosshead warbonnet	4	-	-	-	0.012	0.031	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Merluccius productus</i>	Pacific hake	4	0.035	-	-	-	-	-	0.011	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronectes bilineatus</i>	rock sole	4	-	-	-	-	-	-	-	-	-	-	0.009	-	0.029	-	-	-	-	-	-
<i>Ruscarius creaseri</i>	roughcheek sculpin	4	-	-	-	-	0.010	-	-	-	-	0.012	-	-	-	0.011	-	-	-	-	0.011
Blennioidei	blennies	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.033	-	-	-
<i>Gobiesox maeandricus</i>	northern clingfish	3	-	-	-	-	0.031	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes saxicola</i>	stripetail rockfish	3	0.033	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Climocottus analis</i>	wooly sculpin	2	-	-	-	-	-	-	-	-	-	0.012	-	-	0.010	-	-	-	-	-	-
<i>Genyonemus lineatus</i>	white croaker	2	-	-	-	0.023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	2	-	-	-	-	-	-	-	-	-	-	0.018	-	-	-	-	-	-	-	-
larval/post-larval fish, unid.		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.022	-	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-
Bathylagidae	blacksmelts	1	-	-	-	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclopteridae unid.	snailfishes	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.011	-	-	-
<i>Engraulis mordax</i>	northern anchovy	1	-	-	-	0.012	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gobiesox</i> spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-	0.009	-	-	-	-	-	-	-	-
<i>Heterostichus rostratus</i>	giant kelpfish	1	-	-	-	0.012	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Leptocottus armatus</i>	staghorn sculpin	1	-	-	-	0.018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.011	-	-	-
<i>Nannobranchium</i> spp.	lanternfishes	1	-	-	0.011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Osmeridae unid.	smelts	1	-	-	-	0.018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	righteye flounders	1	-	-	-	-	-	-	-	-	-	-	-	-	0.010	-	-	-	-	-	-
<i>Sardinops sagax</i>	Pacific sardine	1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.011	-	-	-	-	-
<i>Sebastes</i> spp. VD	rockfishes	1	-	-	-	-	-	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes</i> spp. VP	rockfishes	1	-	-	-	-	-	-	-	-	-	-	0.009	-	-	-	-	-	-	-	-
<i>Sebastes</i> spp. V	rockfishes	1	-	-	-	-	-	-	-	-	-	0.013	-	-	-	-	-	-	-	-	-
<i>Tarletonbeania crenularis</i>	blue lanternfish	1	0.011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Typhlogobius californiensis</i>	blind goby	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.010	-	-	-	-
larval fish fragment		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.011	-	-	-
Total		1252	1.171	0.285	0.122	0.630	0.129	1.409	0.074	0.633	0.464	0.501	0.663	0.941	0.763	0.609	0.671	0.196	2.532	0.567	1.135

Table H-7 (continued). 1991: Density of larval fishes (#/m³) collected in Intake Cove surface plankton tows at DCP.

1991	Survey	B301	B304	B306	B308	B310	B312	B314	B316	B318	B320	B322	B324	B326	B328	B330	B332	B334	B336	B338	B340	B342	B344	B346	B348	B350	B352	B360	B362	B364	B366	B368	B370	B372	B374	B376	B378	B380	B382	B383	B385	B387	B389			
	Number of samples sorted	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			
	Date	01/04	01/11	01/18	01/25	02/01	02/08	02/15	02/22	03/05	03/08	03/15	03/22	03/29	04/05	04/12	04/19	04/26	05/03	05/10	05/16	05/24	05/31	06/07	06/14	06/21	07/02	09/13	09/20	09/27	10/04	10/11	10/18	10/25	11/01	11/08	11/15	11/22	11/27	12/06	12/13	12/20	12/27			
Taxa / Common Name	Total # of Individuals per Taxa																																													
Hexagrammidae unid. greenlings	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	0.006	-	-	
Nannobranchium regalis pinpoint lampfish	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.012	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Paralichthys californicus California halibut	2	-	-	-	-	-	0.009	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Platichthys stellatus starry flounder	2	-	-	-	-	0.008	-	-	-	-	-	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Pleuronichthys spp. turbot	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.013	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sardinops sagax Pacific sardine	2	-	-	-	0.009	-	-	-	-	-	0.008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Synodus lucioceps California lizardfish	2	0.009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
poss. Gonostomatidae possible bristlemouths	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
poss. Oligocottus spp. possible sculpins	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Aulorhynchus flavidus tubesnout	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Brosomphycis marginata red brotula	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Chilara taylori spotted cusk-eel	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-	-		
Hexagrammos decagrammus kelp greenling	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	
Kyphosidae sea chubs	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Lythrypnus spp. gobies	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Microstomus pacificus Dover sole	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Osmeridae unid. smelts	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Pleuronichthys verticalis homyhead turbot	1	-	-	-	-	-	0.009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Radulimus spp. sculpins	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes mystinus blue rockfish	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sebastes spp. V_D rockfishes	1	-	-	-	-	-	-	-	-	-	0.008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Syngnathidae unid. pipefishes	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Zanolepis frenata shortspine combfish	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
poss. Gobiesox spp. possible clingfishes	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	4349	0.766	1.182	0.758	1.788	1.955	1.803	0.440	2.244	0.228	0.449	0.227	0.121	0.521	0.067	0.299	3.896	0.284	0.186	0.274	0.262	0.899	0.300	1.356	1.064	0.403	0.137	0.440	0.435	0.222	0.098	0.568	0.130	0.467	0.555	0.059	0.265	0.201	0.325	0.803	0.236	2.497	1.713			

Table H-9. 1993: Density of larval fishes (#/m³) collected in Inlake Cove surface plankton tows at DCPD. (NS = no samples collected)

Taxa / Common Name	Survey	Number of samples sorted	Date	Total # of Individuals per Towa	B530	B532	B534	B536	B538	B540	B542	B544	B546	B548	B550	B552	B554	B556	B558	B560	B562	B564	B566	B568	B570	B572	B574	B576	B578	B580					
<i>Egglestonia mordax</i>		587	3	0.007	0.007	0.008	0.028	0.052	0.021	0.019	0.009	0.009	0.045	0.075	0.008	0.008	0.027	0.066	0.019	0.007	0.008	0.016	0.026	0.017	0.015	0.068	0.057	0.006	0.027	0.022					
<i>Gobionina</i> spp.		348	3	0.052	0.043	0.023	0.111	0.045	0.052	0.021	0.010	0.010	0.045	0.075	0.008	0.016	0.027	0.066	0.019	0.007	0.008	0.016	0.026	0.017	0.015	0.068	0.057	0.006	0.027	0.022					
<i>Gobionina</i> und.		264	3	0.008	0.008	0.008	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008				
<i>Chirocentrus sordidus</i>		238	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007				
<i>Schistoceros</i> spp. V. De		229	3	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015			
<i>Arctichthys lateralis</i>		200	3	0.022	0.016	0.016	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013			
<i>Stenobrachius leucostictus</i>		199	3	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007			
<i>Stenobrachius leucostictus</i> und.		194	3	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007		
<i>Chirocentrus nigricaudus</i>		175	3	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007		
<i>Chirocentrus nigricaudus</i> und.		175	3	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	
<i>Chirocentrus nigricaudus</i> und.		136	3	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015		
<i>Chirocentrus nigricaudus</i> und.		72	3	0.007	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035		
<i>Chirocentrus nigricaudus</i> und.		63	3	0.007	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	
<i>Pleuronectes und.</i>		59	3	0.007	0.024	0.024	0.007	0.007	0.021	0.040	0.040	0.040	0.009	0.023	0.023	0.016	0.016	0.066	0.019	0.015	0.033	0.061	0.038	0.008	0.042	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	
<i>Pleuronectes und.</i>		40	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	
<i>Stenobrachius leucostictus</i>		37	3	0.008	0.008	0.008	0.049	0.049	0.008	0.008	0.019	0.019	0.018	0.015	0.015	0.015	0.015	0.007	0.015	0.010	0.008	0.008	0.019	0.019	0.008	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	
<i>Leptocottus armatus</i>		36	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	
<i>Leptocottus armatus</i> und.		34	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	
<i>Pleuronectes und.</i>		34	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Pleuronectes und.</i>		33	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Scopelogadus marmoratus</i>		29	3	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	
<i>Chirocentrus nigricaudus</i>		25	3	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
<i>Chirocentrus nigricaudus</i> und.		23	3	0.007	0.007	0.0																													

Table H-9 (continued). 1993: Density of larval fishes (#/m³) collected in Intake Cove surface plankton tows at DCP. (NS = no samples collected)

1993		Survey	B582	B584	B586	B588	B590	B592	B594	B596	B598	B600	B602	B604	B606	B608	B610	B612	B614	B616	B618	B620	B622	B624	B626	B628	B630	B632	
		Number of samples sorted	3	3	3	3	3	3	3	3	0	3	3	3	3	3	2	2	3	2	3	3	3	3	3	3	3	3	
		Date	07/09	07/15	07/23	07/28	08/06	08/13	08/20	08/27	09/03	09/10	09/17	09/24	10/01	10/08	10/15	10/22	10/29	11/05	11/12	11/19	11/24	12/03	12/10	12/17	12/22	12/30	
Taxa / Common Name		Total # of Individuals per Taxa									NS																		
<i>Engraulis mordax</i>	northern anchovy	587	-	-	-	-	-	-	0.147	0.098	-	0.133	0.180	0.014	0.148	0.037	6.316	0.062	-	-	0.008	0.007	0.044	0.017	0.045	0.065	0.197	0.008	
<i>Gibbonista</i> spp.	clind kelpfishes	348	0.038	0.007	0.014	-	0.144	0.062	0.074	0.052	-	0.598	0.123	0.124	0.109	0.096	0.017	0.028	0.020	-	0.096	0.040	-	0.042	0.009	0.007	0.121	0.024	
Gobiidae unid.	gobies	264	0.007	-	-	-	0.616	0.014	-	-	-	-	-	0.014	0.007	-	-	-	-	-	-	0.027	-	-	-	-	-	-	
<i>Citharichthys sordidus</i>	Pacific sanddab	258	-	-	-	-	-	-	0.245	0.322	-	-	0.878	0.035	0.428	0.037	0.078	0.083	0.029	-	-	0.007	0.007	-	-	-	-	0.016	
<i>Sebastes</i> spp. V De	rockfishes	229	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Artedius lateralis</i>	smoothhead sculpin	200	0.007	-	0.007	-	0.042	-	0.020	-	-	-	0.011	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Orthopristis triacis</i>	snubnose sculpin	199	-	0.007	0.021	-	0.034	0.054	0.078	0.008	-	0.278	0.039	-	0.107	0.015	-	-	-	0.012	0.008	0.007	-	-	-	-	0.011	-	
Süchacidae unid.	pricklebacks	184	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Genyonemus lineatus</i>	white croaker	179	-	-	-	-	-	-	-	0.009	-	0.007	0.041	0.014	0.053	0.132	0.340	0.104	-	-	0.008	0.034	0.088	0.108	0.018	0.007	0.154	0.016	
<i>Coryphopterus nicholsi</i>	blackeye goby	175	0.022	-	0.097	0.110	0.028	0.014	0.054	0.033	-	0.029	0.049	0.069	0.026	0.029	0.250	0.007	-	-	0.008	-	-	-	-	-	-	-	
Cottidae unid.	sculpins	136	-	-	-	-	0.006	0.007	0.040	-	-	0.125	-	0.014	0.028	-	-	0.007	0.010	-	-	-	-	0.025	-	-	-	-	
Chaenopsidae unid.	tube blennies	72	-	-	0.007	-	-	-	0.006	-	-	0.089	0.011	0.042	0.007	0.029	0.086	0.069	0.010	-	-	-	0.022	-	-	-	0.022	-	
<i>Citharichthys stigmaeus</i>	speckled sanddab	63	-	-	-	-	-	-	0.066	0.069	-	-	0.030	0.041	0.061	0.022	0.074	0.035	0.069	-	-	0.007	-	-	-	0.007	-	0.008	
<i>Oligocottus</i> spp.	sculpins	59	0.015	-	-	-	-	-	-	-	-	0.007	-	-	-	0.007	-	-	-	-	0.008	-	-	-	-	-	-	0.022	0.008
Pleuronectiformes unid.	flatfishes	40	-	-	-	-	-	-	-	-	-	-	0.053	-	0.006	0.022	-	0.207	-	-	-	-	-	-	-	-	-	-	
<i>Stenobranchius leucopsarus</i>	northern lampfish	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	0.010	-	-	-	0.027	0.015	-	0.009	0.021	0.011	-
Bathymasteridae unid.	ronquils	36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Liparis</i> spp.	snailfishes	34	0.008	-	0.007	0.020	-	-	0.006	-	-	-	0.051	-	-	0.029	-	-	-	0.011	-	-	-	-	-	-	-	0.011	-
Pleuronectidae unid.	righteye flounders	34	-	-	-	-	-	-	-	0.028	0.094	-	0.120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pholididae unid.	gunnels	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scorpaenichthys marmoratus</i>	cabezon	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-
<i>Cebidichthys violaceus</i>	monkey face eel	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.061	0.029	0.008	-	0.036	0.022	0.016	
<i>Oligocottus maculosus</i>	tidepool sculpin	23	-	0.008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes</i> spp. V	rockfishes	23	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Typhlogobius californiensis</i>	blind goby	23	0.008	0.015	-	0.034	-	-	-	-	-	-	0.010	0.007	-	0.022	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gobtesox</i> spp.	clingfishes	19	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Lepidogobius lepidus</i>	bay goby	18	-	-	-	-	0.006	-	-	-	-	-	-	-	-	-	0.017	-	-	-	-	-	0.007	-	-	-	-	-	-
<i>Sebastes</i> spp. VD	rockfishes	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Climacottus analis</i>	wooly sculpin	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Climacottus</i> spp.	sculpins	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ruscarius creaseri</i>	roughcheek sculpin	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes</i> spp.	rockfishes	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.008
larval/post-larval fish, unid.		11	-	-	-	0.007	-	-	-	-	-	-	0.030	-	-	-	0.074	-	-	-	-	-	-	-	-	-	-	-	-
<i>Oxyblebis pictus</i>	painted greenling	10	0.007	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hypsoblennius</i> spp.	blennies	8	-	-	-	-	-	-	-	0.009	-	-	-	-	-	0.015	-	0.007	-	-	-	0.007	-	-	0.017	-	0.007	0.011	-
<i>Lepidocottus armatus</i>	staghorn sculpin	8	-	-	-	-	-	-	0.007	-	-	-	-	0.021	-	-	-	-	-	-	-	-	0.014	-	-	-	-	-	-
<i>Bathylagus ochotensis</i>	popoeye blacksmelt	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Merluccius productus</i>	Pacific hake	7	-	-	-	-	-	-	-	-	-	-	0.020	0.007	0.007	-	-	-	-	-	-	0.007	-	-	-	0.007	-	-	-
<i>Neoclinus</i> spp.	fringeheads	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.079	-	-	-	-	-	-	-	-	-	-	-	-
<i>Paralichthys californicus</i>	California halibut	7	-	-	-	0.007	0.007	-	-	-	-	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
larval fish fragment		6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	0.019	-	-	-	-	-	-	-	-	-	-
<i>Sebastes</i> spp. V D	rockfishes	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Brosomphycis marginata</i>	red brotula	4	-	-	-	0.007	-	-	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sciaenidae unid.	croakers	4	-	-	-	-	0.013	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Artedius</i> spp.	sculpins	3	-	-	-	-	-	-	0.014	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Atherinopsis californiensis</i>	jacksmelt	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Blennioidae	blennies	3	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Nannobranchium</i> spp.	lanternfishes	3	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	0.007	-	-	-	-	-	-	-
<i>Platichthys stellatus</i>	starry flounder	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pleuronectes bilineatus</i>	rock sole	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Triphoturus mexicanus</i>	Mexican lampfish	3	-	-	-	-	-	-	-	0.017	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-
<i>Citharichthys</i> spp.	sanddabs	2	-	-	-	-	-	-	-	-	-	-	0.007	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclopteridae unid.	snailfishes	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diogenichthys atlanticus</i>	longfin lanternfish	2	-	-	-	-	-	-	-	-	-	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Leuroglossus stibitus</i>	California smoothtongue	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Peprilus simillimus</i>	Pacific butterfish	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.017	-	-	-	-	-	0.007	-	-	-	-	-	-
<i>Psettichthys melanostictus</i>	sand sole	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Radulinus</i> spp.	sculpins	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinidae unid.	silversides	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Chilara taylori</i>	spotted cusk-eel</																												

Table H-10. 1994: Density of larval fishes (#/m³) collected in Intake Cove surface plankton tows at DCP.

1994		Survey	B634	B636	B638	B640	B642	B644	B646	B648	B650	B652	B654	B656	B658	B660	B662	B664	B666	B668	B670	B672	B674	B676	B678	B680	B682	B729	B731	B733	B735	B737	
		Number of samples sorted	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	2	3	3	3	3	3	3	2	3	3	3	3	3	
		Date	01/07	01/14	01/21	01/28	02/04	02/11	02/18	02/25	03/04	03/11	03/18	03/25	04/01	04/08	04/15	04/22	04/29	05/06	05/13	05/20	05/27	06/03	06/10	06/17	06/24	12/02	12/09	12/16	12/23	12/30	
Taxa / Common Name		Total # of Individuals per Taxa																															
<i>Stenobranchius leucopsarus</i>	northern lampfish	617	0.304	0.036	3.506	0.009	0.080	0.035	0.009	0.129	0.104	0.098	0.013	-	0.008	0.016	0.151	0.008	0.049	-	0.008	0.007	-	-	-	-	-	-	-	-	-	-	0.015
<i>Engraulis mordax</i>	northern anchovy	551	0.562	0.029	2.850	-	0.016	0.101	0.009	0.035	0.377	-	-	0.010	-	-	-	-	-	-	-	0.008	-	-	-	-	-	0.007	0.057	-	-	-	
<i>Sebastes</i> spp. V_De	rockfishes	448	-	-	0.104	-	-	-	-	-	-	0.014	-	-	0.015	0.059	0.046	0.022	0.204	0.042	2.749	0.060	0.069	0.076	0.014	-	0.010	-	-	-	-		
<i>Gibbonsia</i> spp.	climid kelpfishes	341	0.022	0.058	0.091	-	-	0.022	0.009	0.083	0.050	0.926	0.085	0.020	-	0.017	0.047	-	0.049	0.021	0.102	0.030	0.150	0.124	0.210	0.196	0.112	0.014	0.029	0.056	-		
<i>Genyonemus lineatus</i>	white croaker	338	0.058	0.058	0.484	0.036	0.016	0.128	-	0.142	1.412	0.014	-	-	0.008	-	0.008	-	-	-	-	-	-	-	0.007	-	-	0.007	0.014	-	-	0.008	
<i>Artedius lateralis</i>	smoothhead sculpin	306	-	-	-	0.018	-	0.021	-	-	0.169	0.256	0.012	0.039	0.015	-	-	0.008	0.008	0.487	-	0.215	0.110	0.139	0.096	0.410	0.254	-	-	-	-		
<i>Sardinops sagax</i>	Pacific sardine	229	-	-	1.704	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	
Cottidae unid.	sculpins	174	-	0.015	0.007	-	-	-	-	0.013	0.021	0.076	0.024	0.010	0.014	0.025	0.016	0.008	0.033	0.179	0.127	0.103	0.088	0.068	0.228	0.143	0.071	-	-	-	-		
Gobiidae unid.	gobies	160	-	-	-	-	-	0.014	-	0.007	0.118	0.116	-	0.049	0.133	0.008	0.008	0.186	0.033	0.050	0.024	0.037	0.027	0.132	0.144	0.063	0.020	-	-	-	-		
<i>Sebastes</i> spp. V	rockfishes	155	0.007	0.014	0.567	0.018	0.081	0.323	0.018	0.028	0.007	0.021	0.012	-	-	-	0.008	-	0.016	0.007	-	-	0.007	-	-	-	-	0.007	-	-	-	0.015	
<i>Merluccius productus</i>	Pacific hake	135	0.007	-	0.090	0.106	0.143	0.007	0.055	0.184	0.348	0.042	-	-	-	-	-	-	0.016	0.007	-	-	-	-	-	-	-	-	-	-	-	0.015	
<i>Oligocottus</i> spp.	sculpins	132	-	0.007	0.030	0.009	0.007	0.007	0.009	0.158	0.007	0.014	0.182	0.010	0.022	0.041	0.008	0.022	0.008	0.079	0.078	0.169	0.041	0.014	0.015	0.053	-	-	0.049	-	-		
<i>Orithonotus triacis</i>	snubnose sculpin	127	-	0.014	0.045	-	-	0.014	-	0.007	0.120	0.028	-	-	-	-	0.015	0.008	0.024	0.072	0.016	0.052	0.103	0.083	0.121	0.132	0.051	0.014	-	-	-		
Stichaeidae unid.	pricklebacks	126	-	-	-	-	-	-	0.009	0.021	-	0.028	0.050	0.029	0.015	0.050	0.168	0.015	0.074	0.093	0.064	0.059	0.178	0.028	0.049	0.021	-	-	-	-	0.008		
<i>Scorpaenichthys marmoratus</i>	cabezon	89	0.007	0.007	0.045	-	-	-	0.009	0.014	0.027	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.249	-	0.040	-	0.251	
<i>Oligocottus maculosus</i>	tidepool sculpin	86	-	-	0.007	-	-	0.007	-	-	0.007	0.043	-	-	-	-	0.008	-	0.058	0.102	0.059	0.164	0.084	0.044	0.007	0.041	-	-	-	-	-		
<i>Liparis</i> spp.	snailfishes	84	-	-	0.007	-	-	-	-	0.007	0.007	-	-	-	0.007	-	-	0.008	0.008	0.093	-	0.104	0.089	0.034	0.076	0.121	0.030	0.007	-	-	-	-	
Bathymasteridae unid.	ronquils	76	-	-	-	-	-	0.014	-	-	-	-	-	-	-	-	0.008	0.008	0.115	-	0.279	0.062	0.007	0.053	-	-	-	-	-	-	-	-	
<i>Sebastes</i> spp. VD	rockfishes	63	0.007	-	0.180	-	0.159	0.021	-	0.014	-	0.028	-	0.020	-	0.008	0.015	-	0.024	-	-	-	-	-	-	-	-	-	0.007	-	-	-	
<i>Cebidichthys violaceus</i>	monkeyface eel	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.016	-	0.008	-	-	-	0.150	0.014	0.047	0.134	0.031	-	-	-	-	-	
Chaenopsidae unid.	tube blennies	31	-	-	-	0.008	-	-	0.007	-	-	0.026	-	-	0.008	0.015	-	-	0.035	0.039	0.015	0.075	-	-	-	-	0.010	-	-	-	-		
<i>Coryphopterus nicholsti</i>	blackeye goby	31	-	-	-	-	0.024	-	0.019	-	-	0.063	-	-	0.015	0.008	0.008	-	-	0.014	-	0.023	0.020	0.007	0.006	0.007	0.020	-	-	-	-	-	
<i>Gobtesox</i> spp.	clingfishes	27	-	-	-	-	-	0.009	-	-	-	-	0.025	-	0.014	0.025	0.008	-	-	-	-	0.008	0.007	-	-	0.020	0.132	-	-	-	-	-	
<i>Leptocottus armatus</i>	staghorn sculpin	25	-	-	0.007	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	0.079	-	0.089	-	-	-	-	-	-	-	-	-	-	
Blennioidei	blennies	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.008	-	0.013	0.007	0.110	0.013	-	-	-	-	-	-	
<i>Sebastes</i> spp. VP	rockfishes	20	-	-	0.149	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Citharichthys sordidus</i>	Pacific sanddab	19	0.022	-	0.090	-	-	-	-	-	0.014	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	0.007	-	-	-	
<i>Oxylebius pictus</i>	painted greenling	15	-	0.007	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	0.007	-	-	-	-	-	-	-	-	
Pholididae unid.	gunnels	15	-	-	-	-	-	-	0.009	0.021	-	0.007	-	0.059	-	0.025	0.008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ruscarius creaseri</i>	roughcheek sculpin	14	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	-	0.008	0.008	-	-	0.015	0.014	-	0.006	0.042	-	-	-	-	-	-	
<i>Clinocottus analis</i>	wooly sculpin	11	-	-	-	-	-	-	-	-	0.007	-	-	0.010	-	-	-	-	0.007	0.008	-	0.008	0.014	-	0.021	0.013	-	-	-	-	-	-	
<i>Icelinus</i> spp.	sculpins	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.044	0.007	0.007	-	0.021	-	-	-	-	-	-	
<i>Radulinus</i> spp.	sculpins	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.055	-	0.020	-	-	-	-	-	-	-	
<i>Atherinopsis californiensis</i>	jacksmelt	10	-	-	-	-	-	-	0.007	0.065	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Bathylagus ochotensis</i>	popeye blacksmelt	9	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Neoclinus</i> spp.	fringeheads	9	-	-	0.008	-	-	-	0.007	-	0.022	-	-	0.007	-	-	-	-	-	0.014	-	0.007	-	-	-	-	-	-	-	-	-	-	
Pleuronectidae unid.	righteye flounders	9	-	-	-	-	-	-	-	-	0.042	0.022	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Artedius</i> spp.	sculpins	7	-	-	-	-	-	-	-	-	0.014	0.036	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Pleuronectes bilineatus</i>	rock sole	7	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	0.015	0.007	0.021	-	-	-	-	-	-	-	
<i>Sebastes</i> spp.	rockfishes	7	-	-	0.022	-	-	-	-	-	-	0.021	-	-	-	-	-	-	0.008	-	-	-	-	-	-	-	-	-	-	-	-	-	
larval fish fragment		7	-	-	0.046	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Citharichthys stigmaeus</i>	speckled sanddab	5	0.014	-	0.015	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hexagrammidae unid.	greenlings	5	-	-	0.007	-	-	-	-	-	0.021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007
<i>Lepidogobius lepidus</i>	bay goby	4	-	-	0.015	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sebastes</i> spp. V_D	rockfishes	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.014	0.008	0.007	-	-	-	0.007	-	-	-	-	-	-	-
<i>Typhlogobius californiensis</i>	blind goby	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.008	-	-	0.008	-	-	0.007	0.007	-	-	-	-	-	-	-	-
Atherinidae unid.	silversides	3	-	-	-	-	-	-	-	0.020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Nannobranchium</i> spp.	lanternfishes	3	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	0.008	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-
<i>Ophiodon elongatus</i>	lingcod	3	-	-	0.008	-	-	-	-	-	0.014	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish, unid.		3	-	-	-	-	-	0.0																									

Table H-11. 1995: Density of larval fishes (#/m³) collected in Intake Cove surface plankton tows at DCP. (NS = no sample collected)

1995		Survey	B739	B741	B743	B745	B747	B749	B751	B753	B755	B757	B759	B761	B763	B765	B767	B769	B771	B773	B775	B777	B779	B781	B783	B785	B787	B789	B833	B835	B837	B839	B841
		Number of samples sorted	3	3	3	3	3	3	3	3	3	0	3	3	3	3	3	3	3	3	2	3	3	3	3	0	0	3	3	3	3	0	3
		Date	01/06	01/13	01/20	01/27	02/03	02/10	02/17	02/24	03/03	03/10	03/17	03/24	03/31	04/07	04/14	04/19	04/28	05/05	05/12	05/19	05/26	06/02	06/09	06/16	06/23	06/30	12/01	12/08	12/15	12/22	12/29
Taxa / Common Name		Total # of Individuals per Taxa										NS													NS	NS						NS	
<i>Geryonemus lineatus</i>	white croaker	334	-	0.106	0.114	0.028	-	0.083	0.381	0.096	-	0.042	-	0.074	0.103	-	-	0.027	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	0.202
Gobiidae unid.	gobies	213	-	-	-	-	-	-	-	-	-	0.028	-	0.066	0.110	0.007	0.008	0.082	0.020	0.119	0.013	0.303	-	0.775	-	0.016	-	-	-	-	-	-	
Stichaeidae unid.	pricklebacks	182	-	0.009	-	-	-	-	-	-	0.137	-	0.035	-	0.217	0.082	0.029	0.016	0.296	0.314	0.043	-	0.007	-	0.133	-	-	-	-	-	-	-	
<i>Gibbonsia</i> spp.	clinid kelpfishes	161	-	0.009	0.519	0.063	0.010	0.007	0.022	0.007	0.008	-	0.035	0.009	0.015	0.007	0.021	-	0.075	0.083	0.032	-	0.098	0.062	0.063	-	0.075	0.007	0.008	0.019	-	-	
<i>Artedius lateralis</i>	smoothhead sculpin	145	-	0.008	-	-	0.010	-	-	-	-	-	0.042	0.009	0.095	0.139	0.084	0.008	0.054	0.133	0.108	0.034	0.078	-	0.174	-	0.016	-	-	-	-	-	
<i>Sebastes</i> spp. V_De	rockfishes	140	-	-	-	-	-	-	0.007	0.140	0.031	-	0.099	-	0.037	0.043	0.085	-	0.089	0.165	-	0.040	0.084	0.082	0.077	-	0.031	-	-	-	-	-	
<i>Pleuronectiformes</i> unid.	flatfishes	132	-	-	-	-	-	-	-	-	-	-	-	-	0.043	0.897	-	-	0.014	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Orthonopias triacis</i>	snubnose sculpin	91	-	-	-	-	-	-	0.007	0.015	0.081	-	0.021	-	0.029	0.051	-	-	0.047	0.105	0.011	0.027	0.071	-	0.167	-	0.015	-	-	-	-	-	
<i>Engraulis mordax</i>	northern anchovy	82	-	0.037	-	0.007	-	0.015	0.022	0.074	-	-	0.021	-	-	0.037	-	-	0.007	0.007	-	-	-	-	-	-	-	0.097	0.109	0.009	-	0.178	
<i>Sebastes</i> spp. V	rockfishes	62	-	0.090	0.039	0.028	-	0.060	0.029	0.128	0.055	-	0.007	-	-	-	-	-	0.007	-	-	0.013	0.014	0.007	-	-	-	-	-	-	-	-	
Cottidae unid.	sculpins	61	-	-	0.008	-	-	-	-	-	-	-	-	-	0.008	0.051	0.007	-	0.089	0.125	0.043	0.014	0.070	0.007	0.014	-	-	-	0.007	-	-	-	
<i>Liparis</i> spp.	snailfishes	57	-	-	0.008	-	-	-	-	-	0.008	-	0.007	-	-	0.015	0.021	0.007	0.020	0.071	0.086	0.020	0.043	0.028	0.084	-	0.015	-	0.007	-	-	-	
<i>Stenobrachius leucopsarus</i>	northern lampfish	48	-	-	-	0.014	-	0.007	0.007	0.210	-	0.007	-	0.015	0.030	0.007	-	-	0.007	-	-	0.027	0.014	-	-	-	-	-	-	-	-	0.008	
<i>Coryphopterus nicholsi</i>	blackeye goby	40	-	-	-	-	-	-	0.007	0.037	0.024	-	-	0.007	0.015	0.028	-	-	0.020	-	-	0.041	-	0.014	0.021	-	0.031	0.007	0.031	0.029	-	-	
Bathymasteridae unid.	ronquils	35	-	-	-	-	-	-	-	-	0.008	-	-	-	0.036	0.014	-	-	0.061	0.014	0.097	0.007	0.021	0.013	0.007	-	-	-	-	-	-	-	
<i>Scorpaenichthys marmoratus</i>	cabezon	29	-	0.025	0.008	0.014	0.020	-	0.050	0.022	0.008	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	0.063	-	-	-	
<i>Oligocottus</i> spp.	sculpins	25	-	-	0.038	0.007	-	-	0.008	-	-	-	0.014	-	-	-	0.028	-	0.027	0.013	0.032	-	-	-	0.021	-	-	-	-	-	-	-	
<i>Oligocottus maculosus</i>	tidpool sculpin	22	0.008	-	-	-	-	-	-	-	-	-	-	-	-	0.035	-	-	-	0.063	-	-	0.014	0.007	0.021	-	0.016	-	-	-	-	-	
<i>Cebidichthys violaceus</i>	monkeyface eel	20	-	-	-	-	-	-	-	0.015	0.008	-	-	-	0.014	0.008	0.007	-	0.014	0.042	-	-	0.022	-	0.014	-	-	-	-	-	-	-	
<i>Citharichthys sordidus</i>	Pacific sanddab	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.028	0.087	-	-	0.031	
<i>Clinocottus analis</i>	wooly sculpin	17	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	0.007	-	-	-	-	0.007	0.064	-	0.028	-	-	-	-	0.010	-	-	
<i>Parophrys vetulus</i>	English sole	17	-	-	-	-	-	-	0.007	0.007	-	-	-	-	0.089	-	-	0.007	-	-	-	0.007	0.007	-	-	-	-	-	-	-	-	-	
Sciaenidae unid.	croakers	15	-	-	-	0.048	-	-	0.057	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Sebastes</i> spp. V_D	rockfishes	15	-	-	-	-	-	0.008	-	-	0.017	-	-	-	-	-	-	-	0.007	0.058	-	-	0.014	0.007	-	-	-	-	-	-	-	-	
Chaenopsidae unid.	tube blennies	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.061	0.021	-	-	0.014	-	-	-	-	-	-	-	-	-	
<i>Sebastes</i> spp. VD	rockfishes	13	-	-	-	-	-	0.008	-	0.008	-	-	0.042	-	0.007	0.022	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	
<i>Merluccius productus</i>	Pacific hake	12	-	-	-	-	-	-	0.029	-	-	-	-	-	-	-	0.007	-	-	-	-	-	0.007	-	-	-	-	0.007	0.036	-	-	-	
<i>Bothrogomus swanii</i>	rockhead	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	-	0.007	0.057	-	-	-	-	-	-	0.015	-	-	-	-	-	
Pholididae unid.	gunnels	11	-	-	0.031	0.014	-	-	-	-	-	-	0.014	-	0.008	0.014	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Artedius</i> spp.	sculpins	9	-	0.009	-	-	-	-	-	-	0.041	-	-	-	-	-	-	-	-	-	-	-	-	-	0.014	-	0.015	-	-	-	-	-	
<i>Citharichthys stigmaeus</i>	speckled sanddab	9	-	0.009	0.008	0.028	-	-	-	-	-	-	-	-	0.023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
larval fish - damaged		9	-	-	0.023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.042	-	-	-	-	-	-	-	
<i>Leptocottus armatus</i>	staghorn sculpin	8	-	-	-	-	-	-	0.007	-	-	-	-	-	0.015	-	-	0.014	-	0.022	0.007	-	-	-	-	-	-	-	-	-	-	-	
<i>Oxylebius pictus</i>	painted greenling	7	-	0.008	-	-	-	-	0.007	0.015	0.008	-	-	-	0.007	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	
<i>Sebastes</i> spp. V_D	rockfishes	6	-	-	-	-	-	-	-	-	0.037	-	-	-	0.008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Tarletonbeania crenularis</i>	blue lanternfish	6	-	-	-	-	-	-	-	0.014	-	-	-	-	-	-	-	-	-	-	-	-	0.014	-	-	-	-	-	0.014	-	-	-	
larval fish fragment		6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.034	-	-	-	0.007	-	-	-	-	-	-	-	-	
<i>Atherinopsis californiensis</i>	jacksmelt	5	-	-	-	0.028	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Bathylagus ochotensis</i>	pop-eye blacksmelt	5	-	-	-	-	-	-	-	0.007	-	-	-	-	-	-	-	-	-	-	-	0.007	0.014	-	0.007	-	-	-	-	-	-	-	
Engraulidae	anchovies	5	-	-	-	0.028	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.016	-	-	-	-	-	
<i>Lepidogobius lepidus</i>	bay goby	5	-	-	-	-	-	-	-	-	-	0.007	-	-	0.008	-	-	-	-	-	-	-	0.021	-	-	-	-	-	-	-	-	-	
<i>Ophiodon elongatus</i>	lingcod	5	-	-	-	0.016	0.007	-	0.015	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Paralichthys californicus</i>	California halibut	5	-	-	-	-	-	-	-	-	-	-	-	-	0.037	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Pleuronectidae</i> unid.	righteye flounders	5	-	0.009	-	0.007	-	-	-	-</																							

Appendix I

Estimated Number of Target Taxa Larvae Entrained
per Week.

Table I-1. Cancer crab (*Cancer antennarius*/*C. anthonyi*/*C. gracilis*) zoeal stage 1: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	3.54E+06	3.52E+13	4.72E+07	1.72E+07	8.37E+14	5
11	12/09/1996	9.70E+06	4.26E+06	4.97E+13	6.79E+07	2.98E+07	2.44E+15	7
12	12/16/1996	9.70E+06	2.97E+07	3.53E+14	6.79E+07	2.08E+08	1.73E+16	7
13	12/23/1996	9.70E+06	4.17E+06	1.07E+13	6.79E+07	2.92E+07	5.24E+14	7
14	12/30/1996	9.68E+06	2.14E+07	6.90E+14	6.78E+07	1.50E+08	3.39E+16	7
15	01/06/1997	9.69E+06	3.60E+07	1.04E+15	6.79E+07	2.52E+08	5.11E+16	7
16	01/13/1997	9.69E+06	4.05E+07	1.08E+15	6.75E+07	2.82E+08	5.25E+16	7
17	01/20/1997	9.70E+06	3.45E+07	5.75E+14	6.79E+07	2.41E+08	2.81E+16	7
18	01/27/1997	9.70E+06	5.06E+07	2.27E+15	6.68E+07	3.49E+08	1.08E+17	7
19	02/03/1997	9.69E+06	5.97E+07	9.08E+15	6.75E+07	4.16E+08	4.42E+17	7
20	02/10/1997	9.64E+06	3.56E+07	1.05E+15	6.78E+07	2.51E+08	5.17E+16	7
21	02/17/1997	9.71E+06	1.26E+08	5.80E+16	6.76E+07	8.77E+08	2.81E+18	7
22	02/24/1997	9.71E+06	9.35E+07	1.22E+16	6.72E+07	6.47E+08	5.84E+17	7
23	03/03/1997	9.68E+06	2.21E+07	3.59E+14	6.79E+07	1.55E+08	1.77E+16	7
24	03/10/1997	9.70E+06	1.71E+08	2.34E+16	6.75E+07	1.19E+09	1.14E+18	7
25	03/17/1997	9.36E+06	6.43E+08	1.03E+17	6.75E+07	4.64E+09	5.36E+18	7
26	03/24/1997	9.69E+06	7.61E+07	3.73E+15	6.77E+07	5.32E+08	1.82E+17	7
27	03/31/1997	7.31E+06	1.87E+07	2.56E+14	5.18E+07	1.33E+08	1.29E+16	7
28	04/07/1997	9.67E+06	1.86E+08	1.54E+16	6.62E+07	1.27E+09	7.22E+17	7
29	04/14/1997	9.69E+06	1.36E+08	1.50E+16	6.49E+07	9.11E+08	6.73E+17	7
30	04/21/1997	4.91E+06	3.49E+07	2.28E+15	4.04E+07	2.87E+08	1.54E+17	7
31	04/28/1997	4.89E+06	5.08E+06	4.65E+13	3.43E+07	3.56E+07	2.29E+15	7
32	05/05/1997	4.90E+06	3.92E+06	4.47E+13	3.42E+07	2.74E+07	2.18E+15	7
33	05/12/1997	4.91E+06	4.22E+07	6.56E+15	3.44E+07	2.95E+08	3.22E+17	7
34	05/19/1997	4.89E+06	3.14E+07	1.06E+15	3.44E+07	2.21E+08	5.22E+16	7
35	05/27/1997	6.96E+06	4.06E+07	3.14E+15	4.66E+07	2.72E+08	1.41E+17	7
36	06/02/1997	9.70E+06	6.76E+06	2.16E+13	6.18E+07	4.31E+07	8.75E+14	7
37	06/09/1997	9.70E+06	1.83E+08	4.03E+16	6.78E+07	1.28E+09	1.97E+18	7
38	06/16/1997	9.67E+06	1.13E+08	8.23E+15	6.78E+07	7.91E+08	4.05E+17	7
39	06/23/1997	9.71E+06	2.20E+07	8.06E+14	6.78E+07	1.53E+08	3.93E+16	7
40	06/30/1997	9.69E+06	1.66E+07	2.72E+14	6.32E+07	1.08E+08	1.16E+16	7
41	07/07/1997	9.68E+06	9.35E+06	1.09E+14	6.72E+07	6.49E+07	5.26E+15	7
42	07/14/1997	9.69E+06	4.19E+07	1.22E+15	6.78E+07	2.93E+08	5.96E+16	7
43	07/21/1997	9.71E+06	4.23E+07	4.88E+15	6.74E+07	2.93E+08	2.35E+17	7
44	07/28/1997	9.69E+06	7.26E+06	5.66E+13	6.74E+07	5.06E+07	2.74E+15	7
45	08/04/1997	9.69E+06	1.07E+07	3.78E+14	6.78E+07	7.51E+07	1.85E+16	7
46	08/11/1997	9.68E+06	3.56E+06	2.61E+13	6.78E+07	2.49E+07	1.28E+15	7
47	08/18/1997	9.70E+06	2.28E+06	1.83E+13	6.81E+07	1.60E+07	9.01E+14	7
48	08/26/1997	9.70E+06	2.17E+06	7.36E+12	7.41E+07	1.66E+07	4.28E+14	8
49	09/02/1997	9.67E+06	8.20E+06	6.78E+13	5.82E+07	4.94E+07	2.46E+15	6
50	09/08/1997	7.49E+06	4.45E+06	5.10E+13	5.83E+07	3.46E+07	3.08E+15	7
51	09/15/1997	9.68E+06	5.44E+06	5.15E+13	6.78E+07	3.81E+07	2.53E+15	7
52	09/22/1997	9.67E+06	3.67E+06	2.77E+13	6.78E+07	2.57E+07	1.36E+15	7
53	09/30/1997	9.69E+06	3.46E+06	1.31E+13	6.79E+07	2.42E+07	6.42E+14	7
54	10/06/1997	9.70E+06	5.57E+06	2.14E+14	6.80E+07	3.90E+07	1.05E+16	7
55	10/13/1997	9.69E+06	4.82E+06	3.05E+13	6.78E+07	3.38E+07	1.50E+15	7
56	10/21/1997	9.69E+06	6.82E+06	1.32E+13	6.78E+07	4.77E+07	6.47E+14	7
57	10/27/1997	9.81E+06	5.84E+06	2.47E+13	6.61E+07	3.93E+07	1.12E+15	7
58	11/04/1997	9.80E+06	4.39E+06	6.49E+12	6.82E+07	3.05E+07	3.14E+14	7
59	11/10/1997	9.80E+06	6.46E+06	1.73E+14	6.84E+07	4.51E+07	8.40E+15	7
60	11/18/1997	9.76E+06	2.46E+07	2.61E+15	6.86E+07	1.73E+08	1.29E+17	7
61	11/24/1997	9.81E+06	6.66E+06	1.63E+14	6.82E+07	4.63E+07	7.87E+15	7
62	12/02/1997	9.68E+06	1.35E+07	1.71E+14	8.72E+07	1.22E+08	1.38E+16	9

(continued)

Table I-1 (continued). Cancer crab (*Cancer antennarius*/*C. anthonyi*/*C. gracilis*) zoeal stage 1: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	2.36E+07	8.87E+14	6.78E+07	1.65E+08	4.34E+16	7
64	12/16/1997	9.69E+06	3.56E+07	2.29E+15	4.85E+07	1.78E+08	5.72E+16	5
65	12/22/1997	9.70E+06	1.07E+07	5.16E+14	6.78E+07	7.46E+07	2.52E+16	7
66	12/30/1997	9.68E+06	5.61E+07	2.00E+15	6.76E+07	3.92E+08	9.76E+16	7
67	01/05/1998	9.68E+06	4.46E+07	3.71E+15	7.75E+07	3.57E+08	2.38E+17	8
68	01/15/1998	9.67E+06	4.05E+07	3.65E+15	8.72E+07	3.65E+08	2.97E+17	9
69	01/23/1998	9.69E+06	6.26E+07	3.12E+15	6.79E+07	4.38E+08	1.53E+17	7
70	01/28/1998	9.69E+06	3.63E+07	1.25E+15	8.38E+07	3.13E+08	9.31E+16	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	2.51E+07	4.03E+14	1.23E+08	3.27E+08	6.85E+16	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	1.70E+07	2.42E+14	5.15E+07	1.87E+08	2.93E+16	11
75	03/04/1998	4.69E+06	5.28E+07	2.98E+15	2.34E+07	2.64E+08	7.46E+16	5
76	03/09/1998	4.69E+06	6.16E+07	8.78E+15	3.37E+07	4.43E+08	4.54E+17	7
77	03/19/1998	7.29E+06	1.74E+08	5.98E+16	5.44E+07	1.30E+09	3.33E+18	9
78	03/27/1998	8.44E+06	8.97E+07	3.99E+15	5.67E+07	6.03E+08	1.81E+17	7
79	04/01/1998	9.67E+06	5.78E+07	3.30E+15	4.81E+07	2.88E+08	8.18E+16	5
80	04/07/1998	9.73E+06	9.79E+06	9.60E+13	7.73E+07	7.78E+07	6.06E+15	8
81	04/16/1998	9.73E+06	7.83E+07	7.87E+15	1.07E+08	8.58E+08	9.46E+17	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	3.53E+08	2.69E+17	8.72E+07	3.18E+09	2.18E+19	9
84	05/04/1998	9.70E+06	2.37E+08	5.63E+16	6.78E+07	1.66E+09	2.75E+18	7
85	05/14/1998	9.68E+06	3.84E+08	6.60E+16	7.75E+07	3.07E+09	4.23E+18	8
86	05/19/1998	9.70E+06	2.80E+07	6.66E+14	5.81E+07	1.68E+08	2.39E+16	6
87	05/26/1998	9.70E+06	2.46E+07	6.78E+14	5.82E+07	1.48E+08	2.44E+16	6
88	06/01/1998	9.69E+06	5.82E+07	2.73E+15	6.78E+07	4.08E+08	1.34E+17	7
89	06/09/1998	9.70E+06	7.43E+07	2.61E+16	6.78E+07	5.20E+08	1.28E+18	7
90	06/15/1998	9.69E+06	2.88E+07	4.52E+14	6.78E+07	2.02E+08	2.21E+16	7
91	06/22/1998	9.69E+06	2.02E+08	8.81E+16	6.78E+07	1.41E+09	4.32E+18	7
92	06/29/1998	9.69E+06	2.13E+07	8.39E+14	4.85E+07	1.06E+08	2.10E+16	

Table I-2. Brown rock crab (*Cancer antennarius*) zoea stage 2: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	0	0	4.72E+07	0	0	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	1.69E+05	3.95E+10	6.79E+07	1.18E+06	1.93E+12	7
13	12/23/1996	9.70E+06	2.35E+04	4.40E+09	6.79E+07	1.64E+05	2.16E+11	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	5.18E+04	9.20E+09	6.75E+07	3.61E+05	4.47E+11	7
17	01/20/1997	9.70E+06	2.14E+04	3.66E+09	6.79E+07	1.50E+05	1.79E+11	7
18	01/27/1997	9.70E+06	8.0E+06	1.31E+14	6.68E+07	5.51E+07	6.20E+15	7
19	02/03/1997	9.69E+06	5.65E+05	2.55E+12	6.75E+07	3.94E+06	1.24E+14	7
20	02/10/1997	9.64E+06	5.13E+04	9.03E+09	6.78E+07	3.61E+05	4.46E+11	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	1.62E+06	1.28E+13	6.72E+07	1.12E+07	6.14E+14	7
23	03/03/1997	9.68E+06	2.61E+04	5.44E+09	6.79E+07	1.83E+05	2.68E+11	7
24	03/10/1997	9.70E+06	6.57E+06	6.69E+13	6.75E+07	4.57E+07	3.24E+15	7
25	03/17/1997	9.36E+06	5.66E+08	2.22E+17	6.75E+07	4.08E+09	1.16E+19	7
26	03/24/1997	9.69E+06	7.64E+06	1.03E+14	6.77E+07	5.34E+07	5.03E+15	7
27	03/31/1997	7.31E+06	1.40E+06	2.62E+12	5.18E+07	9.96E+06	1.32E+14	7
28	04/07/1997	9.67E+06	8.06E+06	2.55E+14	6.62E+07	5.52E+07	1.20E+16	7
29	04/14/1997	9.69E+06	1.12E+05	1.0E+11	6.49E+07	7.48E+05	4.47E+12	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	9.56E+04	3.17E+10	3.43E+07	6.71E+05	1.56E+12	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	6.92E+05	1.14E+12	3.44E+07	4.85E+06	5.60E+13	7
34	05/19/1997	4.89E+06	3.65E+05	4.85E+11	3.44E+07	2.56E+06	2.39E+13	7
35	05/27/1997	6.96E+06	1.06E+06	2.82E+12	4.66E+07	7.08E+06	1.26E+14	7
36	06/02/1997	9.70E+06	8.68E+04	3.08E+10	6.18E+07	5.53E+05	1.25E+12	7
37	06/09/1997	9.70E+06	6.69E+06	8.86E+13	6.78E+07	4.67E+07	4.32E+15	7
38	06/16/1997	9.67E+06	1.07E+07	1.47E+14	6.78E+07	7.50E+07	7.24E+15	7
39	06/23/1997	9.71E+06	8.33E+06	1.35E+14	6.78E+07	5.82E+07	6.59E+15	7
40	06/30/1997	9.69E+06	3.90E+06	2.54E+13	6.32E+07	2.55E+07	1.08E+15	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	3.93E+06	2.61E+13	6.78E+07	2.75E+07	1.28E+15	7
43	07/21/1997	9.71E+06	6.88E+05	1.15E+12	6.74E+07	4.77E+06	5.53E+13	7
44	07/28/1997	9.69E+06	2.07E+05	3.43E+11	6.74E+07	1.44E+06	1.66E+13	7
45	08/04/1997	9.69E+06	1.26E+05	7.33E+10	6.78E+07	8.80E+05	3.59E+12	7
46	08/11/1997	9.68E+06	5.83E+05	2.47E+12	6.78E+07	4.08E+06	1.21E+14	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	4.39E+04	6.63E+09	6.79E+07	3.08E+05	3.25E+11	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	2.35E+04	4.43E+09	6.78E+07	1.65E+05	2.17E+11	7
56	10/21/1997	9.69E+06	2.10E+04	3.54E+09	6.78E+07	1.47E+05	1.73E+11	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	1.77E+05	5.50E+10	6.86E+07	1.24E+06	2.71E+12	7
61	11/24/1997	9.81E+06	2.51E+04	5.04E+09	6.82E+07	1.75E+05	2.44E+11	7
62	12/02/1997	9.68E+06	6.67E+04	1.73E+10	8.72E+07	6.01E+05	1.40E+12	9

(continued)

Table I-2 (continued). Brown rock crab (*Cancer antennarius*) zoea stage 2: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	2.47E+04	4.87E+09	6.78E+07	1.73E+05	2.38E+11	7
64	12/16/1997	9.69E+06	4.64E+04	7.42E+09	4.85E+07	2.32E+05	1.85E+11	5
65	12/22/1997	9.70E+06	2.12E+05	3.58E+11	6.78E+07	1.48E+06	1.75E+13	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	5.74E+05	1.41E+12	7.75E+07	4.59E+06	9.06E+13	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	1.61E+05	2.06E+11	5.44E+07	1.20E+06	1.15E+13	9
78	03/27/1998	8.44E+06	6.33E+04	7.73E+09	5.67E+07	4.26E+05	3.49E+11	7
79	04/01/1998	9.67E+06	2.64E+05	5.59E+11	4.81E+07	1.32E+06	1.39E+13	5
80	04/07/1998	9.73E+06	4.0E+05	1.28E+12	7.73E+07	3.18E+06	8.08E+13	8
81	04/16/1998	9.73E+06	1.03E+06	2.45E+12	1.07E+08	1.12E+07	2.95E+14	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	5.0E+07	6.43E+15	8.72E+07	4.50E+08	5.21E+17	9
84	05/04/1998	9.70E+06	2.25E+08	4.34E+16	6.78E+07	1.58E+09	2.12E+18	7
85	05/14/1998	9.68E+06	1.62E+08	1.29E+16	7.75E+07	1.30E+09	8.28E+17	8
86	05/19/1998	9.70E+06	3.78E+06	3.34E+13	5.81E+07	2.26E+07	1.20E+15	6
87	05/26/1998	9.70E+06	1.45E+05	1.67E+11	5.82E+07	8.66E+05	6.0E+12	6
88	06/01/1998	9.69E+06	2.33E+07	9.77E+14	6.78E+07	1.63E+08	4.79E+16	7
89	06/09/1998	9.70E+06	2.47E+05	3.28E+11	6.78E+07	1.73E+06	1.60E+13	7
90	06/15/1998	9.69E+06	5.78E+05	5.64E+11	6.78E+07	4.04E+06	2.76E+13	7
91	06/22/1998	9.69E+06	2.55E+07	1.68E+15	6.78E+07	1.79E+08	8.23E+16	7
92	06/29/1998	9.69E+06	6.25E+05	9.76E+11	4.85E+07	3.13E+06	2.44E+13	5

Table I-3. Brown rock crab (*Cancer antennarius*) zoea stage 3: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	0	0	4.72E+07	0	0	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	2.86E+04	6.55E+09	6.79E+07	2.0E+05	3.21E+11	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	5.07E+05	6.41E+11	6.68E+07	3.49E+06	3.04E+13	7
19	02/03/1997	9.69E+06	2.69E+04	5.78E+09	6.75E+07	1.88E+05	2.81E+11	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	5.11E+04	2.09E+10	6.72E+07	3.53E+05	9.99E+11	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	2.57E+05	9.90E+10	6.75E+07	1.79E+06	4.79E+12	7
25	03/17/1997	9.36E+06	6.24E+08	3.65E+17	6.75E+07	4.50E+09	1.90E+19	7
26	03/24/1997	9.69E+06	2.06E+07	1.82E+15	6.77E+07	1.44E+08	8.86E+16	7
27	03/31/1997	7.31E+06	6.33E+05	9.24E+11	5.18E+07	4.49E+06	4.65E+13	7
28	04/07/1997	9.67E+06	1.0E+06	1.86E+12	6.62E+07	6.86E+06	8.71E+13	7
29	04/14/1997	9.69E+06	1.15E+05	1.06E+11	6.49E+07	7.69E+05	4.73E+12	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	3.48E+04	9.70E+09	3.43E+07	2.44E+05	4.78E+11	7
32	05/05/1997	4.90E+06	1.33E+04	1.42E+09	3.42E+07	9.29E+04	6.91E+10	7
33	05/12/1997	4.91E+06	7.51E+04	4.51E+10	3.44E+07	5.26E+05	2.21E+12	7
34	05/19/1997	4.89E+06	8.53E+04	2.50E+10	3.44E+07	5.99E+05	1.23E+12	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	5.90E+05	1.39E+12	6.78E+07	4.12E+06	6.78E+13	7
38	06/16/1997	9.67E+06	4.54E+06	5.35E+13	6.78E+07	3.18E+07	2.63E+15	7
39	06/23/1997	9.71E+06	1.55E+06	5.90E+12	6.78E+07	1.08E+07	2.88E+14	7
40	06/30/1997	9.69E+06	4.60E+05	7.27E+11	6.32E+07	3.0E+06	3.09E+13	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	3.91E+05	5.25E+11	6.78E+07	2.74E+06	2.57E+13	7
43	07/21/1997	9.71E+06	3.18E+05	4.09E+11	6.74E+07	2.21E+06	1.97E+13	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-3 (continued). Brown rock crab (*Cancer antennarius*) zoea stage 3: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	9.62E+04	7.40E+10	4.81E+07	4.79E+05	1.83E+12	5
80	04/07/1998	9.73E+06	2.28E+05	4.14E+11	7.73E+07	1.81E+06	2.62E+13	8
81	04/16/1998	9.73E+06	4.33E+04	1.50E+10	1.07E+08	4.75E+05	1.81E+12	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	6.09E+06	1.43E+14	8.72E+07	5.48E+07	1.16E+16	9
84	05/04/1998	9.70E+06	2.90E+08	6.24E+16	6.78E+07	2.03E+09	3.05E+18	7
85	05/14/1998	9.68E+06	2.02E+07	1.92E+14	7.75E+07	1.62E+08	1.23E+16	8
86	05/19/1998	9.70E+06	3.03E+06	2.35E+13	5.81E+07	1.82E+07	8.42E+14	6
87	05/26/1998	9.70E+06	4.82E+04	1.86E+10	5.82E+07	2.89E+05	6.67E+11	6
88	06/01/1998	9.69E+06	1.60E+07	3.07E+14	6.78E+07	1.12E+08	1.51E+16	7
89	06/09/1998	9.70E+06	2.45E+05	3.28E+11	6.78E+07	1.71E+06	1.60E+13	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	4.04E+06	8.77E+13	6.78E+07	2.83E+07	4.30E+15	7
92	06/29/1998	9.69E+06	1.95E+05	1.92E+11	4.85E+07	9.76E+05	4.80E+12	5

Table I-4. Brown rock crab (*Cancer antennarius*) zoea stage 4: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	0	0	4.72E+07	0	0	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	0	0	6.68E+07	0	0	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	0	0	6.72E+07	0	0	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	0	0	6.75E+07	0	0	7
25	03/17/1997	9.36E+06	8.02E+07	5.76E+15	6.75E+07	5.79E+08	3.0E+17	7
26	03/24/1997	9.69E+06	1.15E+07	5.50E+14	6.77E+07	8.0E+07	2.69E+16	7
27	03/31/1997	7.31E+06	4.46E+05	6.85E+11	5.18E+07	3.16E+06	3.45E+13	7
28	04/07/1997	9.67E+06	9.79E+04	7.67E+10	6.62E+07	6.71E+05	3.60E+12	7
29	04/14/1997	9.69E+06	0	0	6.49E+07	0	0	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	0	0	3.44E+07	0	0	7
34	05/19/1997	4.89E+06	1.52E+05	1.19E+11	3.44E+07	1.07E+06	5.89E+12	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	1.27E+05	1.30E+11	6.78E+07	8.93E+05	6.38E+12	7
39	06/23/1997	9.71E+06	0	0	6.78E+07	0	0	7
40	06/30/1997	9.69E+06	0	0	6.32E+07	0	0	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-4 (continued). Brown rock crab (*Cancer antennarius*) zoea stage 4: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	0	0	7.73E+07	0	0	8
81	04/16/1998	9.73E+06	0	0	1.07E+08	0	0	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	1.20E+06	4.94E+12	8.72E+07	1.08E+07	4.0E+14	9
84	05/04/1998	9.70E+06	9.28E+07	1.66E+16	6.78E+07	6.49E+08	8.11E+17	7
85	05/14/1998	9.68E+06	6.18E+05	7.43E+11	7.75E+07	4.95E+06	4.77E+13	8
86	05/19/1998	9.70E+06	1.41E+06	4.85E+12	5.81E+07	8.45E+06	1.74E+14	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	1.43E+07	3.22E+14	6.78E+07	1.0E+08	1.58E+16	7
89	06/09/1998	9.70E+06	0	0	6.78E+07	0	0	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	1.13E+06	1.01E+13	6.78E+07	7.87E+06	4.96E+14	7
92	06/29/1998	9.69E+06	0	0	4.85E+07	0	0	5

Table I-5. Brown rock crab (*Cancer antennarius*) zoea stage 5: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	0	0	4.72E+07	0	0	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	0	0	6.68E+07	0	0	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	0	0	6.72E+07	0	0	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	0	0	6.75E+07	0	0	7
25	03/17/1997	9.36E+06	1.18E+05	1.12E+11	6.75E+07	8.53E+05	5.82E+12	7
26	03/24/1997	9.69E+06	2.13E+05	1.56E+11	6.77E+07	1.49E+06	7.63E+12	7
27	03/31/1997	7.31E+06	1.20E+05	5.95E+10	5.18E+07	8.51E+05	3.0E+12	7
28	04/07/1997	9.67E+06	0	0	6.62E+07	0	0	7
29	04/14/1997	9.69E+06	0	0	6.49E+07	0	0	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	0	0	3.44E+07	0	0	7
34	05/19/1997	4.89E+06	4.10E+04	1.34E+10	3.44E+07	2.88E+05	6.61E+11	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	0	0	6.78E+07	0	0	7
39	06/23/1997	9.71E+06	0	0	6.78E+07	0	0	7
40	06/30/1997	9.69E+06	0	0	6.32E+07	0	0	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-5 (continued). Brown rock crab (*Cancer antennarius*) zoea stage 5: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	0	0	7.73E+07	0	0	8
81	04/16/1998	9.73E+06	0	0	1.07E+08	0	0	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	0	0	8.72E+07	0	0	9
84	05/04/1998	9.70E+06	1.24E+07	3.51E+14	6.78E+07	8.67E+07	1.72E+16	7
85	05/14/1998	9.68E+06	0	0	7.75E+07	0	0	8
86	05/19/1998	9.70E+06	8.64E+05	2.71E+12	5.81E+07	5.17E+06	9.72E+13	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	2.75E+06	1.83E+13	6.78E+07	1.93E+07	8.97E+14	7
89	06/09/1998	9.70E+06	0	0	6.78E+07	0	0	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	0	0	6.78E+07	0	0	7
92	06/29/1998	9.69E+06	0	0	4.85E+07	0	0	5

Table I-6. Brown rock crab (*Cancer antennarius*) megalops: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 1, 2 and 9 are not presented.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	2.48E+03	6.16E+06	6.79E+07	1.74E+04	3.02E+08	7
4	10/30/1996	9.70E+06	1.01E+04	5.92E+07	6.77E+07	7.08E+04	2.88E+09	7
5	11/06/1996	9.70E+06	1.20E+05	1.38E+09	6.63E+07	8.21E+05	6.41E+10	7
6	11/13/1996	9.73E+06	2.85E+04	1.38E+08	5.84E+07	1.71E+05	4.98E+09	6
7	11/18/1996	9.69E+06	1.37E+04	6.28E+07	5.82E+07	8.19E+04	2.26E+09	6
8	11/25/1996	7.31E+06	0	0	5.33E+07	0	0	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	1.85E+04	5.04E+07	6.36E+07	1.21E+05	2.17E+09	7
11	12/09/1996	9.70E+06	3.63E+04	1.47E+08	6.79E+07	2.54E+05	7.18E+09	7
12	12/16/1996	9.70E+06	2.46E+05	1.35E+09	6.79E+07	1.72E+06	6.61E+10	7
13	12/23/1996	9.70E+06	1.08E+04	3.88E+07	6.79E+07	7.55E+04	1.90E+09	7
14	12/30/1996	9.68E+06	5.13E+04	2.44E+08	6.78E+07	3.60E+05	1.20E+10	7
15	01/06/1997	9.69E+06	1.44E+05	9.03E+08	6.79E+07	1.01E+06	4.43E+10	7
16	01/13/1997	9.69E+06	2.24E+04	9.25E+07	6.75E+07	1.56E+05	4.49E+09	7
17	01/20/1997	9.70E+06	8.49E+04	5.27E+08	6.79E+07	5.94E+05	2.58E+10	7
18	01/27/1997	9.70E+06	1.21E+05	2.94E+08	6.68E+07	8.32E+05	1.40E+10	7
19	02/03/1997	9.69E+06	7.40E+04	3.25E+08	6.75E+07	5.16E+05	1.58E+10	7
20	02/10/1997	9.64E+06	1.08E+04	3.90E+07	6.78E+07	7.59E+04	1.93E+09	7
21	02/17/1997	9.71E+06	6.71E+03	1.52E+07	6.76E+07	4.67E+04	7.35E+08	7
22	02/24/1997	9.71E+06	9.05E+03	4.16E+07	6.72E+07	6.27E+04	1.99E+09	7
23	03/03/1997	9.68E+06	7.06E+03	2.49E+07	6.79E+07	4.95E+04	1.23E+09	7
24	03/10/1997	9.70E+06	4.08E+04	3.15E+08	6.75E+07	2.84E+05	1.52E+10	7
25	03/17/1997	9.36E+06	1.97E+05	2.09E+09	6.75E+07	1.42E+06	1.09E+11	7
26	03/24/1997	9.69E+06	5.23E+05	9.90E+09	6.77E+07	3.65E+06	4.83E+11	7
27	03/31/1997	7.31E+06	2.62E+06	2.54E+11	5.18E+07	1.86E+07	1.28E+13	7
28	04/07/1997	9.67E+06	1.73E+06	1.08E+11	6.62E+07	1.19E+07	5.05E+12	7
29	04/14/1997	9.69E+06	3.19E+05	3.85E+09	6.49E+07	2.13E+06	1.72E+11	7
30	04/21/1997	4.91E+06	4.23E+04	2.23E+08	4.04E+07	3.48E+05	1.51E+10	7
31	04/28/1997	4.89E+06	2.06E+05	1.25E+09	3.43E+07	1.45E+06	6.17E+10	7
32	05/05/1997	4.90E+06	5.42E+04	2.88E+08	3.42E+07	3.78E+05	1.40E+10	7
33	05/12/1997	4.91E+06	4.99E+04	3.07E+08	3.44E+07	3.49E+05	1.51E+10	7
34	05/19/1997	4.89E+06	1.49E+05	6.47E+08	3.44E+07	1.05E+06	3.19E+10	7
35	05/27/1997	6.96E+06	4.67E+05	9.80E+09	4.66E+07	3.13E+06	4.39E+11	7
36	06/02/1997	9.70E+06	1.08E+05	8.84E+08	6.18E+07	6.90E+05	3.59E+10	7
37	06/09/1997	9.70E+06	3.37E+04	3.17E+08	6.78E+07	2.35E+05	1.55E+10	7
38	06/16/1997	9.67E+06	3.30E+05	8.82E+09	6.78E+07	2.32E+06	4.33E+11	7
39	06/23/1997	9.71E+06	1.50E+05	1.19E+09	6.78E+07	1.05E+06	5.81E+10	7
40	06/30/1997	9.69E+06	1.59E+05	1.51E+09	6.32E+07	1.04E+06	6.43E+10	7
41	07/07/1997	9.68E+06	1.22E+04	7.40E+07	6.72E+07	8.44E+04	3.56E+09	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	8.60E+03	7.39E+07	6.74E+07	5.98E+04	3.58E+09	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	2.01E+04	2.29E+08	6.78E+07	1.41E+05	1.12E+10	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7

(continued)

Table I-6 (continued). Brown rock crab (*Cancer antennarius*) megalops: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
54	10/06/1997	9.70E+06	5.82E+03	3.39E+07	6.80E+07	4.08E+04	1.66E+09	7
55	10/13/1997	9.69E+06	1.11E+04	1.24E+08	6.78E+07	7.79E+04	6.07E+09	7
56	10/21/1997	9.69E+06	1.61E+04	6.83E+07	6.78E+07	1.13E+05	3.34E+09	7
57	10/27/1997	9.81E+06	1.69E+04	1.63E+08	6.61E+07	1.14E+05	7.39E+09	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	5.59E+03	3.12E+07	6.86E+07	3.92E+04	1.54E+09	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	5.10E+03	2.60E+07	4.85E+07	2.55E+04	6.49E+08	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	7.34E+03	5.39E+07	7.75E+07	5.88E+04	3.45E+09	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	6.03E+03	3.64E+07	1.23E+08	7.86E+04	6.18E+09	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	3.06E+04	2.02E+08	4.81E+07	1.52E+05	5.0E+09	5
80	04/07/1998	9.73E+06	2.03E+04	1.37E+08	7.73E+07	1.61E+05	8.65E+09	8
81	04/16/1998	9.73E+06	2.49E+04	1.80E+08	1.07E+08	2.74E+05	2.16E+10	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	8.25E+04	1.19E+09	8.72E+07	7.43E+05	9.62E+10	9
84	05/04/1998	9.70E+06	3.60E+04	2.29E+08	6.78E+07	2.52E+05	1.12E+10	7
85	05/14/1998	9.68E+06	5.77E+05	2.05E+10	7.75E+07	4.62E+06	1.32E+12	8
86	05/19/1998	9.70E+06	2.29E+05	3.04E+09	5.81E+07	1.37E+06	1.09E+11	6
87	05/26/1998	9.70E+06	1.19E+05	3.18E+09	5.82E+07	7.14E+05	1.14E+11	6
88	06/01/1998	9.69E+06	4.59E+05	5.38E+09	6.78E+07	3.21E+06	2.64E+11	7
89	06/09/1998	9.70E+06	1.38E+05	2.90E+09	6.78E+07	9.64E+05	1.42E+11	7
90	06/15/1998	9.69E+06	1.73E+05	3.86E+09	6.78E+07	1.21E+06	1.89E+11	7
91	06/22/1998	9.69E+06	1.25E+06	4.86E+10	6.78E+07	8.74E+06	2.38E+12	7
92	06/29/1998	9.69E+06	1.60E+05	5.38E+09	6.79E+07	1.12E+06	2.64E+11	7
93	07/06/1998	9.73E+06	9.35E+04	5.03E+08	6.79E+07	6.53E+05	2.45E+10	7
94	07/13/1998	9.67E+06	3.71E+05	9.50E+09	6.78E+07	2.60E+06	4.67E+11	7
95	07/21/1998	9.69E+06	7.28E+03	5.30E+07	6.78E+07	5.09E+04	2.59E+09	7
96	07/27/1998	9.70E+06	5.67E+03	3.02E+07	6.78E+07	3.96E+04	1.47E+09	7
97	08/03/1998	9.69E+06	6.50E+03	4.23E+07	6.78E+07	4.55E+04	2.07E+09	7
98	08/10/1998	9.68E+06	1.15E+04	6.63E+07	6.78E+07	8.07E+04	3.26E+09	7
99	08/18/1998	9.69E+06	0	0	7.66E+07	0	0	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	7.90E+03	6.24E+07	6.78E+07	5.53E+04	3.06E+09	7

(continued)

Table I-6 (continued). Brown rock crab (*Cancer antennarius*) megalops: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
107	10/12/1998	9.69E+06	0	0	6.78E+07	0	0	7
108	10/20/1998	9.69E+06	1.28E+04	8.29E+07	7.75E+07	1.03E+05	5.31E+09	8
109	10/27/1998	9.66E+06	0	0	6.81E+07	0	0	7
110	11/03/1998	9.67E+06	0	0	6.78E+07	0	0	7
111	11/11/1998	9.68E+06	6.09E+03	3.70E+07	6.78E+07	4.27E+04	1.82E+09	7
112	11/17/1998	9.69E+06	0	0	5.82E+07	0	0	6
113	11/23/1998	9.69E+06	0	0	1.05E+08	0	0	11
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	1.38E+04	9.56E+07	1.01E+08	1.44E+05	1.03E+10	12
116	12/16/1998	9.70E+06	0	0	5.80E+07	0	0	6
117	12/21/1998	7.34E+06	0	0	4.98E+07	0	0	6
118	12/28/1998	9.69E+06	0	0	6.78E+07	0	0	7
119	01/04/1999	9.71E+06	5.98E+03	3.58E+07	6.79E+07	4.18E+04	1.75E+09	7
120	01/12/1999	9.68E+06	0	0	7.72E+07	0	0	8
121	01/20/1999	9.69E+06	7.42E+03	5.50E+07	6.77E+07	5.18E+04	2.69E+09	7
122	01/25/1999	9.67E+06	0	0	6.78E+07	0	0	7
123	02/03/1999	9.71E+06	0	0	7.76E+07	0	0	8
124	02/11/1999	4.91E+06	0	0	3.34E+07	0	0	6
125	02/15/1999	4.90E+06	0	0	2.94E+07	0	0	6
126	02/23/1999	4.89E+06	0	0	4.41E+07	0	0	9
127	03/04/1999	7.28E+06	0	0	4.48E+07	0	0	7
128	03/10/1999	7.31E+06	0	0	5.19E+07	0	0	7
129	03/17/1999	7.29E+06	0	0	6.0E+07	0	0	7
130	03/24/1999	8.80E+06	0	0	5.62E+07	0	0	6
131	03/29/1999	9.68E+06	0	0	6.78E+07	0	0	7
132	04/07/1999	9.67E+06	1.39E+04	9.72E+07	7.74E+07	1.11E+05	6.23E+09	8
133	04/14/1999	9.70E+06	0	0	5.81E+07	0	0	6
134	04/20/1999	9.67E+06	0	0	5.81E+07	0	0	6
135	04/26/1999	7.29E+06	0	0	6.92E+07	0	0	8
136	05/05/1999	9.41E+06	0	0	7.52E+07	0	0	8
137	05/12/1999	9.41E+06	0	0	7.52E+07	0	0	8
138	05/21/1999	9.41E+06	5.06E+04	5.92E+08	5.64E+07	3.04E+05	2.13E+10	6
139	05/24/1999	9.41E+06	0	0	4.70E+07	0	0	5
140	06/01/1999	9.41E+06	7.41E+04	4.82E+08	7.52E+07	5.93E+05	3.08E+10	8
141	06/09/1999	9.41E+06	0	0	1.04E+08	0	0	11
142	06/07/1999				Not sampled			
143	06/23/1999	9.41E+06	2.48E+04	2.39E+08	9.41E+07	2.48E+05	2.39E+10	10
144	06/29/1999	9.41E+06	6.08E+03	3.70E+07	4.70E+07	3.04E+04	9.24E+08	5

Table I-7. Slender crab (*Cancer gracilis*) zoea stage 2: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	0	0	4.72E+07	0	0	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	8.25E+04	2.66E+10	6.79E+07	5.78E+05	1.31E+12	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	0	0	6.68E+07	0	0	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	2.75E+04	6.05E+09	6.72E+07	1.90E+05	2.90E+11	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	2.82E+04	6.38E+09	6.75E+07	1.97E+05	3.09E+11	7
25	03/17/1997	9.36E+06	4.13E+06	7.63E+13	6.75E+07	2.98E+07	3.97E+15	7
26	03/24/1997	9.69E+06	1.12E+05	1.00E+11	6.77E+07	7.81E+05	4.88E+12	7
27	03/31/1997	7.31E+06	0	0	5.18E+07	0	0	7
28	04/07/1997	9.67E+06	8.15E+05	5.32E+12	6.62E+07	5.58E+06	2.49E+14	7
29	04/14/1997	9.69E+06	2.30E+05	4.23E+11	6.49E+07	1.54E+06	1.89E+13	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	4.45E+05	2.40E+11	3.44E+07	3.12E+06	1.18E+13	7
34	05/19/1997	4.89E+06	1.36E+05	1.05E+11	3.44E+07	9.54E+05	5.15E+12	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	2.05E+05	3.38E+11	6.78E+07	1.44E+06	1.66E+13	7
39	06/23/1997	9.71E+06	0	0	6.78E+07	0	0	7
40	06/30/1997	9.69E+06	2.31E+05	4.28E+11	6.32E+07	1.51E+06	1.82E+13	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	4.47E+04	6.87E+09	6.86E+07	3.14E+05	3.39E+11	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-7 (continued). Slender crab (*Cancer gracilis*) zoea stage 2: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	5.45E+04	1.03E+10	7.75E+07	4.36E+05	6.63E+11	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	0	0	7.73E+07	0	0	8
81	04/16/1998	9.73E+06	0	0	1.07E+08	0	0	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	2.57E+06	3.35E+13	8.72E+07	2.31E+07	2.71E+15	9
84	05/04/1998	9.70E+06	2.18E+06	5.46E+12	6.78E+07	1.52E+07	2.67E+14	7
85	05/14/1998	9.68E+06	3.05E+06	7.29E+12	7.75E+07	2.45E+07	4.68E+14	8
86	05/19/1998	9.70E+06	0	0	5.81E+07	0	0	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	2.64E+06	1.64E+13	6.78E+07	1.85E+07	8.03E+14	7
89	06/09/1998	9.70E+06	2.19E+05	3.37E+11	6.78E+07	1.53E+06	1.65E+13	7
90	06/15/1998	9.69E+06	2.29E+04	4.18E+09	6.78E+07	1.60E+05	2.04E+11	7
91	06/22/1998	9.69E+06	1.93E+06	5.03E+12	6.78E+07	1.35E+07	2.46E+14	7
92	06/29/1998	9.69E+06	0	0	4.85E+07	0	0	5

Table I-8. Slender crab (*Cancer gracilis*) zoea stage 3: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	0	0	4.72E+07	0	0	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	0	0	6.68E+07	0	0	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	0	0	6.72E+07	0	0	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	0	0	6.75E+07	0	0	7
25	03/17/1997	9.36E+06	3.82E+05	5.95E+11	6.75E+07	2.75E+06	3.10E+13	7
26	03/24/1997	9.69E+06	1.01E+05	8.21E+10	6.77E+07	7.08E+05	4.01E+12	7
27	03/31/1997	7.31E+06	0	0	5.18E+07	0	0	7
28	04/07/1997	9.67E+06	0	0	6.62E+07	0	0	7
29	04/14/1997	9.69E+06	0	0	6.49E+07	0	0	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	1.60E+04	2.06E+09	3.42E+07	1.12E+05	1.00E+11	7
33	05/12/1997	4.91E+06	3.07E+05	2.46E+11	3.44E+07	2.15E+06	1.21E+13	7
34	05/19/1997	4.89E+06	3.41E+04	4.09E+09	3.44E+07	2.40E+05	2.02E+11	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	2.53E+05	5.11E+11	6.78E+07	1.77E+06	2.51E+13	7
39	06/23/1997	9.71E+06	0	0	6.78E+07	0	0	7
40	06/30/1997	9.69E+06	0	0	6.32E+07	0	0	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-8 (continued). Slender crab (*Cancer gracilis*) zoea stage 3: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	0	0	7.73E+07	0	0	8
81	04/16/1998	9.73E+06	0	0	1.07E+08	0	0	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	0	0	8.72E+07	0	0	9
84	05/04/1998	9.70E+06	1.49E+06	4.75E+12	6.78E+07	1.04E+07	2.32E+14	7
85	05/14/1998	9.68E+06	1.14E+06	2.27E+12	7.75E+07	9.14E+06	1.46E+14	8
86	05/19/1998	9.70E+06	0	0	5.81E+07	0	0	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	6.28E+05	1.62E+12	6.78E+07	4.40E+06	7.92E+13	7
89	06/09/1998	9.70E+06	0	0	6.78E+07	0	0	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	2.21E+05	3.91E+11	6.78E+07	1.55E+06	1.92E+13	7
92	06/29/1998	9.69E+06	0	0	4.85E+07	0	0	5

Table I-9. Slender crab (*Cancer gracilis*) zoea stage 4: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	0	0	4.72E+07	0	0	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	0	0	6.68E+07	0	0	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	0	0	6.72E+07	0	0	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	0	0	6.75E+07	0	0	7
25	03/17/1997	9.36E+06	0	0	6.75E+07	0	0	7
26	03/24/1997	9.69E+06	1.01E+05	8.21E+10	6.77E+07	7.08E+05	4.01E+12	7
27	03/31/1997	7.31E+06	0	0	5.18E+07	0	0	7
28	04/07/1997	9.67E+06	0	0	6.62E+07	0	0	7
29	04/14/1997	9.69E+06	0	0	6.49E+07	0	0	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	1.62E+04	2.10E+09	3.44E+07	1.14E+05	1.03E+11	7
34	05/19/1997	4.89E+06	1.35E+05	1.04E+11	3.44E+07	9.46E+05	5.15E+12	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	0	0	6.78E+07	0	0	7
39	06/23/1997	9.71E+06	0	0	6.78E+07	0	0	7
40	06/30/1997	9.69E+06	0	0	6.32E+07	0	0	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-9 (continued). Slender crab (*Cancer gracilis*) zoea stage 4: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	0	0	7.73E+07	0	0	8
81	04/16/1998	9.73E+06	0	0	1.07E+08	0	0	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	0	0	8.72E+07	0	0	9
84	05/04/1998	9.70E+06	0	0	6.78E+07	0	0	7
85	05/14/1998	9.68E+06	0	0	7.75E+07	0	0	8
86	05/19/1998	9.70E+06	0	0	5.81E+07	0	0	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	0	0	6.78E+07	0	0	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	0	0	6.78E+07	0	0	7
92	06/29/1998	9.69E+06	0	0	4.85E+07	0	0	5

Table I-10. Slender crab (*Cancer gracilis*) zoea stage 5: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	0	0	4.72E+07	0	0	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	0	0	6.68E+07	0	0	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	0	0	6.72E+07	0	0	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	0	0	6.75E+07	0	0	7
25	03/17/1997	9.36E+06	0	0	6.75E+07	0	0	7
26	03/24/1997	9.69E+06	0	0	6.77E+07	0	0	7
27	03/31/1997	7.31E+06	0	0	5.18E+07	0	0	7
28	04/07/1997	9.67E+06	0	0	6.62E+07	0	0	7
29	04/14/1997	9.69E+06	0	0	6.49E+07	0	0	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	0	0	3.44E+07	0	0	7
34	05/19/1997	4.89E+06	0	0	3.44E+07	0	0	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	0	0	6.78E+07	0	0	7
39	06/23/1997	9.71E+06	0	0	6.78E+07	0	0	7
40	06/30/1997	9.69E+06	0	0	6.32E+07	0	0	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-10 (continued). Slender crab (*Cancer gracilis*) zoea stage 5: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	0	0	7.73E+07	0	0	8
81	04/16/1998	9.73E+06	0	0	1.07E+08	0	0	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	0	0	8.72E+07	0	0	9
84	05/04/1998	9.70E+06	0	0	6.78E+07	0	0	7
85	05/14/1998	9.68E+06	0	0	7.75E+07	0	0	8
86	05/19/1998	9.70E+06	0	0	5.81E+07	0	0	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	0	0	6.78E+07	0	0	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	0	0	6.78E+07	0	0	7
92	06/29/1998	9.69E+06	0	0	4.85E+07	0	0	5

Table I-11. Slender crab (*Cancer gracilis*) megalops: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 1, 2 and 9 are not presented.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	8.95E+03	2.05E+07	6.79E+07	6.26E+04	1.01E+09	7
4	10/30/1996	9.70E+06	6.42E+04	5.80E+08	6.77E+07	4.48E+05	2.82E+10	7
5	11/06/1996	9.70E+06	4.18E+04	1.09E+08	6.63E+07	2.85E+05	5.08E+09	7
6	11/13/1996	9.73E+06	5.60E+04	1.14E+08	5.84E+07	3.36E+05	4.11E+09	6
7	11/18/1996	9.69E+06	5.12E+04	2.73E+08	5.82E+07	3.07E+05	9.84E+09	6
9	12/02/1996				Data not analyzed			
8	11/25/1996	7.31E+06	5.30E+04	2.35E+08	5.33E+07	3.87E+05	1.25E+10	7
10	12/03/1996	9.69E+06	3.30E+04	8.18E+07	6.36E+07	2.16E+05	3.52E+09	7
11	12/09/1996	9.70E+06	5.26E+04	3.62E+08	6.79E+07	3.68E+05	1.78E+10	7
12	12/16/1996	9.70E+06	3.24E+05	1.77E+09	6.79E+07	2.27E+06	8.69E+10	7
13	12/23/1996	9.70E+06	2.15E+04	1.47E+08	6.79E+07	1.51E+05	7.22E+09	7
14	12/30/1996	9.68E+06	1.59E+05	1.22E+09	6.78E+07	1.11E+06	5.98E+10	7
15	01/06/1997	9.69E+06	1.76E+05	1.81E+09	6.79E+07	1.24E+06	8.86E+10	7
16	01/13/1997	9.69E+06	3.50E+04	1.36E+08	6.75E+07	2.44E+05	6.59E+09	7
17	01/20/1997	9.70E+06	1.51E+05	7.74E+08	6.79E+07	1.06E+06	3.79E+10	7
18	01/27/1997	9.70E+06	2.39E+05	8.91E+08	6.68E+07	1.65E+06	4.23E+10	7
19	02/03/1997	9.69E+06	5.20E+04	1.81E+08	6.75E+07	3.62E+05	8.78E+09	7
20	02/10/1997	9.64E+06	3.20E+04	1.15E+08	6.78E+07	2.25E+05	5.70E+09	7
21	02/17/1997	9.71E+06	5.93E+04	5.38E+08	6.76E+07	4.12E+05	2.60E+10	7
22	02/24/1997	9.71E+06	1.74E+04	4.09E+07	6.72E+07	1.20E+05	1.96E+09	7
23	03/03/1997	9.68E+06	1.84E+05	2.07E+09	6.79E+07	1.29E+06	1.02E+11	7
24	03/10/1997	9.70E+06	1.08E+05	1.78E+09	6.75E+07	7.54E+05	8.61E+10	7
25	03/17/1997	9.36E+06	1.32E+05	1.49E+09	6.75E+07	9.55E+05	7.73E+10	7
26	03/24/1997	9.69E+06	5.44E+04	2.86E+08	6.77E+07	3.80E+05	1.40E+10	7
27	03/31/1997	7.31E+06	1.37E+05	6.00E+08	5.18E+07	9.69E+05	3.02E+10	7
28	04/07/1997	9.67E+06	2.96E+05	5.77E+09	6.62E+07	2.03E+06	2.71E+11	7
29	04/14/1997	9.69E+06	5.34E+04	7.37E+08	6.49E+07	3.57E+05	3.30E+10	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	2.14E+03	4.57E+06	3.43E+07	1.50E+04	2.25E+08	7
32	05/05/1997	4.90E+06	3.61E+03	1.30E+07	3.42E+07	2.52E+04	6.34E+08	7
33	05/12/1997	4.91E+06	2.83E+04	1.23E+08	3.44E+07	1.98E+05	6.03E+09	7
34	05/19/1997	4.89E+06	1.06E+04	1.83E+07	3.44E+07	7.44E+04	9.00E+08	7
35	05/27/1997	6.96E+06	5.28E+03	2.79E+07	4.66E+07	3.54E+04	1.25E+09	7
36	06/02/1997	9.70E+06	4.22E+04	2.24E+08	6.18E+07	2.69E+05	9.11E+09	7
37	06/09/1997	9.70E+06	3.10E+04	4.43E+08	6.78E+07	2.17E+05	2.16E+10	7
38	06/16/1997	9.67E+06	9.04E+04	1.39E+09	6.78E+07	6.34E+05	6.83E+10	7
39	06/23/1997	9.71E+06	7.62E+04	9.41E+08	6.78E+07	5.32E+05	4.58E+10	7
40	06/30/1997	9.69E+06	7.69E+04	5.17E+08	6.32E+07	5.02E+05	2.20E+10	7
41	07/07/1997	9.68E+06	5.83E+03	3.39E+07	6.72E+07	4.04E+04	1.63E+09	7
42	07/14/1997	9.69E+06	1.24E+04	7.73E+07	6.78E+07	8.66E+04	3.78E+09	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	1.57E+04	1.24E+08	6.74E+07	1.09E+05	5.98E+09	7
45	08/04/1997	9.69E+06	6.43E+03	6.90E+07	6.78E+07	4.50E+04	3.38E+09	7
46	08/11/1997	9.68E+06	2.64E+04	4.55E+08	6.78E+07	1.85E+05	2.23E+10	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	3.24E+03	1.05E+07	7.41E+07	2.47E+04	6.12E+08	8
49	09/02/1997	9.67E+06	2.16E+04	1.27E+08	5.82E+07	1.30E+05	4.59E+09	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	5.02E+03	2.52E+07	6.78E+07	3.52E+04	1.24E+09	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7

(continued)

Table I-11 (continued). Slender crab (*Cancer gracilis*) megalops: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
54	10/06/1997	9.70E+06	4.53E+04	8.39E+08	6.80E+07	3.17E+05	4.12E+10	7
55	10/13/1997	9.69E+06	5.56E+03	3.10E+07	6.78E+07	3.90E+04	1.52E+09	7
56	10/21/1997	9.69E+06	3.77E+04	2.32E+08	6.78E+07	2.64E+05	1.13E+10	7
57	10/27/1997	9.81E+06	1.13E+04	6.36E+07	6.61E+07	7.60E+04	2.89E+09	7
58	11/04/1997	9.80E+06	2.38E+04	2.24E+08	6.82E+07	1.66E+05	1.08E+10	7
59	11/10/1997	9.80E+06	1.16E+04	6.75E+07	6.84E+07	8.11E+04	3.29E+09	7
60	11/18/1997	9.76E+06	4.90E+03	2.40E+07	6.86E+07	3.44E+04	1.18E+09	7
61	11/24/1997	9.81E+06	1.30E+04	8.50E+07	6.82E+07	9.06E+04	4.11E+09	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	3.19E+03	1.02E+07	3.37E+07	2.30E+04	5.27E+08	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	1.20E+04	1.45E+08	7.73E+07	9.56E+04	9.14E+09	8
81	04/16/1998	9.73E+06	1.26E+04	1.58E+08	1.07E+08	1.38E+05	1.90E+10	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	4.87E+04	2.96E+08	8.72E+07	4.39E+05	2.40E+10	9
84	05/04/1998	9.70E+06	0	0	6.78E+07	0	0	7
85	05/14/1998	9.68E+06	4.38E+04	5.36E+08	7.75E+07	3.51E+05	3.44E+10	8
86	05/19/1998	9.70E+06	2.32E+04	6.64E+07	5.81E+07	1.39E+05	2.38E+09	6
87	05/26/1998	9.70E+06	3.60E+04	2.62E+08	5.82E+07	2.16E+05	9.42E+09	6
88	06/01/1998	9.69E+06	1.15E+05	2.80E+09	6.78E+07	8.05E+05	1.38E+11	7
89	06/09/1998	9.70E+06	1.23E+04	6.26E+07	6.78E+07	8.59E+04	3.06E+09	7
90	06/15/1998	9.69E+06	2.63E+04	1.45E+08	6.78E+07	1.84E+05	7.11E+09	7
91	06/22/1998	9.69E+06	5.56E+04	5.37E+08	6.78E+07	3.90E+05	2.63E+10	7
92	06/29/1998	9.69E+06	1.79E+04	1.93E+08	6.79E+07	1.25E+05	9.45E+09	7
93	07/06/1998	9.73E+06	7.23E+03	5.23E+07	6.79E+07	5.04E+04	2.55E+09	7
94	07/13/1998	9.67E+06	1.30E+04	1.69E+08	6.78E+07	9.10E+04	8.29E+09	7
95	07/21/1998	9.69E+06	0	0	6.78E+07	0	0	7
96	07/27/1998	9.70E+06	2.43E+04	1.57E+08	6.78E+07	1.70E+05	7.69E+09	7
97	08/03/1998	9.69E+06	0	0	6.78E+07	0	0	7
98	08/10/1998	9.68E+06	3.56E+04	1.70E+08	6.78E+07	2.49E+05	8.32E+09	7
99	08/18/1998	9.69E+06	1.14E+04	6.52E+07	7.66E+07	9.03E+04	4.08E+09	8
100	08/26/1998	9.69E+06	6.37E+03	3.57E+07	6.78E+07	4.46E+04	1.75E+09	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	1.33E+04	8.84E+07	6.78E+07	9.29E+04	4.32E+09	7
104	09/21/1998	7.44E+06	4.65E+03	2.16E+07	4.70E+07	2.94E+04	8.64E+08	6
105	09/28/1998	9.67E+06	7.71E+03	5.95E+07	6.78E+07	5.41E+04	2.92E+09	7
106	10/06/1998	9.69E+06	3.27E+04	3.96E+08	6.78E+07	2.29E+05	1.94E+10	7

(continued)

Table I-11 (continued). Slender crab (*Cancer gracilis*) megalops: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
107	10/12/1998	9.69E+06	2.75E+04	8.90E+07	6.78E+07	1.92E+05	4.36E+09	7
108	10/20/1998	9.69E+06	2.37E+05	6.50E+09	7.75E+07	1.90E+06	4.16E+11	8
109	10/27/1998	9.66E+06	0	0	6.81E+07	0	0	7
110	11/03/1998	9.67E+06	6.10E+03	3.50E+07	6.78E+07	4.28E+04	1.72E+09	7
111	11/11/1998	9.68E+06	7.11E+03	5.05E+07	6.78E+07	4.98E+04	2.48E+09	7
112	11/17/1998	9.69E+06	1.40E+05	1.62E+09	5.82E+07	8.43E+05	5.82E+10	6
113	11/23/1998	9.69E+06	3.12E+04	1.38E+08	1.05E+08	3.38E+05	1.62E+10	11
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	1.38E+04	9.48E+07	1.01E+08	1.43E+05	1.03E+10	12
116	12/16/1998	9.70E+06	0	0	5.80E+07	0	0	6
117	12/21/1998	7.34E+06	1.29E+04	5.67E+07	4.98E+07	8.76E+04	2.60E+09	6
118	12/28/1998	9.69E+06	6.14E+03	3.77E+07	6.78E+07	4.30E+04	1.85E+09	7
119	01/04/1999	9.71E+06	0	0	6.79E+07	0	0	7
120	01/12/1999	9.68E+06	5.30E+03	2.81E+07	7.72E+07	4.22E+04	1.78E+09	8
121	01/20/1999	9.69E+06	1.41E+04	9.96E+07	6.77E+07	9.82E+04	4.87E+09	7
122	01/25/1999	9.67E+06	6.22E+03	3.87E+07	6.78E+07	4.36E+04	1.90E+09	7
123	02/03/1999	9.71E+06	0	0	7.76E+07	0	0	8
124	02/11/1999	4.91E+06	4.22E+03	1.78E+07	3.34E+07	2.87E+04	8.21E+08	6
125	02/15/1999	4.90E+06	0	0	2.94E+07	0	0	6
126	02/23/1999	4.89E+06	0	0	4.41E+07	0	0	9
127	03/04/1999	7.28E+06	6.69E+03	4.48E+07	4.48E+07	4.12E+04	1.70E+09	7
128	03/10/1999	7.31E+06	0	0	5.19E+07	0	0	7
129	03/17/1999	7.29E+06	1.04E+04	5.36E+07	6.00E+07	8.53E+04	3.64E+09	7
130	03/24/1999	8.80E+06	3.34E+04	1.67E+08	5.62E+07	2.13E+05	6.83E+09	6
131	03/29/1999	9.68E+06	0	0	6.78E+07	0	0	7
132	04/07/1999	9.67E+06	2.49E+04	1.92E+08	7.74E+07	2.00E+05	1.23E+10	8
133	04/14/1999	9.70E+06	0	0	5.81E+07	0	0	6
134	04/20/1999	9.67E+06	6.57E+04	1.97E+09	5.81E+07	3.94E+05	7.09E+10	6
135	04/26/1999	7.29E+06	0	0	6.92E+07	0	0	8
136	05/05/1999	9.41E+06	2.90E+04	1.04E+08	7.52E+07	2.32E+05	6.63E+09	8
137	05/12/1999	9.41E+06	2.60E+04	2.13E+08	7.52E+07	2.08E+05	1.37E+10	8
138	05/21/1999	9.41E+06	5.78E+03	3.33E+07	5.64E+07	3.47E+04	1.20E+09	6
139	05/24/1999	9.41E+06	1.49E+04	1.12E+08	4.70E+07	7.47E+04	2.79E+09	5
140	06/01/1999	9.41E+06	2.42E+04	1.21E+08	7.52E+07	1.93E+05	7.77E+09	8
141	06/09/1999	9.41E+06	5.82E+03	3.39E+07	1.04E+08	6.40E+04	4.10E+09	11
142	06/07/1999				Not sampled			
143	06/23/1999	9.41E+06	2.08E+04	1.16E+08	9.41E+07	2.08E+05	1.16E+10	10
144	06/29/1999	9.41E+06	0	0	4.70E+07	0	0	5

Table I-12. Pacific sardine (*Sardinops sagax*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
4	10/30/1996	9.70E+06	0	0	6.77E+07	0	0	7
5	11/06/1996	9.70E+06	0	0	6.63E+07	0	0	7
6	11/13/1996	9.73E+06	0	0	5.84E+07	0	0	6
7	11/18/1996	9.69E+06	3.06E+03	9.34E+06	5.82E+07	1.83E+04	3.37E+08	6
8	11/25/1996	7.31E+06	0	0	5.33E+07	0	0	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	0	0	6.36E+07	0	0	7
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	0	0	6.68E+07	0	0	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	0	0	6.72E+07	0	0	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	0	0	6.75E+07	0	0	7
25	03/17/1997	9.36E+06	7.36E+03	1.81E+07	6.75E+07	5.31E+04	9.45E+08	7
26	03/24/1997	9.69E+06	0	0	6.77E+07	0	0	7
27	03/31/1997	7.31E+06	0	0	5.18E+07	0	0	7
28	04/07/1997	9.67E+06	0	0	6.62E+07	0	0	7
29	04/14/1997	9.69E+06	9.53E+03	5.29E+07	6.49E+07	6.38E+04	2.37E+09	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	0	0	3.44E+07	0	0	7
34	05/19/1997	4.89E+06	2.26E+04	7.64E+07	3.44E+07	1.59E+05	3.77E+09	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	3.83E+03	1.47E+07	6.18E+07	2.44E+04	5.96E+08	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	0	0	6.78E+07	0	0	7
39	06/23/1997	9.71E+06	0	0	6.78E+07	0	0	7
40	06/30/1997	9.69E+06	0	0	6.32E+07	0	0	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	7.17E+03	5.14E+07	6.78E+07	5.02E+04	2.52E+09	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7

(continued)

Table I-12 (continued). Pacific sardine (*Sardinops sagax*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	6.29E+03	3.96E+07	6.80E+07	4.41E+04	1.94E-09	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	5.56E+03	3.09E+07	7.75E+07	4.45E+04	1.98E+09	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	5
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	7
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	9
77	03/19/1998	7.29E+06	4.73E+05	2.20E+09	5.44E+07	3.53E+06	1.22E-11	7
78	03/27/1998	8.44E+06	3.37E+05	3.22E+09	5.67E+07	2.27E+06	1.46E-11	5
79	04/01/1998	9.67E+06	5.44E+05	3.37E+09	4.81E+07	2.71E+06	8.35E+10	8
80	04/07/1998	9.73E+06	6.30E+04	5.74E+08	7.73E+07	5.01E+05	3.62E-10	11
81	04/16/1998	9.73E+06	4.05E+05	9.70E+09	1.07E+08	4.44E+06	1.17E-12	9
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	6.92E+05	1.54E+10	8.72E-07	6.23E+06	1.25E+12	7
84	05/04/1998	9.70E+06	1.11E+07	1.05E+12	6.78E+07	7.74E+07	5.11E+13	8
85	05/14/1998	9.68E+06	5.41E+05	1.73E+10	7.75E+07	4.34E+06	1.11E+12	6
86	05/19/1998	9.70E+06	8.90E+04	8.39E+08	5.81E+07	5.33E+05	3.01E+10	6
87	05/26/1998	9.70E+06	1.91E+05	2.50E+09	5.82E+07	1.14E+06	8.96E+10	7
88	06/01/1998	9.69E+06	2.16E+04	2.76E-08	6.78E+07	1.51E+05	1.35E+10	7
89	06/09/1998	9.70E+06	3.78E+04	2.25E-08	6.78E+07	2.64E+05	1.10E+10	7
90	06/15/1998	9.69E+06	5.72E-04	1.22E-09	6.78E-07	4.0E+05	5.95E+10	7
91	06/22/1998	9.69E+06	0	0	6.78E-07	0	0	7
92	06/29/1998	9.69E+06	0	0	6.79E-07	0	0	7
93	07/06/1998	9.73E+06	0	0	6.79E+07	0	0	7
94	07/13/1998	9.67E+06	0	0	6.78E+07	0	0	7
95	07/21/1998	9.69E+06	0	0	6.78E+07	0	0	7
96	07/27/1998	9.70E+06	0	0	6.78E+07	0	0	7
97	08/03/1998	9.69E+06	0	0	6.78E+07	0	0	7
98	08/10/1998	9.68E+06	0	0	6.78E-07	0	0	8
99	08/18/1998	9.69E+06	0	0	7.66E-07	0	0	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6

(continued)

Table I-12 (continued). Pacific sardine (*Sardinops sagax*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E+08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	0	0	2.75E+08	0	0	31
120	01/12/1999	9.68E+06	5.39E+03	2.90E+07	2.71E+08	1.51E+05	2.27E+10	28
123	02/03/1999	9.71E+06	0	0	2.33E+08	0	0	32
129	03/17/1999	7.29E+06	0	0	2.71E+08	0	0	35
133	04/14/1999	9.70E+06	0	0	3.20E+08	0	0	34
139	05/24/1999	9.41E+06	0	0	3.29E+08	0	0	35
143	06/23/1999	9.41E+06	0	0	2.16E+08	0	0	23

Table I-13. Northern anchovy (*Engraulis mordax*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
4	10/30/1996	9.70E+06	2.27E+04	6.03E+07	6.77E+07	1.58E+05	2.93E+09	7
5	11/06/1996	9.70E+06	8.96E+04	2.06E+08	6.63E+07	6.12E+05	9.61E+09	7
6	11/13/1996	9.73E+06	3.01E+05	1.81E+09	5.84E+07	1.81E+06	6.53E+10	6
7	11/18/1996	9.69E+06	1.06E+05	1.39E+09	5.82E+07	6.38E+05	5.01E+10	6
8	11/25/1996	7.31E+06	1.29E+04	2.96E+07	5.33E+07	9.43E+04	1.58E+09	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	1.03E+04	2.74E+07	6.36E+07	6.77E+04	1.18E+09	7
11	12/09/1996	9.70E+06	2.73E+05	2.46E+09	6.79E+07	1.91E+06	1.21E+11	7
12	12/16/1996	9.70E+06	1.69E+05	1.09E+09	6.79E+07	1.19E+06	5.31E+10	7
13	12/23/1996	9.70E+06	3.03E+05	3.78E+09	6.79E+07	2.12E+06	1.85E+11	7
14	12/30/1996	9.68E+06	1.27E+05	6.98E+08	6.78E+07	8.93E+05	3.42E+10	7
15	01/06/1997	9.69E+06	6.49E+04	2.65E+08	6.79E+07	4.55E+05	1.30E+10	7
16	01/13/1997	9.69E+06	1.26E+04	5.66E+07	6.75E+07	8.76E+04	2.75E+09	7
17	01/20/1997	9.70E+06	1.98E+05	7.72E+09	6.79E+07	1.39E+06	3.78E+11	7
18	01/27/1997	9.70E+06	4.97E+05	1.04E+10	6.68E+07	3.42E+06	4.92E+11	7
19	02/03/1997	9.69E+06	2.98E+04	1.35E+08	6.75E+07	2.08E+05	6.56E+09	7
20	02/10/1997	9.64E+06	3.37E+03	1.13E+07	6.78E+07	2.37E+04	5.60E+08	7
21	02/17/1997	9.71E+06	6.28E+03	1.98E+07	6.76E+07	4.37E+04	9.57E+08	7
22	02/24/1997	9.71E+06	4.48E+04	1.67E+08	6.72E+07	3.10E+05	7.99E+09	7
23	03/03/1997	9.68E+06	2.83E+04	2.0E+08	6.79E+07	1.98E+05	9.84E+09	7
24	03/10/1997	9.70E+06	1.03E+04	2.83E+07	6.75E+07	7.15E+04	1.37E+09	7
25	03/17/1997	9.36E+06	6.31E+05	1.17E+10	6.75E+07	4.55E+06	6.08E+11	7
26	03/24/1997	9.69E+06	2.19E+05	8.89E+08	6.77E+07	1.53E+06	4.34E+10	7
27	03/31/1997	7.31E+06	3.27E+04	9.93E+07	5.18E+07	2.32E+05	5.0E+09	7
28	04/07/1997	9.67E+06	2.88E+04	9.76E+07	6.62E+07	1.98E+05	4.58E+09	7
29	04/14/1997	9.69E+06	5.37E+04	2.23E+08	6.49E+07	3.59E+05	9.97E+09	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	1.93E+03	3.74E+06	3.43E+07	1.36E+04	1.84E+08	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	0	0	3.44E+07	0	0	7
34	05/19/1997	4.89E+06	2.09E+05	6.44E+08	3.44E+07	1.47E+06	3.17E+10	7
35	05/27/1997	6.96E+06	2.16E+04	9.70E+07	4.66E+07	1.44E+05	4.35E+09	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	1.48E+04	1.10E+08	6.78E+07	1.04E+05	5.38E+09	7
38	06/16/1997	9.67E+06	0	0	6.78E+07	0	0	7
39	06/23/1997	9.71E+06	7.15E+03	5.11E+07	6.78E+07	4.99E+04	2.49E+09	7
40	06/30/1997	9.69E+06	3.29E+04	1.65E+08	6.32E+07	2.15E+05	7.02E+09	7
41	07/07/1997	9.68E+06	5.67E+03	3.21E+07	6.72E+07	3.93E+04	1.55E+09	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	2.73E+03	7.46E+06	6.74E+07	1.90E+04	3.60E+08	7
44	07/28/1997	9.69E+06	1.33E+04	8.83E+07	6.74E+07	9.25E+04	4.28E+09	7
45	08/04/1997	9.69E+06	4.90E+04	6.87E+08	6.78E+07	3.43E+05	3.36E+10	7
46	08/11/1997	9.68E+06	6.33E+04	3.73E+08	6.78E+07	4.43E+05	1.83E+10	7
47	08/18/1997	9.70E+06	1.25E+04	7.83E+07	6.81E+07	8.78E+04	3.86E+09	7
48	08/26/1997	9.70E+06	3.75E+03	1.41E+07	7.41E+07	2.86E+04	8.19E+08	8
49	09/02/1997	9.67E+06	8.25E+04	4.94E+08	5.82E+07	4.97E+05	1.79E+10	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	1.27E+04	8.15E+07	6.78E+07	8.92E+04	4.0E+09	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7

(continued)

Table I-13 (continued). Northern anchovy (*Engraulis mordax*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	7.03E+04	9.30E+08	6.79E+07	4.93E+05	4.56E+10	7
54	10/06/1997	9.70E+06	3.90E+04	1.11E+08	6.80E+07	2.73E+05	5.42E+09	7
55	10/13/1997	9.69E+06	3.46E+04	1.93E+08	6.78E+07	2.42E+05	9.45E+09	7
56	10/21/1997	9.69E+06	3.21E+04	1.33E+08	6.78E+07	2.25E+05	6.51E+09	7
57	10/27/1997	9.81E+06	1.14E+04	6.49E+07	6.61E+07	7.68E+04	2.95E+09	7
58	11/04/1997	9.80E+06	8.62E+04	7.42E+09	6.82E+07	5.99E+05	3.59E+11	7
59	11/10/1997	9.80E+06	1.16E+04	6.75E+07	6.84E+07	8.09E+04	3.29E+09	7
60	11/18/1997	9.76E+06	1.06E+04	5.70E+07	6.86E+07	7.47E+04	2.81E+09	7
61	11/24/1997	9.81E+06	1.15E+04	6.65E+07	6.82E+07	8.02E+04	3.22E+09	7
62	12/02/1997	9.68E+06	1.68E+04	7.36E+07	8.72E+07	1.51E+05	5.97E+09	9
63	12/11/1997	9.69E+06	6.42E+04	7.04E+08	6.78E+07	4.49E+05	3.45E+10	7
64	12/16/1997	9.69E+06	5.44E+03	2.95E+07	4.85E+07	2.72E+04	7.38E+08	5
65	12/22/1997	9.70E+06	2.18E+05	2.21E+09	6.78E+07	1.52E+06	1.08E+11	7
66	12/30/1997	9.68E+06	5.85E+04	3.38E+08	6.76E+07	4.08E+05	1.65E+10	7
67	01/05/1998	9.68E+06	6.03E+06	7.30E+11	7.75E+07	4.83E+07	4.68E+13	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	3.80E+04	3.46E+08	6.79E+07	2.66E+05	1.70E+10	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	1.77E+04	1.04E+08	1.23E+08	2.30E+05	1.77E+10	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	9.74E+03	3.18E+07	2.34E+07	4.87E+04	7.94E+08	5
76	03/09/1998	4.69E+06	3.77E+04	1.46E+08	3.37E+07	2.71E+05	7.53E+09	7
77	03/19/1998	7.29E+06	4.57E+04	4.30E+08	5.44E+07	3.41E+05	2.39E+10	9
78	03/27/1998	8.44E+06	1.71E+06	3.41E+10	5.67E+07	1.15E+07	1.54E+12	7
79	04/01/1998	9.67E+06	2.07E+06	3.51E+10	4.81E+07	1.03E+07	8.69E+11	5
80	04/07/1998	9.73E+06	2.13E+05	8.91E+08	7.73E+07	1.69E+06	5.62E+10	8
81	04/16/1998	9.73E+06	7.90E+04	8.51E+08	1.07E+08	8.67E+05	1.02E+11	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	2.20E+05	1.96E+09	8.72E+07	1.98E+06	1.59E+11	9
84	05/04/1998	9.70E+06	8.68E+05	1.59E+10	6.78E+07	6.07E+06	7.79E+11	7
85	05/14/1998	9.68E+06	1.53E+06	3.62E+10	7.75E+07	1.23E+07	2.32E+12	8
86	05/19/1998	9.70E+06	2.65E+05	3.09E+09	5.81E+07	1.58E+06	1.11E+11	6
87	05/26/1998	9.70E+06	1.10E+05	1.44E+09	5.82E+07	6.58E+05	5.18E+10	6
88	06/01/1998	9.69E+06	1.09E+04	5.90E+07	6.78E+07	7.60E+04	2.89E+09	7
89	06/09/1998	9.70E+06	1.21E+05	9.76E+08	6.78E+07	8.42E+05	4.77E+10	7
90	06/15/1998	9.69E+06	3.64E+04	2.84E+08	6.78E+07	2.55E+05	1.39E+10	7
91	06/22/1998	9.69E+06	2.69E+04	1.42E+08	6.78E+07	1.89E+05	6.97E+09	7
92	06/29/1998	9.69E+06	0	0	6.79E+07	0	0	7
93	07/06/1998	9.73E+06	6.58E+03	4.33E+07	6.79E+07	4.59E+04	2.11E+09	7
94	07/13/1998	9.67E+06	1.26E+04	1.59E+08	6.78E+07	8.85E+04	7.83E+09	7
95	07/21/1998	9.69E+06	2.15E+04	1.18E+08	6.78E+07	1.50E+05	5.79E+09	7
96	07/27/1998	9.70E+06	2.0E+04	1.60E+08	6.78E+07	1.40E+05	7.80E+09	7
97	08/03/1998	9.69E+06	1.38E+04	9.61E+07	6.78E+07	9.69E+04	4.71E+09	7
98	08/10/1998	9.68E+06	3.11E+04	9.29E+07	6.78E+07	2.18E+05	4.56E+09	7
99	08/18/1998	9.69E+06	6.41E+03	4.10E+07	7.66E+07	5.07E+04	2.57E+09	8
100	08/26/1998	9.69E+06	7.89E+04	3.38E+08	6.78E+07	5.52E+05	1.66E+10	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	4.44E+03	1.98E+07	4.70E+07	2.81E+04	7.90E+08	6

(continued)

Table I-13 (continued). Northern anchovy (*Engraulis mordax*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E+08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	6.67E+03	4.44E+07	2.75E+08	1.89E+05	3.59E+10	31
120	01/12/1999	9.68E+06	1.60E+04	1.41E+08	2.71E+08	4.47E+05	1.11E+11	28
123	02/03/1999	9.71E+06	7.43E+03	5.52E+07	2.33E+08	1.78E+05	3.16E+10	32
129	03/17/1999	7.29E+06	0	0	2.71E+08	0	0	35
133	04/14/1999	9.70E+06	0	0	3.20E+08	0	0	34
139	05/24/1999	9.41E+06	1.30E+04	8.52E+07	3.29E+08	4.57E+05	1.04E+11	35
143	06/23/1999	9.41E+06	0	0	2.16E+08	0	0	23

Table I-14. KGB rockfish complex (*Sebastes* spp. V_De/V_D_) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
4	10/30/1996	9.70E+06	0	0	6.77E+07	0	0	7
5	11/06/1996	9.70E+06	0	0	6.63E+07	0	0	7
6	11/13/1996	9.73E+06	0	0	5.84E+07	0	0	6
7	11/18/1996	9.69E+06	0	0	5.82E+07	0	0	6
8	11/25/1996	7.31E+06	0	0	5.33E+07	0	0	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	0	0	6.36E+07	0	0	7
11	12/09/1996	9.70E+06	1.12E+04	1.25E+08	6.79E+07	7.83E+04	6.13E+09	7
12	12/16/1996	9.70E+06	4.15E+03	1.72E+07	6.79E+07	2.90E+04	8.42E+08	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	3.21E+03	1.03E+07	6.68E+07	2.21E+04	4.90E+08	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	6.36E+04	2.17E+09	6.78E+07	4.47E+05	1.07E+11	7
21	02/17/1997	9.71E+06	1.09E+04	6.79E+07	6.76E+07	7.55E+04	3.28E+09	7
22	02/24/1997	9.71E+06	1.24E+05	9.82E+08	6.72E+07	8.58E+05	4.71E+10	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	1.60E+05	6.25E+09	6.75E+07	1.12E+06	3.03E+11	7
25	03/17/1997	9.36E+06	1.38E+06	2.89E+11	6.75E+07	9.97E+06	1.50E+13	7
26	03/24/1997	9.69E+06	2.53E+06	3.46E+12	6.77E+07	1.77E+07	1.69E+14	7
27	03/31/1997	7.31E+06	1.44E+06	1.05E+11	5.18E+07	1.02E+07	5.29E+12	7
28	04/07/1997	9.67E+06	2.03E+06	6.64E+11	6.62E+07	1.39E+07	3.12E+13	7
29	04/14/1997	9.69E+06	6.39E+06	2.24E+12	6.49E+07	4.28E+07	1.0E+14	7
30	04/21/1997	4.91E+06	2.25E+06	9.63E+10	4.04E+07	1.85E+07	6.51E+12	7
31	04/28/1997	4.89E+06	1.23E+06	1.60E+11	3.43E+07	8.62E+06	7.88E+12	7
32	05/05/1997	4.90E+06	3.12E+06	1.92E+12	3.42E+07	2.18E+07	9.37E+13	7
33	05/12/1997	4.91E+06	2.62E+06	3.03E+11	3.44E+07	1.84E+07	1.49E+13	7
34	05/19/1997	4.89E+06	3.92E+06	6.87E+11	3.44E+07	2.75E+07	3.39E+13	7
35	05/27/1997	6.96E+06	4.33E+06	1.04E+12	4.66E+07	2.90E+07	4.64E+13	7
36	06/02/1997	9.70E+06	2.25E+06	6.58E+11	6.18E+07	1.43E+07	2.67E+13	7
37	06/09/1997	9.70E+06	1.99E+06	2.48E+11	6.78E+07	1.39E+07	1.21E+13	7
38	06/16/1997	9.67E+06	1.82E+06	1.91E+11	6.78E+07	1.28E+07	9.40E+12	7
39	06/23/1997	9.71E+06	7.70E+05	9.89E+10	6.78E+07	5.37E+06	4.82E+12	7
40	06/30/1997	9.69E+06	6.78E+04	2.09E+08	6.32E+07	4.42E+05	8.88E+09	7
41	07/07/1997	9.68E+06	7.09E+04	1.72E+09	6.72E+07	4.92E+05	8.28E+10	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	2.89E+03	8.36E+06	6.74E+07	2.01E+04	4.03E+08	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7

(continued)

Table I-14 (continued). KGB rockfish complex (*Sebastes* spp. V_De/V_D_) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	5.99E+03	3.58E+07	7.75E+07	4.79E+04	2.30E+09	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	6.54E+03	4.27E+07	6.79E+07	4.58E+04	2.10E+09	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	2.99E+04	1.37E+08	1.23E+08	3.89E+05	2.33E+10	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	1.20E+04	4.87E+07	5.15E+07	1.32E+05	5.90E+09	11
75	03/04/1998	4.69E+06	4.39E+04	2.82E+08	2.34E+07	2.19E+05	7.06E+09	5
76	03/09/1998	4.69E+06	2.10E+05	1.07E+09	3.37E+07	1.51E+06	5.51E+10	7
77	03/19/1998	7.29E+06	8.22E+05	1.55E+11	5.44E+07	6.14E+06	8.64E+12	9
78	03/27/1998	8.44E+06	1.08E+06	3.34E+11	5.67E+07	7.28E+06	1.51E+13	7
79	04/01/1998	9.67E+06	7.69E+05	2.17E+11	4.81E+07	3.83E+06	5.36E+12	5
80	04/07/1998	9.73E+06	2.79E+05	8.55E+09	7.73E+07	2.22E+06	5.40E+11	8
81	04/16/1998	9.73E+06	8.85E+05	1.54E+11	1.07E+08	9.71E+06	1.85E+13	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	1.29E+06	1.15E+11	8.72E+07	1.16E+07	9.28E-12	9
84	05/04/1998	9.70E+06	5.26E+06	1.09E+13	6.78E+07	3.68E+07	5.31E+14	7
85	05/14/1998	9.68E+06	3.23E+06	2.04E+11	7.75E+07	2.59E+07	1.31E+13	8
86	05/19/1998	9.70E+06	1.53E+06	9.04E+10	5.81E+07	9.16E+06	3.24E-12	6
87	05/26/1998	9.70E+06	4.20E+06	5.45E+11	5.82E+07	2.52E+07	1.96E-13	6
88	06/01/1998	9.69E+06	3.21E+06	2.91E+11	6.78E+07	2.25E+07	1.43E+13	7
89	06/09/1998	9.70E+06	3.38E+06	4.20E+11	6.78E+07	2.36E+07	2.05E+13	7
90	06/15/1998	9.69E+06	9.10E+05	1.20E+11	6.78E+07	6.36E+06	5.86E+12	7
91	06/22/1998	9.69E+06	7.35E+05	9.65E+10	6.78E+07	5.14E+06	4.73E+12	7
92	06/29/1998	9.69E+06	1.41E+05	1.98E+09	6.79E+07	9.87E+05	9.74E+10	7
93	07/06/1998	9.73E+06	1.62E+04	8.76E+07	6.79E+07	1.13E+05	4.27E+09	7
94	07/13/1998	9.67E+06	6.52E+03	4.25E+07	6.78E+07	4.57E+04	2.09E+09	7
95	07/21/1998	9.69E+06	7.28E+03	5.30E+07	6.78E+07	5.09E+04	2.59E+09	7
96	07/27/1998	9.70E+06	0	0	6.78E+07	0	0	7
97	08/03/1998	9.69E+06	0	0	6.78E+07	0	0	7
98	08/10/1998	9.68E+06	0	0	6.78E+07	0	0	7
99	08/18/1998	9.69E+06	0	0	7.66E+07	0	0	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6

(continued)

Table I-14 (continued). KGB rockfish complex (*Sebastes* spp. V_De/V_D_) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E+08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	0	0	2.75E+08	0	0	31
120	01/12/1999	9.68E+06	0	0	2.71E+08	0	0	28
123	02/03/1999	9.71E+06	7.12E+03	5.07E+07	2.33E+08	1.71E+05	2.91E+10	32
129	03/17/1999	7.29E+06	1.27E+06	5.72E+11	2.71E+08	4.72E+07	7.93E+14	35
133	04/14/1999	9.70E+06	1.67E+06	7.38E+11	3.20E+08	5.50E+07	8.04E+14	34
139	05/24/1999	9.41E+06	4.21E+06	7.68E+11	3.29E+08	1.47E+08	9.41E+14	35
143	06/23/1999	9.41E+06	8.86E+05	8.39E+10	2.16E+08	2.04E+07	4.44E+13	23

Table I-15. Blue rockfish complex (*Sebastes* spp. *V/Sebastes mystinus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	2.75E+03	7.58E+06	6.79E+07	1.93E+04	3.71E-08	7
4	10/30/1996	9.70E+06	0	0	6.77E+07	0	0	7
5	11/06/1996	9.70E+06	0	0	6.63E+07	0	0	7
6	11/13/1996	9.73E+06	0	0	5.84E+07	0	0	6
7	11/18/1996	9.69E+06	0	0	5.82E+07	0	0	6
8	11/25/1996	7.31E+06	0	0	5.33E+07	0	0	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	0	0	6.36E+07	0	0	7
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	6.37E+03	2.04E+07	6.78E+07	4.46E+04	1.0E+09	7
15	01/06/1997	9.69E+06	1.07E+05	3.59E+08	6.79E+07	7.46E+05	1.76E+10	7
16	01/13/1997	9.69E+06	1.01E+05	3.32E+08	6.75E+07	7.03E+05	1.62E+10	7
17	01/20/1997	9.70E+06	1.61E+05	1.69E+09	6.79E+07	1.13E+06	8.27E+10	7
18	01/27/1997	9.70E+06	1.10E+06	2.03E+10	6.68E+07	7.56E+06	9.62E+11	7
19	02/03/1997	9.69E+06	8.77E+05	1.31E+11	6.75E+07	6.11E+06	6.36E+12	7
20	02/10/1997	9.64E+06	1.66E+06	4.86E+11	6.78E+07	1.17E+07	2.40E+13	7
21	02/17/1997	9.71E+06	1.30E+06	4.66E+11	6.76E+07	9.03E+06	2.25E+13	7
22	02/24/1997	9.71E+06	1.84E+05	5.61E+09	6.72E+07	1.27E+06	2.69E+11	7
23	03/03/1997	9.68E+06	5.95E+05	1.67E+11	6.79E+07	4.17E+06	8.21E+12	7
24	03/10/1997	9.70E+06	2.83E+05	7.73E+09	6.75E+07	1.97E+06	3.75E+11	7
25	03/17/1997	9.36E+06	5.92E+04	4.16E+08	6.75E+07	4.27E+05	2.17E+10	7
26	03/24/1997	9.69E+06	1.45E+05	2.21E+09	6.77E+07	1.01E+06	1.08E+11	7
27	03/31/1997	7.31E+06	2.19E+04	6.48E+07	5.18E+07	1.55E+05	3.26E+09	7
28	04/07/1997	9.67E+06	2.84E+03	8.06E+06	6.62E+07	1.94E+04	3.78E+08	7
29	04/14/1997	9.69E+06	4.03E+04	9.38E+07	6.49E+07	2.70E+05	4.20E+09	7
30	04/21/1997	4.91E+06	1.49E+04	4.59E+07	4.04E+07	1.23E+05	3.11E+09	7
31	04/28/1997	4.89E+06	3.64E+03	6.62E+06	3.43E+07	2.55E+04	3.26E+08	7
32	05/05/1997	4.90E+06	1.68E+04	1.78E+07	3.42E+07	1.18E+05	8.69E+08	7
33	05/12/1997	4.91E+06	1.81E+04	6.94E+07	3.44E+07	1.26E+05	3.41E+09	7
34	05/19/1997	4.89E+06	7.50E+03	3.25E+07	3.44E+07	5.27E+04	1.60E+09	7
35	05/27/1997	6.96E+06	2.14E+04	9.68E+07	4.66E+07	1.43E+05	4.34E+09	7
36	06/02/1997	9.70E+06	5.12E+04	2.61E+08	6.18E+07	3.26E+05	1.06E+10	7
37	06/09/1997	9.70E+06	2.15E+04	2.63E+08	6.78E+07	1.50E+05	1.28E+10	7
38	06/16/1997	9.67E+06	4.43E+04	2.42E+08	6.78E+07	3.10E+05	1.19E+10	7
39	06/23/1997	9.71E+06	5.37E+04	2.40E+08	6.78E+07	3.75E+05	1.17E+10	7
40	06/30/1997	9.69E+06	8.76E+04	7.31E+08	6.32E+07	5.71E+05	3.11E+10	7
41	07/07/1997	9.68E+06	5.53E+04	3.51E+08	6.72E+07	3.84E+05	1.69E+10	7
42	07/14/1997	9.69E+06	1.28E+04	8.15E+07	6.78E+07	8.93E+04	3.99E+09	7
43	07/21/1997	9.71E+06	1.30E+04	3.54E+07	6.74E+07	9.0E+04	1.70E+09	7
44	07/28/1997	9.69E+06	2.87E+04	1.68E+08	6.74E+07	2.0E+05	8.13E+09	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	1.93E+04	1.01E+08	6.78E+07	1.35E+05	4.95E+09	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	6.49E+03	1.46E+07	7.41E+07	4.95E+04	8.49E+08	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	1.02E+04	5.23E+07	5.83E+07	7.89E+04	3.16E+09	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7

(continued)

Table I-15 (continued). Blue rockfish complex (*Sebastes* spp. V/*Sebastes mystinus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	5.95E+03	3.54E+07	6.78E+07	4.16E+04	1.73E+09	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	5.29E+03	2.80E+07	6.61E+07	3.57E+04	1.27E+09	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	5.51E+04	4.06E+08	7.75E+07	4.41E+05	2.60E+10	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	4.64E+04	2.75E+08	6.79E+07	3.25E+05	1.35E+10	7
70	01/28/1998	9.69E+06	1.90E+04	1.02E+08	8.38E+07	1.64E+05	7.60E+09	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	6.93E+03	4.81E+07	1.23E+08	9.03E+04	8.16E+09	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	1.70E+05	1.12E+09	2.34E+07	8.48E+05	2.81E+10	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	5.18E+03	2.69E+07	5.44E+07	3.87E+04	1.50E+09	9
78	03/27/1998	8.44E+06	3.45E+04	3.84E+08	5.67E+07	2.32E+05	1.74E+10	7
79	04/01/1998	9.67E+06	2.91E+04	1.23E+08	4.81E+07	1.45E+05	3.05E+09	5
80	04/07/1998	9.73E+06	7.09E+03	5.02E+07	7.73E+07	5.63E+04	3.17E+09	8
81	04/16/1998	9.73E+06	8.91E+04	3.78E+09	1.07E+08	9.78E+05	4.54E+11	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	3.43E+04	3.51E+08	8.72E+07	3.08E+05	2.84E+10	9
84	05/04/1998	9.70E+06	8.08E+03	6.53E+07	6.78E+07	5.65E+04	3.20E+09	7
85	05/14/1998	9.68E+06	4.23E+04	3.91E+08	7.75E+07	3.39E+05	2.51E+10	8
86	05/19/1998	9.70E+06	1.74E+04	7.86E+07	5.81E+07	1.04E+05	2.82E+09	6
87	05/26/1998	9.70E+06	4.60E+04	6.27E+08	5.82E+07	2.76E+05	2.25E+10	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	6.55E+05	1.17E+10	6.78E+07	4.58E+06	5.70E+11	7
90	06/15/1998	9.69E+06	2.64E+05	3.59E+09	6.78E+07	1.85E+06	1.76E+11	7
91	06/22/1998	9.69E+06	1.02E+06	3.46E+10	6.78E+07	7.15E+06	1.70E+12	7
92	06/29/1998	9.69E+06	1.17E+06	3.74E+10	6.79E+07	8.19E+06	1.84E+12	7
93	07/06/1998	9.73E+06	4.03E+05	4.42E+09	6.79E+07	2.81E+06	2.15E+11	7
94	07/13/1998	9.67E+06	5.37E+05	5.91E+10	6.78E+07	3.76E+06	2.90E+12	7
95	07/21/1998	9.69E+06	5.01E+04	3.49E+08	6.78E+07	3.51E+05	1.71E+10	7
96	07/27/1998	9.70E+06	5.29E+04	1.62E+08	6.78E+07	3.70E+05	7.92E+09	7
97	08/03/1998	9.69E+06	5.09E+04	4.30E+08	6.78E+07	3.57E+05	2.11E+10	7
98	08/10/1998	9.68E+06	4.45E+04	3.26E+08	6.78E+07	3.11E+05	1.60E+10	7
99	08/18/1998	9.69E+06	6.41E+03	4.10E+07	7.66E+07	5.07E+04	2.57E+09	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	1.05E+04	5.47E+07	4.70E+07	6.61E+04	2.19E+09	6

(continued)

Table I-15 (continued). Blue rockfish complex (*Sebastes* spp. V/*Sebastes mystinus*) larvae:
 Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	6.56E+03	4.31E-07	6.78E+07	4.60E+04	2.12E+09	7
106	10/06/1998	9.69E+06	3.32E+04	1.65E+08	2.13E+08	7.30E+05	7.98E+10	22
111	11/11/1998	9.68E+06	2.59E+04	2.59E+08	3.10E+08	8.31E+05	2.67E+11	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	6.88E+03	4.74E+07	2.75E+08	1.96E+05	3.82E-10	31
120	01/12/1999	9.68E+06	4.78E+04	4.62E+08	2.71E+08	1.34E+06	3.62E+11	28
123	02/03/1999	9.71E+06	9.56E+04	1.22E+09	2.33E-08	2.29E+06	6.98E+11	32
129	03/17/1999	7.29E+06	2.35E+05	2.18E+09	2.71E-08	8.76E+06	3.02E+12	35
133	04/14/1999	9.70E+06	3.96E+05	5.24E+09	3.20E+08	1.31E+07	5.71E+12	34
139	05/24/1999	9.41E+06	2.12E+05	1.37E+09	3.29E+08	7.44E+06	1.67E+12	35
143	06/23/1999	9.41E+06	3.93E+05	8.03E+09	2.16E+08	9.03E+06	4.25E+12	23

Table I-16. Painted greenling (*Oxylebius pictus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	8.25E+03	3.94E+07	6.79E+07	5.77E+04	1.93E+09	7
4	10/30/1996	9.70E+06	1.96E+04	6.83E+07	6.77E+07	1.37E+05	3.32E+09	7
5	11/06/1996	9.70E+06	4.68E+04	2.57E+08	6.63E+07	3.20E+05	1.20E+10	7
6	11/13/1996	9.73E+06	9.46E+03	2.42E+07	5.84E+07	5.68E+04	8.73E+08	6
7	11/18/1996	9.69E+06	2.43E+04	2.26E+08	5.82E+07	1.46E+05	8.14E+09	6
8	11/25/1996	7.31E+06	6.29E+04	5.10E+08	5.33E+07	4.59E+05	2.72E+10	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	1.43E+04	2.54E+07	6.36E+07	9.35E+04	1.09E+09	7
11	12/09/1996	9.70E+06	3.56E+04	1.83E+08	6.79E+07	2.49E+05	8.95E+09	7
12	12/16/1996	9.70E+06	1.23E+05	1.59E+09	6.79E+07	8.57E+05	7.81E+10	7
13	12/23/1996	9.70E+06	7.34E+04	6.52E+08	6.79E+07	5.13E+05	3.20E+10	7
14	12/30/1996	9.68E+06	5.35E+04	5.24E+08	6.78E+07	3.75E+05	2.57E+10	7
15	01/06/1997	9.69E+06	1.20E+05	9.42E+08	6.79E+07	8.38E+05	4.62E+10	7
16	01/13/1997	9.69E+06	8.91E+04	2.95E+08	6.75E+07	6.21E+05	1.43E+10	7
17	01/20/1997	9.70E+06	1.57E+05	1.74E+09	6.79E+07	1.10E+06	8.53E+10	7
18	01/27/1997	9.70E+06	1.65E+05	5.41E+09	6.68E+07	1.13E+06	2.57E+11	7
19	02/03/1997	9.69E+06	1.98E+05	7.54E+09	6.75E+07	1.38E+06	3.67E+11	7
20	02/10/1997	9.64E+06	8.26E+04	8.81E+08	6.78E+07	5.81E+05	4.35E+10	7
21	02/17/1997	9.71E+06	9.93E+04	3.93E+09	6.76E+07	6.91E+05	1.90E+11	7
22	02/24/1997	9.71E+06	4.72E+04	1.88E+08	6.72E+07	3.26E+05	9.0E+09	7
23	03/03/1997	9.68E+06	1.09E+05	1.33E+09	6.79E+07	7.62E+05	6.55E+10	7
24	03/10/1997	9.70E+06	1.24E+05	2.03E+09	6.75E+07	8.63E+05	9.84E+10	7
25	03/17/1997	9.36E+06	1.14E+05	1.10E+09	6.75E+07	8.24E+05	5.75E+10	7
26	03/24/1997	9.69E+06	2.47E+05	1.07E+10	6.77E+07	1.72E+06	5.22E+11	7
27	03/31/1997	7.31E+06	9.11E+04	1.58E+09	5.18E+07	6.47E+05	7.97E+10	7
28	04/07/1997	9.67E+06	1.83E+04	6.65E+07	6.62E+07	1.25E+05	3.12E+09	7
29	04/14/1997	9.69E+06	1.24E+05	9.33E+08	6.49E+07	8.29E+05	4.18E+10	7
30	04/21/1997	4.91E+06	3.34E+04	3.10E+08	4.04E+07	2.75E+05	2.10E+10	7
31	04/28/1997	4.89E+06	2.46E+04	7.54E+07	3.43E+07	1.73E+05	3.72E+09	7
32	05/05/1997	4.90E+06	3.14E+04	6.23E+07	3.42E+07	2.19E+05	3.04E+09	7
33	05/12/1997	4.91E+06	1.31E+05	9.30E+08	3.44E+07	9.20E+05	4.56E+10	7
34	05/19/1997	4.89E+06	3.68E+04	7.11E+07	3.44E+07	2.58E+05	3.50E+09	7
35	05/27/1997	6.96E+06	4.04E+04	3.48E+08	4.66E+07	2.71E+05	1.56E+10	7
36	06/02/1997	9.70E+06	1.71E+04	6.67E+07	6.18E+07	1.09E+05	2.71E+09	7
37	06/09/1997	9.70E+06	1.93E+04	1.25E+08	6.78E+07	1.35E+05	6.12E+09	7
38	06/16/1997	9.67E+06	4.53E+04	8.61E+07	6.78E+07	3.18E+05	4.23E+09	7
39	06/23/1997	9.71E+06	5.66E+04	9.19E+08	6.78E+07	3.95E+05	4.48E+10	7
40	06/30/1997	9.69E+06	1.37E+04	3.89E+07	6.32E+07	8.93E+04	1.66E+09	7
41	07/07/1997	9.68E+06	3.71E+04	2.58E+08	6.72E+07	2.57E+05	1.24E+10	7
42	07/14/1997	9.69E+06	8.97E+04	2.12E+09	6.78E+07	6.27E+05	1.04E+11	7
43	07/21/1997	9.71E+06	7.39E+04	2.19E+09	6.74E+07	5.13E+05	1.05E+11	7
44	07/28/1997	9.69E+06	1.57E+05	1.49E+09	6.74E+07	1.09E+06	7.23E+10	7
45	08/04/1997	9.69E+06	4.15E+04	4.20E+08	6.78E+07	2.90E+05	2.05E+10	7
46	08/11/1997	9.68E+06	3.67E+04	2.94E+08	6.78E+07	2.57E+05	1.44E+10	7
47	08/18/1997	9.70E+06	1.21E+04	7.34E+07	6.81E+07	8.50E+04	3.61E+09	7
48	08/26/1997	9.70E+06	2.80E+03	7.83E+06	7.41E+07	2.14E+04	4.56E+08	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7

(continued)

Table I-16 (continued). Painted greenling (*Oxylebius pictus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	4.92E+03	2.42E+07	6.78E+07	3.45E+04	1.19E+09	7
56	10/21/1997	9.69E+06	1.08E+04	5.87E+07	6.78E+07	7.55E+04	2.87E+09	7
57	10/27/1997	9.81E+06	1.70E+04	7.85E+07	6.61E+07	1.15E+05	3.57E+09	7
58	11/04/1997	9.80E+06	3.98E+04	3.47E+08	6.82E+07	2.77E+05	1.68E+10	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	6.40E+03	4.10E+07	6.86E+07	4.50E+04	2.02E+09	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	6.40E+03	4.10E+07	8.72E+07	5.77E+04	3.32E+09	9
63	12/11/1997	9.69E+06	1.08E+04	1.16E+08	6.78E+07	7.54E+04	5.69E+09	7
64	12/16/1997	9.69E+06	6.24E+03	3.89E+07	4.85E+07	3.12E+04	9.72E+08	5
65	12/22/1997	9.70E+06	7.23E+03	5.23E+07	6.78E+07	5.05E+04	2.55E+09	7
66	12/30/1997	9.68E+06	2.67E+04	2.36E+08	6.76E+07	1.86E+05	1.15E+10	7
67	01/05/1998	9.68E+06	2.27E+04	1.44E+08	7.75E+07	1.81E+05	9.23E+09	8
68	01/15/1998	9.67E+06	1.34E+04	8.92E+07	8.72E+07	1.20E+05	7.26E+09	9
69	01/23/1998	9.69E+06	8.54E+04	8.33E+08	6.79E+07	5.98E+05	4.09E+10	7
70	01/28/1998	9.69E+06	9.82E+04	1.39E+09	8.38E+07	8.48E+05	1.04E+11	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	2.08E+04	1.13E+08	1.23E+08	2.71E+05	1.92E+10	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	1.06E+04	4.44E+07	5.15E+07	1.17E+05	5.37E+09	11
75	03/04/1998	4.69E+06	6.70E+03	4.49E+07	2.34E+07	3.35E+04	1.12E+09	5
76	03/09/1998	4.69E+06	9.46E+03	5.02E+07	3.37E+07	6.80E+04	2.59E+09	7
77	03/19/1998	7.29E+06	2.63E+04	1.76E+08	5.44E+07	1.97E+05	9.78E+09	9
78	03/27/1998	8.44E+06	1.47E+04	1.19E+08	5.67E+07	9.87E+04	5.38E+09	7
79	04/01/1998	9.67E+06	1.38E+04	9.46E+07	4.81E+07	6.85E+04	2.35E+09	5
80	04/07/1998	9.73E+06	7.44E+04	1.72E+09	7.73E+07	5.91E+05	1.09E+11	8
81	04/16/1998	9.73E+06	1.47E+04	1.10E+08	1.07E+08	1.62E+05	1.33E+10	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	3.54E+04	2.74E+08	8.72E+07	3.19E+05	2.22E+10	9
84	05/04/1998	9.70E+06	4.02E+04	2.94E+08	6.78E+07	2.81E+05	1.44E+10	7
85	05/14/1998	9.68E+06	3.14E+04	3.07E+08	7.75E+07	2.52E+05	1.97E+10	8
86	05/19/1998	9.70E+06	5.28E+04	3.30E+08	5.81E+07	3.16E+05	1.18E+10	6
87	05/26/1998	9.70E+06	2.29E+04	1.10E+08	5.82E+07	1.38E+05	3.96E+09	6
88	06/01/1998	9.69E+06	3.68E+04	5.19E+08	6.78E+07	2.58E+05	2.54E+10	7
89	06/09/1998	9.70E+06	1.23E+05	9.18E+08	6.78E+07	8.63E+05	4.49E+10	7
90	06/15/1998	9.69E+06	9.36E+04	4.06E+08	6.78E+07	6.55E+05	1.99E+10	7
91	06/22/1998	9.69E+06	5.71E+04	1.30E+09	6.78E+07	4.0E+05	6.38E+10	7
92	06/29/1998	9.69E+06	2.20E+04	5.75E+07	6.79E+07	1.54E+05	2.82E+09	7
93	07/06/1998	9.73E+06	3.46E+04	3.37E+08	6.79E+07	2.41E+05	1.64E+10	7
94	07/13/1998	9.67E+06	2.69E+04	2.73E+08	6.78E+07	1.89E+05	1.34E+10	7
95	07/21/1998	9.69E+06	6.41E+03	4.11E+07	6.78E+07	4.48E+04	2.01E+09	7
96	07/27/1998	9.70E+06	0	0	6.78E+07	0	0	7
97	08/03/1998	9.69E+06	0	0	6.78E+07	0	0	7
98	08/10/1998	9.68E+06	0	0	6.78E+07	0	0	7
99	08/18/1998	9.69E+06	0	0	7.66E+07	0	0	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6

(continued)

Table I-16 (continued). Painted greenling (*Oxylebius pictus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E+08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	6.88E+03	4.74E+07	2.75E+08	1.96E+05	3.82E+10	31
120	01/12/1999	9.68E+06	8.05E+04	2.90E+08	2.71E+08	2.25E+06	2.28E+11	28
123	02/03/1999	9.71E+06	1.27E+05	5.03E+08	2.33E+08	3.05E+06	2.89E+11	32
129	03/17/1999	7.29E+06	1.15E+05	1.04E+09	2.71E+08	4.27E+06	1.45E+12	35
133	04/14/1999	9.70E+06	4.26E+04	3.02E+08	3.20E+08	1.40E+06	3.29E+11	34
139	05/24/1999	9.41E+06	1.21E+05	1.24E+09	3.29E+08	4.23E+06	1.52E+12	35
143	06/23/1999	9.41E+06	9.82E+04	5.66E+08	2.16E+08	2.26E+06	3.0E+11	23

Table I-17. Smoothhead sculpin (*Artedius lateralis*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E-07	0	0	7
4	10/30/1996	9.70E+06	0	0	6.77E+07	0	0	7
5	11/06/1996	9.70E+06	0	0	6.63E+07	0	0	7
6	11/13/1996	9.73E+06	1.03E+04	3.52E+07	5.84E+07	6.17E+04	1.27E+09	6
7	11/18/1996	9.69E+06	0	0	5.82E+07	0	0	6
8	11/25/1996	7.31E+06	0	0	5.33E+07	0	0	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	3.40E+03	1.16E+07	6.36E+07	2.23E+04	4.98E+08	7
11	12/09/1996	9.70E+06	7.27E+03	2.65E+07	6.79E+07	5.09E+04	1.30E+09	7
12	12/16/1996	9.70E+06	1.82E+04	1.44E+08	6.79E+07	1.28E+05	7.07E+09	7
13	12/23/1996	9.70E+06	1.43E+04	7.19E+07	6.79E+07	1.0E+05	3.52E+09	7
14	12/30/1996	9.68E+06	4.60E+04	2.10E+08	6.78E+07	3.22E-05	1.03E+10	7
15	01/06/1997	9.69E+06	5.91E+04	2.11E+08	6.79E+07	4.14E-05	1.03E+10	7
16	01/13/1997	9.69E+06	2.54E+04	9.69E+07	6.75E+07	1.77E-05	4.71E+09	7
17	01/20/1997	9.70E+06	2.24E+04	9.15E+07	6.79E+07	1.57E-05	4.48E+09	7
18	01/27/1997	9.70E+06	9.83E+04	1.07E+09	6.68E+07	6.77E+05	5.08E+10	7
19	02/03/1997	9.69E+06	9.34E+04	3.36E+08	6.75E+07	6.51E+05	1.63E+10	7
20	02/10/1997	9.64E+06	6.79E+04	2.68E+08	6.78E+07	4.77E+05	1.32E+10	7
21	02/17/1997	9.71E+06	1.84E+05	2.27E+09	6.76E-07	1.28E+06	1.10E+11	7
22	02/24/1997	9.71E+06	8.43E+04	7.71E+08	6.72E-07	5.84E+05	3.69E+10	7
23	03/03/1997	9.68E+06	1.97E+05	2.94E+09	6.79E+07	1.38E+06	1.45E+11	7
24	03/10/1997	9.70E+06	4.78E+05	3.65E+09	6.75E+07	3.33E+06	1.77E+11	7
25	03/17/1997	9.36E+06	4.56E+05	8.41E+09	6.75E+07	3.29E+06	4.38E+11	7
26	03/24/1997	9.69E+06	3.53E+05	7.49E+09	6.77E+07	2.46E+06	3.66E+11	7
27	03/31/1997	7.31E+06	2.32E-05	2.24E+09	5.18E+07	1.64E+06	1.13E+11	7
28	04/07/1997	9.67E+06	1.52E+06	6.01E+10	6.62E+07	1.04E+07	2.82E+12	7
29	04/14/1997	9.69E+06	4.51E+05	6.43E+09	6.49E+07	3.01E+06	2.88E+11	7
30	04/21/1997	4.91E+06	2.91E+05	3.59E+09	4.04E+07	2.40E+06	2.43E+11	7
31	04/28/1997	4.89E+06	3.29E-04	1.68E+08	3.43E-07	2.31E+05	8.30E+09	7
32	05/05/1997	4.90E+06	4.45E+04	1.72E+08	3.42E-07	3.11E+05	8.41E+09	7
33	05/12/1997	4.91E+06	5.21E+05	1.55E+10	3.44E+07	3.65E+06	7.58E+11	7
34	05/19/1997	4.89E+06	4.24E+05	6.52E+09	3.44E-07	2.98E+06	3.21E+11	7
35	05/27/1997	6.96E+06	1.40E+06	2.88E+10	4.66E+07	9.39E+06	1.29E+12	7
36	06/02/1997	9.70E+06	5.96E+05	6.34E+09	6.18E+07	3.80E+06	2.57E+11	7
37	06/09/1997	9.70E+06	7.58E+05	1.44E+10	6.78E+07	5.30E+06	7.02E+11	7
38	06/16/1997	9.67E+06	1.14E+06	4.47E+10	6.78E+07	7.96E+06	2.20E+12	7
39	06/23/1997	9.71E+06	5.07E+05	7.45E+09	6.78E+07	3.54E+06	3.63E+11	7
40	06/30/1997	9.69E+06	7.67E+05	1.93E+10	6.32E+07	5.0E+06	8.21E+11	7
41	07/07/1997	9.68E+06	2.93E+05	4.34E+09	6.72E+07	2.04E+06	2.09E+11	7
42	07/14/1997	9.69E+06	7.62E+05	1.58E+10	6.78E+07	5.33E+06	7.71E+11	7
43	07/21/1997	9.71E+06	1.86E+05	4.33E+09	6.74E+07	1.29E+06	2.09E+11	7
44	07/28/1997	9.69E+06	1.08E-05	1.96E+09	6.74E+07	7.50E+05	9.50E+10	7
45	08/04/1997	9.69E+06	3.33E-05	8.52E+09	6.78E+07	2.33E+06	4.17E+11	7
46	08/11/1997	9.68E+06	9.33E-04	4.57E+08	6.78E+07	6.53E+05	2.24E+10	7
47	08/18/1997	9.70E+06	6.59E+04	5.95E+08	6.81E+07	4.63E+05	2.93E+10	7
48	08/26/1997	9.70E+06	7.07E-04	2.83E+08	7.41E+07	5.40E+05	1.65E+10	8
49	09/02/1997	9.67E+06	1.83E+04	1.90E+08	5.82E+07	1.10E+05	6.88E+09	6
50	09/08/1997	7.49E+06	9.15E+03	2.80E+07	5.83E+07	7.11E+04	1.69E+09	7
51	09/15/1997	9.68E+06	1.93E+04	2.16E+08	6.78E+07	1.35E+05	1.06E-10	7
52	09/22/1997	9.67E+06	1.08E+04	5.84E+07	6.78E+07	7.54E+04	2.87E+09	7

(continued)

Table I-17 (continued). Smoothhead sculpin (*Artedius lateralis*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	5.20E+03	2.70E+07	6.80E+07	3.64E+04	1.32E+09	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	5.67E+03	3.22E+07	6.82E+07	3.95E+04	1.56E+09	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	7.59E+03	5.76E+07	7.75E+07	6.07E+04	3.69E+09	8
68	01/15/1998	9.67E+06	6.83E+03	4.66E+07	8.72E+07	6.16E+04	3.79E+09	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	1.64E+04	1.51E+08	8.38E+07	1.41E+05	1.12E+10	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	3.58E+04	1.22E+08	2.34E+07	1.79E+05	3.04E+09	5
76	03/09/1998	4.69E+06	3.31E+03	1.10E+07	3.37E+07	2.38E+04	5.67E+08	7
77	03/19/1998	7.29E+06	1.65E+05	7.70E+08	5.44E+07	1.23E+06	4.28E+10	9
78	03/27/1998	8.44E+06	2.82E+05	2.29E+09	5.67E+07	1.90E+06	1.03E+11	7
79	04/01/1998	9.67E+06	9.44E+04	5.54E+08	4.81E+07	4.70E+05	1.37E+10	5
80	04/07/1998	9.73E+06	9.75E+04	5.78E+08	7.73E+07	7.75E+05	3.65E+10	8
81	04/16/1998	9.73E+06	4.94E+05	1.24E+10	1.07E+08	5.42E+06	1.49E+12	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	4.57E+06	9.93E+11	8.72E+07	4.12E+07	8.04E+13	9
84	05/04/1998	9.70E+06	4.49E+05	3.72E+09	6.78E+07	3.14E+06	1.82E+11	7
85	05/14/1998	9.68E+06	7.82E+05	1.62E+10	7.75E+07	6.26E+06	1.04E+12	8
86	05/19/1998	9.70E+06	7.49E+05	1.24E+10	5.81E+07	4.48E+06	4.44E+11	6
87	05/26/1998	9.70E+06	5.04E+05	1.01E+10	5.82E+07	3.02E+06	3.64E+11	6
88	06/01/1998	9.69E+06	5.69E+05	6.80E+09	6.78E+07	3.98E+06	3.33E+11	7
89	06/09/1998	9.70E+06	7.57E+05	8.41E+09	6.78E+07	5.29E+06	4.11E+11	7
90	06/15/1998	9.69E+06	2.51E+05	1.96E+09	6.78E+07	1.75E+06	9.58E+10	7
91	06/22/1998	9.69E+06	1.19E+06	5.53E+10	6.78E+07	8.31E+06	2.71E+12	7
92	06/29/1998	9.69E+06	7.36E+05	1.60E+10	6.79E+07	5.16E+06	7.83E+11	7
93	07/06/1998	9.73E+06	2.52E+05	2.15E+09	6.79E+07	1.76E+06	1.05E+11	7
94	07/13/1998	9.67E+06	1.10E+05	7.34E+08	6.78E+07	7.71E+05	3.61E+10	7
95	07/21/1998	9.69E+06	3.09E+04	1.76E+08	6.78E+07	2.16E+05	8.62E+09	7
96	07/27/1998	9.70E+06	2.59E+04	1.59E+08	6.78E+07	1.81E+05	7.76E+09	7
97	08/03/1998	9.69E+06	7.34E+03	5.39E+07	6.78E+07	5.14E+04	2.64E+09	7
98	08/10/1998	9.68E+06	6.80E+03	4.62E+07	6.78E+07	4.76E+04	2.27E+09	7
99	08/18/1998	9.69E+06	6.32E+03	4.00E+07	7.66E+07	5.00E+04	2.50E+09	8
100	08/26/1998	9.69E+06	7.10E+03	4.43E+07	6.78E+07	4.97E+04	2.17E+09	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6

(continued)

Table I-17 (continued). Smoothhead sculpin (*Artedius lateralis*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E+08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	0	0	2.75E+08	0	0	31
120	01/12/1999	9.68E+06	5.53E+04	6.15E+08	2.71E+08	1.55E+06	4.82E+11	28
123	02/03/1999	9.71E+06	2.11E+05	2.19E+09	2.33E+08	5.05E+06	1.25E+12	32
129	03/17/1999	7.29E+06	2.43E+05	2.99E+09	2.71E+08	9.06E+06	4.14E+12	35
133	04/14/1999	9.70E+06	9.01E+05	2.74E+10	3.20E+08	2.98E+07	2.99E+13	34
139	05/24/1999	9.41E+06	9.31E+05	2.97E+10	3.29E+08	3.26E+07	3.63E+13	35
143	06/23/1999	9.41E+06	7.76E+05	9.60E+09	2.16E+08	1.78E+07	5.08E+12	23

Table I-18. Snubnose sculpin (*Orthonopias triacis*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	4.49E+04	1.71E+08	6.79E+07	3.14E+05	8.39E+09	7
4	10/30/1996	9.70E+06	8.86E+03	2.63E+07	6.77E+07	6.18E+04	1.28E+09	7
5	11/06/1996	9.70E+06	1.85E+04	4.36E+07	6.63E+07	1.26E+05	2.03E+09	7
6	11/13/1996	9.73E+06	3.24E+04	6.85E+07	5.84E+07	1.94E+05	2.47E+09	6
7	11/18/1996	9.69E+06	3.84E+04	8.14E+07	5.82E+07	2.31E+05	2.93E+09	6
8	11/25/1996	7.31E+06	2.92E+03	8.51E+06	5.33E+07	2.13E+04	4.54E+08	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	1.41E+04	4.16E+07	6.36E+07	9.27E+04	1.79E+09	7
11	12/09/1996	9.70E+06	3.66E+04	9.05E+07	6.79E+07	2.57E+05	4.44E+09	7
12	12/16/1996	9.70E+06	1.99E+05	1.74E+09	6.79E+07	1.39E+06	8.51E+10	7
13	12/23/1996	9.70E+06	1.34E+05	8.10E+08	6.79E+07	9.38E+05	3.97E+10	7
14	12/30/1996	9.68E+06	4.11E+04	1.39E+08	6.78E+07	2.88E+05	6.80E+09	7
15	01/06/1997	9.69E+06	8.79E+04	2.26E+08	6.79E+07	6.15E+05	1.11E+10	7
16	01/13/1997	9.69E+06	4.75E+04	5.68E+08	6.75E+07	3.31E+05	2.76E+10	7
17	01/20/1997	9.70E+06	2.68E+04	7.36E+07	6.79E+07	1.88E+05	3.60E+09	7
18	01/27/1997	9.70E+06	1.84E+05	1.63E+09	6.68E+07	1.27E+06	7.75E+10	7
19	02/03/1997	9.69E+06	1.16E+05	9.43E+08	6.75E+07	8.06E+05	4.58E+10	7
20	02/10/1997	9.64E+06	7.06E+04	3.36E+08	6.78E+07	4.97E+05	1.66E+10	7
21	02/17/1997	9.71E+06	1.38E+05	1.23E+09	6.76E+07	9.59E+05	5.94E+10	7
22	02/24/1997	9.71E+06	1.19E+05	1.39E+09	6.72E+07	8.25E+05	6.65E+10	7
23	03/03/1997	9.68E+06	7.52E+04	3.65E+08	6.79E+07	5.27E+05	1.80E+10	7
24	03/10/1997	9.70E+06	2.06E+05	1.82E+09	6.75E+07	1.43E+06	8.80E+10	7
25	03/17/1997	9.36E+06	2.31E+05	2.03E+09	6.75E+07	1.67E+06	1.06E+11	7
26	03/24/1997	9.69E+06	9.41E+04	7.55E+08	6.77E+07	6.58E+05	3.68E+10	7
27	03/31/1997	7.31E+06	9.38E+04	4.58E+08	5.18E+07	6.66E+05	2.30E+10	7
28	04/07/1997	9.67E+06	6.47E+05	1.40E+10	6.62E+07	4.43E+06	6.57E+11	7
29	04/14/1997	9.69E+06	5.04E+05	2.88E+09	6.49E+07	3.37E+06	1.29E+11	7
30	04/21/1997	4.91E+06	1.47E+05	1.44E+09	4.04E+07	1.21E+06	9.74E+10	7
31	04/28/1997	4.89E+06	3.20E+04	1.47E+08	3.43E+07	2.24E+05	7.25E+09	7
32	05/05/1997	4.90E+06	2.43E+04	3.72E+07	3.42E+07	1.69E+05	1.82E+09	7
33	05/12/1997	4.91E+06	3.53E+05	7.01E+09	3.44E+07	2.47E+06	3.44E+11	7
34	05/19/1997	4.89E+06	2.93E+05	3.05E+09	3.44E+07	2.05E+06	1.50E+11	7
35	05/27/1997	6.96E+06	6.09E+05	9.27E+09	4.66E+07	4.08E+06	4.16E+11	7
36	06/02/1997	9.70E+06	3.09E+05	2.36E+09	6.18E+07	1.97E+06	9.57E+10	7
37	06/09/1997	9.70E+06	8.33E+05	9.63E+09	6.78E+07	5.82E+06	4.70E+11	7
38	06/16/1997	9.67E+06	1.76E+06	8.38E+10	6.78E+07	1.23E+07	4.12E+12	7
39	06/23/1997	9.71E+06	5.43E+05	1.31E+10	6.78E+07	3.79E+06	6.39E+11	7
40	06/30/1997	9.69E+06	7.13E+05	1.20E+10	6.32E+07	4.65E+06	5.09E+11	7
41	07/07/1997	9.68E+06	2.88E+05	2.59E+09	6.72E+07	2.0E+06	1.25E+11	7
42	07/14/1997	9.69E+06	6.36E+05	6.92E+09	6.78E+07	4.45E+06	3.38E+11	7
43	07/21/1997	9.71E+06	8.53E+05	4.59E+10	6.74E+07	5.92E+06	2.21E+12	7
44	07/28/1997	9.69E+06	1.18E+05	1.03E+09	6.74E+07	8.18E+05	4.96E+10	7
45	08/04/1997	9.69E+06	7.09E+05	1.49E+10	6.78E+07	4.96E+06	7.31E+11	7
46	08/11/1997	9.68E+06	2.06E+05	2.19E+09	6.78E+07	1.44E+06	1.07E+11	7
47	08/18/1997	9.70E+06	1.03E+05	1.16E+09	6.81E+07	7.24E+05	5.73E+10	7
48	08/26/1997	9.70E+06	8.32E+04	3.31E+08	7.41E+07	6.35E+05	1.93E+10	8
49	09/02/1997	9.67E+06	2.03E+05	2.94E+09	5.82E+07	1.22E+06	1.06E+11	6
50	09/08/1997	7.49E+06	4.18E+04	1.94E+08	5.83E+07	3.25E+05	1.17E+10	7
51	09/15/1997	9.68E+06	1.93E+05	1.33E+09	6.78E+07	1.35E+06	6.51E+10	7
52	09/22/1997	9.67E+06	7.39E+04	3.97E+08	6.78E+07	5.19E+05	1.95E+10	7

(continued)

Table I-18 (continued). Snubnose sculpin (*Orthonopias triacis*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	6.02E+04	3.62E+08	6.79E+07	4.21E+05	1.78E+10	7
54	10/06/1997	9.70E+06	1.11E+04	6.14E+07	6.80E+07	7.76E+04	3.01E+09	7
55	10/13/1997	9.69E+06	5.46E+03	2.99E+07	6.78E+07	3.83E+04	1.46E+09	7
56	10/21/1997	9.69E+06	1.64E+04	8.98E+07	6.78E+07	1.15E+05	4.39E+09	7
57	10/27/1997	9.81E+06	3.25E+04	2.40E+08	6.61E+07	2.19E+05	1.09E+10	7
58	11/04/1997	9.80E+06	2.09E+04	7.31E+07	6.82E+07	1.45E+05	3.54E+09	7
59	11/10/1997	9.80E+06	1.73E+04	1.19E+08	6.84E+07	1.21E+05	5.78E+09	7
60	11/18/1997	9.76E+06	5.24E+03	2.75E+07	6.86E+07	3.68E+04	1.35E+09	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	1.19E+04	7.04E+07	8.72E+07	1.07E+05	5.71E+09	9
63	12/11/1997	9.69E+06	6.65E+03	4.43E+07	6.78E+07	4.65E+04	2.17E+09	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	1.37E+04	8.80E+07	6.76E+07	9.56E+04	4.29E+09	7
67	01/05/1998	9.68E+06	5.88E+03	3.46E+07	7.75E+07	4.71E+04	2.22E+09	8
68	01/15/1998	9.67E+06	2.54E+04	1.36E+08	8.72E+07	2.29E+05	1.11E+10	9
69	01/23/1998	9.69E+06	4.55E+04	4.38E+08	6.79E+07	3.18E+05	2.15E+10	7
70	01/28/1998	9.69E+06	1.78E+04	6.0E+07	8.38E+07	1.54E+05	4.48E+09	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	4.30E+04	1.91E+08	1.23E+08	5.60E+05	3.25E+10	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	3.19E+03	1.02E+07	3.37E+07	2.30E+04	5.27E+08	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	6.05E+04	4.89E+08	5.67E+07	4.07E+05	2.21E+10	7
79	04/01/1998	9.67E+06	2.56E+04	1.40E+08	4.81E+07	1.27E+05	3.46E+09	5
80	04/07/1998	9.73E+06	7.0E+04	6.66E+08	7.73E+07	5.56E+05	4.21E+10	8
81	04/16/1998	9.73E+06	4.38E+05	1.39E+10	1.07E+08	4.80E+06	1.67E+12	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	1.17E+06	8.14E+10	8.72E+07	1.05E+07	6.59E+12	9
84	05/04/1998	9.70E+06	1.87E+05	2.51E+09	6.78E+07	1.31E+06	1.23E+11	7
85	05/14/1998	9.68E+06	2.89E+05	3.49E+09	7.75E+07	2.31E+06	2.24E+11	8
86	05/19/1998	9.70E+06	4.74E+05	9.91E+09	5.81E+07	2.84E+06	3.55E+11	6
87	05/26/1998	9.70E+06	3.57E+05	3.40E+09	5.82E+07	2.14E+06	1.22E+11	6
88	06/01/1998	9.69E+06	3.13E+05	3.85E+09	6.78E+07	2.19E+06	1.89E+11	7
89	06/09/1998	9.70E+06	6.55E+05	1.17E+10	6.78E+07	4.58E+06	5.70E+11	7
90	06/15/1998	9.69E+06	2.64E+05	3.59E+09	6.78E+07	1.85E+06	1.76E+11	7
91	06/22/1998	9.69E+06	1.02E+06	3.46E+10	6.78E+07	7.15E+06	1.70E+12	7
92	06/29/1998	9.69E+06	1.17E+06	3.74E+10	6.79E+07	8.19E+06	1.84E+12	7
93	07/06/1998	9.73E+06	4.03E+05	4.42E+09	6.79E+07	2.81E+06	2.15E+11	7
94	07/13/1998	9.67E+06	5.37E+05	5.91E+10	6.78E+07	3.76E+06	2.90E+12	7
95	07/21/1998	9.69E+06	5.01E+04	3.49E+08	6.78E+07	3.51E+05	1.71E+10	7
96	07/27/1998	9.70E+06	5.29E+04	1.62E+08	6.78E+07	3.70E+05	7.92E+09	7
97	08/03/1998	9.69E+06	5.09E+04	4.30E+08	6.78E+07	3.57E+05	2.11E+10	7
98	08/10/1998	9.68E+06	4.45E+04	3.26E+08	6.78E+07	3.11E+05	1.60E+10	7
99	08/18/1998	9.69E+06	0	0	7.66E+07	0	0	8
100	08/26/1998	9.69E+06	1.40E+04	8.65E+07	6.78E+07	9.78E+04	4.24E+09	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	1.13E+04	4.23E+07	6.78E+07	7.88E+04	2.07E+09	7
104	09/21/1998	7.44E+06	1.05E+04	5.47E+07	4.70E+07	6.61E+04	2.19E+09	6

(continued)

Table I-18 (continued). Snubnose sculpin (*Orthonopias triacis*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	6.56E+03	4.31E+07	6.78E+07	4.60E+04	2.12E+09	7
106	10/06/1998	9.69E+06	3.32E+04	1.65E+08	2.13E+08	7.30E+05	7.98E+10	22
111	11/11/1998	9.68E+06	2.59E+04	2.59E+08	3.10E+08	8.31E+05	2.67E+11	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	6.88E+03	4.74E+07	2.75E+08	1.96E+05	3.82E+10	31
120	01/12/1999	9.68E+06	4.78E+04	4.62E+08	2.71E+08	1.34E+06	3.62E+11	28
123	02/03/1999	9.71E+06	9.56E+04	1.22E+09	2.33E+08	2.29E+06	6.98E+11	32
129	03/17/1999	7.29E+06	2.35E+05	2.18E+09	2.71E+08	8.76E+06	3.02E+12	35
133	04/14/1999	9.70E+06	3.96E+05	5.24E+09	3.20E+08	1.31E+07	5.71E+12	34
139	05/24/1999	9.41E+06	2.12E+05	1.37E+09	3.29E+08	7.44E+06	1.67E+12	35
143	06/23/1999	9.41E+06	3.93E+05	8.03E+09	2.16E+08	9.03E+06	4.25E+12	23

Table I-19. Cabezon (*Scorpaenichthys marmoratus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
4	10/30/1996	9.70E+06	3.87E+04	1.43E+08	6.77E+07	2.70E+05	6.94E+09	7
5	11/06/1996	9.70E+06	8.17E+04	4.43E+08	6.63E+07	5.58E+05	2.06E+10	7
6	11/13/1996	9.73E+06	1.99E+04	1.32E+08	5.84E+07	1.20E+05	4.77E+09	6
7	11/18/1996	9.69E+06	2.11E+05	8.02E+09	5.82E+07	1.27E+06	2.89E+11	6
8	11/25/1996	7.31E+06	2.60E+05	3.73E+09	5.33E+07	1.90E+06	1.99E+11	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	2.52E+05	7.23E+09	6.36E+07	1.65E+06	3.11E+11	7
11	12/09/1996	9.70E+06	1.97E+05	1.16E+09	6.79E+07	1.38E+06	5.66E+10	7
12	12/16/1996	9.70E+06	7.49E+05	4.31E+10	6.79E+07	5.24E+06	2.11E+12	7
13	12/23/1996	9.70E+06	2.96E+05	1.48E+10	6.79E+07	2.07E+06	7.24E+11	7
14	12/30/1996	9.68E+06	3.64E+05	3.81E+09	6.78E+07	2.55E+06	1.87E+11	7
15	01/06/1997	9.69E+06	7.25E+05	1.06E+10	6.79E+07	5.08E+06	5.18E+11	7
16	01/13/1997	9.69E+06	2.35E+05	1.30E+10	6.75E+07	1.64E+06	6.31E+11	7
17	01/20/1997	9.70E+06	4.81E+05	2.11E+10	6.79E+07	3.37E+06	1.03E+12	7
18	01/27/1997	9.70E+06	2.21E+05	3.43E+09	6.68E+07	1.52E+06	1.63E+11	7
19	02/03/1997	9.69E+06	1.62E+05	3.23E+09	6.75E+07	1.13E+06	1.57E+11	7
20	02/10/1997	9.64E+06	2.56E+05	1.23E+10	6.78E+07	1.80E+06	6.10E+11	7
21	02/17/1997	9.71E+06	8.36E+04	8.72E+08	6.76E+07	5.81E+05	4.22E+10	7
22	02/24/1997	9.71E+06	5.78E+04	7.99E+08	6.72E+07	4.0E+05	3.83E+10	7
23	03/03/1997	9.68E+06	4.65E+04	6.97E+08	6.79E+07	3.26E+05	3.43E+10	7
24	03/10/1997	9.70E+06	4.71E+04	1.63E+08	6.75E+07	3.28E+05	7.92E+09	7
25	03/17/1997	9.36E+06	1.16E+05	2.74E+09	6.75E+07	8.33E+05	1.42E+11	7
26	03/24/1997	9.69E+06	1.59E+05	1.82E+09	6.77E+07	1.11E+06	8.88E+10	7
27	03/31/1997	7.31E+06	2.55E+04	1.38E+08	5.18E+07	1.81E+05	6.94E+09	7
28	04/07/1997	9.67E+06	2.84E+03	8.05E+06	6.62E+07	1.94E+04	3.77E+08	7
29	04/14/1997	9.69E+06	3.42E+04	1.15E+08	6.49E+07	2.29E+05	5.13E+09	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	1.77E+03	3.13E+06	3.43E+07	1.24E+04	1.54E+08	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	0	0	3.44E+07	0	0	7
34	05/19/1997	4.89E+06	2.89E+04	1.56E+08	3.44E+07	2.03E+05	7.68E+09	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	0	0	6.78E+07	0	0	7
39	06/23/1997	9.71E+06	0	0	6.78E+07	0	0	7
40	06/30/1997	9.69E+06	0	0	6.32E+07	0	0	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	0	0	6.74E+07	0	0	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7

(continued)

Table I-19 (continued). Cabezon (*Scorpaenichthys marmoratus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	4.0E+04	2.72E+08	6.78E+07	2.80E+05	1.33E+10	7
57	10/27/1997	9.81E+06	1.13E+05	1.53E+09	6.61E+07	7.64E+05	6.94E+10	7
58	11/04/1997	9.80E+06	1.12E+05	1.23E+09	6.82E+07	7.78E+05	5.95E+10	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	3.11E+04	2.38E+08	6.86E+07	2.19E+05	1.18E+10	7
61	11/24/1997	9.81E+06	1.80E+04	1.08E+08	6.82E+07	1.25E+05	5.23E+09	7
62	12/02/1997	9.68E+06	8.55E+04	5.97E+08	8.72E+07	7.70E+05	4.84E+10	9
63	12/11/1997	9.69E+06	1.40E+05	8.90E+08	6.78E+07	9.79E+05	4.36E+10	7
64	12/16/1997	9.69E+06	1.27E+05	1.85E+09	4.85E+07	6.35E+05	4.62E+10	5
65	12/22/1997	9.70E+06	4.99E+04	8.41E+08	6.78E+07	3.49E+05	4.10E+10	7
66	12/30/1997	9.68E+06	2.68E+05	3.51E+09	6.76E+07	1.87E+06	1.71E+11	7
67	01/05/1998	9.68E+06	6.51E+04	5.18E+08	7.75E+07	5.21E+05	3.32E+10	8
68	01/15/1998	9.67E+06	6.85E+04	6.31E+08	8.72E+07	6.17E+05	5.13E+10	9
69	01/23/1998	9.69E+06	1.82E+05	1.58E+10	6.79E+07	1.28E+06	7.73E+11	7
70	01/28/1998	9.69E+06	3.08E+05	4.82E+09	8.38E+07	2.66E+06	3.60E+11	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	1.89E+05	2.31E+09	1.23E+08	2.46E+06	3.92E+11	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	9.80E+03	2.52E+07	2.34E+07	4.90E+04	6.30E+08	5
76	03/09/1998	4.69E+06	1.67E+04	1.06E+08	3.37E+07	1.20E+05	5.45E+09	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	4.86E+03	2.36E+07	5.67E+07	3.27E+04	1.07E+09	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	1.98E+04	1.31E+08	7.73E+07	1.57E+05	8.26E+09	8
81	04/16/1998	9.73E+06	0	0	1.07E+08	0	0	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	0	0	8.72E+07	0	0	9
84	05/04/1998	9.70E+06	0	0	6.78E+07	0	0	7
85	05/14/1998	9.68E+06	0	0	7.75E+07	0	0	8
86	05/19/1998	9.70E+06	0	0	5.81E+07	0	0	6
87	05/26/1998	9.70E+06	6.88E+03	4.73E+07	5.82E+07	4.12E+04	1.70E+09	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	0	0	6.78E+07	0	0	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	0	0	6.78E+07	0	0	7
92	06/29/1998	9.69E+06	0	0	6.79E+07	0	0	7
93	07/06/1998	9.73E+06	0	0	6.79E+07	0	0	7
94	07/13/1998	9.67E+06	0	0	6.78E+07	0	0	7
95	07/21/1998	9.69E+06	0	0	6.78E+07	0	0	7
96	07/27/1998	9.70E+06	0	0	6.78E+07	0	0	7
97	08/03/1998	9.69E+06	0	0	6.78E+07	0	0	7
98	08/10/1998	9.68E+06	0	0	6.78E+07	0	0	7
99	08/18/1998	9.69E+06	0	0	7.66E+07	0	0	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6

(continued)

Table I-19 (continued). Cabezon (*Scorpaenichthys marmoratus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E+08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	3.37E+04	2.54E+08	2.75E+08	9.57E+05	2.05E+11	31
120	01/12/1999	9.68E+06	1.93E+05	3.70E+09	2.71E+08	5.40E+06	2.90E-12	28
123	02/03/1999	9.71E+06	6.81E+04	5.09E+08	2.33E+08	1.63E+06	2.92E+11	32
129	03/17/1999	7.29E+06	2.54E+04	1.10E+08	2.71E+08	9.45E+05	1.53E-11	35
133	04/14/1999	9.70E+06	7.90E+03	6.24E+07	3.20E+08	2.61E+05	6.79E-10	34
139	05/24/1999	9.41E+06	0	0	3.29E+08	0	0	35
143	06/23/1999	9.41E+06	0	0	2.16E+08	0	0	23

Table I-20. White croaker (*Genyonemus lineatus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
4	10/30/1996	9.70E+06	3.44E+04	1.33E+08	6.77E+07	2.40E+05	6.48E+09	7
5	11/06/1996	9.70E+06	5.38E+05	2.91E+09	6.63E+07	3.67E+06	1.36E+11	7
6	11/13/1996	9.73E+06	3.47E+05	3.71E+09	5.84E+07	2.08E+06	1.34E+11	6
7	11/18/1996	9.69E+06	1.08E+05	9.10E+08	5.82E+07	6.50E+05	3.28E+10	6
8	11/25/1996	7.31E+06	2.20E+05	2.19E+09	5.33E+07	1.61E+06	1.17E+11	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	3.40E+03	1.16E+07	6.36E+07	2.23E+04	4.98E+08	7
11	12/09/1996	9.70E+06	1.51E+05	1.37E+09	6.79E+07	1.06E+06	6.70E+10	7
12	12/16/1996	9.70E+06	6.38E+05	1.07E+10	6.79E+07	4.46E+06	5.23E+11	7
13	12/23/1996	9.70E+06	2.02E+05	1.58E+09	6.79E+07	1.42E+06	7.76E+10	7
14	12/30/1996	9.68E+06	2.91E+05	1.78E+09	6.78E+07	2.04E+06	8.72E+10	7
15	01/06/1997	9.69E+06	1.49E+05	7.95E+08	6.79E+07	1.04E+06	3.90E+10	7
16	01/13/1997	9.69E+06	4.61E+04	1.71E+08	6.75E+07	3.22E+05	8.29E+09	7
17	01/20/1997	9.70E+06	6.46E+05	3.03E+09	6.79E+07	4.52E+06	1.49E+11	7
18	01/27/1997	9.70E+06	1.26E+06	1.26E+10	6.68E+07	8.66E+06	6.0E+11	7
19	02/03/1997	9.69E+06	7.87E+04	3.83E+08	6.75E+07	5.49E+05	1.86E+10	7
20	02/10/1997	9.64E+06	3.76E+04	2.43E+08	6.78E+07	2.64E+05	1.20E+10	7
21	02/17/1997	9.71E+06	5.07E+05	3.95E+09	6.76E+07	3.53E+06	1.91E+11	7
22	02/24/1997	9.71E+06	9.15E+05	8.82E+09	6.72E+07	6.33E+06	4.22E+11	7
23	03/03/1997	9.68E+06	1.63E+04	6.80E+07	6.79E+07	1.15E+05	3.35E+09	7
24	03/10/1997	9.70E+06	6.83E+04	3.52E+08	6.75E+07	4.75E+05	1.71E+10	7
25	03/17/1997	9.36E+06	3.23E+06	7.88E+10	6.75E+07	2.33E+07	4.11E+12	7
26	03/24/1997	9.69E+06	1.95E+05	1.01E+09	6.77E+07	1.36E+06	4.95E+10	7
27	03/31/1997	7.31E+06	9.16E+04	2.29E+08	5.18E+07	6.50E+05	1.16E+10	7
28	04/07/1997	9.67E+06	6.23E+04	1.62E+08	6.62E+07	4.26E+05	7.57E+09	7
29	04/14/1997	9.69E+06	3.48E+03	1.21E+07	6.49E+07	2.33E+04	5.42E+08	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	4.28E+03	1.83E+07	3.44E+07	3.0E+04	8.97E+08	7
34	05/19/1997	4.89E+06	4.76E+04	1.71E+08	3.44E+07	3.34E+05	8.42E+09	7
35	05/27/1997	6.96E+06	1.53E+04	2.61E+07	4.66E+07	1.03E+05	1.17E+09	7
36	06/02/1997	9.70E+06	3.39E+03	1.15E+07	6.18E+07	2.16E+04	4.67E+08	7
37	06/09/1997	9.70E+06	0	0	6.78E+07	0	0	7
38	06/16/1997	9.67E+06	0	0	6.78E+07	0	0	7
39	06/23/1997	9.71E+06	7.67E+03	5.89E+07	6.78E+07	5.36E+04	2.87E+09	7
40	06/30/1997	9.69E+06	0	0	6.32E+07	0	0	7
41	07/07/1997	9.68E+06	0	0	6.72E+07	0	0	7
42	07/14/1997	9.69E+06	0	0	6.78E+07	0	0	7
43	07/21/1997	9.71E+06	6.59E+03	2.18E+07	6.74E+07	4.58E+04	1.05E+09	7
44	07/28/1997	9.69E+06	7.54E+03	5.68E+07	6.74E+07	5.25E+04	2.75E+09	7
45	08/04/1997	9.69E+06	5.25E+04	4.12E+08	6.78E+07	3.67E+05	2.02E+10	7
46	08/11/1997	9.68E+06	2.56E+04	1.39E+08	6.78E+07	1.79E+05	6.79E+09	7
47	08/18/1997	9.70E+06	7.04E+03	4.95E+07	6.81E+07	4.94E+04	2.44E+09	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	5.15E+03	2.65E+07	5.82E+07	3.10E+04	9.62E+08	6
50	09/08/1997	7.49E+06	4.63E+03	2.14E+07	5.83E+07	3.60E+04	1.29E+09	7
51	09/15/1997	9.68E+06	4.40E+04	2.29E+08	6.78E+07	3.09E+05	1.12E+10	7
52	09/22/1997	9.67E+06	5.76E+03	3.31E+07	6.78E+07	4.04E+04	1.63E+09	7

(continued)

Table I-20 (continued). White croaker (*Genyonemus lineatus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	5.37E-03	2.88E-07	6.80E-07	3.76E+04	1.41E+09	7
55	10/13/1997	9.69E+06	5.42E+03	2.94E+07	6.78E-07	3.80E+04	1.44E+09	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	8.88E+04	5.79E+08	8.72E+07	7.99E+05	4.70E+10	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	5.18E+03	2.68E+07	4.85E+07	2.59E-04	6.70E+08	5
65	12/22/1997	9.70E+06	7.97E+04	5.93E+08	6.78E+07	5.57E-05	2.89E+10	7
66	12/30/1997	9.68E+06	4.78E+05	1.47E+10	6.76E+07	3.34E+06	7.15E+11	7
67	01/05/1998	9.68E+06	8.42E+05	9.09E+09	7.75E+07	6.74E+06	5.82E+11	8
68	01/15/1998	9.67E+06	4.53E+04	1.84E+08	8.72E+07	4.09E+05	1.50E+10	9
69	01/23/1998	9.69E+06	2.10E-05	7.77E+08	6.79E+07	1.47E+06	3.81E+10	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	1.92E+04	1.23E+08	1.23E+08	2.50E+05	2.09E+10	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	7.15E+03	2.58E+07	5.15E+07	7.86E+04	3.12E+09	11
75	03/04/1998	4.69E+06	4.88E+04	2.06E+08	2.34E+07	2.44E+05	5.14E+09	5
76	03/09/1998	4.69E+06	3.92E+04	2.21E+08	3.37E+07	2.82E+05	1.14E+10	7
77	03/19/1998	7.29E+06	7.40E+04	3.82E+08	5.44E+07	5.52E+05	2.13E+10	9
78	03/27/1998	8.44E+06	3.20E+05	3.63E+09	5.67E+07	2.15E+06	1.64E+11	7
79	04/01/1998	9.67E+06	2.89E+05	1.98E+09	4.81E+07	1.44E+06	4.90E+10	5
80	04/07/1998	9.73E+06	1.74E+05	1.29E+09	7.73E+07	1.38E+06	8.11E+10	8
81	04/16/1998	9.73E+06	5.04E+04	2.70E+08	1.07E+08	5.53E+05	3.25E+10	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	1.84E+06	5.72E+10	8.72E+07	1.66E+07	4.63E+12	9
84	05/04/1998	9.70E+06	7.85E+05	1.32E+10	6.78E+07	5.49E+06	6.44E+11	7
85	05/14/1998	9.68E+06	2.73E+06	1.24E+11	7.75E+07	2.19E+07	7.93E+12	8
86	05/19/1998	9.70E+06	1.17E+05	8.09E+08	5.81E+07	7.01E+05	2.90E+10	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	5.58E+03	2.55E+07	6.78E+07	3.90E+04	1.25E+09	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	0	0	6.78E+07	0	0	7
92	06/29/1998	9.69E+06	0	0	6.79E+07	0	0	7
93	07/06/1998	9.73E+06	0	0	6.79E+07	0	0	7
94	07/13/1998	9.67E+06	0	0	6.78E+07	0	0	7
95	07/21/1998	9.69E+06	0	0	6.78E+07	0	0	7
96	07/27/1998	9.70E+06	6.27E+03	3.69E+07	6.78E+07	4.38E+04	1.80E+09	7
97	08/03/1998	9.69E+06	0	0	6.78E+07	0	0	7
98	08/10/1998	9.68E+06	0	0	6.78E+07	0	0	7
99	08/18/1998	9.69E+06	0	0	7.66E+07	0	0	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E-07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E-07	0	0	6

(continued)

Table I-20 (continued). White croaker (*Genyonemus lineatus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E+08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	2.43E+04	1.72E+08	2.75E+08	6.91E+05	1.39E+11	31
120	01/12/1999	9.68E+06	4.78E+05	4.72E+09	2.71E+08	1.34E+07	3.70E+12	28
123	02/03/1999	9.71E+06	8.60E+04	8.03E+08	2.33E+08	2.06E+06	4.60E+11	32
129	03/17/1999	7.29E+06	9.93E+04	5.67E+08	2.71E+08	3.70E+06	7.87E+11	35
133	04/14/1999	9.70E+06	0	0	3.20E+08	0	0	34
139	05/24/1999	9.41E+06	0	0	3.29E+08	0	0	35
143	06/23/1999	9.41E+06	0	0	2.16E+08	0	0	23

Table I-21. Monkeyface-eel (*Cebidichthys violaceus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
4	10/30/1996	9.70E+06	0	0	6.77E+07	0	0	7
5	11/06/1996	9.70E+06	0	0	6.63E+07	0	0	7
6	11/13/1996	9.73E+06	0	0	5.84E+07	0	0	6
7	11/18/1996	9.69E+06	0	0	5.82E+07	0	0	6
8	11/25/1996	7.31E+06	0	0	5.33E+07	0	0	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	0	0	6.36E+07	0	0	7
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	1.77E+04	4.62E+07	6.79E+07	1.24E+05	2.26E+09	7
14	12/30/1996	9.68E+06	8.99E+04	1.07E+09	6.78E+07	6.30E+05	5.23E+10	7
15	01/06/1997	9.69E+06	1.25E+04	5.71E+07	6.79E+07	8.74E+04	2.80E+09	7
16	01/13/1997	9.69E+06	7.51E+04	1.62E+09	6.75E+07	5.24E+05	7.89E+10	7
17	01/20/1997	9.70E+06	1.15E+05	1.48E+09	6.79E+07	8.03E+05	7.24E+10	7
18	01/27/1997	9.70E+06	2.03E+05	4.94E+09	6.68E+07	1.40E+06	2.35E+11	7
19	02/03/1997	9.69E+06	6.29E+05	2.50E+11	6.75E+07	4.39E+06	1.22E+13	7
20	02/10/1997	9.64E+06	4.82E+05	6.92E+10	6.78E+07	3.39E+06	3.42E+12	7
21	02/17/1997	9.71E+06	1.44E+06	1.33E+12	6.76E+07	1.0E+07	6.45E+13	7
22	02/24/1997	9.71E+06	5.98E+05	2.48E+10	6.72E+07	4.14E+06	1.19E+12	7
23	03/03/1997	9.68E+06	2.81E+05	6.91E+09	6.79E+07	1.97E+06	3.40E+11	7
24	03/10/1997	9.70E+06	7.52E+05	2.93E+10	6.75E+07	5.23E+06	1.42E+12	7
25	03/17/1997	9.36E+06	2.39E+06	2.64E+11	6.75E+07	1.72E+07	1.37E+13	7
26	03/24/1997	9.69E+06	4.82E+05	1.47E+10	6.77E+07	3.37E+06	7.17E+11	7
27	03/31/1997	7.31E+06	2.63E+05	5.29E+09	5.18E+07	1.87E+06	2.66E+11	7
28	04/07/1997	9.67E+06	4.77E+05	2.25E+10	6.62E+07	3.27E+06	1.06E+12	7
29	04/14/1997	9.69E+06	1.35E+06	5.72E+10	6.49E+07	9.03E+06	2.56E+12	7
30	04/21/1997	4.91E+06	2.35E+05	8.52E+09	4.04E+07	1.94E+06	5.76E+11	7
31	04/28/1997	4.89E+06	6.55E+04	1.20E+09	3.43E+07	4.60E+05	5.92E+10	7
32	05/05/1997	4.90E+06	1.89E+05	2.29E+09	3.42E+07	1.32E+06	1.12E+11	7
33	05/12/1997	4.91E+06	2.35E+05	1.81E+09	3.44E+07	1.65E+06	8.89E+10	7
34	05/19/1997	4.89E+06	3.22E+05	1.74E+10	3.44E+07	2.26E+06	8.60E+11	7
35	05/27/1997	6.96E+06	4.94E+05	1.11E+10	4.66E+07	3.31E+06	4.96E+11	7
36	06/02/1997	9.70E+06	2.15E+05	3.63E+09	6.18E+07	1.37E+06	1.47E+11	7
37	06/09/1997	9.70E+06	4.62E+05	1.15E+10	6.78E+07	3.23E+06	5.63E+11	7
38	06/16/1997	9.67E+06	1.71E+06	5.72E+10	6.78E+07	1.20E+07	2.81E+12	7
39	06/23/1997	9.71E+06	5.68E+05	9.95E+09	6.78E+07	3.97E+06	4.85E+11	7
40	06/30/1997	9.69E+06	3.45E+05	4.73E+09	6.32E+07	2.25E+06	2.01E+11	7
41	07/07/1997	9.68E+06	2.0E+05	1.90E+09	6.72E+07	1.39E+06	9.15E+10	7
42	07/14/1997	9.69E+06	2.47E+05	3.02E+09	6.78E+07	1.73E+06	1.48E+11	7
43	07/21/1997	9.71E+06	2.53E+05	3.84E+09	6.74E+07	1.75E+06	1.85E+11	7
44	07/28/1997	9.69E+06	0	0	6.74E+07	0	0	7
45	08/04/1997	9.69E+06	2.59E+04	4.81E+08	6.78E+07	1.81E+05	2.35E+10	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7

(continued)

Table I-21 (continued). Monkeyface-eel (*Cebidichthys violaceus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	0	0	4.85E+07	0	0	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	7.40E+04	6.70E+08	1.23E+08	9.64E+05	1.14E+11	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	1.99E+04	1.12E+08	5.15E+07	2.19E+05	1.36E+10	11
75	03/04/1998	4.69E+06	1.09E+05	1.14E+09	2.34E+07	5.44E+05	2.86E+10	5
76	03/09/1998	4.69E+06	5.18E+04	3.96E+08	3.37E+07	3.73E+05	2.04E+10	7
77	03/19/1998	7.29E+06	1.88E+05	8.01E+09	5.44E+07	1.41E+06	4.46E+11	9
78	03/27/1998	8.44E+06	2.51E+05	2.36E+10	5.67E+07	1.69E+06	1.07E+12	7
79	04/01/1998	9.67E+06	4.88E+05	6.09E+10	4.81E+07	2.43E+06	1.51E+12	5
80	04/07/1998	9.73E+06	3.83E+05	1.59E+10	7.73E+07	3.04E+06	1.01E+12	8
81	04/16/1998	9.73E+06	2.45E+06	5.89E+11	1.07E+08	2.68E+07	7.08E+13	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	1.69E+06	1.59E+11	8.72E+07	1.52E+07	1.29E+13	9
84	05/04/1998	9.70E+06	9.16E+05	4.39E+10	6.78E+07	6.41E+06	2.15E+12	7
85	05/14/1998	9.68E+06	5.52E+05	1.47E+10	7.75E+07	4.42E+06	9.44E+11	8
86	05/19/1998	9.70E+06	7.0E+05	1.04E+10	5.81E+07	4.19E+06	3.71E+11	6
87	05/26/1998	9.70E+06	1.11E+06	1.46E+11	5.82E+07	6.67E+06	5.25E+12	6
88	06/01/1998	9.69E+06	8.93E+05	2.97E+10	6.78E+07	6.25E+06	1.46E+12	7
89	06/09/1998	9.70E+06	6.73E+05	1.64E+10	6.78E+07	4.71E+06	8.0E+11	7
90	06/15/1998	9.69E+06	4.29E+05	8.80E+09	6.78E+07	3.0E+06	4.31E+11	7
91	06/22/1998	9.69E+06	2.74E+06	2.84E+11	6.78E+07	1.92E+07	1.39E+13	7
92	06/29/1998	9.69E+06	6.03E+05	1.06E+10	6.79E+07	4.22E+06	5.22E+11	7
93	07/06/1998	9.73E+06	4.74E+05	9.55E+09	6.79E+07	3.31E+06	4.65E+11	7
94	07/13/1998	9.67E+06	2.72E+05	5.48E+09	6.78E+07	1.90E+06	2.69E+11	7
95	07/21/1998	9.69E+06	2.13E+04	2.57E+08	6.78E+07	1.49E+05	1.26E+10	7
96	07/27/1998	9.70E+06	2.55E+05	3.65E+10	6.78E+07	1.78E+06	1.78E+12	7
97	08/03/1998	9.69E+06	0	0	6.78E+07	0	0	7
98	08/10/1998	9.68E+06	0	0	6.78E+07	0	0	7
99	08/18/1998	9.69E+06	0	0	7.66E+07	0	0	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6

(continued)

Table I-21 (continued). Monkeyface-eel (*Cebidichthys violaceus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	= days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E+07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E+08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	0	0	2.75E+08	0	0	31
120	01/12/1999	9.68E+06	5.11E+04	6.77E+08	2.71E+08	1.43E+06	5.30E+11	28
123	02/03/1999	9.71E+06	2.0E+05	9.19E+09	2.33E+08	4.79E+06	5.27E+12	32
129	03/17/1999	7.29E+06	3.93E+05	9.31E+09	2.71E+08	1.46E+07	1.29E+13	35
133	04/14/1999	9.70E+06	1.62E+06	2.48E+11	3.20E+08	5.35E+07	2.70E+14	34
139	05/24/1999	9.41E+06	6.25E+05	2.14E+10	3.29E+08	2.19E+07	2.62E+13	35
143	06/23/1999	9.41E+06	8.64E+05	2.62E+10	2.16E+08	1.99E+07	1.39E+13	23

Table I-22. Kelpfish (*Gibbonsia* spp.) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 1, 2 and 9 are not presented. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	1.25E+05	5.71E+08	6.79E+07	8.73E+05	2.80E+10	7
4	10/30/1996	9.70E+06	1.91E+05	4.77E+08	6.77E+07	1.33E+06	2.32E+10	7
5	11/06/1996	9.70E+06	1.75E+05	7.96E+08	6.63E+07	1.19E+06	3.71E+10	7
6	11/13/1996	9.73E+06	7.55E+05	6.44E+09	5.84E+07	4.53E+06	2.32E+11	6
7	11/18/1996	9.69E+06	1.32E+05	4.87E+08	5.82E+07	7.91E+05	1.75E+10	6
8	11/25/1996	7.31E+06	1.63E+05	8.42E+08	5.33E+07	1.19E+06	4.49E+10	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	4.64E+05	3.21E+09	6.36E+07	3.04E+06	1.38E+11	7
11	12/09/1996	9.70E+06	6.09E+05	4.61E+09	6.79E+07	4.26E+06	2.26E+11	7
12	12/16/1996	9.70E+06	1.90E+05	8.84E+08	6.79E+07	1.33E+06	4.33E+10	7
13	12/23/1996	9.70E+06	5.93E+05	7.87E+09	6.79E+07	4.15E+06	3.85E+11	7
14	12/30/1996	9.68E+06	9.33E+05	1.16E+10	6.78E+07	6.54E+06	5.70E+11	7
15	01/06/1997	9.69E+06	6.76E+05	1.58E+10	6.79E+07	4.73E+06	7.73E+11	7
16	01/13/1997	9.69E+06	3.22E+05	2.87E+09	6.75E+07	2.25E+06	1.40E+11	7
17	01/20/1997	9.70E+06	6.89E+05	6.44E+09	6.79E+07	4.82E+06	3.15E+11	7
18	01/27/1997	9.70E+06	1.56E+05	1.16E+09	6.68E+07	1.08E+06	5.51E+10	7
19	02/03/1997	9.69E+06	1.01E+06	1.44E+10	6.75E+07	7.06E+06	6.99E+11	7
20	02/10/1997	9.64E+06	4.95E+05	4.18E+09	6.78E+07	3.48E+06	2.07E+11	7
21	02/17/1997	9.71E+06	2.64E+05	2.34E+09	6.76E+07	1.84E+06	1.13E+11	7
22	02/24/1997	9.71E+06	1.15E+06	3.71E+10	6.72E+07	7.95E+06	1.78E+12	7
23	03/03/1997	9.68E+06	2.58E+05	1.73E+09	6.79E+07	1.81E+06	8.49E+10	7
24	03/10/1997	9.70E+06	2.71E+05	1.29E+09	6.75E+07	1.88E+06	6.27E+10	7
25	03/17/1997	9.36E+06	2.17E+05	1.46E+09	6.75E+07	1.56E+06	7.60E+10	7
26	03/24/1997	9.69E+06	2.51E+05	2.79E+09	6.77E+07	1.75E+06	1.36E+11	7
27	03/31/1997	7.31E+06	5.98E+05	4.27E+09	5.18E+07	4.24E+06	2.15E+11	7
28	04/07/1997	9.67E+06	5.44E+05	3.68E+09	6.62E+07	3.73E+06	1.73E+11	7
29	04/14/1997	9.69E+06	5.15E+05	3.47E+09	6.49E+07	3.45E+06	1.55E+11	7
30	04/21/1997	4.91E+06	3.27E+05	2.15E+09	4.04E+07	2.69E+06	1.45E+11	7
31	04/28/1997	4.89E+06	1.01E+05	2.04E+08	3.43E+07	7.06E+05	1.01E+10	7
32	05/05/1997	4.90E+06	2.22E+05	1.65E+09	3.42E+07	1.55E+06	8.05E+10	7
33	05/12/1997	4.91E+06	2.54E+05	3.68E+09	3.44E+07	1.78E+06	1.81E+11	7
34	05/19/1997	4.89E+06	2.19E+05	1.44E+09	3.44E+07	1.54E+06	7.11E+10	7
35	05/27/1997	6.96E+06	5.43E+05	5.64E+09	4.66E+07	3.64E+06	2.53E+11	7
36	06/02/1997	9.70E+06	2.05E+06	6.43E+10	6.18E+07	1.30E+07	2.61E+12	7
37	06/09/1997	9.70E+06	9.23E+05	1.96E+10	6.78E+07	6.45E+06	9.56E+11	7
38	06/16/1997	9.67E+06	3.60E+05	2.15E+09	6.78E+07	2.53E+06	1.06E+11	7
39	06/23/1997	9.71E+06	9.79E+05	1.52E+10	6.78E+07	6.83E+06	7.38E+11	7
40	06/30/1997	9.69E+06	1.43E+06	1.78E+10	6.32E+07	9.30E+06	7.58E+11	7
41	07/07/1997	9.68E+06	4.59E+05	1.05E+10	6.72E+07	3.19E+06	5.08E+11	7
42	07/14/1997	9.69E+06	5.17E+05	7.92E+09	6.78E+07	3.62E+06	3.87E+11	7
43	07/21/1997	9.71E+06	1.06E+06	4.61E+10	6.74E+07	7.39E+06	2.22E+12	7
44	07/28/1997	9.69E+06	6.84E+05	1.78E+10	6.74E+07	4.76E+06	8.62E+11	7
45	08/04/1997	9.69E+06	1.16E+06	2.53E+10	6.78E+07	8.09E+06	1.24E+12	7
46	08/11/1997	9.68E+06	9.99E+05	1.96E+10	6.78E+07	6.99E+06	9.58E+11	7
47	08/18/1997	9.70E+06	3.71E+05	6.45E+09	6.81E+07	2.61E+06	3.17E+11	7
48	08/26/1997	9.70E+06	8.40E+05	1.50E+10	7.41E+07	6.41E+06	8.70E+11	8
49	09/02/1997	9.67E+06	3.84E+05	4.27E+09	5.82E+07	2.31E+06	1.55E+11	6
50	09/08/1997	7.49E+06	3.13E+05	1.95E+09	5.83E+07	2.44E+06	1.18E+11	7
51	09/15/1997	9.68E+06	6.08E+05	2.85E+10	6.78E+07	4.26E+06	1.40E+12	7
52	09/22/1997	9.67E+06	3.05E+05	1.50E+10	6.78E+07	2.14E+06	7.40E+11	7

(continued)

Table I-22 (continued). Kelpfish (*Gibbonsia* spp.) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	9.32E+04	8.20E-08	6.79E+07	6.52E-05	4.02E+10	7
54	10/06/1997	9.70E+06	1.46E+05	1.13E+09	6.80E+07	1.02E-06	5.54E+10	7
55	10/13/1997	9.69E+06	1.60E+05	1.30E+09	6.78E+07	1.12E-06	6.39E+10	7
56	10/21/1997	9.69E+06	9.39E+04	1.06E+09	6.78E+07	6.56E-05	5.20E+10	7
57	10/27/1997	9.81E+06	2.80E+05	2.79E+09	6.61E+07	1.89E+06	1.27E+11	7
58	11/04/1997	9.80E+06	1.04E+05	8.11E+08	6.82E+07	7.23E-05	3.92E+10	7
59	11/10/1997	9.80E+06	2.69E+05	1.65E+09	6.84E+07	1.87E+06	8.06E+10	7
60	11/18/1997	9.76E+06	1.25E+05	2.10E+09	6.86E+07	8.81E-05	1.04E+11	7
61	11/24/1997	9.81E+06	6.52E+04	4.86E+08	6.82E+07	4.54E-05	2.35E+10	7
62	12/02/1997	9.68E+06	8.54E+04	6.88E+08	8.72E+07	7.69E+05	5.58E+10	9
63	12/11/1997	9.69E+06	5.74E+04	2.63E+08	6.78E+07	4.02E+05	1.28E+10	7
64	12/16/1997	9.69E+06	2.21E+04	1.02E+08	4.85E+07	1.10E+05	2.55E-09	5
65	12/22/1997	9.70E+06	2.41E+04	2.10E+08	6.78E+07	1.68E+05	1.03E+10	7
66	12/30/1997	9.68E+06	1.87E+05	1.59E+09	6.76E+07	1.31E+06	7.78E+10	7
67	01/05/1998	9.68E+06	2.22E+05	1.80E+09	7.75E+07	1.78E+06	1.15E+11	8
68	01/15/1998	9.67E+06	1.07E+05	1.28E+09	8.72E+07	9.64E+05	1.04E+11	9
69	01/23/1998	9.69E+06	1.14E+05	7.88E+08	6.79E+07	7.95E+05	3.86E+10	7
70	01/28/1998	9.69E+06	1.31E+05	1.66E+09	8.38E+07	1.13E+06	1.24E+11	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	1.54E+05	9.99E+08	1.23E+08	2.01E+06	1.70E+11	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	8.56E+04	3.33E+08	5.15E+07	9.42E+05	4.02E+10	11
75	03/04/1998	4.69E+06	1.10E+05	5.35E+08	2.34E+07	5.50E+05	1.34E+10	5
76	03/09/1998	4.69E+06	3.77E+04	1.89E+08	3.37E+07	2.71E+05	9.76E+09	7
77	03/19/1998	7.29E+06	5.32E+03	2.83E-07	5.44E-07	3.97E+04	1.58E+09	9
78	03/27/1998	8.44E+06	9.86E+04	1.20E+09	5.67E+07	6.63E+05	5.41E+10	7
79	04/01/1998	9.67E+06	1.06E+05	5.50E+08	4.81E+07	5.29E+05	1.36E+10	5
80	04/07/1998	9.73E+06	8.98E+04	4.42E+08	7.73E+07	7.14E+05	2.79E+10	8
81	04/16/1998	9.73E+06	2.14E+05	1.83E+09	1.07E+08	2.34E+06	2.20E+11	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	2.53E+05	1.85E+09	8.72E+07	2.27E+06	1.50E+11	9
84	05/04/1998	9.70E+06	8.32E+04	5.62E+08	6.78E+07	5.82E+05	2.75E-10	7
85	05/14/1998	9.68E+06	1.57E+05	1.14E+09	7.75E+07	1.25E+06	7.31E-10	8
86	05/19/1998	9.70E+06	6.56E+05	8.18E+09	5.81E+07	3.92E+06	2.93E-11	6
87	05/26/1998	9.70E+06	6.81E+05	2.53E+10	5.82E+07	4.08E+06	9.07E+11	6
88	06/01/1998	9.69E+06	8.12E+05	1.39E+10	6.78E+07	5.69E+06	6.83E+11	7
89	06/09/1998	9.70E+06	6.44E+05	2.05E-10	6.78E+07	4.50E+06	1.00E+12	7
90	06/15/1998	9.69E+06	2.07E+06	2.04E-11	6.78E+07	1.45E+07	9.99E+12	7
91	06/22/1998	9.69E+06	3.92E+05	5.16E-09	6.78E+07	2.74E+06	2.53E+11	7
92	06/29/1998	9.69E+06	4.77E+05	3.23E-09	6.79E+07	3.34E+06	1.58E+11	7
93	07/06/1998	9.73E+06	4.42E+05	7.85E-09	6.79E+07	3.09E+06	3.82E+11	7
94	07/13/1998	9.67E+06	1.30E-05	1.67E+09	6.78E+07	9.11E+05	8.19E+10	7
95	07/21/1998	9.69E+06	1.18E+05	1.00E+09	6.78E+07	8.26E+05	4.90E+10	7
96	07/27/1998	9.70E+06	3.41E+05	4.16E+09	6.78E+07	2.38E+06	2.03E+11	7
97	08/03/1998	9.69E+06	6.59E-04	5.46E+08	6.78E+07	4.62E+05	2.68E-10	7
98	08/10/1998	9.68E+06	1.42E-05	1.66E+09	6.78E+07	9.98E+05	8.16E-10	7
99	08/18/1998	9.69E+06	1.90E+05	2.13E+09	7.66E+07	1.50E+06	1.33E-11	8
100	08/26/1998	9.69E+06	1.73E+05	2.73E+09	6.78E+07	1.21E+06	1.34E+11	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	1.35E+05	2.04E+09	6.78E+07	9.46E+05	9.98E+10	7
104	09/21/1998	7.44E+06	1.04E+05	7.96E+08	4.70E+07	6.57E+05	3.18E-10	6

(continued)

Table I-22 (continued). Kelpfish (*Gibbonsia* spp.) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	2.25E+05	3.11E+09	6.78E+07	1.58E+06	1.53E+11	7
106	10/06/1998	9.69E+06	1.73E+05	1.92E+09	2.13E+08	3.81E+06	9.30E+11	22
111	11/11/1998	9.68E+06	3.70E+05	2.26E+09	3.10E+08	1.19E+07	2.32E+12	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	5.94E+05	7.38E+09	2.75E+08	1.69E+07	5.95E+12	31
120	01/12/1999	9.68E+06	3.12E+05	2.07E+09	2.71E+08	8.72E+06	1.62E+12	28
123	02/03/1999	9.71E+06	3.96E+05	3.86E+09	2.33E+08	9.47E+06	2.21E+12	32
129	03/17/1999	7.29E+06	8.69E+04	4.06E+08	2.71E+08	3.24E+06	5.63E+11	35
133	04/14/1999	9.70E+06	2.13E+05	1.07E+09	3.20E+08	7.03E+06	1.16E+12	34
139	05/24/1999	9.41E+06	2.61E+05	2.21E+09	3.29E+08	9.12E+06	2.71E+12	35
143	06/23/1999	9.41E+06	2.32E+05	2.27E+09	2.16E+08	5.35E+06	1.20E+12	23

Table I-23. Blackeye goby (*Coryphopterus nicholsi*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
4	10/30/1996	9.70E+06	0	0	6.77E-07	0	0	7
5	11/06/1996	9.70E+06	6.43E+03	2.10E+07	6.63E-07	4.39E+04	9.77E-08	7
6	11/13/1996	9.73E+06	0	0	5.84E-07	0	0	6
7	11/18/1996	9.69E+06	0	0	5.82E+07	0	0	6
8	11/25/1996	7.31E+06	0	0	5.33E+07	0	0	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	7.34E+03	2.70E+07	6.36E+07	4.82E+04	1.16E+09	7
11	12/09/1996	9.70E+06	1.15E+04	3.49E+07	6.79E+07	8.03E+04	1.71E+09	7
12	12/16/1996	9.70E+06	2.24E+04	1.73E+08	6.79E+07	1.57E+05	8.47E+09	7
13	12/23/1996	9.70E+06	1.07E+04	4.48E+07	6.79E-07	7.45E+04	2.19E+09	7
14	12/30/1996	9.68E+06	0	0	6.78E-07	0	0	7
15	01/06/1997	9.69E-06	0	0	6.79E-07	0	0	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	1.77E-04	1.17E+08	6.79E+07	1.24E+05	5.74E+09	7
18	01/27/1997	9.70E+06	2.60E+05	3.83E+10	6.68E-07	1.79E+06	1.82E-12	7
19	02/03/1997	9.69E+06	2.45E+04	1.80E+08	6.75E-07	1.71E+05	8.75E+09	7
20	02/10/1997	9.64E+06	1.80E+05	5.69E+09	6.78E-07	1.27E+06	2.81E+11	7
21	02/17/1997	9.71E+06	8.73E+04	7.24E+08	6.76E-07	6.07E+05	3.50E+10	7
22	02/24/1997	9.71E+06	1.34E+05	3.34E+09	6.72E+07	9.26E+05	1.60E-11	7
23	03/03/1997	9.68E+06	2.68E+05	1.86E+10	6.79E+07	1.88E+06	9.15E-11	7
24	03/10/1997	9.70E+06	3.29E+05	3.88E+10	6.75E+07	2.29E+06	1.88E+12	7
25	03/17/1997	9.36E+06	1.51E+05	3.16E+09	6.75E+07	1.09E+06	1.65E+11	7
26	03/24/1997	9.69E-06	1.58E+05	5.50E+09	6.77E+07	1.11E+06	2.69E+11	7
27	03/31/1997	7.31E+06	4.09E+05	2.26E+10	5.18E-07	2.90E+06	1.14E+12	7
28	04/07/1997	9.67E+06	5.24E-05	4.73E+10	6.62E-07	3.59E+06	2.22E+12	7
29	04/14/1997	9.69E+06	3.93E+05	4.53E+10	6.49E-07	2.63E+06	2.03E+12	7
30	04/21/1997	4.91E+06	9.59E+04	9.07E+08	4.04E-07	7.89E+05	6.13E+10	7
31	04/28/1997	4.89E+06	1.38E+05	1.14E+10	3.43E-07	9.68E+05	5.60E+11	7
32	05/05/1997	4.90E+06	2.45E+05	2.82E+10	3.42E-07	1.71E+06	1.37E+12	7
33	05/12/1997	4.91E+06	3.50E+05	4.77E+10	3.44E+07	2.45E-06	2.34E+12	7
34	05/19/1997	4.89E+06	2.54E+05	1.53E+10	3.44E-07	1.78E-06	7.54E-11	7
35	05/27/1997	6.96E+06	7.31E+05	1.43E+11	4.66E-07	4.89E+06	6.42E+12	7
36	06/02/1997	9.70E+06	6.71E+05	9.41E+10	6.18E-07	4.27E+06	3.82E+12	7
37	06/09/1997	9.70E+06	5.48E+05	6.20E+10	6.78E-07	3.83E+06	3.03E+12	7
38	06/16/1997	9.67E+06	7.61E+05	1.35E+11	6.78E+07	5.34E+06	6.62E-12	7
39	06/23/1997	9.71E+06	6.76E+05	1.72E+11	6.78E+07	4.72E+06	8.40E+12	7
40	06/30/1997	9.69E+06	3.85E+05	9.85E+09	6.32E+07	2.51E+06	4.19E+11	7
41	07/07/1997	9.68E+06	3.06E+05	1.14E+10	6.72E+07	2.12E+06	5.49E+11	7
42	07/14/1997	9.69E+06	5.56E+05	3.30E+10	6.78E+07	3.89E+06	1.62E+12	7
43	07/21/1997	9.71E+06	8.70E+05	2.37E+11	6.74E+07	6.04E+06	1.14E+13	7
44	07/28/1997	9.69E+06	1.94E+06	1.01E+12	6.74E+07	1.35E+07	4.90E+13	7
45	08/04/1997	9.69E-06	9.37E+05	4.76E+11	6.78E+07	6.56E+06	2.33E+13	7
46	08/11/1997	9.68E-06	9.82E+05	2.64E+11	6.78E-07	6.88E+06	1.30E+13	7
47	08/18/1997	9.70E+06	4.31E+05	2.42E+10	6.81E-07	3.03E+06	1.19E+12	7
48	08/26/1997	9.70E+06	1.36E+06	2.17E+11	7.41E-07	1.04E+07	1.27E+13	8
49	09/02/1997	9.67E+06	1.30E+06	2.34E+11	5.82E+07	7.80E+06	8.47E+12	6
50	09/08/1997	7.49E-06	7.97E+05	9.48E+10	5.83E+07	6.20E+06	5.73E+12	7
51	09/15/1997	9.68E+06	1.24E+06	3.38E+11	6.78E-07	8.70E+06	1.66E+13	7
52	09/22/1997	9.67E+06	6.41E+05	1.50E+11	6.78E-07	4.50E+06	7.39E+12	7

(continued)

Table I-23 (continued). Blackeye goby (*Coryphopterus nicholsi*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	9.31E+05	1.50E+11	6.79E+07	6.52E+06	7.37E+12	7
54	10/06/1997	9.70E+06	3.81E+05	2.57E+10	6.80E+07	2.67E+06	1.26E+12	7
55	10/13/1997	9.69E+06	1.17E+05	2.16E+09	6.78E+07	8.20E+05	1.06E+11	7
56	10/21/1997	9.69E+06	5.35E+05	7.98E+10	6.78E+07	3.74E+06	3.90E+12	7
57	10/27/1997	9.81E+06	1.51E+05	2.92E+09	6.61E+07	1.02E+06	1.33E+11	7
58	11/04/1997	9.80E+06	1.70E+05	7.12E+09	6.82E+07	1.18E+06	3.45E+11	7
59	11/10/1997	9.80E+06	2.58E+05	1.69E+10	6.84E+07	1.80E+06	8.24E+11	7
60	11/18/1997	9.76E+06	4.04E+05	5.64E+10	6.86E+07	2.84E+06	2.78E+12	7
61	11/24/1997	9.81E+06	3.96E+05	2.84E+10	6.82E+07	2.75E+06	1.37E+12	7
62	12/02/1997	9.68E+06	1.09E+05	3.19E+09	8.72E+07	9.86E+05	2.59E+11	9
63	12/11/1997	9.69E+06	1.07E+05	1.25E+09	6.78E+07	7.46E+05	6.11E+10	7
64	12/16/1997	9.69E+06	7.55E+04	1.77E+09	4.85E+07	3.78E+05	4.43E+10	5
65	12/22/1997	9.70E+06	6.72E+04	1.28E+09	6.78E+07	4.69E+05	6.25E+10	7
66	12/30/1997	9.68E+06	4.17E+04	4.61E+08	6.76E+07	2.92E+05	2.25E+10	7
67	01/05/1998	9.68E+06	5.39E+04	6.19E+08	7.75E+07	4.32E+05	3.97E+10	8
68	01/15/1998	9.67E+06	3.56E+05	7.48E+10	8.72E+07	3.21E+06	6.08E+12	9
69	01/23/1998	9.69E+06	1.36E+05	3.25E+09	6.79E+07	9.49E+05	1.59E+11	7
70	01/28/1998	9.69E+06	1.45E+05	2.93E+09	8.38E+07	1.25E+06	2.19E+11	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	2.21E+05	6.79E+09	1.23E+08	2.88E+06	1.15E+12	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	2.68E+04	2.55E+08	5.15E+07	2.95E+05	3.08E+10	11
75	03/04/1998	4.69E+06	2.28E+04	1.41E+08	2.34E+07	1.14E+05	3.51E+09	5
76	03/09/1998	4.69E+06	1.05E+04	1.11E+08	3.37E+07	7.57E+04	5.73E+09	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	2.29E+04	1.56E+08	5.67E+07	1.54E+05	7.05E+09	7
79	04/01/1998	9.67E+06	2.54E+04	2.33E+08	4.81E+07	1.27E+05	5.77E+09	5
80	04/07/1998	9.73E+06	1.85E+05	2.13E+09	7.73E+07	1.47E+06	1.35E+11	8
81	04/16/1998	9.73E+06	1.36E+05	2.88E+09	1.07E+08	1.49E+06	3.46E+11	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	3.01E+05	1.33E+10	8.72E+07	2.71E+06	1.08E+12	9
84	05/04/1998	9.70E+06	3.24E+05	2.79E+10	6.78E+07	2.27E+06	1.36E+12	7
85	05/14/1998	9.68E+06	4.60E+05	3.53E+10	7.75E+07	3.68E+06	2.26E+12	8
86	05/19/1998	9.70E+06	4.10E+05	1.48E+10	5.81E+07	2.46E+06	5.29E+11	6
87	05/26/1998	9.70E+06	8.22E+05	7.96E+10	5.82E+07	4.93E+06	2.86E+12	6
88	06/01/1998	9.69E+06	5.86E+05	6.79E+10	6.78E+07	4.10E+06	3.33E+12	7
89	06/09/1998	9.70E+06	1.42E+06	4.03E+11	6.78E+07	9.96E+06	1.97E+13	7
90	06/15/1998	9.69E+06	4.66E+05	3.04E+10	6.78E+07	3.26E+06	1.49E+12	7
91	06/22/1998	9.69E+06	3.27E+05	1.89E+10	6.78E+07	2.29E+06	9.24E+11	7
92	06/29/1998	9.69E+06	4.40E+05	6.65E+10	6.79E+07	3.08E+06	3.27E+12	7
93	07/06/1998	9.73E+06	4.44E+05	1.64E+10	6.79E+07	3.10E+06	8.0E+11	7
94	07/13/1998	9.67E+06	6.75E+05	6.74E+10	6.78E+07	4.73E+06	3.31E+12	7
95	07/21/1998	9.69E+06	5.17E+05	4.29E+10	6.78E+07	3.62E+06	2.10E+12	7
96	07/27/1998	9.70E+06	7.79E+05	1.15E+11	6.78E+07	5.44E+06	5.60E+12	7
97	08/03/1998	9.69E+06	3.65E+05	3.70E+10	6.78E+07	2.56E+06	1.81E+12	7
98	08/10/1998	9.68E+06	1.12E+06	2.28E+11	6.78E+07	7.83E+06	1.12E+13	7
99	08/18/1998	9.69E+06	7.67E+05	7.89E+10	7.66E+07	6.06E+06	4.93E+12	8
100	08/26/1998	9.69E+06	7.10E+05	7.40E+10	6.78E+07	4.97E+06	3.63E+12	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	3.53E+05	2.91E+10	6.78E+07	2.47E+06	1.42E+12	7
104	09/21/1998	7.44E+06	4.13E+05	6.43E+10	4.70E+07	2.61E+06	2.57E+12	6

(continued)

Table I-23 (continued). Blackeye goby (*Coryphopterus nicholsi*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	1.61E+06	1.85E+12	6.78E+07	1.13E-07	9.10E-13	7
106	10/06/1998	9.69E+06	4.54E+05	5.22E+10	2.13E+08	9.98E+06	2.53E-13	22
111	11/11/1998	9.68E+06	3.61E+05	7.92E+10	3.10E+08	1.16E+07	8.15E-13	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	3.97E+04	7.90E+08	2.75E+08	1.13E+06	6.38E-11	31
120	01/12/1999	9.68E+06	7.46E+03	5.57E+07	2.71E+08	2.09E+05	4.36E+10	28
123	02/03/1999	9.71E+06	0	0	2.33E+08	0	0	32
129	03/17/1999	7.29E+06	2.60E+05	2.06E+10	2.71E+08	9.67E+06	2.86E+13	35
133	04/14/1999	9.70E+06	3.25E+05	3.09E+10	3.20E+08	1.07E+07	3.37E+13	34
139	05/24/1999	9.41E+06	2.95E+05	1.14E+10	3.29E+08	1.03E+07	1.40E+13	35
143	06/23/1999	9.41E+06	5.32E+05	5.28E+10	2.16E+08	1.22E+07	2.79E+13	23

Table I-24. Sanddab (*Citharichthys* spp.) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	5.82E+03	1.69E+07	6.79E+07	4.07E+04	8.30E+08	7
4	10/30/1996	9.70E+06	0	0	6.77E+07	0	0	7
5	11/06/1996	9.70E+06	5.25E+04	2.40E+08	6.63E+07	3.59E+05	1.12E+10	7
6	11/13/1996	9.73E+06	5.94E+03	1.79E+07	5.84E+07	3.56E+04	6.44E+08	6
7	11/18/1996	9.69E+06	3.06E+03	9.34E+06	5.82E+07	1.83E+04	3.37E+08	6
8	11/25/1996	7.31E+06	2.55E+03	6.52E+06	5.33E+07	1.86E+04	3.47E+08	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	3.76E+03	1.41E+07	6.36E+07	2.47E+04	6.08E+08	7
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	7.44E+03	2.77E+07	6.79E+07	5.21E+04	1.36E+09	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	1.33E+04	5.34E+07	6.78E+07	9.28E+04	2.62E+09	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	5.81E+03	3.38E+07	6.75E+07	4.05E+04	1.64E+09	7
17	01/20/1997	9.70E+06	1.33E+04	4.43E+07	6.79E+07	9.29E+04	2.17E+09	7
18	01/27/1997	9.70E+06	1.88E+04	3.98E+07	6.68E+07	1.30E+05	1.89E+09	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	3.62E+03	1.31E+07	6.76E+07	2.52E+04	6.34E+08	7
22	02/24/1997	9.71E+06	0	0	6.72E+07	0	0	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	3.63E+03	1.32E+07	6.75E+07	2.53E+04	6.38E+08	7
25	03/17/1997	9.36E+06	1.16E+04	4.48E+07	6.75E+07	8.36E+04	2.33E+09	7
26	03/24/1997	9.69E+06	7.05E+03	2.49E+07	6.77E+07	4.93E+04	1.22E+09	7
27	03/31/1997	7.31E+06	0	0	5.18E+07	0	0	7
28	04/07/1997	9.67E+06	0	0	6.62E+07	0	0	7
29	04/14/1997	9.69E+06	0	0	6.49E+07	0	0	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	0	0	3.43E+07	0	0	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	0	0	3.44E+07	0	0	7
34	05/19/1997	4.89E+06	1.61E+04	5.40E+07	3.44E+07	1.13E+05	2.66E+09	7
35	05/27/1997	6.96E+06	0	0	4.66E+07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E+07	0	0	7
37	06/09/1997	9.70E+06	7.37E+03	5.43E+07	6.78E+07	5.15E+04	2.65E+09	7
38	06/16/1997	9.67E+06	4.83E+03	2.33E+07	6.78E+07	3.38E+04	1.14E+09	7
39	06/23/1997	9.71E+06	2.16E+04	1.55E+08	6.78E+07	1.50E+05	7.57E+09	7
40	06/30/1997	9.69E+06	7.56E+03	1.91E+07	6.32E+07	4.93E+04	8.14E+08	7
41	07/07/1997	9.68E+06	5.40E+04	2.47E+08	6.72E+07	3.75E+05	1.19E+10	7
42	07/14/1997	9.69E+06	4.47E+04	3.27E+08	6.78E+07	3.12E+05	1.60E+10	7
43	07/21/1997	9.71E+06	1.22E+05	7.12E+08	6.74E+07	8.45E+05	3.43E+10	7
44	07/28/1997	9.69E+06	7.73E+04	2.17E+09	6.74E+07	5.38E+05	1.05E+11	7
45	08/04/1997	9.69E+06	3.12E+05	4.64E+09	6.78E+07	2.18E+06	2.27E+11	7
46	08/11/1997	9.68E+06	5.51E+04	3.77E+08	6.78E+07	3.86E+05	1.85E+10	7
47	08/18/1997	9.70E+06	1.47E+04	1.08E+08	6.81E+07	1.03E+05	5.33E+09	7
48	08/26/1997	9.70E+06	3.37E+03	1.13E+07	7.41E+07	2.57E+04	6.60E+08	8
49	09/02/1997	9.67E+06	5.02E+03	2.52E+07	5.82E+07	3.02E+04	9.11E+08	6
50	09/08/1997	7.49E+06	9.28E+04	3.94E+08	5.83E+07	7.22E+05	2.38E+10	7
51	09/15/1997	9.68E+06	2.21E+04	1.27E+08	6.78E+07	1.55E+05	6.24E+09	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7

(continued)

Table I-24 (continued). Sanddab (*Citharichthys* spp.) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	5.17E+03	2.67E+07	6.61E+07	3.48E+04	1.21E+09	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	6.35E+03	4.03E+07	8.72E+07	5.72E+04	3.27E+09	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	1.57E+04	1.36E+08	4.85E+07	7.85E+04	3.40E+09	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	5.50E+03	2.83E+07	6.76E+07	3.84E+04	1.38E+09	7
67	01/05/1998	9.68E+06	7.89E+04	5.22E+08	7.75E+07	6.32E+05	3.35E+10	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	3.42E+03	1.17E+07	2.34E+07	1.71E+04	2.92E+08	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	0	0	4.81E+07	0	0	5
80	04/07/1998	9.73E+06	0	0	7.73E+07	0	0	8
81	04/16/1998	9.73E+06	5.37E+03	2.89E+07	1.07E+08	5.89E+04	3.47E+09	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	0	0	8.72E+07	0	0	9
84	05/04/1998	9.70E+06	0	0	6.78E+07	0	0	7
85	05/14/1998	9.68E+06	0	0	7.75E+07	0	0	8
86	05/19/1998	9.70E+06	0	0	5.81E+07	0	0	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	0	0	6.78E+07	0	0	7
90	06/15/1998	9.69E+06	0	0	6.78E+07	0	0	7
91	06/22/1998	9.69E+06	0	0	6.78E+07	0	0	7
92	06/29/1998	9.69E+06	0	0	6.79E+07	0	0	7
93	07/06/1998	9.73E+06	0	0	6.79E+07	0	0	7
94	07/13/1998	9.67E+06	1.48E+04	1.10E+08	6.78E+07	1.03E+05	5.40E+09	7
95	07/21/1998	9.69E+06	1.41E+04	1.0E+08	6.78E+07	9.89E+04	4.90E+09	7
96	07/27/1998	9.70E+06	0	0	6.78E+07	0	0	7
97	08/03/1998	9.69E+06	1.25E+04	7.95E+07	6.78E+07	8.77E+04	3.90E+09	7
98	08/10/1998	9.68E+06	0	0	6.78E+07	0	0	7
99	08/18/1998	9.69E+06	0	0	7.66E+07	0	0	8
100	08/26/1998	9.69E+06	7.30E+03	4.68E+07	6.78E+07	5.11E+04	2.29E+09	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	6.18E+03	3.82E+07	6.78E+07	4.32E+04	1.87E+09	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6

(continued)

Table I-24 (continued). Sanddab (*Citharichthys* spp.) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	2.45E+04	7.43E+07	6.78E+07	1.71E+05	3.65E+09	7
106	10/06/1998	9.69E+06	6.77E+03	4.59E+07	2.13E+08	1.49E+05	2.22E+10	22
111	11/11/1998	9.68E+06	0	0	3.10E+08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	0	0	2.75E+08	0	0	31
120	01/12/1999	9.68E+06	0	0	2.71E+08	0	0	28
123	02/03/1999	9.71E+06	0	0	2.33E+08	0	0	32
129	03/17/1999	7.29E+06	0	0	2.71E+08	0	0	35
133	04/14/1999	9.70E+06	0	0	3.20E+08	0	0	34
139	05/24/1999	9.41E+06	2.16E+04	1.21E+08	3.29E+08	7.57E+05	1.49E+11	35
143	06/23/1999	9.41E+06	3.28E+04	6.74E+08	2.16E+08	7.55E+05	3.57E+11	23

Table I-25. California halibut (*Paralichthys californicus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
1	10/16/1996				Preliminary survey			
2	10/17/1996				Preliminary survey			
3	10/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
4	10/30/1996	9.70E+06	0	0	6.77E+07	0	0	7
5	11/06/1996	9.70E+06	3.65E+03	1.33E-07	6.63E+07	2.49E+04	6.20E+08	7
6	11/13/1996	9.73E+06	0	0	5.84E+07	0	0	6
7	11/18/1996	9.69E+06	0	0	5.82E-07	0	0	6
8	11/25/1996	7.31E+06	0	0	5.33E+07	0	0	7
9	12/02/1996				Data not analyzed			
10	12/03/1996	9.69E+06	0	0	6.36E+07	0	0	7
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	0	0	6.78E+07	0	0	7
15	01/06/1997	9.69E+06	2.94E+03	8.65E+06	6.79E+07	2.06E+04	4.24E+08	7
16	01/13/1997	9.69E+06	0	0	6.75E+07	0	0	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	3.34E+03	1.11E+07	6.68E+07	2.30E+04	5.29E+08	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	0	0	6.76E+07	0	0	7
22	02/24/1997	9.71E+06	9.47E+04	1.92E+08	6.72E-07	6.55E+05	9.18E+09	7
23	03/03/1997	9.68E+06	0	0	6.79E-07	0	0	7
24	03/10/1997	9.70E+06	3.62E+03	1.31E+07	6.75E-07	2.52E+04	6.36E+08	7
25	03/17/1997	9.36E+06	3.76E+03	1.42E+07	6.75E-07	2.72E+04	7.37E+08	7
26	03/24/1997	9.69E+06	4.75E+03	2.25E+07	6.77E-07	3.32E+04	1.10E+09	7
27	03/31/1997	7.31E+06	0	0	5.18E-07	0	0	7
28	04/07/1997	9.67E-06	1.57E+04	9.28E-07	6.62E-07	1.07E+05	4.35E+09	7
29	04/14/1997	9.69E+06	0	0	6.49E-07	0	0	7
30	04/21/1997	4.91E+06	0	0	4.04E+07	0	0	7
31	04/28/1997	4.89E+06	3.94E-03	7.83E-06	3.43E+07	2.77E+04	3.86E+08	7
32	05/05/1997	4.90E+06	0	0	3.42E+07	0	0	7
33	05/12/1997	4.91E+06	5.40E+04	2.42E+08	3.44E+07	3.78E+05	1.19E+10	7
34	05/19/1997	4.89E+06	0	0	3.44E-07	0	0	7
35	05/27/1997	6.96E+06	0	0	4.66E-07	0	0	7
36	06/02/1997	9.70E+06	0	0	6.18E-07	0	0	7
37	06/09/1997	9.70E+06	0	0	6.78E-07	0	0	7
38	06/16/1997	9.67E+06	3.40E+03	1.16E-07	6.78E-07	2.39E+04	5.70E+08	7
39	06/23/1997	9.71E+06	0	0	6.78E-07	0	0	7
40	06/30/1997	9.69E+06	4.35E+03	1.90E-07	6.32E+07	2.84E-04	8.06E+08	7
41	07/07/1997	9.68E+06	0	0	6.72E-07	0	0	7
42	07/14/1997	9.69E+06	1.27E+04	5.33E+07	6.78E+07	8.84E-04	2.61E+09	7
43	07/21/1997	9.71E+06	6.55E-03	2.15E+07	6.74E+07	4.55E+04	1.04E+09	7
44	07/28/1997	9.69E+06	6.47E-03	4.19E+07	6.74E+07	4.50E+04	2.03E+09	7
45	08/04/1997	9.69E+06	1.19E+04	9.68E+07	6.78E+07	8.30E+04	4.73E+09	7
46	08/11/1997	9.68E+06	7.36E+04	8.42E+08	6.78E+07	5.15E+05	4.12E+10	7
47	08/18/1997	9.70E+06	6.29E+03	3.96E+07	6.81E+07	4.41E-04	1.95E+09	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	5.59E+03	3.13E+07	5.82E+07	3.37E-04	1.13E+09	6
50	09/08/1997	7.49E+06	0	0	5.83E+07	0	0	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	5.68E+03	3.22E+07	6.78E-07	3.98E+04	1.59E+09	7

(continued)

Table I-25 (continued). California halibut (*Paralichthys californicus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	5.44E+03	2.95E+07	4.85E+07	2.72E+04	7.38E+08	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	5.48E+03	2.82E+07	6.76E+07	3.83E+04	1.38E+09	7
67	01/05/1998	9.68E+06	1.37E+04	9.59E+07	7.75E+07	1.10E+05	6.14E+09	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	6.62E+03	4.39E+07	6.79E+07	4.64E+04	2.15E+09	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
71	02/02/1998				Not sampled			
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	0	0	5.67E+07	0	0	7
79	04/01/1998	9.67E+06	6.05E+03	3.66E+07	4.81E+07	3.01E+04	9.07E+08	5
80	04/07/1998	9.73E+06	0	0	7.73E+07	0	0	8
81	04/16/1998	9.73E+06	2.36E+04	1.08E+08	1.07E+08	2.59E+05	1.30E+10	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	1.16E+06	5.35E+10	8.72E+07	1.05E+07	4.33E+12	9
84	05/04/1998	9.70E+06	1.27E+05	1.44E+09	6.78E+07	8.86E+05	7.03E+10	7
85	05/14/1998	9.68E+06	1.65E+05	7.32E+08	7.75E+07	1.32E+06	4.69E+10	8
86	05/19/1998	9.70E+06	0	0	5.81E+07	0	0	6
87	05/26/1998	9.70E+06	0	0	5.82E+07	0	0	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	0	0	6.78E+07	0	0	7
90	06/15/1998	9.69E+06	5.51E+03	3.03E+07	6.78E+07	3.85E+04	1.48E+09	7
91	06/22/1998	9.69E+06	0	0	6.78E+07	0	0	7
92	06/29/1998	9.69E+06	0	0	6.79E+07	0	0	7
93	07/06/1998	9.73E+06	0	0	6.79E+07	0	0	7
94	07/13/1998	9.67E+06	1.33E+04	8.89E+07	6.78E+07	9.34E+04	4.37E+09	7
95	07/21/1998	9.69E+06	2.72E+04	1.86E+08	6.78E+07	1.90E+05	9.13E+09	7
96	07/27/1998	9.70E+06	4.02E+04	8.07E+08	6.78E+07	2.81E+05	3.94E+10	7
97	08/03/1998	9.69E+06	4.34E+04	3.0E+08	6.78E+07	3.04E+05	1.47E+10	7
98	08/10/1998	9.68E+06	2.50E+04	1.29E+08	6.78E+07	1.75E+05	6.32E+09	7
99	08/18/1998	9.69E+06	1.19E+04	7.08E+07	7.66E+07	9.40E+04	4.43E+09	8
100	08/26/1998	9.69E+06	0	0	6.78E+07	0	0	7
101	08/31/1998	9.68E+06	0	0	5.81E+07	0	0	6
102	09/08/1998	9.68E+06	0	0	7.54E+07	0	0	8
103	09/16/1998	9.70E+06	0	0	6.78E+07	0	0	7
104	09/21/1998	7.44E+06	0	0	4.70E+07	0	0	6

(continued)

Table I-25 (continued). California halibut (*Paralichthys californicus*) larvae: Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system. Surveys 107-110, 112-113, 116-119, 121-122, 124-128, 130-132, 134-138, 140-141 and 144 were not sorted for fish.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
105	09/28/1998	9.67E+06	0	0	6.78E-07	0	0	7
106	10/06/1998	9.69E+06	0	0	2.13E-08	0	0	22
111	11/11/1998	9.68E+06	0	0	3.10E-08	0	0	32
114	12/01/1998				Not sampled			
115	12/09/1998	9.67E+06	0	0	2.75E+08	0	0	31
120	01/12/1999	9.68E+06	0	0	2.71E+08	0	0	28
123	02/03/1999	9.71E+06	0	0	2.33E+08	0	0	32
129	03/17/1999	7.29E+06	2.27E+05	3.54E+09	2.71E+08	8.46E+06	4.91E+12	35
133	04/14/1999	9.70E+06	6.74E+03	4.55E+07	3.20E+08	2.23E+05	4.95E+10	34
139	05/24/1999	9.41E+06	0	0	3.29E+08	0	0	35
143	06/23/1999	9.41E+06	0	0	2.16E+08	0	0	23

Table I-26. Purple sea urchin (*Strongylocentrotus purpuratus*): Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	3.76E+05	1.86E+11	4.72E+07	1.83E+06	4.41E+12	5
11	12/09/1996	9.70E+06	1.38E+05	9.98E+10	6.79E+07	9.66E+05	4.89E+12	7
12	12/16/1996	9.70E+06	8.42E+04	5.68E+10	6.79E+07	5.90E+05	2.78E+12	7
13	12/23/1996	9.70E+06	6.62E+05	2.66E+12	6.79E+07	4.64E+06	1.30E+14	7
14	12/30/1996	9.68E+06	2.41E+05	6.39E+10	6.78E+07	1.69E+06	3.13E+12	7
15	01/06/1997	9.69E+06	4.76E+04	7.80E+09	6.79E+07	3.33E+05	3.83E+11	7
16	01/13/1997	9.69E+06	2.36E+05	2.51E+11	6.75E+07	1.65E+06	1.22E+13	7
17	01/20/1997	9.70E+06	4.50E+05	1.49E+11	6.79E+07	3.15E+06	7.28E+12	7
18	01/27/1997	9.70E+06	2.55E+05	1.08E+11	6.68E+07	1.76E+06	5.11E+12	7
19	02/03/1997	9.69E+06	3.95E+05	1.69E+11	6.75E+07	2.75E+06	8.24E+12	7
20	02/10/1997	9.64E+06	5.87E+05	8.01E+11	6.78E+07	4.13E+06	3.96E+13	7
21	02/17/1997	9.71E+06	8.86E+06	5.43E+13	6.76E+07	6.16E+07	2.63E+15	7
22	02/24/1997	9.71E+06	5.31E+06	2.14E+13	6.72E+07	3.67E+07	1.03E+15	7
23	03/03/1997	9.68E+06	2.64E+06	1.17E+13	6.79E+07	1.85E+07	5.76E+14	7
24	03/10/1997	9.70E+06	1.06E+06	6.66E+11	6.75E+07	7.35E+06	3.23E+13	7
25	03/17/1997	9.36E+06	2.11E+07	1.13E+14	6.75E+07	1.52E+08	5.90E+15	7
26	03/24/1997	9.69E+06	1.09E+07	1.29E+14	6.77E+07	7.62E+07	6.30E+15	7
27	03/31/1997	7.31E+06	5.76E+06	1.00E+13	5.18E+07	4.09E+07	5.05E+14	7
28	04/07/1997	9.67E+06	2.40E+07	5.95E+14	6.62E+07	1.64E+08	2.79E+16	7
29	04/14/1997	9.69E+06	3.97E+07	1.90E+15	6.49E+07	2.66E+08	8.49E+16	7
30	04/21/1997	4.91E+06	2.83E+06	7.98E+12	4.04E+07	2.33E+07	5.40E+14	7
31	04/28/1997	4.89E+06	1.04E+07	5.36E+13	3.43E+07	7.29E+07	2.64E+15	7
32	05/05/1997	4.90E+06	1.35E+06	1.26E+12	3.42E+07	9.46E+06	6.13E+13	7
33	05/12/1997	4.91E+06	9.18E+06	6.16E+13	3.44E+07	6.43E+07	3.02E+15	7
34	05/19/1997	4.89E+06	4.30E+06	3.20E+13	3.44E+07	3.02E+07	1.58E+15	7
35	05/27/1997	6.96E+06	2.63E+07	1.00E+15	4.66E+07	1.76E+08	4.49E+16	7
36	06/02/1997	9.70E+06	7.51E+06	7.15E+13	6.18E+07	4.78E+07	2.90E+15	7
37	06/09/1997	9.70E+06	7.29E+07	4.65E+15	6.78E+07	5.09E+08	2.27E+17	7
38	06/16/1997	9.67E+06	6.34E+07	1.76E+15	6.78E+07	4.45E+08	8.67E+16	7
39	06/23/1997	9.71E+06	4.38E+06	5.95E+12	6.78E+07	3.06E+07	2.90E+14	7
40	06/30/1997	9.69E+06	1.07E+07	2.73E+14	6.32E+07	6.96E+07	1.16E+16	7
41	07/07/1997	9.68E+06	6.05E+06	9.49E+12	6.72E+07	4.20E+07	4.57E+14	7
42	07/14/1997	9.69E+06	2.54E+07	7.06E+14	6.78E+07	1.78E+08	3.45E+16	7
43	07/21/1997	9.71E+06	4.95E+06	3.65E+13	6.74E+07	3.44E+07	1.76E+15	7
44	07/28/1997	9.69E+06	6.27E+05	5.47E+11	6.74E+07	4.36E+06	2.65E+13	7
45	08/04/1997	9.69E+06	5.00E+05	7.87E+11	6.78E+07	3.50E+06	3.85E+13	7
46	08/11/1997	9.68E+06	3.73E+05	1.11E+12	6.78E+07	2.61E+06	5.44E+13	7
47	08/18/1997	9.70E+06	5.30E+04	9.65E+09	6.81E+07	3.72E+05	4.75E+11	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	8.84E+04	3.90E+10	5.83E+07	6.87E+05	2.36E+12	7
51	09/15/1997	9.68E+06	0	0	6.78E+07	0	0	7
52	09/22/1997	9.67E+06	2.08E+04	3.44E+09	6.78E+07	1.46E+05	1.69E+11	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-26 (continued). Purple sea urchin (*Strongylocentrotus purpuratus*): Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	2.20E+04	3.86E+09	4.85E+07	1.10E+05	9.64E+10	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	0	0	7.75E+07	0	0	8
68	01/15/1998	9.67E+06	0	0	8.72E+07	0	0	9
69	01/23/1998	9.69E+06	0	0	6.79E+07	0	0	7
70	01/28/1998	9.69E+06	0	0	8.38E+07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E+08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E+07	0	0	11
75	03/04/1998	4.69E+06	4.25E+04	3.53E+09	2.34E+07	2.13E+05	8.84E+10	5
76	03/09/1998	4.69E+06	6.90E+04	1.37E+10	3.37E+07	4.96E+05	7.06E+11	7
77	03/19/1998	7.29E+06	1.64E+06	3.25E+12	5.44E+07	1.23E+07	1.81E+14	9
78	03/27/1998	8.44E+06	3.48E+06	4.58E+12	5.67E+07	2.34E+07	2.07E+14	7
79	04/01/1998	9.67E+06	3.39E+06	1.23E+13	4.81E+07	1.69E+07	3.04E+14	5
80	04/07/1998	9.73E+06	1.03E+06	6.33E+11	7.73E+07	8.16E+06	3.99E+13	8
81	04/16/1998	9.73E+06	1.65E+06	4.52E+12	1.07E+08	1.80E+07	5.44E+14	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	2.30E+06	2.78E+13	8.72E+07	2.07E+07	2.25E+15	9
84	05/04/1998	9.70E+06	2.64E+06	1.46E+13	6.78E+07	1.84E+07	7.13E+14	7
85	05/14/1998	9.68E+06	1.65E+06	3.33E+12	7.75E+07	1.32E+07	2.13E+14	8
86	05/19/1998	9.70E+06	2.32E+04	4.29E+09	5.81E+07	1.39E+05	1.54E+11	6
87	05/26/1998	9.70E+06	8.86E+05	1.58E+12	5.82E+07	5.31E+06	5.67E+13	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	2.77E+04	5.39E+09	6.78E+07	1.94E+05	2.63E+11	7
90	06/15/1998	9.69E+06	6.12E+05	4.24E+11	6.78E+07	4.28E+06	2.07E+13	7
91	06/22/1998	9.69E+06	2.39E+06	2.12E+13	6.78E+07	1.67E+07	1.04E+15	7
92	06/29/1998	9.69E+06	3.35E+05	1.29E+11	4.85E+07	1.68E+06	3.22E+12	5

Table I-27. Red sea urchin (*Strongylocentrotus franciscanus*): Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m³/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
10	12/03/1996	9.69E+06	2.83E+04	6.40E+09	4.72E+07	1.38E+05	1.52E+11	5
11	12/09/1996	9.70E+06	0	0	6.79E+07	0	0	7
12	12/16/1996	9.70E+06	0	0	6.79E+07	0	0	7
13	12/23/1996	9.70E+06	0	0	6.79E+07	0	0	7
14	12/30/1996	9.68E+06	2.67E+04	5.69E+09	6.78E+07	1.87E+05	2.80E+11	7
15	01/06/1997	9.69E+06	0	0	6.79E+07	0	0	7
16	01/13/1997	9.69E+06	3.03E+04	7.36E+09	6.75E+07	2.12E+05	3.58E+11	7
17	01/20/1997	9.70E+06	0	0	6.79E+07	0	0	7
18	01/27/1997	9.70E+06	0	0	6.68E+07	0	0	7
19	02/03/1997	9.69E+06	0	0	6.75E+07	0	0	7
20	02/10/1997	9.64E+06	0	0	6.78E+07	0	0	7
21	02/17/1997	9.71E+06	2.57E+04	5.28E+09	6.76E+07	1.79E+05	2.55E+11	7
22	02/24/1997	9.71E+06	3.35E+05	1.58E+11	6.72E+07	2.32E+06	7.55E+12	7
23	03/03/1997	9.68E+06	0	0	6.79E+07	0	0	7
24	03/10/1997	9.70E+06	0	0	6.75E+07	0	0	7
25	03/17/1997	9.36E+06	5.85E+06	9.10E+13	6.75E+07	4.22E+07	4.74E+15	7
26	03/24/1997	9.69E+06	7.48E+05	3.00E+12	6.77E+07	5.23E+06	1.46E+14	7
27	03/31/1997	7.31E+06	4.19E+05	9.72E+10	5.18E+07	2.97E+06	4.89E+12	7
28	04/07/1997	9.67E+06	7.51E+05	1.46E+12	6.62E+07	5.14E+06	6.85E+13	7
29	04/14/1997	9.69E+06	9.43E+05	1.25E+12	6.49E+07	6.31E+06	5.58E+13	7
30	04/21/1997	4.91E+06	4.38E+04	3.68E+09	4.04E+07	3.60E+05	2.49E+11	7
31	04/28/1997	4.89E+06	7.03E+04	1.06E+10	3.43E+07	4.93E+05	5.20E+11	7
32	05/05/1997	4.90E+06	9.07E+04	1.16E+10	3.42E+07	6.33E+05	5.64E+11	7
33	05/12/1997	4.91E+06	3.77E+04	4.99E+09	3.44E+07	2.64E+05	2.45E+11	7
34	05/19/1997	4.89E+06	3.00E+05	3.09E+11	3.44E+07	2.10E+06	1.52E+13	7
35	05/27/1997	6.96E+06	1.45E+06	1.33E+12	4.66E+07	9.71E+06	5.96E+13	7
36	06/02/1997	9.70E+06	8.81E+04	3.03E+10	6.18E+07	5.62E+05	1.23E+12	7
37	06/09/1997	9.70E+06	1.03E+06	2.24E+12	6.78E+07	7.17E+06	1.09E+14	7
38	06/16/1997	9.67E+06	1.58E+06	2.55E+12	6.78E+07	1.11E+07	1.25E+14	7
39	06/23/1997	9.71E+06	1.25E+06	4.08E+12	6.78E+07	8.70E+06	1.99E+14	7
40	06/30/1997	9.69E+06	1.00E+06	2.55E+12	6.32E+07	6.54E+06	1.08E+14	7
41	07/07/1997	9.68E+06	9.27E+05	7.57E+11	6.72E+07	6.43E+06	3.64E+13	7
42	07/14/1997	9.69E+06	2.99E+06	6.94E+12	6.78E+07	2.09E+07	3.40E+14	7
43	07/21/1997	9.71E+06	8.66E+04	6.00E+10	6.74E+07	6.01E+05	2.89E+12	7
44	07/28/1997	9.69E+06	2.36E+05	4.45E+11	6.74E+07	1.64E+06	2.16E+13	7
45	08/04/1997	9.69E+06	0	0	6.78E+07	0	0	7
46	08/11/1997	9.68E+06	0	0	6.78E+07	0	0	7
47	08/18/1997	9.70E+06	0	0	6.81E+07	0	0	7
48	08/26/1997	9.70E+06	0	0	7.41E+07	0	0	8
49	09/02/1997	9.67E+06	0	0	5.82E+07	0	0	6
50	09/08/1997	7.49E+06	6.39E+04	1.74E+10	5.83E+07	4.97E+05	1.05E+12	7
51	09/15/1997	9.68E+06	2.08E+05	5.89E+10	6.78E+07	1.45E+06	2.90E+12	7
52	09/22/1997	9.67E+06	0	0	6.78E+07	0	0	7
53	09/30/1997	9.69E+06	0	0	6.79E+07	0	0	7
54	10/06/1997	9.70E+06	0	0	6.80E+07	0	0	7
55	10/13/1997	9.69E+06	0	0	6.78E+07	0	0	7
56	10/21/1997	9.69E+06	0	0	6.78E+07	0	0	7
57	10/27/1997	9.81E+06	0	0	6.61E+07	0	0	7
58	11/04/1997	9.80E+06	0	0	6.82E+07	0	0	7
59	11/10/1997	9.80E+06	0	0	6.84E+07	0	0	7
60	11/18/1997	9.76E+06	0	0	6.86E+07	0	0	7
61	11/24/1997	9.81E+06	0	0	6.82E+07	0	0	7
62	12/02/1997	9.68E+06	0	0	8.72E+07	0	0	9

(continued)

Table I-27 (continued). Red sea urchin (*Strongylocentrotus franciscanus*): Survey collection dates and estimated numbers entrained per 24 hours and per survey period based on daily flow rates (m^3/d) through the circulating water system.

Survey #	Collection Date	Daily water flow through CWS	Estimated # entrained per 24 hrs	Variance of # entrained per 24 hrs	Survey period water flow through CWS	Estimated # entrained per survey period	Variance of # entrained per survey period	# days in survey period
63	12/11/1997	9.69E+06	0	0	6.78E+07	0	0	7
64	12/16/1997	9.69E+06	4.76E+04	7.77E-09	4.85E+07	2.38E+05	1.94E+11	5
65	12/22/1997	9.70E+06	0	0	6.78E+07	0	0	7
66	12/30/1997	9.68E+06	0	0	6.76E+07	0	0	7
67	01/05/1998	9.68E+06	4.82E-04	1.86E+10	7.75E+07	3.86E+05	1.19E+12	8
68	01/15/1998	9.67E+06	0	0	8.72E-07	0	0	9
69	01/23/1998	9.69E+06	7.32E+04	2.10E+10	6.79E+07	5.12E+05	1.03E-12	7
70	01/28/1998	9.69E+06	0	0	8.38E-07	0	0	9
71	02/02/1998				Not sampled			
72	02/11/1998	9.41E+06	0	0	1.23E-08	0	0	15
73	02/16/1998				Not sampled			
74	02/27/1998	4.69E+06	0	0	5.15E-07	0	0	11
75	03/04/1998	4.69E+06	0	0	2.34E+07	0	0	5
76	03/09/1998	4.69E+06	0	0	3.37E+07	0	0	7
77	03/19/1998	7.29E+06	0	0	5.44E+07	0	0	9
78	03/27/1998	8.44E+06	2.09E+05	2.06E+11	5.67E+07	1.41E+06	9.31E+12	7
79	04/01/1998	9.67E+06	1.52E+05	7.76E+10	4.81E+07	7.54E+05	1.92E+12	5
80	04/07/1998	9.73E+06	5.53E+04	1.05E+10	7.73E+07	4.39E-05	6.62E-11	8
81	04/16/1998	9.73E+06	3.37E+05	9.10E+11	1.07E+08	3.70E+06	1.09E+14	11
82	04/24/1998				Not sampled			
83	04/29/1998	9.69E+06	4.79E+05	5.15E+11	8.72E-07	4.31E+06	4.17E+13	9
84	05/04/1998	9.70E+06	1.08E+06	2.47E+12	6.78E-07	7.52E+06	1.21E+14	7
85	05/14/1998	9.68E+06	1.10E+06	2.24E+12	7.75E+07	8.85E+06	1.44E+14	8
86	05/19/1998	9.70E+06	0	0	5.81E+07	0	0	6
87	05/26/1998	9.70E+06	5.71E+05	5.10E+11	5.82E+07	3.42E+06	1.83E+13	6
88	06/01/1998	9.69E+06	0	0	6.78E+07	0	0	7
89	06/09/1998	9.70E+06	5.55E+04	2.16E+10	6.78E-07	3.88E+05	1.05E+12	7
90	06/15/1998	9.69E+06	1.46E+05	5.28E+10	6.78E-07	1.02E+06	2.58E+12	7
91	06/22/1998	9.69E+06	3.73E+05	1.11E+12	6.78E+07	2.61E+06	5.46E+13	7
92	06/29/1998	9.69E+06	0	0	4.85E+07	0	0	5

Appendix J

Results of *t*-tests and Kolmogorov-Smirnov tests on length frequency data from paired entrainment and study grid samples.

Table J-1. Results of t-test on mean lengths for larval fishes comparing study grid and paired entrainment survey subsamples from July 1997 - June 1999 with a variable of length.a) Pacific sardine (*Sardinops sagax*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	155	5.60110675	3.19100484	0.25630768	Unequal	-1.3295	181.3	0.1854
Grid	2882	5.95608088	4.01529358	0.07479461	Equal	-1.0824	3035.0	0.2792

For Ho: Variances are equal, F' = 1.58, DF = (2881, 154), Prob>F' = 0.0003

b) Northern anchovy (*Engraulis mordax*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	121	9.18842727	4.13825959	0.37620542	Unequal	0.9982	126.4	0.3201
Grid	5432	8.80797425	4.50745533	0.06115776	Equal	0.9199	5551.0	0.3577

For Ho: Variances are equal, F' = 1.19, DF = (5431, 120), Prob>F' = 0.2178

c) KGB rockfish complex (*Sebastes* spp. V_De / V_D_)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	1282	4.18065392	0.34523637	0.00964212	Unequal	2.8271	2393.3	0.0047
Grid	2850	4.14817068	0.33360777	0.00624905	Equal	2.8641	4130.0	0.0042

For Ho: Variances are equal, F' = 1.07, DF = (1281, 2849), Prob>F' = 0.1464

d) Blue rockfish complex (*Sebastes* spp. V / S. *mstimus*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	443	3.63792239	0.39654277	0.01884032	Unequal	6.4142	624.2	0.0001
Grid	2159	3.50593710	0.38444742	0.00827391	Equal	6.5466	2600.0	0.0000

For Ho: Variances are equal, F' = 1.06, DF = (442, 2158), Prob>F' = 0.3893

e) Painted greenling (*Oxylebius pictus*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	107	4.14485858	0.44978660	0.04348251	Unequal	2.0630	226.6	0.0403
Grid	178	4.03056072	0.45809792	0.03433589	Equal	2.0535	283.0	0.0409

For Ho: Variances are equal, F' = 1.04, DF = (177, 106), Prob>F' = 0.8449

(continued)

Table J-1 (continued). Results of t-test on mean lengths for larval fishes comparing study grid and paired entrainment survey subsamples from July 1997 - June 1999 with a variable of length.f) Smoothhead sculpin (*Artedius lateralis*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	655	3.14412137	0.39895668	0.01558853	Unequal	-6.3809	298.6	0.0001
Grid	280	3.68674906	1.39887744	0.08359892	Equal	-9.1046	933.0	0.0000
For Ho: Variances are equal, F' = 12.29, DF = (279, 654), Prob>F' = 0.0000								

g) Snubnose sculpin (*Orthonopias triacis*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	380	3.45052543	0.49730086	0.02551100	Unequal	-2.4977	187.3	0.0134
Grid	161	3.67987762	1.11925147	0.08820937	Equal	-3.3015	539.0	0.0010
For Ho: Variances are equal, F' = 5.07, DF = (160, 379), Prob>F' = 0.0000								

h) Cabezon (*Scorpaenichthys marmoratus*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	104	4.67788302	0.54075751	0.05302564	Unequal	-2.7674	127.6	0.0065
Grid	705	4.83276442	0.47534535	0.01790254	Equal	-3.0453	807.0	0.0024
For Ho: Variances are equal, F' = 1.29, DF = (103, 704), Prob>F' = 0.0688								

i) White croaker (*Genyonemus lineatus*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	150	2.72266584	1.29600004	0.10581796	Unequal	3.4002	162.1	0.0008
Grid	1263	2.35516156	0.78211897	0.02200752	Equal	4.9995	1411.0	0.0000
For Ho: Variances are equal, F' = 2.75, DF = (149, 1262), Prob>F' = 0.0000								

j) Monkeyface eel (*Cebidichthys violaceus*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	816	7.31433645	1.05534055	0.03694431	Unequal	0.3186	869.9	0.7501
Grid	430	7.29425405	1.05926014	0.05108206	Equal	0.3189	1244.0	0.7498
For Ho: Variances are equal, F' = 1.01, DF = (429, 815), Prob>F' = 0.9230								

(continued)

Table J-1 (continued). Results of t-test on mean lengths for larval fishes comparing study grid and paired entrainment survey subsamples from July 1997 - June 1999 with a variable of length.

k) Kelpfishes

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	612	6.44901790	2.23623908	0.09039461	Unequal	-0.2713	887.8	0.7862
Grid	311	6.48144536	1.37879543	0.07818432	Equal	-0.2341	921.0	0.8150

For Ho: Variances are equal, F' = 2.63, DF = (611, 310), Prob>F' = 0.0000

l) Blackeye goby (*Coryphopterus nicholsi*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	699	2.57267454	0.28688647	0.01085104	Unequal	-2.1049	146.6	0.0370
Grid	144	2.77916578	1.16995415	0.09749618	Equal	-4.1123	841.0	0.0000

For Ho: Variances are equal, F' = 16.63, DF = (143, 698), Prob>F' = 0.0000

m) Sanddabs (*Citharichthys* spp.)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	4	9.57499933	14.95601930	7.47800965	Unequal	0.3078	3.3	0.7771
Grid	52	7.22499924	11.07300002	1.53554882	Equal	0.4000	54.0	0.6908

For Ho: Variances are equal, F' = 1.82, DF = (3, 51), Prob>F' = 0.3089

n) California halibut (*Paralichthys californicus*)

Type	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>(T)
Entrainment	9	2.62222120	1.41313288	0.47104429	Unequal	-3.2713	9.4	0.0092
Grid	115	4.22495537	1.44527949	0.13477301	Equal	-3.2085	122.0	0.0017

For Ho: Variances are equal, F' = 1.05, DF = (114, 8), Prob>F' = 1.0000

Table J-2. Results of the Kolmogorov-Smirnov 2-Sample test on mean lengths for larval fishes comparing study grid and paired entrainment survey subsamples from July 1997 - June 1999.

a) Pacific sardine (*Sardinops sagax*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	155	0.464516129	-1.77612767
Grid	2882	0.614850798	0.41190118
	3037	0.607178136	
Maximum Deviation Occurred at Observation = 1529			
Value of length at Maximum = 4.9099985			
KSa = 1.82326		Prob > KSa = 0.0026	

b) Northern anchovy (*Engraulis mordax*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	121	0.016528926	-.963148503
Grid	5432	0.106038292	0.143749406
	5553	0.104087880	
Maximum Deviation Occurred at Observation = 2415			
Value of length at Maximum = 3.00999832			
KSa = 0.973817		Prob > KSa = 0.2992	

c) KGB complex (*Sebastes* spp. V_De / V_D_)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	1282	0.450078003	-1.77879317
Grid	2850	0.522105263	1.19301811
	4132	0.499757986	
Maximum Deviation Occurred at Observation = 1431			
Value of length at Maximum = 4.10999680			
KSa = 2.14182		Prob > KSa = 0.0002	

(continued)

Table J-2 (continued). Results of the Kolmogorov-Smirnov 2-Sample test on mean lengths for larval fishes comparing study grid and paired entrainment survey subsamples from July 1997 - June 1999.

d) Blue rockfish complex (*Sebastes* spp. V / *S. mystinus*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	443	0.297968397	-2.40798245
Grid	2159	0.435849931	1.09075914
	2602	0.412375096	
Maximum Deviation Occurred at Observation = 1287			
Value of length at Maximum = 3.39999962			
KSa = 2.64351		Prob > KSa = 0.0001	

e) Painted greenling (*Oxylebius pictus*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	107	0.485981308	-1.46977867
Grid	178	0.713483146	1.13955116
	285	0.628070175	
Maximum Deviation Occurred at Observation = 141			
Value of length at Maximum = 4.09999847			
KSa = 1.85979		Prob > KSa = 0.0020	

f) Smoothhead sculpin (*Artedius lateralis*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	655	0.964885496	1.37320475
Grid	280	0.785714286	-2.10027872
	935	0.911229947	
Maximum Deviation Occurred at Observation = 505			
Value of length at Maximum = 3.89999962			
KSa = 2.509356		Prob > KSa = 0.0001	

(continued)

Table J-2 (continued). Results of the Kolmogorov-Smirnov 2-Sample test on mean lengths for larval fishes comparing study grid and paired entrainment survey subsamples from July 1997 - June 1999.g) Snubnose sculpin (*Orthonopias triacis*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	380	0.828947368	0.629146614
Grid	161	0.720496894	-.966564241
	541	0.796672828	
Maximum Deviation Occurred at Observation = 258			
Value of length at Maximum = 3.69999886			
KSa = 1.15329		Prob > KSa = 0.1398	

h) Cabezon (*Scorpaenichthys marmoratus*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	104	0.375000000	1.81995289
Grid	705	0.170212766	-0.69900818
	809	0.196538937	
Maximum Deviation Occurred at Observation = 369			
Value of length at Maximum = 4.39999771			
KSa = 1.94957		Prob > KSa = 0.0010	

i) White croaker (*Genyonemus lineatus*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	150	0.626666667	-2.32744864
Grid	1263	0.839271576	0.80209177
	1413	0.816702052	
Maximum Deviation Occurred at Observation = 635			
Value of length at Maximum = 2.80999947			
KSa = 2.46178		Prob > KSa = 0.0001	

(continued)

Table J-2 (continued). Results of the Kolmogorov-Smirnov 2-Sample test on mean lengths for larval fishes comparing study grid and paired entrainment survey subsamples from July 1997 - June 1999.

j) Monkeyface eel (*Cebidichthys violaceus*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	816	0.627450980	-.577643630
Grid	430	-0.686046512	0.795739360
	1246	0.647672552	
Maximum Deviation Occurred at Observation = 866			
Value of length at Maximum = 7.20999908			
KSa = 0.983297		Prob > KSa = 0.2884	

k) Kelpfishes

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	612	0.305555556	1.20685342
Grid	311	0.160771704	-1.69297303
	923	0.256771398	
Maximum Deviation Occurred at Observation = 456			
Value of length at Maximum = 5.39999771			
KSa = 2.07910		Prob > KSa = 0.0004	

l) Blackeye goby (*Coryphopterus nicholsi*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	699	0.510729614	1.11478295
Grid	144	0.263888889	-2.45610913
	843	0.468564650	
Maximum Deviation Occurred at Observation = 455			
Value of length at Maximum = 2.50000000			
KSa = 2.69726		Prob > KSa = 0.0001	

(continued)

Table J-2 (continued) Results of the Kolmogorov-Smirnov 2-Sample test on mean lengths for larval fishes comparing study grid and paired entrainment survey subsamples from July 1997 - June 1999.

m) Sanddabs (*Citharichthys* spp.)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	4	0.500000000	0.892857143
Grid	52	0.019230769	-0.247634016
	56	0.053571429	
Maximum Deviation Occurred at Observation = 39			
Value of length at Maximum = 1.79999924			
KSa = 0.926562		Prob > KSa = 0.3571	

n) California halibut (*Paralichthys californicus*)

Type	N	EDF at maximum	Deviation from mean at maximum
Entrainment	9	0.888888889	2.11021505
Grid	115	0.130434783	-0.59033571
	124	0.185483871	
Maximum Deviation Occurred at Observation = 86			
Value of length at Maximum = 2.69999886			
KSa = 2.19123		Prob > KSa = 0.0001	

Appendix K

Genetic Identification of Larval *Sebastes* spp.

Summary Report:

Molecular Identification of Rockfish (*Sebastes* spp.) Larvae

**Prepared For: Tenera Environmental
July 19, 1999**

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Introduction

Larval descriptions are available for the majority of North Pacific *Sebastes* species. However, interspecific similarity and intraspecific variability of larval characters (e.g. pigmentation, morphology and meristic characters) prevents species-specific identification of field-caught specimens. Because of this difficulty, investigators are forced to sort larvae into multispecies groups sharing a common pigment pattern. This approach remains largely invalidated and fails to provide species-level identifications necessary for detailed measurements of larval occurrence and abundance.

The purpose of this project was to use molecular techniques to identify preflexion *Sebastes* larvae that had been assigned to one of two pigment groups (V & V_De) by ichthyoplankton specialists from Tenara Environmental. Larvae assigned to the V pigment group have a short ventral pigment series, no dorsal series, and no pectoral pigmentation. Larvae that have been described with this pigmentation pattern include the following: *S. aleutianus*, *alutus*, *brevispinis*, *crameri*, *diploproa*, *elongatus*, *macdonaldi*, *miniatus*, *nigrocinctus*, *proriger*, *rosaceus*, *ruberrimus*, *serriceps*, *umbrosus*, *wilsoni*, and *zacentrus*. However, small preflexion larvae that subsequently develop either dorsal or pectoral pigment may also be assigned to this pigment group. Larvae in the V_De pigment group have a long ventral pigment series, an elongating dorsal series and may have pectoral pigment. This group includes *S. auriculatus*, *carnatus*, *caurinus*, *dalli*, and *rastrelliger*. However, young larvae that will later develop pectoral pigment or an elongating dorsal series may also be assigned to this pigment group. Results from molecular analyses of preflexion larvae will provide information necessary for the validation, or adjustment, of defined pigment groups as well as estimates of larval-species composition.

In our laboratory we have developed an extensive data base for the *Sebastes* that includes mitochondrial cytochrome *b* sequences for over 61 species (Rocha-Olivares et al. 1999a,b; Vetter lab, unpublished data). On the basis of a 780 base-pair segment of the gene, most, but not all species of *Sebastes* can be uniquely identified. In cases where two species have only recently diverged there may not have been sufficient evolutionary time for the two species to develop unique sequence differences (e.g. *carnatus* and *chrysomelas*). In these cases an individual can usually be assigned to a species pair or species complex. In this study we generated partial mitochondrial DNA (mtDNA) cytochrome *b* gene sequences for 40 unknown larval specimens provided by Tenara

Environmental. We compared them to existing orthologous sequences derived from adults of 61 *Sebastes* species. Comparative analyses of intra/interspecific DNA-level differences, measured in terms of nucleotide mutations, provided enough resolution to assign larvae to a species or to a species-complex.

Methodology / Analysis

Total genomic DNA was extracted from larval *Sebastes* specimens using a proteinase K / phenol-chloroform protocol adjusted for small sample/tissue size. Whole larvae were digested in 50ul CTAB (cetyltrimethyl ammonium bromide) extraction buffer and 1ul proteinase K (20mg/ml) for 4-6 hours. DNA was extracted once each, respectively, in 50ul volumes of Phenol/Chloroform/Isoamyl Alcohol (25:24:1) and Chloroform/Isoamyl Alcohol (24:1). Precipitated DNA was rinsed twice (70% ethanol), vacuum dried and resuspended in 20ul sterile water. DNA yield and purity was assayed by spectrophotometry. The quality and molecular weight of extracted DNA was checked by running stock DNA, and Lambda HindIII size standards, on 2% agarose gels stained with ethidium bromide.

A majority of the provided specimens yielded limited quantities of semi-degraded DNA. Preliminary attempts to amplify standard sections of mtDNA cytochrome *b* gene (approx. 800bp) using polymerase chain reaction (PCR: an *in vitro* method of amplifying target DNA sequences) met with limited success. Negative results were attributed to poor quality template DNA, and this was confirmed after control larvae (15 preflexion *Sebastes* larvae placed directly into 100% ethanol after collection) yielded good quality products.

Due to the degraded nature of larval template DNA, a two stage nested (nPCR) protocol was used: 1) "Primary" PCR (Primers: GluDG/CB3RF) 2) "Secondary" PCR (Primers: GluRF/CB2RF). Positive primary PCR amplifications were used in cycle-sequence reactions when possible. Negative, or low yield, primary PCR amplifications were utilized as template for secondary PCR amplifications. Individual specimens that failed to yield usable product in both primary and secondary amplifications were disregarded. PCR conditions for both series were as follows: 50ng genomic DNA (Secondary: 1ul Primary PCR product) and 1 unit *Taq* per 25ul reaction with 36 cycles of 1min@94°C, 1.5min @53°C, 1.5min@72°C and a final 6 minute extension at 72°C. PCR products were purified using a QIAquick PCR Cleanup Kit according to manufacturer protocols.

Complementary strand sequence data was obtained using ABI PRISM DyeDeoxy terminator cycle sequence chemistry according to manufacturer protocols on an ABI 377 automated sequencer.

Sequence data (approx. 425 bp section of mtDNA cytochrome *b*) was generated for the larval specimens and aligned with orthologous sequence from 116 verified adults representing 61 *Sebastes* species. Pairwise comparisons of sequence divergence (expressed as percentage) were calculated as the absolute number of nucleotide differences divided by the total number of base pairs (bp) sequenced. Individual larvae were assigned to a species, or species-complex, based on similarity to adult references. Distance based phylogenetic reconstructions (UPGMA) clustered larval specimens with adult references and aided in identifying alternative species used in comparative analyses.

Results

Adequate sequence data for species identification were obtained from 40 out of 58 attempted larval DNA extractions. (Note: DNA extractions were not attempted for four of the provided specimens - 22B, 25B, 27B and 30B). Molecular analyses identified a total of 7 *Sebastes* species plus two additional unresolved species-complexes: 1) "K/G/B", which includes *S. atrovirens*, *S. carnatus*, and *S. chrysomelas* (*Sebastes* V_D, V_De) 2) "E/W", which includes *S. emphaeus* and *S. wilsoni* (*Sebastes* V). The identity of one individual (GB 04) remains inconclusive due to the limited degree of sequence similarity between this specimen and all available reference sequences. Contamination is a possibility, however negative-control reactions (PCR) had no visible products.

A summary of individual extraction/molecular identifications and associated vial/survey/sample numbers is listed in Appendix A: Table 1 & Table 2. The following two result sections are ordered by pre-assigned pigment groups (V & V_De):

Individual larvae pre-assigned to pigment group V_De

Molecular Identification Species/Species Complex	"V_De" Larvae # of Individuals	Reference Adults # of Individuals
"K/G/B"	18	2 / 5 / 1
<i>S.dalli</i>	1	1
<i>S.rastrelliger</i>	1	2
"E/W"	1	2 / 2

A total of 21 out of the 39 sequenced individuals (excluding specimen GB04) were assigned, by Tenera personnel, to pigment group V_De. 18 of these 21 individuals (86%) were placed, based on molecular analyses, into the species-complex ("K/G/B") which includes *S.atrovirens*, *S.carnatus*, and *S.chrysomelas*. Individual larval specimens within this complex differed from the three adult species by a range of 0-5 mutations (0-1.1% sequence divergence). The inability to attain species-specific identifications within this complex is due to several factors: 1) Both past and present molecular work with *S.chrysomelas* and *S.carnatus* has failed to find clear interspecific genetic differences which suggests possible hybridization and/or incipient speciation events. 2) Due to the quality of larval DNA, only 425bp of mtDNA Cyt. *b* sequence was attained (as compared to 780bp attained from adult reference specimens); and at this level no diagnostic mutations distinguish *S.atrovirens* from *S.carnatus*/*S.chrysomelas*.

One individual (GB 08) was placed into the species complex "E/W" which includes *S.emphaeus* and *S.wilsoni* (0-1bp; 0-0.2% seq.div.). Lack of species-specific resolution was again due to the lack diagnostic mutations available in only 425 base pairs.

Of the remaining pre-assigned V_De specimens that were sequenced, one individual (GB 03) was identified as *S.dalli* (2bp; 0.5% seq. div.); and one individual (GE 09) was identified as *S.rastrelliger* (2bp; 0.5% seq. div.).

Individual larvae pre-assigned to pigment group V:

Molecular Identification Species/Species Complex	"V" Larvae # of Individuals	Reference Adults # of Individuals
<i>S.mystinus</i>	10	5
<i>S.rosaceus</i>	2	7
<i>S.constellatus</i>	2	9
"K/G/B"	2	2 / 5 / 1
<i>S.serriceps</i>	1	1
<i>S.serranoides</i>	1	5

A total of 18 out of 39 sequenced individuals (excluding specimen GB04) were assigned, by Tenera personnel, to pigment group V. Of these individuals, 10 out of the 18 (56%) were identified as *S.mystinus* (0-4bp; 0-0.9% seq. div.). Two individuals (GD 06/GE 04) were identified as *S.rosaceus* (0% seq. div. with 3 of 7 adult specimens); two individuals (GD 10/GE 02) were identified as *S.constellatus* (0% seq. div. with 6 of 9 adults); and two individuals (FP 03/GE 03) were placed into the "K/G/B" species complex (0-1bp; 0-0.2% seq. div.). A single individual (GD 09) was identified as *S.serriceps* (0% seq. div.) and another individual (GE 06) as *S.serranoides* (2-3bp; 0.5-0.7% seq. div.).

Conclusions

Larval haplotypes were identical to adult reference species (i.e. 0% seq.div.), or had very low levels of sequence divergence (0.2-0.9%), which strongly supports molecular identifications to the species-specific level. Assignment of individual larval specimens to the "K/G/B" and "E/W" species-complexes were also well supported ("K/G/B" 0-1.1%; "E/W" 0-0.2%). Further resolution, however, would require examination of alternative genomic locations (mtDNA d-loop or nDNA microsatellite loci), and this would require further time and resources. Results from further analyses would help distinguish *S.emphaeus* from *S.wilsoni*, and the majority of individual *S.atrovirens* larvae from those of *S.chrysomelas/S.carnatus*. No molecular marker is currently available that can conclusively discern between *S.chrysomelas* and *S.carnatus*.

The sampling protocol was never designed to accommodate molecular analyses, and the quality of DNA was less than ideal for this type of study. Modifications to sample

collection/preservation methods should enhance future molecular efforts with the following recommendations: 1) Specimens should be placed directly into 100% ethanol immediately after collection 2) All microscope meristic /morphological counts should be completed while specimens remain in 100% ethanol.

Some discrepancies were detected among pigment groupings and molecular identifications. In particular, the assigned V group specimens contained members of group VP (*S. constellatus*) and Vdp (*S. mystinus* and *serranoides*), as well as two misplaced K/G/B specimens from group V_De. Assigned V_De group specimens contained a member of group V (*S. emphaeus/S. wilsoni*) and possibly members of VD ("K/G/B"). Given the individual, developmental and regional variation in larval pigmentation patterns, defined pigment groups probably represent the limits of identification of preflexion *Sebastes* larvae using visual methods. The inclusion of the molecular analyses does allow Tenera Environmental to begin to determine which species are present and the overall proportions captured in the sampling program.

References:

Rocha-Olivares, A., C. A. Kimbrell, B. J. Eitner, and R. D. Vetter. 1999a. Evolution of a mitochondrial cytochrome *b* gene sequence and its utility in testing the monophyly and the subgenus *Sebastomus* *Molecular Phylogenetics and Evolution* 11: 426-440.

Rocha-Olivares, A., R. H. Rosenblatt, and R. D. Vetter. 1999b. Molecular evolution, systematics, and zoogeography of the rockfish subgenus *Sebastomus* (*Sebastes*, Scorpaenidae) based on mitochondrial cytochrome *b* and control region sequences. *Molecular Phylogenetics and Evolution* 11: 441-458.

Appendix A

TABLE 1:

- Listing of individual larval DNA extractions and molecular identifications with associated vial/survey/sample numbers and pigment groups.
- Shaded areas represent individuals pre-assigned to pigment group “V”.
White areas represent individuals pre-assigned to pigment group “V_De”
- Molecular identifications assigned “-” represent disregarded individuals due to lack of adequate sequence data.

TABLE 2:

- Listing of species/species-complex and common names with respective totals (out of 40 individual specimens analyzed)

TABLE 1: Individual specimens

Vial #	Survey #	Sample #	Pigment Group	Extraction ID	Molecular ID
1	15	26	V	FP 01	<i>S.mystinus</i>
2	15	42	V	FP 02	<i>S.mystinus</i>
3	20	25	V	FP 03	K/G/B
4	20	50	V	FP 04	<i>S.mystinus</i>
5	23	42	V	FP 05	-
6	23	57	V	FP 06	<i>S.mystinus</i>
7	32	41	V	FP 07	-
8	35	49	V	FP 08	-
9	67	26	V	FP 09	<i>S.mystinus</i>
10	67	58	V	FP 10	<i>S.mystinus</i>
11	75	33	V	FP 11	<i>S.mystinus</i>
12	75	57	V	FP 12	-
14	87	33	V_De	FP 13	-
13	87	26	V_De	FP 14	K/G/B
15	20	50	V_De	FP 15	-
16	20	50	V_De	FP 16	K/G/B
27	81	49	V_De	GB 01	K/G/B
20	29	57	V_De	GB 02	K/G/B
18	25	57	V_De	GB 03	<i>S.dalli</i>
23	38	34	V_De	GB 04	Inconclusive
19	29	10	V_De	GB 05	K/G/B
17	25	34	V_De	GB 06	K/G/B
31	89	34	V_De	GB 07	K/G/B
24	38	50	V_De	GB 08	E/W
25	77	34	V_De	GB 09	K/G/B
32	89	50	V_De	GB 10	K/G/B
22	34	58	V_De	GB 11	K/G/B
26	77	41	V_De	GB 12	K/G/B
29	84	34	V_De	GD 01	-
30	84	34	V_De	GD 02	K/G/B
21	34	33	V_De	GD 03	K/G/B
28	81	58	V_De	GD 04	K/G/B
3B	22	33	V	GD 05	<i>S.mystinus</i>
14B	86	25	V	GD 06	<i>S.rosaceus</i>
1B	16	2	V	GD 07	-
2B	18	50	V	GD 08	<i>S.mystinus</i>
12B	81	49	V	GD 09	<i>S.serriceps</i>
7B	41	25	V	GD 10	<i>S.constellatus</i>

TABLE 1 (Continued): Individual specimens

Vial #	Survey #	Sample #	Pigment Group	Extraction ID	Molecular ID
6B	36	57	V	GE 01	-
5B	33	42	V	GE 02	<i>S.constellatus</i>
15B	87	33	V	GE 03	K/G/B
11B	77	58	V	GE 04	<i>S.rosaceus</i>
8B	43	9	V	GE 05	-
10B	69	49	V	GE 06	<i>S.serranoides</i>
21B	69	42	V_De	GE 07	-
20B	67	26	V_De	GE 08	-
16B	24	34	V_De	GE 09	<i>S.rastrelliger</i>
26B	85	49	V_De	GE 10	-
19B	43	1	V_De	GE 11	-
23B	74	10	V_De	GE 12	K/G/B
9B	46	49	V	GF 01	-
13B	83	57	V	GF 02	-
4B	25	34	V	GF 03	<i>S.mystinus</i>
28B	88	33	V_De	GF 04	K/G/B
17B	36	49	V_De	GF 05	-
18B	40	34	V_De	GF 06	K/G/B
24B	75	42	V_De	GF 07	K/G/B
29B	90	49	V_De	GF 08	-

TABLE 2: Species or Species-complex totals from 40 larval specimens

<u>Molecular ID</u>	<u>Common Name</u>	<u># of Individuals</u>
<u>"K/G/B" (3 species)</u>		
<i>S.atrovirens</i>	Kelp	20
<i>S.carnatus</i>	Gopher	
<i>S.chrysomelas</i>	Black & Yellow	
<i>S.mystinus</i>	Blue	10
<i>S.constellatus</i>	Starry	2
<i>S.rosaceus</i>	Rosy	2
<i>S.dalli</i>	Calico	1
<i>S.rastrelliger</i>	Grass	1
<i>S.serranoides</i>	Olive	1
<i>S.serriceps</i>	Tree	1
Inconclusive	N/A	1
<u>"E/W" (2 species)</u>		
<i>S.wilsoni</i>	Pygmy	1
<i>S.emphaeus</i>	Puget Sound	

Appendix L

Technologies that do not have demonstrated commercial operability or reliability at power plants of a scale similar to DCP.

APPENDIX L

The following technologies (**Table L-1**) do not have demonstrated commercial operability or reliability at power plants of a scale similar to DCP. Consequently, they are not considered currently available for implementation at DCP.

An expanded discussion of each technology appears in Appendix D of the 1988 316(b) Demonstration report (PG&E 1988a).

Table L-1. Alternative intake technologies not commercially demonstrated at power plants of similar scale to DCP.

Category	Alternate Intake Technology: Operation Not Demonstrated
Cooling Water System	Modification to cooling water system components
Behavioral Barriers	Velocity Gradient (water jet or other turbulence) Electrical Barrier Louvers Chemical Barriers Magnetic Field Barriers Chains and Cable Barriers
Physical Barrier	Media Filter Horizontal Traveling Screen Inclined Plane Screen

L.1 Modifications to Cooling System Components

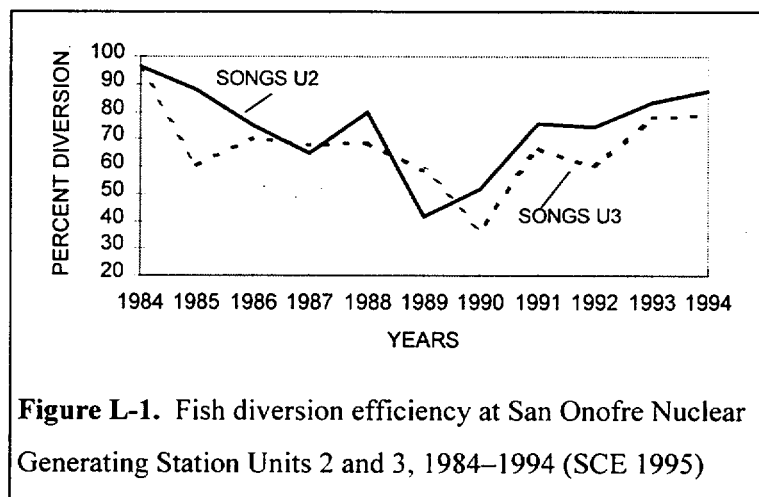
Structural modification of cooling system components (pumps, conduits, condensers) is not considered to be an effective alternative to reduce the mortality of entrained organisms. Too little quantitative information is available to isolate specific sources of mortality within a cooling water system. Design parameters for specifying pressure regimes, circulating water pump design and operation, tolerable shear stresses, and cooling system designs for minimizing mechanical abrasion have not been developed. This alternative is not considered to be available and proven.

L.2 Behavioral Barriers

Most behavioral barriers are designed to alter the behavior of fish in a manner that will prevent their entry into water intakes or enhance fish diversion to a bypass. Many systems are species specific; often evaluated to protect a single species at a particular age during a specific time of year. The systems attempt to produce avoidance responses in fish (e.g. strobe lights, sound, air bubbles), while others have been developed to attract fish (underwater mercury light, overhead lights). Guidance systems such as flow vanes and louvers also try to direct fish away from the screening systems. These guidance systems do not provide a barrier to planktonic organisms.

Numerous studies have demonstrated that louvers can be on the order of 80 to 95 percent effective in diverting a wide variety of species over a wide range of conditions (EPRI 1994). Louver systems consist of an array of evenly

spaced, vertical slats aligned across the cooling flow. San Onofre Nuclear Generating Station (SONGS) has a system of concrete guide bars and louvers that direct fish away from the traveling screens to a fish collection area. An evaluation of the fish diversion at SONGS was estimated at 96 and 75%



efficient in 1984 and 1985, respectively (Love et al. 1989). Over the ten year period of 1984–1994 diversion efficiency varied (**Figure L-1**) and ranged 87–37% for both units 2 and 3 (SCE 1995). Despite installation of guide bars and louvers, the plant still impinged 3,530–50,400 kg (4–55 tons) of fish per year between 1984 and 1995 (Tenera 1998a). If a system like that used at SONGS were installed at DCPD debris could foul a barrier system and lead to reduced operating reliability.

Test applications of light systems have also been considered as behavioral barriers at water intakes. To date, there are no permanent fish protection systems that include the use of strobe lights. There are, however, four hydroelectric facilities that are considering permanent installations (EPRI 1999).

Lighting systems have been tried at SONGS in recent year with mixed results. Laboratory simulations with northern anchovy, white croaker, and Pacific sardine found no indication of preference toward or away from strobe lights (Jahn and Herbinson 1999).

Overhead incandescent flood lamps were also tested for feasibility at SONGS. In communicating with K. Herbinson (SCE pers. comm. 2/17/2000) he stated:

“The lights don't seem to help. We tested the lights at our Redondo [Beach, CA] Lab with the intention of attracting fish away from the screens and more quickly into the fish return elevator chamber by focusing lights on the back of the screenwell. The lights worked in the experimental tank; the fish went where we wanted them to go, but it didn't help at SONGS. [There] the fish seemed to linger in the lights and spent more time in the screenwell and more were impinged. We reduced the light a little, which helped, but impingement was still higher with the lights on. Next we tried total darkness by covering all gratings and openings where ambient light could enter. Impingement also increased with this treatment. Our conclusion was that the current system (low light levels from ambient sources) was optimum.”

Water jet curtains, electrical barriers, hanging chains, visual keys and chemicals have all been researched and have not been shown to be biologically effective (EPRI 1999). There are no permanent installations of any of these technologies, nor is there any scientific data currently available to indicate that they are worthy of further research. Electric barriers have been used with limited success in freshwater, but because of low electrical resistance no application of electric fish barriers has been made in salt or brackish waters. These technologies are not considered proven for use at DCPD (EPRI 1999).

L.3 Physical Barriers

Media filters such as sand filters, porous dikes, and radial well intakes have not been used in providing power plant cooling water in the volumes required to operate DCPD. Prototype tests have been conducted that have identified debris accumulation, biofouling, and sedimentation as major constraints in the application of media filters. In the absence of demonstrated performance capabilities and operational reliability in a once-through power plant cooling water system, media filters are not an available technology for DCPD.

Under the proper hydraulic conditions (primarily low velocity) and without heavy debris loading, barrier-nets have been effective in blocking adult and juvenile fish passage into water intakes.

Michaud and Taft (1999) summarized recent applications of barrier-nets in the Midwest United States. At the Ludington Pumped Storage Plant on Lake Michigan, a 4 km (2.5 mi) long barrier-net first deployed in 1989 in open water around the intake jetties, has been successful in reducing impingement of all fish species that occur in the vicinity of the intake (Reider et al. 1997). Modifications to the design in subsequent years led to a net effectiveness for target species (five salmonid species, yellow perch, rainbow smelt, alewife, and chub) of over 80 percent since 1991, with an effectiveness of 96 percent in 1995 and 1996. In conclusion, barrier-nets can be considered a viable option for protecting adult and juvenile fishes provided that relatively low velocities, generally less than 30 cm/sec (1 ft/sec), can be achieved and debris loading is light. The application of barrier-nets at DCPD is not considered practicable given the potential for plugging with debris and kelp and severe wave action.

Physical barrier technologies have been developed to reduce entrainment of plankton into water intakes. One passive barrier-net called Gunderboom consists of polyester fiber strands that are pressed into a water-permeable fabric mat. Since 1995, Orange & Rockland Utilities, Inc. has sponsored an evaluation of the Gunderboom to determine its ability to minimize ichthyoplankton entrainment at the Lovett Generating Station on the Hudson River (EPRI 1999). Despite difficulties in keeping the boom deployed and providing adequate cleaning in 1995–1997 studies, results of studies in 1998 show a large reduction in entrainment. Even though it was successful at Lovett, the Gunderboom system is still considered to be experimental. The application of Gunderboom at DCPD is not considered practicable given the potential for plugging with debris and severe wave action.

In addition to the above, another important consideration at a nuclear facility is the potential that the safety related cooling water pumps would become blocked if a debris-loaded net or Gunderboom should become loose and block the water flow to the intake. This potential accident would make such an installation very difficult to justify from a nuclear safety perspective. Because of the potential of these systems to impact safety-related systems at DCPD, it is doubtful that either a barrier net or Gunderboom installation would be approved by the NRC.

Stationary screens, such as perforated plate and pipe systems and cylindrical wedge-wire screens, were also eliminated from consideration because they do not show either demonstrated performance or operational reliability in once-through cooling systems in a marine environment. Accumulation of debris and colonization by fouling organisms have been identified as factors that would substantially

decrease the operational reliability of stationary screen intake structures sited in a marine environment.

The horizontal traveling screen concept combines elements of diversion and collection devices and might have been an effective fish protection system if engineering problems could have been overcome. Years of design, research, and development efforts at two sites did not result in a screen that could operate reliably, even for relatively short periods of time (EPRI 1999). There has been no additional work on this technology and it is not considered available for application at DCP.

Inclined plane (Eicher) screens are under development and have been used on hydro plant intakes (EPRI 1998). These screens have been installed in penstocks and consist of a large, pivoted screen set at an angle to the penstock flow. The screens divert fish to a bypass flow path. The screens are designed to be rotated periodically to allow debris to be washed off. A Modular Inclined Screen (MIS) intake has been proposed (EPRI 1999) as a design for fish diversion in intake structures. This technology has been evaluated on a pilot scale as a retrofit for thermal power plant intakes (EPRI 1999). The Eicher or MIS screens have not been evaluated or tested in an environment similar to that of DCP, where the inclined screens would be subject to high debris loading and wave action. This would potentially compromise the ability of these screens to function for extended periods. Without operational experience in an ocean environment, these screens are not considered currently available for implementation at DCP.

An angled traveling screen is being evaluated for installation at an ocean-sited facility in California. The cooling water intakes for this plant draw water from an embayment that experiences substantially lower swell energy than at DCP. If this installation proves successful, this design could be considered at DCP.

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Appendix M

Technologies that are currently available but would not reduce impingement or entrainment to levels lower than observed at DCP.

APPENDIX M

The following technologies are currently available but would not reduce impingement nor entrainment to levels lower than observed at the DCPD site. **Table M-1** summarizes the technology's impact on impingement and entrainment. A detailed discussion of each technology follows the table.

Table M-1. Technologies not proven to reduce impingement nor entrainment.

Category	Intake Technology Evaluated	Change to Impingement	Change to Entrainment
Intake Configuration	Offshore Intake Location / Velocity Cap	Increased impingement	Possible change in species composition.
	Alternate Onshore Intake Location	Minimal Change	Minimal Change
	Recessed	Increased impingement	Minimal Change
Behavioral Barriers	Light	Minimal Change	Minimal Change
	Sound	Minimal Change (can work with some specific species)	Minimal Change
	Bubble Screen	Minimal Change	Minimal Change
Physical Barriers	Drum Screen	Minimal Change	Minimal Change
	Centerflow Screen with fine mesh baskets	Some designs could increase impingement	Will convert entrainment to impingement
Maintenance and Operational Modifications	Dredging	No Change	No Change

M.1 Intake Configuration

M.1.1 Offshore Intake Location

The degree of benefit of an offshore intake in reducing entrainment depends to a large degree on the vertical stratification of entrainable organisms in the water column at the point of water withdrawal. In such a system, a reduction in entrainment is achieved by locating the offshore submerged intake at a location where the density of entrainable organisms is less than at other locations (USEPA1977).

Several studies conducted since 1974 (Icanberry et al. 1978; Tenera 1998; **Section 5.0**) show that entrainable organisms are distributed throughout the water column in nearshore and offshore areas as a result of strong tidal and current mixing and the relatively shallow depths offshore of the Diablo Canyon Power Plant (DCPP).

Before the power plant was operational, larval fish surveys were conducted at two sampling locations offshore DCPD during 1974 and 1975 by Icanberry et al. (1978). Comparison of larval fish densities collected in oblique near-bottom to surface plankton net hauls at sampling stations located 300 m (1,000 ft) and 1,500 m (5,000 ft) offshore showed no statistically significant differences in total larval fish densities between the two locations. Statistical differences were found between locations for two of the six most abundant fish taxa. Densities of larval sculpin (*Artedius* spp.) were found to be greater at the 300 m station and densities of larval northern lampfish (*Stenobranchius leucopsarus*) were found to be greater at the 1,000 m station. Results of these larval fish studies provide no evidence that larval fish densities are consistently lower at locations where an offshore intake could be constructed (Tenera 1988a).

Densities of larval fish collected during 1986 and 1987 (Tenera 1988a) were compared between sampling locations within the DCPD Intake Cove and at an offshore location in close proximity to Icanberry's 300 m station (Icanberry et al. 1978). Results of the comparison indicate that although the plankton densities at both locations are characterized by high variability, densities were generally higher in the Intake Cove than at the offshore location. A more detailed examination of the trends in species-specific densities between the two locations indicated that the higher densities observed in the Intake Cove were largely attributable to the presence of cottid (sculpin) larvae during 1986–1987 (Table M-2; Tenera 1988a). No significant differences in larval fish densities were detected between the two sampling locations when larval sculpin were excluded from the analysis.

Based on results of the 1986–1987 plankton data and information reported by Icanberry et al. (1978) for the DCPD area, it was concluded that relocation of the existing shoreline intake structure to a location offshore would reduce entrainment of larval sculpin while increasing entrainment of other species, such as rockfish and northern anchovy (Tenera 1988a).

Density and seasonality of larval fish populations are also reported in the 1996–1999 assessment of fishes collected in entrainment and study grid samples (Section 5.0). Larval fish populations demonstrate wide variability in density affected by episodic oceanographic events such as El Niño.

Table M-2. Percent composition (number of larvae/total larvae in each study area) of selected larval fish at the DCPD intake and two offshore areas from three studies.

Taxon	Icanberry et al. (1978) 1974–1975		Tenera (1988a) 1986–1987		Present Study 1996–1999	
	300 m offshore	1,000 m offshore	Intake Cove	ca. 300m offshore	Entrain- ment	Study Grid
Sculpins	11	5	43	24	9	5
White croaker	29 ¹	14 ¹	8	19	4	4
Rockfish	21	52	5	17	22	22
Northern anchovy	10	8	2	7	4	20

¹ All sciaenids including white croaker reported as *Cynosion* spp. in Icanberry et al. (1978).

Fish composition analysis indicates that a diverse assemblage of fish larvae inhabit the waters where an offshore intake could be constructed (**Table M-3**). We analyzed the cumulative density of fishes collected in paired entrainment and study grid surveys. The cumulative density of each species collected was quantified as a percentage of the entire density of fishes collected and summarized by family. For this two year comparison, the paired intake–grid samples for Analysis Period 3 were collected between July 1, 1997 and June 30, 1998, and Analysis Period 4 samples were collected from July 1, 1998 to June 30, 1999. To illustrate fishes at risk at a hypothetical offshore intake, we combined data collected in study grid cells D2–5 and E2–5. For details about sample collection see **Section 4.0** of this report.

Fishes collected in both entrainment and study grid surveys represent diverse group of species that inhabit shallow and deeper habitats near DCPD (**Section 5.0**). Many fishes that typically inhabit shallow nearshore areas comprised a larger portion of the species collected in entrainment samples. At the same time, a high diversity of larval fishes were collected in the study grid in areas where an offshore intake could be constructed (**Appendix H, Table H-2**). A change in location of the intake would essentially become a trade-off in taxa at risk. The differences in mean percent composition (**Table M-3**) indicate that bathymastrids (ronquil), blenioids (blenny), clupeids (herring and sardine), engraulids (anchovy), myctophids (lanternfish), scorpaenids (rockfish), and many others would become susceptible to entrainment at an offshore location compared to the clinid (kelpfish), cottids (sculpin), gobiids (goby), stichaeids (prickleback), and others now entrained from the shoreline intake location.

Table M-3. Larval fish densities expressed as cumulative percent composition collected at the current DCPD shoreline intake structure (entrainment) and in the area of a hypothesized offshore intake (Study Grid cells D2–5 and E2–5) during Analysis Periods 3 and 4. Positive differences indicate a greater mean percentage entrained while negative differences indicate a greater mean percent collected in study grid cells.

Families of fishes collected	Analysis Period 3		Analysis Period 4		Mean Percent Composition		
	Entrainment	Study Grid	Entrainment	Study Grid	Entrainment	Study Grid	Difference
Agonidae	0.00	0.00	0.29	0.15	0.14	0.07	0.07
Atheriniidae	0.06	0.08	0.00	0.04	0.03	0.06	-0.03
Bathylagidae	0.37	0.77	0.03	0.11	0.20	0.44	-0.24
Bathymasteridae	2.94	6.64	2.23	5.81	2.58	6.22	-3.64
Blenniidae	0.53	1.68	1.10	5.66	0.81	3.67	-2.86
Clinidae	9.71	0.41	7.59	2.07	8.65	1.24	7.41
Clupeidae	2.74	14.56	0.01	0.06	1.38	7.31	-5.94
Cottidae	20.36	9.98	21.77	8.20	21.07	9.09	11.98
Engraulidae	1.99	24.04	0.34	4.29	1.17	14.16	-12.99
Gobiesocidae	0.68	0.00	0.39	0.00	0.53	0.00	0.53
Gobiidae	20.02	3.47	11.63	5.98	15.83	4.73	11.10
Hexagrammidae	1.07	1.48	1.72	3.69	1.40	2.58	-1.19
Labridae	0.00	0.04	0.03	0.21	0.02	0.13	-0.11
Liparididae	0.43	1.35	1.19	1.62	0.81	1.48	-0.67
Myctophidae	2.28	4.60	4.52	12.44	3.40	8.52	-5.12
Paralichthyidae	0.42	1.93	1.05	1.12	0.73	1.53	-0.79
Pleuronectidae	0.51	2.27	0.54	1.66	0.53	1.96	-1.43
Sciaenidae	1.25	2.70	2.02	2.23	1.63	2.46	-0.83
Scorpaenidae	17.62	19.89	28.94	39.65	23.28	29.77	-6.49
Stichaeidae	13.74	2.45	11.97	3.03	12.86	2.74	10.11
Other ¹	3.27	1.67	2.63	1.98	2.95	1.83	1.12
Total	100.00	100.00	100.00	100.00	100.00	100.00	

¹Other includes rare and infrequently collected taxa; refer to **Appendix H** for more detail.

Constructing a new cooling water intake and conduit 610–915 m (2,000–3,000 ft) offshore DCPD would provide a large surface area for the colonization of marine organisms that grow rapidly and become effective predators on entrained larval fish and invertebrates. Control of these communities to minimize their impact on power plant operation would pose additional ecological consequences to the local marine environment. The large surface area would require an increase in either treatment chemicals or the use of heat treatments to keep biofouling communities low. Biofouling inhibiting coatings would not be practical because they could not be maintained over the life of the submerged structure.

Lowering the number of impinged organisms requires that the effectiveness of a submerged offshore intake be located in an area where such impingeable organisms are less abundant (Tenera 1988a). Many of the dominant groups of fish and invertebrates (e.g., flounder and sole, rockfish, white croaker, surfperch, crabs, shrimp) are typically associated with the offshore bottom habitat in the vicinity of the DCPD site. Many of the typically pelagic fish species, such as northern anchovy, are commonly found in large schools that move through the water column, often concentrating near the bottom during the daytime (Love 1996). Submerged offshore intakes generally have higher approach velocities than onshore systems and use long conduits within which fish can become entrapped, resulting in an increase in the number of organisms impinged (PG&E 1988a, Appendix D). Velocity caps (described in PG&E 1988a, Appendix D) used in conjunction with offshore intakes are effective in reducing entrapment and subsequent impingement of schooling fishes. It is likely, however, that the physical presence and nature of an intake in the coastal waters offshore of the DCPD site would attract fish and invertebrates, offsetting the effect of the velocity cap. Louvers can be added within the intake to direct a percentage of the entrapped fishes away from the traveling screens. Experience at San Onofre (EPRI 1994) shows, however, that the number of fishes attracted to and entrapped in an offshore intake and those redirected inside the intake will probably exceed the low numbers currently impinged (**Section L.2**).

An offshore intake structure and cooling water conduit would provide habitat similar to an artificial reef. Detailed surveys and observations of the colonization of reef structures formed from the DCPD breakwater that was partially destroyed by storm activity (Wilson et al. 1988) provide regional confirmation of the attraction of juvenile rockfish to reef habitat. The attraction of juvenile fish, including species such as rockfish, cabezon, and surfperch, to an offshore intake structure would increase their susceptibility to impingement. Thus, use of a submerged offshore intake system is expected to result in higher rates of impingement than those observed at the existing intake.

In summary, relocating the intake offshore would not reduce the susceptibility of planktonic organisms to entrainment, but would probably change the entrainment species composition. The offshore intake would also contribute to the entrapment of fish and invertebrates, many of which may be behaviorally attracted to the offshore intake. In the absence of any evidence of a clear

potential for reducing entrainment and impingement losses, an offshore intake location does not meet Criterion 2 for DCP.

M.1.2 Alternate Onshore Location

The general similarity of the rocky coastal habitat along the shoreline adjacent to the DCP site suggests that entrainment and impingement would not be substantially different at other available shoreline locations. The pattern of currents and wave mixing in the area supports the idea that the densities of organisms are similar throughout the local shore zone. The majority of larval fish and invertebrates entrained at the DCP are characterized by planktonic life stages that promote wide geographic dispersal throughout the nearshore coastal waters adjacent to the site. The distribution of many of the juvenile and adult fish and macroinvertebrates impinged at the plant is determined by habitat preferences. The rocky coastal habitat in the Diablo Canyon Intake Cove is not unique; similar rocky intertidal and subtidal habitat exist both to the north and south of the existing intake location. No evidence suggests that relocation of the DCP shoreline intake structure to an alternative site would contribute to a reduction in either entrainment or impingement losses.

The relocation of the intake structure does not meet Criterion 2 for DCP.

M.1.3 Recessed Intake

The recessed intake consists of an intake conduit or channel leading from the point of water withdrawal to intake screens located inland. Approach channel intake configurations are used to provide a protected area for intake screens, to separate intake and discharge locations to minimize thermal recirculation, or to meet other engineering concerns (EPRI 1999). Fish can become trapped within the confined intake conduit, where velocities are generally high, and may become stressed or fatigued and eventually impinged. The numbers of larval fish and invertebrates entrained are independent of intake configuration because these organisms are carried in the water flow.

The Moss Landing Power Plant impingement monitoring program provided a direct comparison between impingement with the recessed intake screens of Units 1-5 and the shoreline intake screens of Units 6 and 7. Impingement rates for fish (all species combined) were approximately

1.6 times greater at the Units 1-5 recessed intake screens than at the Units 6 and 7 shoreline intake screens (PG&E 1983; Tenera 1998a).

Underwater observations of juvenile fish at the DCPD shoreline intake structure (PG&E 1988a, Chapter 4) confirmed that fish were able to avoid entrapment within the intake structure and readily pass into and out of the intake through the bar racks and laterally across the intake structure. Observations at power plants with recessed intake structures indicate that fish entrapment and subsequent impingement is greater, in part because of higher velocities and longer forebays, than at shoreline intake structures with design characteristics similar to those at the existing DCPD intake. Therefore, a recessed intake screen configuration is not an effective alternative to the existing shoreline intake configuration of the DCPD intake structure for reducing either entrainment or impingement.

M.2 Behavioral Barriers

A considerable amount of research and experimentation has recently been directed at evaluating and improving the effectiveness of behavioral barriers such as light, sound, and air bubbles (EPRI 1986, 1994, 1998). Effectiveness of light, sound, and air bubbles varied substantially between sites and between species. Results of this research effort failed to demonstrate that behavioral barriers, used singly and in combination, are effective in consistently reducing fish impingement at power plant cooling water intakes and other water diversions. Furthermore, effectiveness of behavioral barriers generally declined over time as organisms became accustomed to the stimuli.

Investigations in the use of underwater sound to repel fish includes low-frequency, mechanical sound generators (e.g., poppers and hammers) and acoustic transducer systems that cover a wide range of frequencies. The effectiveness of transducer-based sound systems causing fish to avoid intakes has been variable. Lower frequency (100 Hz to 20kHz) systems have achieved limited success in field trials with riverine fishes. High-frequency systems have been effective in eliciting avoidance of herring species on the east coast (EPRI 1999).

Bubble curtains have been ineffective at cooling water intake systems. This technology appears limited as no trials have shown that bubble curtains can effectively and consistently repel any species from entering intake structures (EPRI 1999).

In conclusion, Behavioral barriers are not considered an effective alternative for reducing entrainment or impingement losses at DCPD.

M.3 Physical Barriers

M.3.1 Drum Screens

Drum screens are mounted on a cylindrical frame rotating, partially submerged, in the water stream. Typically, water is drawn into the center of the screens and flows radially outward. Debris is removed from the inside surface of the screen by high pressure spray wash as the drum rotates up and out of the fluid stream. Drum screens do not reduce the numbers of organisms entrained or impinged when compared to vertical screens. There is no information available to suggest that survival of organisms impinged on drum screens would be significantly different from impingement survival on conventional vertical traveling screens. In the absence of any predicted biological advantages, drum screens do not meet Criterion 2.

M.3.2 Center flow Traveling Screens

The centerflow traveling screen represents a relatively new intake screen technology in the United States although it has been used extensively in European industrial and electricity generating facilities. Centerflow screens are oriented parallel to the approaching water flow, and water enters through the center of the screen and exits through both vertical faces (PG&E 1988a, Appendix D). As with vertical traveling screens, the screen panels are attached to a continuous drive chain but, unlike vertical traveling screens, each screen panel forms a concave basket that increases the available screening surface area. Screen mesh sizes range from 0.5–9.5 mm (0.02 to 0.4 in), with many sites using 1.0–2.5mm (0.04 to 0.1in) mesh (fine mesh screening is discussed in **Section 6.2.2.3**). As a result of potentially rapid debris accumulation on the small mesh commonly used in centerflow, screens they are designed for continuous screen rotation.

The hydraulic flow patterns associated with centerflow screens are more complex than those associated with vertical traveling screens. Water flows into the screen chamber through an opening in the front wall of the screen structure and turns 90° to complete its transit to the circulating water pump. Effective screening occurs on both the ascending and descending sides of centerflow screens, increasing the available screen surface area. As a result, the average

through-screen velocity of the centerflow screen is less than the approach velocity to the screen. However, through-screen velocities are highly variable because of flow patterns and screen orientation, as the flow has to rotate 90 degrees downstream of the chamber entrance. For retrofit applications, the screen entrance is smaller in area than typical through flow screens, so the entrance velocities are higher. Center flow traveling screens do not offer any major biological advantages over conventional or modified vertical traveling screens (Cada et al. 1979). The numbers of organisms impinged on centerflow screens would not be reduced, and significantly increased impingement survival has not been satisfactorily demonstrated for these systems.

The turbulence of the flow may negate the potential biological benefits of reduced average through-screen velocities. Irregular velocity patterns, turbulence, and attendant head losses are inherent in the water flow patterns of centerflow screens. The highest water velocities occur in the entrance area, and this could contribute to fish entrapment. Within the screen chamber, velocity varies irregularly as the water changes direction, resulting in non-uniform flow through the screening surface.

Several alternative design configurations for the centerflow screen concept have been proposed to minimize the probability of organisms becoming entrapped within the screen structure (PG&E 1988a, Appendix D). In addition to the single-entrance/dual-exit design, there is a double-entrance/single-exit design in which water enters the screen from two sides and passes out through one end. This design can be either located within a screenwell or supported from a platform with no confining concrete housing. A double-entrance/double-exit screen design has also been proposed.

A review of screen system alternatives to manage debris loading at the DCP intake has been performed (PG&E 1996). This study determined that the centerflow screens would be a viable option to enhance screening capabilities for debris removal, but it was not recommended due to the cost of the retrofit. The main advantages of the through flow screen would be an increase in screen area that would allow a decrease in screen mesh size. The impact of using this type of screen on impingement has not been evaluated, but based on the semicircular screen basket design and the non-uniform flow described above some increase in impingement of fish and invertebrates is assumed.

In summary, centerflow screens have not been proven to reduce impingement and may have the potential to increase impingement.

M.4 Maintenance and Operational Modifications

Maintenance and operational modifications are alternatives that can be implemented with existing plant equipment that reduce entrainment or impingement.

Maintenance Dredging

Sediment accumulation in front of or within a cooling water intake structure may reduce the open area of the intake, resulting in increased water velocities. Increased velocities approaching the intake structure will, in many cases, result in increased rates of impingement. Depth measurements made in the DCPD intake structure (Wyman 1988) indicated that sediment had not accumulated to a level that would reduce the available cross-sectional area of the intake. Since then, weekly observations of intake bar racks by divers (J. Kelly PG&E pers. comm.) and within the intake by commercial divers during outages have not indicated any reduction in intake area by silting.

Some fine sediment does accumulate in low flow areas within the ASW forebays, between the traveling screens and ASW pumps. Flow rates through the 1.5 x 9 m opening to the ASW pumps are slow, approximately 0.05 m/sec (0.15 fps). The rates of sedimentation are low. Prior to each refueling outage commercial divers remove approximately 50 cm of sediment from the floors of the ASW forebays. In addition, the small amount of sediment and shell debris that collect in the six CWP intake forebays is also removed during each outage.

No evidence suggests that dredging of the sea floor outside of the intake will ever be needed to maintain the existing velocity profile. Sediment accumulation within the intake structure is controlled by current practice and does not contribute to increased impingement losses. Sediment is removed for operability (reduction of potential condenser plugging by debris) and safety (personnel inspecting confined spaces) concerns. There is no biological benefit to dredging at DCPD.

Appendix N

Technologies and methods currently available and proven effective at facilities of the same size as DCPP but determined to not be effective at DCPP.

APPENDIX N

The following technologies and methods are currently available and proven effective at facilities of the same scale as DCP. These technologies and methods will not be effective at the DCP plant site for the reasons cited below.

N.1 Closed-Cycle Cooling Pond or Canal

The use of a closed cycle cooling pond or canal was evaluated for DCP (TERA 1982). The use of a closed-cycle cooling system at DCP would reduce both impingement and entrainment of organisms by reducing the saltwater flow through the intake structure. Saltwater would only be required as makeup to the closed-cycle system due to evaporative loss. Based on a required pond size of approximately 890–4,452 ha (2,000–11,000 ac) it was determined that there was insufficient land suitable for construction of a pond or canal system at DCP. The use of cooling canals or ponds is not considered feasible at DCP.

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