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M E C BIOLOGICAL PROJECT
SAN ONOFRE NUCLEAR GENERATING STATION
MONITORING STUDIES ON ICHTHYOPLANKTON AND ZOOPLANKTON
FINAL REPORT

Prepared by Arthur M. Barnett, Principal Investigator

Contributing Staff:

William Watson
Linda G. Gleye
Susan D. Watts
Karen D. Green
Thomas D. Johnson
Douglas N. Beanan

Consultant:

Janice D. Callahan

MARINE ECOLOGICAL CONSULTANTS OF SOUTHERN CALIFORNIA
531 Encinitas Boulevard Suite 110
Encinitas, California 92024

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EXECUTIVE SUMMARY

Marine Ecological Consultants (MEC) has conducted monitoring studies of the plankton community in the vicinity of the San Onofre Nuclear Generating Station (SONGS) on behalf of the Marine Review Committee (MRC) since 1976. The major thrust of these studies since 1979 has been to predict, and subsequently to measure, the effects of SONGS Units 2 and 3 on the plankton (studies prior to 1979 were largely directed toward measuring the effects of Unit 1). This report is MEC's Final Report to the Marine Review Committee describing the results of our Units 2 and 3 monitoring studies of ichthyoplankton, macrozooplankton, and phytoplankton.

SONGS Units 2 and 3 began commercial operations in 1983 and 1984, respectively. Units 2 and 3 account for 85 percent of the 7800 m^3/min of cooling water used by the three SONGS units. Long diffusers discharge the cooling water 1 to 2.5 km offshore, where it is diluted six- to tenfold by entrained ambient water. One of the concerns originally raised during the planning stages of Units 2 and 3 was that the use of so much cooling water (the amount withdrawn every day corresponds to the volume under one square kilometer in the vicinity of the intakes) could lead to large-scale reductions in the plankton, since cooling water withdrawal and discharge subjects plankton to death in the intake system, to entrainment and offshore translocation in the discharge plume, and to habitat alterations (which can be favorable--e.g., increased food or the creation of favorable physical conditions, or unfavorable--e.g., increased turbidity, altered physical conditions). This report addresses the original concern, and also considers the potential direct and indirect effects of SONGS operation. The report consists of five major text sections and a separate volume of supporting appendices.

MEC's study was designed to meet the objectives of the MRC's monitoring program. As part of the permitting process for SONGS, the MRC was charged with monitoring the effects of Units 2 and 3. This monitoring was to provide information that would enable the California Coastal Commission to evaluate the impacts of SONGS Units 2 and 3 operations. The goals of the MRC Units 2 and 3 monitoring studies were: 1) to predict the effects of Units 2 and 3 operations on the marine biota; 2) to measure the magnitude and extent of any such changes; and 3) to determine whether the operation of Units 2 and 3 caused those changes. The MRC defined a significant change as a 50 percent increase or reduction in abundance from what would be expected in the absence of SONGS. The sampling programs were designed to detect such a change if it occurred over an area of several square kilometers.

The planktonic communities near SONGS that the MRC monitored in order to meet these goals were the ichthyoplankton, the macrozooplankton, and the phytoplankton. MEC's monitoring studies sought to determine whether the operation of SONGS had caused a marked reduction in the abundance of ichthyoplankton, or marked changes in the abundances of macrozooplankton and phytoplankton, and whether SONGS operations caused changes in the distributions of the ichthyoplankton and macrozooplankton.

Ichthyoplankton was sampled at two locations: an Impact site about 1-3 km south of SONGS (to permit the detection of large-scale changes) and a Control area about 18 km south (to correspond with the MRC adult fish studies). Samples were collected with towed nets from the neuston, midwater, and epibenthos in four onshore/offshore blocks between the 6 and 45 m isobaths at each site (which permitted descriptions of changes in distribution) on 38 preoperational (1979 through 1981) and 27 operational (1984 through 1986) period surveys.

The macrozooplankton and phytoplankton were sampled at three onshore/offshore locations (the 8, 13, and 30 m isobaths) along an Impact transect off Unit 1, and along a Control transect about 12 km south. Pumped samples were collected from the surface, from one or two midwater strata, depending on water depth, and from the epibenthos at each location. This arrangement permitted descriptions of changes in spatial distributions. Thirty-two preoperational (1976 through 1981) and 23 operational (1983 through 1986) period surveys were taken.

The data were analyzed to detect changes in abundance (using the BACI--Before/After, Control/Impact--approach), and changes in spatial distribution (using MANOVA/ANOVA/Bonferroni pattern analyses). The BACI approach is described in detail in Section 3.7.1. The BACI approach tests whether the difference between abundances at the Impact and Control sites in the Before (preoperational) period was different, on average, from the difference between Impact and Control abundances in the After (operational) period. The primary test is a two-sample t-test of means. When the nature of the data did not permit the use of a t-test, the t-test was replaced by the Wilcoxon rank sum test, the autoregressive errors t-test, the binomial test, and regressions of SONGS versus Control data. These secondary tests were also used to provide insight into the data. Additional secondary tests consisted of BACI tests performed on two subsets of the After data, one containing surveys taken when the Impact site was influenced by the Units 2 and 3 diffuser plume ("Plume" surveys), and the other containing surveys taken when it was not (Non-plume"). These test results were used to aid in the interpretation of the results based on the full After data set.

The MANOVA/ANOVA/Bonferroni pattern analysis on each ichthyoplankton and macrozooplankton taxon compared the cross-shelf pattern of abundance ranks at the Impact site in the After period with a composite pattern of ranks derived from the distributions at SONGS in the Before period and at Control in the Before and After periods. The pattern analysis is described in detail in Section 3.7.2.

Statistically-significant large-scale general reductions in plankton abundance near SONGS were not detected. However, statistically significant reductions in the relative abundances of total larvae (i.e., the sum of the developmental stages) were detected in the full operational data set for five of the 19 ichthyoplankton taxa tested (of the approximately 150 types identified during the SONGS studies). In addition, one or more developmental stages of six taxa (including four of the above five) declined significantly in relative abundance. In all, therefore, seven taxa (the gobies _Clevelandia ios_, _Quietula y-cauda_, and _Ilypnus gilberti_, the queenfish _Seriphus politus_, the kelp and seabasses _Paralabrax_ spp., the jacksmelt _Atherinopsis californiensis_, and the northern anchovy _Engraulis mordax_) exhibited relative decreases in abundance, either of total larvae, or of various developmental stages, or both. One taxon, the California grunion, would have been shown to increase significantly had we done two-tailed tests rather than the lower-tail tests that were used. This means that for one of the 19 ichthyoplankton taxa analyzed, our _a priori_ alternative hypothesis--that abundance could only decrease--was wrong. Two of the relative decreases in total larvae -- those for the shadow goby and cheekspot goby -- were due to smaller increases in abundance at SONGS than at Control. The relative decrease in jacksmelt larvae was due to a greater decrease at SONGS than at Control, and the relative decreases in the abundances of the arrow goby and the northern anchovy were due to decreased abundances at SONGS and increased abundances at Control.

A significant relative increase was detected in the full operational data set for one (barnacle larvae) of the sixteen macrozooplankton taxa tested (of the twenty taxa and categories counted during the SONGS studies); there were no significant relative decreases in the full data set for the macrozooplankton. Two additional taxa (Evadne nordmanni and cyphonautes larvae) increased in relative abundance on plume dates. The phytoplankton standing crop, measured as chlorophyll-a concentration, showed no significant relative change.

None of the significant relative changes detected for the ichthyoplankton and macrozooplankton could be ascribed solely to the operation of SONGS Units 2 and 3. This was because except for the nearshore gobies, estimated losses due to intake withdrawal--the only SONGS mechanism known to operate--were too small to have accounted for the significant relative reductions detected, and could not have produced increases. Although estimated losses could have caused the changes in the abundance of gobies, alternative mechanism could be postulated. SONGS operations may, however, have contributed to the significant relative reductions that were detected among the ichthyoplankton, and to the three relative increases detected among the zooplankton taxa. SONGS mechanisms that were postulated as contributors to the ichthyoplankton decreases included intake withdrawal, secondary entrainment in the diffuser plume, and losses to predators attracted to the vicinity of the plume. We were unable to postulate the mechanism(s) that might have produced the relative increases among the macrozooplankton.

The pattern analysis detected statistically significant, but relatively minor, shifts in the distribution of total larvae of three ichthyoplankton taxa, and of one of the three life stages of an additional five taxa. The shifts were variable and generally occurred in areas of low larval abundance. These were not considered SONGS effects.

Total macrozooplankton and four macrozooplankton taxa (cyphonautes larvae and the copepods Acartia tonsa, Corycaeus anglicus, and Oithona plumifera) also displayed statistically significant shifts in distribution. These formed a relatively coherent pattern which was considered evidence of a SONGS effect, and from which a conceptual model of SONGS-induced circulation was derived. The major elements of this model are a shoreward flow of make-up water required to replace the water withdrawn at the intakes and entrained by the seaward-directed discharge plume. The shoreward motion of the make-up flow and the seaward motion of the plume are maintained whenever Units 2 and 3 operate. The model was derived from two principal elements of the macrozooplankton pattern analysis results. The first included the relative decreases in the mean ranks of abundance seaward of the Units 2 and 3 offshore cooling structures, which were interpreted as reflecting shoreward motion of the make-up water containing lower concentrations of the coastal macrozooplankton species, and relative increases in mean ranks of abundance in midwater and relative decreases in the epibenthos of the depth zone encompassing the Units 2 and 3 intakes and diffusers, interpreted as reflecting the combined effects of secondary entrainment and shoreward make-up flow. Since these various pattern shifts were redistributions within strata normally occupied by the taxa involved, and since they were unaccompanied by substantial relative decreases in abundance, they were considered only minor SONGS effects.

BACI tests of chlorophyll data from all stations and from a station that was expected to experience the maximum influence of SONGS operations yielded no statistically significant indications of an effect of SONGS operation.

The fate of planktonic organisms withdrawn at the Units 2 and 3 intakes is addressed in Section 5. Measured through-plant losses were

85-100% when the intake conduit fouling community was well established, and lower, but still substantial, when the fouling community was reduced following heat treatment. There was no significant through-plant gain or loss of dissolved, particulate, or total organic carbon. A relatively large (150%) and significant through-plant increase of inorganic seston occurred which was only partially attributable to inputs from the biofouling community.

Estimates of the average annual losses of ichthyoplankton and macrozooplankton to Units 2 and 3 withdrawal are also presented in Section 5 and are compared with the original MRC projections of losses. Loss estimates are presented for average 1981-1986 withdrawal volumes, for withdrawal at 75% of capacity (closely approximating the actual level of operation during the 1983-1986 operational monitoring period), and for continuous full-power operation (100%). Operation at the 75% level was considered the most realistic estimate of future Units 2 and 3 operations and was used in the comparisons. The final estimated losses of species of sport and commercial fishery value tended to be higher than the original projections. Estimated losses of fodder fish, in contrast, tended to be much lower than the original projections. This reflected the lower abundances of sport and commercial species, and higher abundance of fodder species, in 1978--the basis for the original projections--than were found in most later years. Estimated losses of total macrozooplankton were nearly one and one-half to two times higher than the originally-projected losses, whereas estimated losses for individual taxa ranged from as low as about one-half to as high as about three and one-half times the earlier projections. Macrozooplankton losses were estimated to be equivalent to natural mortality under a nearshore area of ocean of about 4.8 km^2.

In summary, no large-scale reductions in the abundance
in the SONGS area were detected. However, statistically si
smaller-scale changes in relative abundance and cross-shelf pat
both ichthyoplankton and macrozooplankton were detected,
demonstrating that the program design was sufficiently robus
identify large-scale changes had they occurred. Of those that
found, the changes in the relative abundances of 7 ichthyoplankton an
macrozooplankton taxa, and changes in the patterns of distribution o
four macrozooplankton taxa and the category total macrozooplankton
could be plausibly linked with operations of the SONGS Units 2 and 3
cooling systems as a contributing factor. It was shown that intake
withdrawal and secondary entrainment in the discharge plume were
unlikely to have fully accounted for the significant changes in cross-shelf abundance that were detected; other mechanisms must have
contributed as well. MEC concluded that the effects detected were of
relatively minor importance during the 1983-1986 operational
monitoring period for the following reasons: (1) no general large-scale reduction of plankton abundance was detected; (2) although there
were suggestions of relatively uniform patterns of change within some
subsets of the ichthyoplankton and macrozooplankton, there was no
evidence of an overall uniform pattern of change in the plankton
community; (3) in many cases where significant changes were detected,
plausible alternative explanations for those changes could be
postulated; and (4) for the ichthyoplankton, significant test re
ended to reflect changes in the more numerous younger la
s important than the older larvae in terms of a
Synopses of biological information
ssing protocols, details
ations of our re

1.0 INTRODUCTION

1.1 Overview

The San Onofre Nuclear Generating Station, located on the coast of southern California (Figure 1-1), consists of three units, each powered by a pressurized water reactor. Unit 1, rated at 456 megawatts, began operation in 1968. Units 2 and 3, each rated at 1180 megawatts, began operation in 1983 and 1984, respectively.

All three units use seawater for once-through condenser cooling. The cooling water intakes are located approximately 0.9 km offshore, in about 9 m of water (Figure 1-2). The maximum cooling water flow of the three units is 7,800 m^3/min (11.2 million m^3, or 3 billion gallons, per day). Note that this volume of water roughly corresponds to the volume contained under 1 km^2 of a water column 9 m deep (9 million m^3). Cooling water passes through the Unit 1 system approximately 15 minutes, and takes 25 to 30 minutes to pass through Units 2 and 3. The cooling water for Unit 1 is discharged at approximately 2 m/sec from a single large port located in 8 m of water approximately 0.8 km from shore. Units 2 and 3, however, use long, multiple-port diffuser pipes; water is discharged at approximately 4 m/sec. The Unit 2 diffuser discharges in 12 to 15 m of water 1.8 to 2.6 km offshore, and Unit 3 discharges in 10 to 12 m of water 1.1 to 1.9 km offshore. Figure 1-3 shows the history of Units 2 and 3 cooling water flow through 1986. The cooling water is raised approximately 12°C above ambient during normal operations. The discharged water is diluted approximately six to ten-fold with ambient water that is entrained in the discharge jets. The volume entrained per day roughly corresponds to the water under 9 km^2 (i.e., a square 3 km on each side) of a water column 10 m deep.

Power plants that use once-through condenser cooling can affect the aquatic biota in ways that can be detrimental and beneficial. The withdrawal of planktonic organisms and the larvae of fish and benthic species in the cooling water results in the death of a large proportion of those organisms (Barnett et al., 1982, for Unit 2 and 3 losses and a review of Unit 1), thus removing them from the system and reducing their populations. Their carcasses, and the carcasses of invertebrates that live in the intake conduits and feed upon the material in the withdrawn water, are discharged into the environment, and may serve as an additional food source for the surrounding animals. Discharged material and animals entrained from the nearshore zone may be transported to the faster longshore currents farther offshore, and thus be lost to the inner nearshore zone. Sediments may be altered as a result of the transport of water high in suspended matter from inshore to farther offshore by the discharge currents. Predator/prey interactions may be altered as a result of changes in the abundances of predators or their prey. Discharges of the biocides, metals, and radionuclides that are present in low concentrations in the effluent may contribute to any net reductions in abundance; however, evaluations of such potential contributions are outside this scope of the SONGS study.

One of the original concerns that was raised when Units 2 and 3 were being planned was that the use of so much cooling water--the amount under one square kilometer every day--and the entrainment in the discharge of water representing an average of about eight times that volume could have cumulative effects that would lead to large-scale reductions in the aquatic biota, possibly extending several kilometers from SONGS. An alternative view was that the longshore currents, eddy diffusivity, and cross-shelf circulation would be sufficiently strong to rapidly dilute the effects of SONGS to below detectable levels.

In 1974, as part of the permitting process for the San Onofre Nuclear Generating Station Units 2 and 3, the California Coastal Zone Conservation Commission (now the California Coastal Commission) issued Permit No. 183-73. The permit formed the Marine Review Committee (MRC), an independent committee whose members were drawn from academia, environmental groups, and Southern California Edison (SCE). One of the charges to the MRC was to monitor the effects of Units 2 and 3, placing emphasis "... on the plankton and larval forms that are the basis of the ocean's food chain and thus of the ocean's sport and commercial fisheries ...". The purpose of the MRC study was to obtain information that the Commission could use to decide whether or not changes in the cooling system should be required in order to prevent or reduce any adverse effects of Units 2 and 3.

The goals of the MRC studies were to detect significant changes in the marine biota, to determine the magnitude and extent of those changes, and to determine whether the operation of SONGS Units 2 and 3 caused the changes. In designing the program, the MRC (1983) defined a significant change to be a 50% reduction or increase between observed abundances and the abundances that would have been observed had SONGS not been operational. The sampling program was designed in a way that would permit the detection of such a change if it occurred over an area of several square kilometers, representing a very large zone in which biological communities are severely affected. To achieve that goal the MRC had to decide how to study the complex marine environment in a manageable but meaningful way.

Two fundamentally different approaches to impact monitoring have been considered by the MRC. The first is a sequential approach. The available effort is first devoted to determining whether there are detectable and significant net changes among the populations in the receiving water species assemblages, and whether those changes can be attributed to the effects of the potential disturbance being studied. If a net effect can not be determined, then future monitoring may be curtailed or eliminated. If a net effect can be detected, then, depending upon how important the effect is judged to be, appropriate isolating studies can be conducted to determine the specific source(s) of the observed change and the mechanism(s) by which the change is effected. Note that it is possible that the sum of the positive effects and the negative effects can result in a zero net sum. Thus, a drawback to this approach is that there could be effects, but they might not be identified or measured.

The second approach is to design each of the monitoring elements, possibly in conjunction with controlled laboratory and field experiments, in such a way as to make that element relate specifically to a particular source of, and/or mechanism for, potential effects. Negative results allow one to remove that source or mechanism from continued scrutiny. Positive results permit a more rapid determination of effects and potential mitigations. This approach is costly at a facility such as SONGS, at which a variety of mechanisms can cause changes in many different marine populations. Furthermore, it may or may not be possible to integrate the results of the various elements arithmetically, since some effects may interact synergistically to cause an impact far different from their arithmetic sum. These could include opposing effects that cancel each other. For these reasons, isolating specific hypothesized mechanisms, even with the support of laboratory experiments, is difficult, and in some cases may be impossible.

In general, the MRC has taken the first approach in designing and implementing its studies. The resultant monitoring program, called BACI (an acronym for Before/After, Control/Impact), has been the MRC's primary tool for investigating SONGS net effects. The second approach, i.e., the study of mechanisms, was the primary approach to the study of the kelp , and was also used to investigate differences revealed by the BACI approach. Other methods of analysis have been used to evaluate SONGS' local effects. For example, biological features at stations along a gradient stretching outward from SONGS have been examined, various measures of changes in community structure and dominance relationships among the species assemblages being studied have been applied, and the spatial and temporal patterns of physical and chemical variables have been monitored over the course of the biological studies.

The MRC studied the biological community in each of the major marine habitats in the vicinity of SONGS, including the planktonic habitat. Plankton has been categorized on a number of criteria, including taxonomy and life history. The broad taxonomic groups are the bacterioplankton (the bacteria), phytoplankton (the plants), and zooplankton (the animals). The life history categories include the holoplankton (those organisms that spend all of their lives as plankton) and the meroplankton (immature planktonic stages of organisms with non-planktonic adults, such as barnacle nauplii and kelp spores). The meroplanktonic stage typically lasts on the order of days to weeks before the organism settles from the water column to the benthos or increases in mobility to become a member of the nekton.

Two of the communities selected by the MRC for detailed study in the planktonic habitat were the zooplankton and the ichthyoplankton. The zooplankton is composed of small animals suspended in the water, whose distribution is largely determined by the movement of the water. The nearshore marine zooplankton is dominated by crustaceans, especially copepods, cladocerans, and the larval stages of barnacles. The majority of these animals are herbivores, feeding on the minute algae that comprise the phytoplankton, and are, in turn, fed upon by larval and adult fish and other planktivores, such as benthic suspension feeders. The zooplankton is, therefore, an important link between primary producers and higher trophic levels. The zooplankton is abundant in the study area year-round, and is apparently fairly stable in time and space (Barnett and Jahn, 1987), which suggests that the assemblages should reflect any added stresses imposed by SONGS. The ichthyoplankton consists of eggs and larvae of fish, specifically free-floating eggs and larvae collected in plankton nets. Planktonic early developmental stages are characteristic of most marine fish species.

Prominent members of the nearshore ichthyoplankton include gobies, clinids, and atherinids, as well as older larvae of the California halibut, white croaker, and northern anchovy. Thus the inner nearshore area is an important nursery area for local fish, and factors that affect the survival of these larvae can have repercussions on recruitment to the population of adults. More detailed descriptions of the plankton and ichthyoplankton, and of the environmental setting of the study area, are presented in Section 2 and Appendix A.1.

SONGS was thought to be likely to affect the abundances of zooplankton and ichthyoplankton near the plant by killing individuals withdrawn in the cooling water, which would result in a decrease in abundance in the discharged waters; by seaward transport by the diffuser plumes, with possible attendant mortality from predation; and by "dilution" by the replacement water, which could contain fewer individuals of the more nearshore species. In addition, the standing crop of phytoplankton (expressed as chlorophyll-a) could increase in the vicinity of SONGS in response to plume-induced upwelling.

1.2 The Issues Addressed by Marine Ecological Consultants Studies

Marine Ecological Consultants (MEC) has studied zooplankton in the vicinity of SONGS since 1976, and ichthyoplankton since 1977. The earliest zooplankton samples used in the monitoring studies were collected in 1976; ichthyoplankton monitoring studies began in 1979. The fundamental questions that MEC's monitoring study design asked were:

1) whether power plant operations had caused marked changes in the abundance of fish larvae, zooplankton, and chlorophyll;
2) whether power plant operations had caused marked changes in the spatial distribution of fish larvae and zooplankters; and
3) how many ichthyoplankton and macrozooplankton organisms are lost as a result of withdrawal and entrainment.

All of the analyses of zooplankton and ichthyoplankton addressed individual taxa, rather than groups of species or measures of community structure. Individual taxa were studied for three reasons. First, direct effects of the plant, namely removal of individuals, can be detected as changes in the abundance of a species if those effects are sufficiently large. Second, alterations to a species' habitat may be revealed as a redistribution of the population of that species. Third, changes in individual species are, ultimately, the driving force behind changes in larger groups of species, such as functional groups and communities.

Groups of species and community structure were not analyzed because, unlike the case in benthic studies, applicable and generally accepted theories and models of the effects of change on plankton assemblages have not been developed. There is no agreement on the implications of species composition and dominance structure in zooplankton assemblages, in particular. As a result, there are no guidelines for establishing measures of the community or for interpreting changes in those measures.

Much of the basic biological work at San Onofre was conducted during the preoperational (prior to 1982) period. It served to establish a baseline description of the local "unperturbed" (by Units 2 and 3, not Unit 1) plankton communities and to yield insight into the relationships between community structure and environmental variables, to the extent that this could be done for a reasonable investment of time and money. These baseline studies were intended to aid in the interpretation of the studies of SONGS effects. More importantly, however, they were to provide data for the Before cells of the BACI matrix. A synopsis of past studies of plankton and ichthyoplankton at SONGS is presented in Section 2.

1.3 Approach

MEC's approach to the questions posed in the study design consisted of collecting samples at locations and times so as to provide cells of the BACI model and spatial coverage of the study area. The results were analyzed using a suite of tests that would detect changes in abundance and distribution, and served as the basis of calculations of intake and entrainment losses.

1.3.1 Synopsis of Sampling Design

The details of, and rationales for, station locations, sampling schemes, and sample analysis procedures are presented in Section 3 and Appendix B. This section presents an outline of the sampling schemes used in the ichthyoplankton, zooplankton and phytoplankton studies.

1.3.1.1 Ichthyoplankton Sampling

Ichthyoplankton were collected along two transects, representing the Control and Impact areas in the BACI model. The Impact, or SONGS, transect was located 1 km downcoast (southeast) of the SONGS intakes, and the Control transect was 18.5 km downcoast of SONGS. Each transect ran offshore from 6 to 45 m depth (a distance of approximately 7 km), and was divided into four contiguous blocks on the basis of depth contours. Three samples--surface, mid-water, and epibenthic--were collected in each block on each date.

Ichthyoplankton were sampled on a total of 70 occasions: 38 times during the preoperational period (July 1979 to November 1981), 5 times during the interim period (March 1982 to June 1983), and 27 times during the operational period (July 1983 to September 1986). An additional six studies of intake losses were conducted triweekly between October 1985 and January 1986. In those studies, samples were collected near the intakes, but not at Control, using the same gear and methods as in the monitoring surveys.

1.3.1.2 Zooplankton and Phytoplankton Sampling

Zooplankton were collected along two transects, corresponding to the Impact and Control cells in the BACI model. The Impact, or SONGS, transect was located off the SONGS intakes, and the Control transect was located approximately 12 km downcoast of SONGS. Three stations, defined by depth, were sampled on each transect. Samples for the analysis of zooplankton and chlorophyll were collected by pumping from three depths at each station. Whole water phytoplankton samples were collected and analyzed during the preoperational period, but not during the operational period, so that no BACI analyses of phytoplankton cell counts are possible.

Zooplankton were sampled 61 times: 32 times in the preoperational period (August 1975 to November 1981), 6 times during the interim period (January 1982 to June 1983), and 23 times during the operational period (August 1983 to September 1986). In addition, six studies of intake losses were conducted at the same time as the ichthyoplankton intake loss studies, using the same gear and techniques as the monitoring surveys.

1.3.2 Analytical Design

1.3.2.1 Changes in Abundance

The difficulties inherent in attempting to determine the differences between potential SONGS effects and natural variation in an open marine system were appreciated at an early stage by the MRC, their consultants, their contractors, and others. Accordingly, in 1979 the BACI analysis scheme was developed by the MRC and its consultants. The BACI analytical procedure is described in detail in Section 3. Briefly, however, samples are collected from Control sites and from potential Impact sites near SONGS many times during both the preoperational (Before) and operational (After) periods. On each occasion the results of the Control are subtracted from the results of the Impact, yielding a set of Before differences and a set of After differences, or "Deltas."

The mean of the differences between the Impact and Control samples in the Before period--the Before Deltas--is then tested against the mean of the After Deltas by a two-sample t-test to determine whether a statistically significant change occurred. A significant change would imply an effect due to SONGS.

As a technique for analyzing monitoring measurements of marine organisms, BACI has some definite advantages. Marine populations integrate effects over time as well as effects arising from different stresses or enhancements. Using the differences between Impact and Control should eliminate, or at least minimize, the effects of natural changes in time. Therefore, BACI analyses should detect net changes in marine populations occurring over large scales.

MEC used the BACI approach as the primary means of analyzing changes in the abundance of both ichthyoplankton and zooplankton taxa. Nineteen ichthyoplankton taxa were analyzed, both individually and by developmental stage. A total of 17 individual taxa (usually species) of 20 plankton were analyzed. The details of which taxa were analyzed, and of the processes by which the number of samples and the level of significance of the BACI tests were chosen, are presented in Section 3.4. In general, the taxa chosen comprised the most abundant species and the ecologically most important taxa representing a variety of feeding types.

The BACI t-tests of changes in abundance were supplemented by the Wilcoxon rank sum test, the binomial test, and regressions of SONGS vs. Control data. These other tests enabled us to examine the data in different ways, thus increasing our insight into the changes that we observed. For example, the Wilcoxon rank sum test compares the sum of the ranks of the Delta values, rather than the actual values, and is therefore less sensitive to outliers. In the regression technique, the regression of the Impact vs. Control data in the Before period can be compared to the same regression for the After period to examine whether the relationship between Impact and Control has changed between the two periods, and to describe the nature of that relationship. These other tests also served as the primary tests when, because the data did not fit the assumptions of the t-tests, we could not use the t-tests.

Further BACI analyses were performed incorporating the presence or absence of water from the discharge plume. The major effect of SONGS on the macrozooplankton and ichthyoplankton was assumed to result from intake and entrainment mortality. If such a mechanism was, in fact, affecting a given species, then water largely derived from the plume could be expected to contain fewer individuals of that species. Once that water was diluted by the ambient receiving water, the reduction in abundance might not be detectable. During the routine monitoring, MEC often sampled on dates when the plume was advected away from the sampling station, or when the hydrodynamic regime resulted in substantial dilution of the plume by the time it reached the sampling station. Analysis of the data set as a whole might not, therefore, detect SONGS-induced changes in abundance if they were not as large as 50% on average. By analyzing "plume" dates separately --i.e., by taking a worse than average case -- MEC hoped to determine whether intake and entrainment mortality did, in fact, affect the species tested by the BACI procedure, but to a lesser degree than 50% on average.

Plume dates were defined as dates on which the waters over the stations along the Impact transect were comprised of a total at least 50% plume water at the time of sampling. The percentage at each station along the transect was estimated using a model developed by ECO-M

(Reitzel et al., 1987). The model used current velocity, pumping volumes, and eddy diffusion recorded during the two days prior to plankton sampling to backtrack the water at the sampling station. The BACI tests were then carried out on both the plume data set and the remaining, non-plume, data set.

This technique results in a trade-off. The number of data points, and thus the degrees of freedom, is reduced, but since the magnitude of change being tested for is, presumably, increased in the plume date subset over what would occur on average, the likelihood of detecting change is also increased. MEC expected to find at least those effects that were detected using the full data set, and possibly further effects not noted in the full data set. Thus, MEC employed the plume/non-plume BACI analysis as an extension of the full BACI analysis, not as a primary test in lieu of the BACI analysis of the full data set. However, if an effect was observed in the plume dates subset of data but not in the full data set, then the results would be interpreted to mean that an effect had occurred, but at a level lower than the average 50% change originally defined as serious.

1.3.2.2 Changes in Distribution

MEC structured the sampling scheme to permit the examination of changes in the spatial (inshore/offshore) distribution of the various taxa over time. We thought that the plant could cause redistributions of organisms without necessarily changing their overall abundance. Conversely, abundance could change everywhere, without showing a spatial change. The pattern analysis allowed MEC to determine in each instance which of the two alternatives was correct, and to localize the changes in distribution. Superficially, one might expect that the application of the BACI model to the pattern analysis would be appropriate, i.e., that MANOVAs should be used to test the four cells of the BACI matrix. In fact, however, such an approach simply tests whether or not a change in distribution has occurred, and does not permit one to locate that change in space. MEC chose, instead, to apply a somewhat different pattern analysis that would permit us to identify the location of any changes.

MEC's pattern analysis employed a series of three tests on ranks of abundances. First, MANOVA (multivariate analysis of variance) was used to determine whether there were differences between a taxon's distribution at SONGS in the After period and its general distribution in the area. Then, ANOVA and the Bonferroni t-test were applied to identify where in the cross-shelf the changes occurred. For each taxon, the ANOVA and Bonferroni t-tests compared the mean ranks along each sampling transect in the SONGS Before plus Control in both periods data set to the same statistic in the After period at SONGS, then identified which changes were significant and which points were statistically indistinguishable from one another.

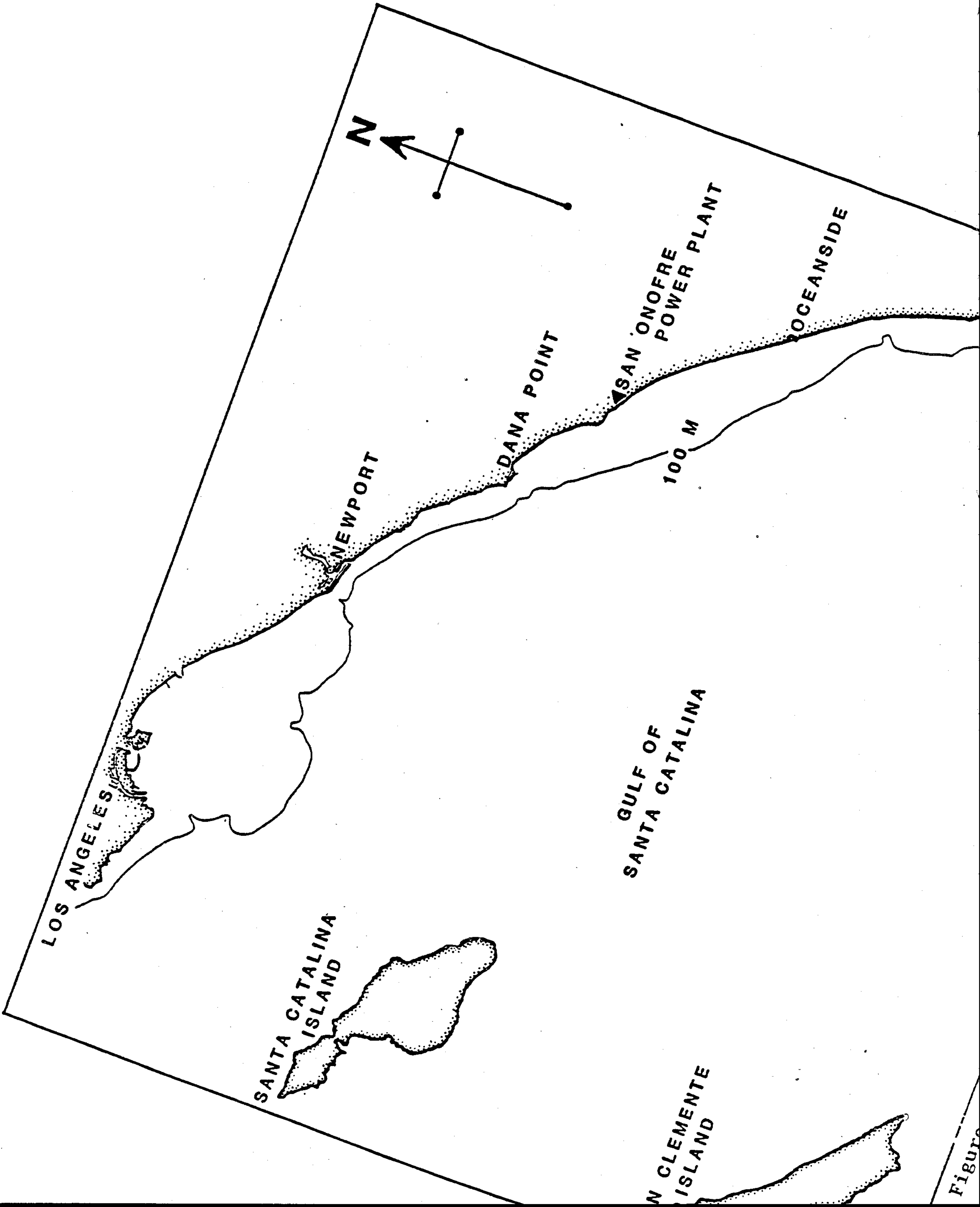
1.3.2.3 Intake Losses

The MRC wished to obtain estimates of losses in order to use them in assessments of the possible impacts of such losses on populations of fish and plankton in the study area. MEC used the abundance estimates produced in the course of the monitoring studies to estimate how many organisms can be expected to be lost by cooling water withdrawal under normal operations of SONGS. These estimates were produced by combining various scenarios of cooling water pumping volumes (actual, 75% operation, and 100% operation) with the abundances of the species being considered. The abundances were adjusted to reflect the various spatial and temporal distributions of the species in relation to the locations of the intakes and diffusers, and were then expressed as long-term averages. The details of which taxa were chosen, and the mathematical treatments of the abundances, are given in Section 5.

Briefly, there were two major problems facing MEC in the calculation of intake losses. The first was the nature of the abundance data. Ideally, one wishes to use abundance data from water going into the intakes. This would yield the most accurate loss estimates. However, abundance estimates were available only from the Impact and Control sites. Using data from one site or the other as an estimate of the number of animals available to be withdrawn would either underestimate the potential impact of SONGS by using data influenced by the discharge plume, or overestimate the potential impact of SONGS by ignoring the effects of recirculation. A reasonable compromise would be to take an average of the two sites, and this was done for most of the monitoring period. However, there was period during the operational phase when data were not available from the Control site, and it was necessary to use only the Impact site data (see Section 5 for further detail).

The second problem was that species and life stages vary in their susceptibility to withdrawal because they have different behaviors and because they occupy different parts of the water column and of the cross-shelf dimension. In addition, it is not known from what depth strata the intakes withdraw water under the various current and mixing conditions that actually occur. To overcome this problem, MEC calculated intake losses on the basis of withdrawal from midwater only and from the entire water column. The abundances of animals at the depth of the intakes were weighted by their vertical distributions to arrive at the concentration of animals in the withdrawn water.

A different set of loss estimates was calculated to support interpretations of the BACI analyses. The intention of these estimates was to determine whether intake and diffuser losses could account for the changes in abundance detected by the BACI analyses. These estimates were produced in much the same way as the estimates in Section 5, but differed from them in two main respects. First, the data base only included the period when the Unit 2 and/or Unit 3 pumps were operating (i.e., 1981 -- during pump testing -- through 1986). Second, the loss estimates included several scenarios of mortality due to diffuser entrainment, which could affect animals directly, for example through turbulent shear, and indirectly, for example by moving them to unfavorable areas. These estimates are described in Section 3 and presented in Section 4.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SANTA CATALINA ISLAND
N CLEMENTE ISLAND

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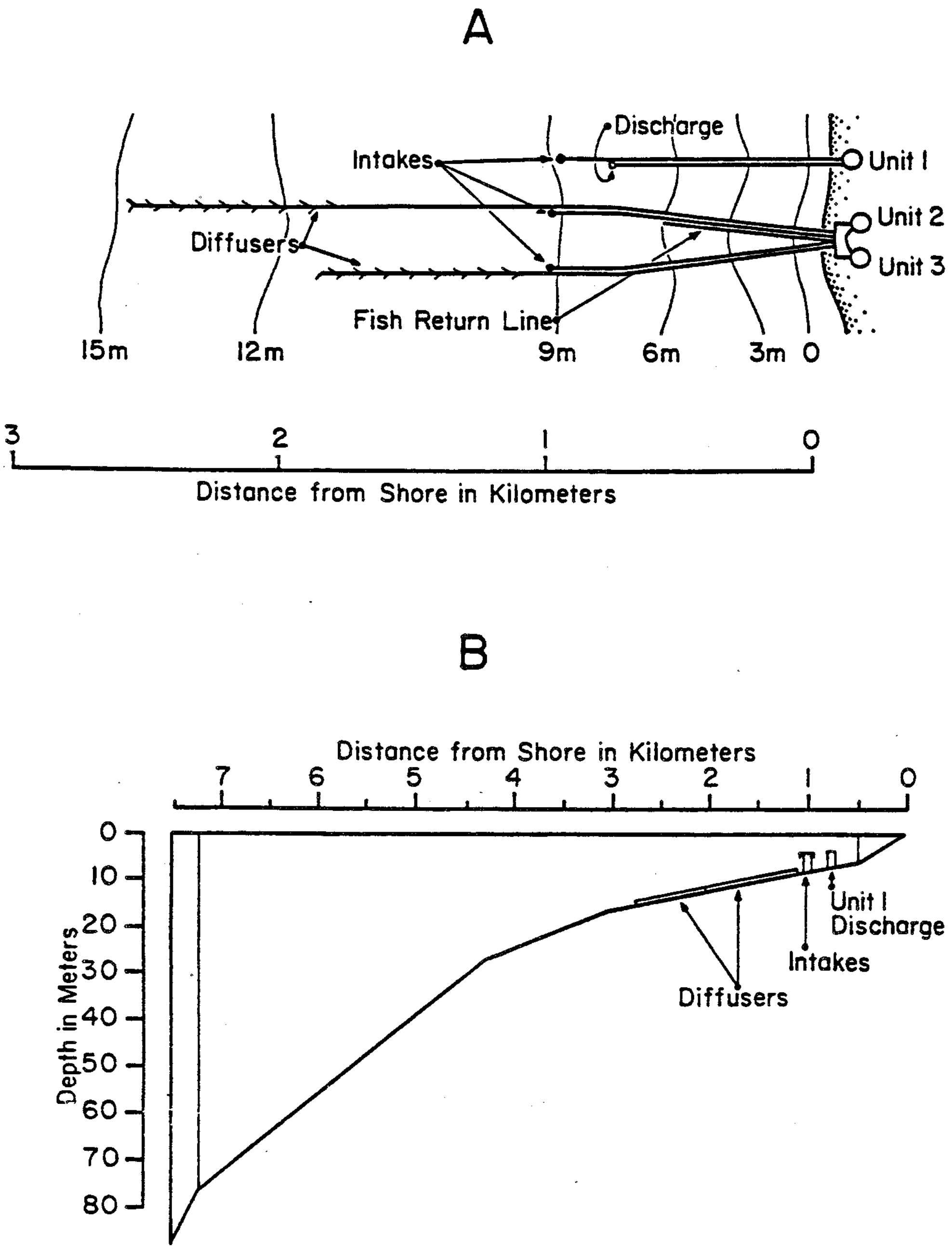

Figure 1-2. Expanded plan view (A) and side (cross-shelf) view (B) diagrams of the placement of the San Onofre Nuclear Generating Station structures. Note that the distance scales differ for the two diagrams.

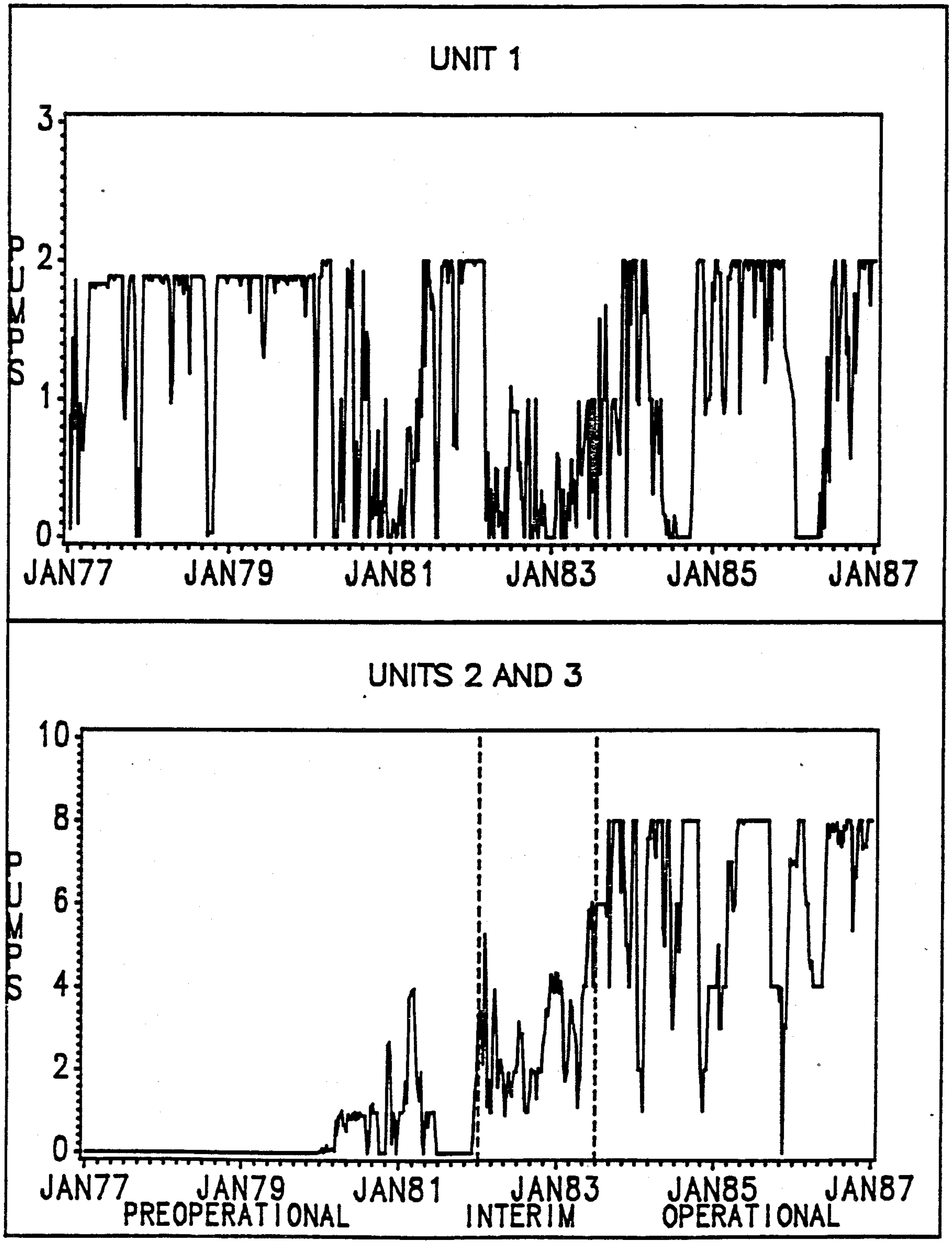

Figure 1-3. Weekly averages of circulating pumps in operation at SONGS Unit 1 and Units 2 and 3 combined from January 1977 to January 1987.

2.0 BACKGROUND

This section is intended for the reader who is not familiar with the MRC studies of SONGS. In addition to information on the environmental setting of the MRC studies, it presents a synopsis of the results of previous plankton studies in the San Onofre area and in the Southern California Bight. The studies of SONGS effects were of two kinds: (1) studies of the effects of Unit 1 operations on the plankton; and (2) predictive studies of Units 2 and 3 effects, which drew upon both the Unit 1 studies and baseline studies conducted early in the preoperational period to generate estimates of the changes that might occur. Unit 1 studies included analyses of patchiness, local changes in abundance of zooplankton, and intake losses of zooplankton and ichthyoplankton (Barnett and Sertic, 1976, 1977, 1978, 1979, 1980; Tetra Tech, 1977; Marine Biological Consultants, 1979; Barnett et al., 1980a, 1985). The MEC and Tetra Tech studies were conducted for the MRC, the MBC studies for Southern California Edison. The overall conclusions of the various Unit 1 studies of zooplankton distribution and abundance were: (1) Unit 1 does indeed have detectable, but very localized, effects; and (2) these effects are probably ecologically insignificant (Barnett and Sertic, 1979). The detectable effects consisted of changes in the intensity of patchiness and in the vertical distribution of some zooplankters within about 500 m from the discharge.

2.1 The Environmental Setting

The irregular bottom topography of the Southern California Bight strongly influences its circulation. The general pattern of circulation within the Bight is counterclockwise in the north and northward elsewhere, except near shore, where the average flow is to the south. The major components of this pattern are the southerly-flowing California Current along the western boundary of the Bight, the northerly-flowing California Undercurrent and Southern California Countercurrent within the Bight, and the southerly coastal currents (e.g., Reid et al., 1958; Hickey, 1979). The northerly and coastal currents are seasonal in intensity and/or occurrence (e.g., Hickey, 1979; Schwartzlose and Reid, 1972; Tsuchiya, 1980).

Longshore coastal currents tend to flow in the same direction throughout the water column, particularly in areas less than 60 m deep, and to be strongest around the 60 m depth contour (Jackson, 1986). Shoreward, these coastal currents are slowed by bottom friction and modified by kelp beds (e.g., Jackson and Winant, 1983). Cross-shelf currents, on the other hand, tend to reverse direction between surface and bottom (Winant and Bratkovich, 1981). The cross-shelf currents are seasonal and tend to have near-tidal periodicities (Jackson, 1986). The effects of wind shear, internal waves, and bottom topography add to the complexity of local current driving forces in the SONGS area (MRC, 1977; USNRC, 1981). The two resultant major flow patterns near SONGS are: 1) a flow that alternates between upcoast and downcoast, and that has a net downcoast movement, and 2) a flow that alternates between onshore and offshore, and that apparently has a net onshore movement (MRC, 1977). A ten-year study of currents near SONGS (Reitzel et al., 1987) has shown that mean longshore current speeds are roughly 2 to 5 cm/sec., tending to be faster in summer than winter.

Anomalous warming events occur in the Pacific Ocean at irregular intervals on a scale of years. For example, events of this type occurred during the MEC studies at San Onofre in 1976 - 1977 and 1982 -

1984. These warming events may result from local heating by solar radiation, but are more commonly associated with tropical El Nino events and/or regional wind-induced shoreward transport of warm surface water (McLain et al., 1985). Both of these latter two processes result in an intensification of the seasonal poleward flow.

The California Current and its eddies bring low-salinity subarctic water into the Bight (Reid et al., 1958), while the water moving northward below 250 m is mostly of southern origin (e.g., Hickey, 1979; Jackson, 1986). Above the thermocline, lower salinity subarctic water from the north is mixed in the California Current with saltier central North Pacific water. Below the thermocline, saltier equatorial Pacific water moves into the Bight from the south. In the deep basins, there is a mixture of subarctic and equatorial Pacific water (Reid et al., 1958). Waters from these sources are mixed by the various currents to produce the water types observed in the Bight.

The water column in the Bight is vertically stratified, and its properties tend to be most variable in the upper 100 m (Jackson, 1986). The nearshore water column tends to be well mixed during the winter but becomes stratified, with a well-developed thermocline, in the summer (Brown and Caldwell et al., 1979; USNRC, 1981; Reitzel and Zabloudil, 1982; Petersen et al., 1986; Barnett and Jahn, 1987). Surface temperatures near San Onofre range from about 12° to 23°C (e.g., USNRC, 1981; Reitzel and Zabloudil, 1982; Reitzel et al., 1986; Petersen et al., 1986); horizontal temperature gradients can reach 1.1°C per 1.6 km (USNRC, 1981). Sea surface temperatures are highest in summer (August-September average: 19°C) and lowest in winter (December-March average: 14°C). Salinity in the nearshore San Onofre vicinity ranges from about 33 to 34 ppt (USNRC, 1981), but is generally between 33.5 and 33.6 ppt.

It varies little between seasons, but tends to be slightly higher nearshore (Reitzel and Zabloudil, 1982).

2.2 The Plankton of the Study Area

The plankton near SONGS resembles that of the Bight as a whole. The transitional nature of this biogeographic region, as described by Fleminger (1964), Valentine (1966), Briggs (1975), Newman (1979), and Horn and Allen (1978), is demonstrated by the fact that temperate species dominate the flora and fauna, but taxa having subtropical, tropical, or boreal affinities are also present.

The plankton of the offshore waters of the Southern California Bight have been extensively studied for many years, especially during the CalCOFI surveys of the last four decades. The nearshore environment, however, has been much less extensively sampled; the MRC plankton studies at San Onofre are among the first in the area. Plankton studies in shallow areas, including the MRC studies, have shown that the shallow shelf is a distinct faunal zone, and have emphasized the unique nature of the very nearshore portion of this zone--the portion characterized by water depths less than about 20-30 m. For this reason, and because the principal effect expected of SONGS on the plankton would occur mainly within the shallow nearshore zone, the following synopses emphasize studies conducted in nearshore waters, and especially those conducted near San Onofre.

2.2.1 Primary Production

Chlorophyll-a, the dominant photosynthetic pigment, is a common measure of phytoplankton standing stock and has been used to estimate primary productivity (Eppley and Holm-Hansen, 1986). Although the chlorophyll content may vary with the size and type of phytoplankton being measured, the composite chlorophyll concentration in a sample is strongly correlated with such measures of phytoplankton biomass as particulate organic carbon (POC) (Carlucci et al., 1986). Typical chlorophyll concentrations near SONGS range from 0 to 5 µg/ℓ, although values as high as 60µg/ℓ have been measured (Reitzel et al., 1986).

Primary production in the Bight is limited by the availability of nutrients, especially nitrogen, in the euphotic zone. The most likely sources of nitrogen in the San Onofre area during non-upwelling periods are eddy diffusion from below the thermocline/nitracline, enhanced by tidal stirring and in situ nutrient regeneration (Barnett and Jahn, 1987; Eppley et al., 1979). Longshore advection toward SONGS of nutrients from a more persistent upwelling area may occur as well, but there is no evidence to confirm or refute this possibility.

The spatial scale of nearshore phytoplankton blooms may be related to the structure of the coastal currents (Goodman et al., 1984). Studies by Tont (1976), Hendricks (1977), Winant (1983), Eppley et al. (1984), and Goodman et al. (1984) have suggested that the longshore patch size of the phytoplankton is on the order of 22-27 km.

2.2.2 Zooplankton

The zooplankton includes protozoan (e.g., tintinnids, radiolarians, foraminiferans) and metazoan (e.g., larvae of copepods and benthic invertebrates) microzooplankton and macrozooplankton (e.g., chaetognaths, copepods, and cladocerans). Microzooplankton biomass has been estimated to be about 10 -25% of the biomass of the macrozooplankton in both nearshore and offshore waters of the Bight (Beers and Stewart, 1969, 1970). Micrometazoans make the largest contribution to the microzooplankton biomass, although the microprotozoans are numerically more important (Beers and Stewart, 1967, 1969, 1970). Since the monitoring studies at SONGS have concentrated on the macrozooplankton, the microzooplankton will not be discussed further.

The macrozooplankton comprises a large and diverse group of taxa that includes such organisms as crustaceans (copepods and cladocera), ctenophores, salps, and other gelatinous plankton, and chaetognaths. Copepods, the best known constituents of the crustacean macrozooplankton, usually dominate the nearshore macrozooplankton assemblage of the Southern California Bight. The calanoid copepods Acartia tonsa and Paracalanus parvus are the dominant macrozooplankters off San Onofre (Lockheed, 1978; Barnett and Sertic, 1979) and one or both dominate in other nearshore areas of the Bight as well (e.g., Brewer et al., 1984; MBC, 1976; Soule and Oguri, 1977). Other abundant nearshore organisms include the copepods Euterpina acutifrons, Corycaeus anglicus, the cladocerans Podon polyphemoides and Penilia avirostris, the chaetognath Sagitta euneritica, and bryozoan larvae.

Biomass of the total macrozooplankton tends not to vary in a systematic way with distance from shore across the entire Bight (Mullin, 1986; O'Connell, 1971), although a biomass peak has been reported 100 -200 km offshore of southern California (Smith, 1971; Bernal and McGowan, 1981). In the nearshore zone, biomass tends to be persistently higher in the region of the 15 - 36 m depth contours than at the 75 m contour (Petersen et al., 1986). The biomass maximum within the nearshore zone tends to shift seaward from 15 m to 36 m between late winter and early summer (Petersen et al., 1986). Jahn and Lavenberg (1986) reported that at the 7 m depth contour off Seal Beach, zooplankton biomass increased exponentially with depth in the bottom 1 m, meaning that the zooplankton was concentrated near the bottom.

Individual taxa are known to have persistent distributional patterns in the nearshore waters of the Bight (e.g., Barnett, 1974; Barnett et al., 1980a, 1981; Barnett and Jahn, 1987). Studies at San Onofre have identified persistent nearshore (<30 m depth), transitional, and offshore (>30 m depth) plankton faunas, and have emphasized the very nearshore affinities of Acartia clausi, Oithona oculata, barnacle cypris larvae, and the copepodite stages of Acartia tonsa, Labidocera trispinosa, and Paracalanus parvus. Barnett and Jahn (1987) showed that the smaller, younger stages of crustaceans tend to be most abundant close to shore, and speculated that planktonic biomass may turn over more rapidly in this area than farther offshore, where the older stages tend to be located. A multivariate analysis of variance (MANOVA) on the abundances of individual species at samples near SONGS and at a Control transect 12 km downcoast showed no difference between the two areas (Barnett et al., 1981). Since the analysis was sensitive to differences in abundance patterns, an average longshore coherence scale of at least 12 km can be inferred.

2.2.3 Ichthyoplankton

Nearly 150 taxa of larval fishes were collected during SONGS monitoring studies. Northern anchovy (Engraulis mordax) and the sciaenids Genyonemus lineatus (white croaker) and Seriphus politus (queenfish) ranked one, two, and three in abundance. The remainder of the top fifteen taxa were: Sebastes spp. (rockfish), Paralabrax spp. (kelp and sandbasses), Paralichthys californicus (California halibut), Hypsoblennius spp. (blennies), Citharichthys spp. (sanddabs), Stenobrachius leucopsarus (lampfish), Atherinidae (grunion and jacksmelt), Gibbonsia spp. (kelp fish), Hypsopsetta guttulata (diamond turbot), Gobiesox rhessodon (California clingfish), and a composite of three goby species.

Persistent onshore-offshore patterns of abundance have been documented for the ichthyoplankton of the Bight (e.g., Ahlstrom, 1965; Barnett et al., 1984; Brewer et al., 1981; Gruber et al., 1982; Lavenberg et al., 1986; Loeb et al., 1983a). All studies that sampled nearshore waters have identified an inshore shallow-water assemblage of larval fishes that includes sciaenids, gobies, clinids, and atherinids (e.g., Barnett et al., 1984; Brewer et al., 1981; Gruber et al., 1982). Brewer et al. (1981), sampling along a series of nearshore transects from Point Conception to San Diego, noted that the abundances of these nearshore larvae were strongly correlated with water depth but not with distance from shore. At San Onofre, Barnett et al. (1984, 1985) identified an inner nearshore larval fish assemblage consisting of species most abundant within about 2 km (12 m depth) of shore, a transitional assemblage, and an outer nearshore/offshore assemblage most abundant seaward of about 4 km from shore (about 22 m depth). The inner nearshore assemblage, of particular interest because of its potentially high susceptibility to SONGS entrainment effects, consisted of gobies (4 species), gobiesocids (clingfish; 2 species), clinids (3 species), sciaenids (2 species), a pleuronectid (the diamond turbot), and a cynoglossid (tonguefish). The assemblage also included atherinids and two additional sciaenid species whose distributions extended offshore beyond the SONGS diffusers (Barnett et al., 1985). Most of the inner nearshore taxa were most abundant in the epibenthos (bottom-most 0.5 m of the water column). The transitional zone assemblage was shown to be most abundant at mid-depth, 2 - 4 km from shore (water depths of 12 - 22 m), while the group of offshore taxa was most abundant at mid-depths seaward of about 4 km from shore (Barnett et al., 1985). The geographic affinities of the most abundant species identified by Barnett et al. (1984, 1985), and of additional species used in the BACI analyses, are presented in Table 2-1. The geographical affinities reflect the complete data set, and are thus somewhat different from Barnett et al. (1984, 1985); the two inner nearshore sciaenids were re-assigned, on the basis of their early larvae, to the transitional assemblage, and a new assemblage, termed "broadly distributed," was established.

2.3 Intake Losses

The intake loss studies indicated that losses through the plant of four representative zooplankton species were sufficiently close to 100% to allow the assumption of 100% mortality of all entrained organisms in the subsequent loss calculations. Zooplankton losses were estimated to be equivalent to 10% of daily natural mortality (i.e., a loss of 1% of the population per day) within an area of approximately 80 km^2 around the plant, or about 110 x 10^9 individuals killed per day. Analogous calculations placed ichthyoplankton losses at about 3.5 x 10^6 individuals per day (Barnett and Sertic, 1979).

Despite the magnitude of these estimated losses, depressions in zooplankton abundance were not detectable, except near Unit 1 on some occasions, as noted above (Barnett and Sertic, 1979). This was interpreted as the rapid dilution of Unit 1 effects by mixing with adjacent unaffected water. Compensatory mechanisms such as increased growth or reproduction, or improved survival of the surrounding population, were assumed to operate as well, although on a longer time scale. Therefore, mixing was thought to be the principal mechanism masking the detection of Unit 1 effects (Barnett and Sertic, 1979).

Units 2 and 3 studies have included predictive extrapolations of intake losses, and the BACI monitoring studies. Preliminary BACI analyses were presented by Barnett et al. (1986), and will not be discussed further. Total maximum intake and entrainment losses to SONGS Units 1, 2 and 3 combined operations were initially predicted, on the basis of preoperational data, to be 6267 x 10^9 zooplankters and 340 x 10^6 ichthyoplankters per day. This was considered about equivalent to natural mortality in an area of 80 km^2 around SONGS (Barnett and Sertic, 1979). Intake loss estimates for zooplankton and ichthyoplankton were recalculated in 1986 using a much larger plankton abundance data base. Losses based on both actual water volumes withdrawn by Units 2 and 3 from 1981 through 1985 and on pumping volumes based upon 100% operations were calculated (Barnett et al., 1986). The estimates of losses based on the actual volume of water withdrawn by Units 2 and 3 (equivalent to operation at about 50% of capacity) tended to be about the same as or a little lower than the earlier predictions, but estimates assuming operation at 100% of capacity (as in the earlier predictions) tended to be much higher for both ichthyoplankton and zooplankton than the earlier predictions.

In order to assess the ecological significance of entrainment losses of the eggs and larvae of nearshore pelagic-spawning fishes, a complex set of calculations was used to estimate the number of adults that could have been produced from these immature stages had SONGS been absent (DeMartini and Larson, 1980). These estimates are being recalculated by the UCSB Adult Fish Program on the basis of a more sophisticated model and using the entire data set.

Table 2-1. Onshore-Offshore distribution of the most abundant larval fish off San Onofre (from Barnett et al., 1984, 1985).

INNER NEARSHORE

- Gobiesocidae
  - *Gobiesox rhessodon*
    - (California clingfish)
- Gobiidae
  - *Clevelandia ios*
    - (Arrow goby)
  - *Quietula y-cauda*
    - (Shadow goby)
  - *Ilypnus gilberti*
    - (Cheekspot goby)
- Clinidae
  - *Paraclinus integripinnis*
    - (Reef finspot)
  - *Heterostichus rostrata*
    - (giant kelpfish)
  - *Gibbonsia* spp.
    - (kelpfish)

NEARSHORE/TRANSITIONAL

- Atherinidae
  - *Atherinopsis californiensis*
    - (Jacksmelt)
  - *Leuresthes affinis*
    - (California grunion)
- Sciaenidae
  - *Seriphus politus*
    - (Queenfish)
  - *Genyonemus lineatus*
    - (White croaker)
  - *Menticirrhus undulatus*
    - (California corbina)
  - *Cheilotrema saturnum*
    - (Black croaker)
- Pleuronectidae
  - *Hypsopsetta guttulata*
    - (Diamond turbot)
  - *Paralichthys californicus*
    - (California halibut)
- Serranidae
  - *Paralabrax* spp.
    - (Sandbasses, kelp bass)

BROADLY-DISTRIBUTED

- Engraulidae
  - *Engraulis mordax*
    - (Northern anchovy)
- Pleuronectidae
  - *Citharichthys* spp.
    - (Sanddabs)
  - *Pleuronichthys verticalis*
    - (Hornyhead turbot)
- Bleniidae
  - *Hypsoblennius* spp.
    - (Blennies)

OFFSHORE

- Myctophidae
  - *Stenobrachius leucopsarus*
    - (Northern lampfish)
- Scorpaenidae
  - *Sebastes* spp.
    - (Rockfishes)

3.0 METHODS

Ichthyoplankton and zooplankton were sampled at locations that are considered as Control or Impact areas relative to SONGS. The collection of samples specifically for use in the BACI model began in 1980; however, several earlier surveys taken for other purposes also matched the BACI sampling plan and thus were incorporated in the monitoring studies. By including these early surveys with the monitoring studies, sampling of zooplankton could be considered to have begun in August 1976 and ichthyoplankton in July 1979. Both continued through September 1986. This sampling has encompassed the periods when only Unit 1 was in operation, but included the time during the construction of Units 2 and 3 (= preoperational period), test operations of Units 2 and 3 (= interim period), and at least 75% of full capacity operation of Units 2 and 3 (= operational period) (see Figure 1-3).

From October 1985 through January 1986 when ichthyoplankton and plankton monitoring surveys were not conducted, intake loss samples were collected. In addition, one longshore gradient survey was conducted for anchovy larvae (March 1986) and one intake-diffuser survey was conducted for zooplankton (December 1986).

Methods pertinent to the field collection and laboratory analysis of these samples are presented in the following subsections. Specific monitoring survey protocols are presented in Appendix B. Unless stated otherwise, methods are similar for the preoperational, interim, and operational phases of the monitoring.

Survey dates for the monitoring surveys, the intake loss surveys, and the longshore gradient survey are listed in Table 3-1.

3.1 Ichthyoplankton Monitoring

3.1.1 Field Sampling

Ichthyoplankton was collected along two transect lines: an Impact line 1.0 km downcoast of SONGS and a Control line 18.5 km downcoast of SONGS (Figure 3-1). Each transect consisted of five contiguous blocks in the inshore-offshore direction within 7.2 km of shore (between the 6 m and 75 m isobaths). The offshore blocks were defined by depth contours, designated by letter as follows: (A) 6-9 m, which generally corresponded to SONGS intake locations; (B) 9-12 m and (C) 12-22 m, which generally corresponded to diffuser locations; (D) 22-45 m, which corresponded to a faunal break between inshore and coastal plankton assemblages (Barnett and Sertic, 1978); and (E) 45-75 m, which was chosen as the likely offshore extent of 90-95% of the numbers of inshore fish larvae (Barnett and Sertic, 1979a; MRC, 1979a, Doc. No. 79-01, Appendix Table 2). These blocks ranged as follows in distance from shore: (A) 0.5-1.1 km; (B) 1.1-1.9 km; (C) 1.9-3.7 km; (D) 3.7-5.4 km; and (E) 5.4-7.2 km.

The placement of the Impact study site 1 km downcoast from SONGS was dictated by a combination of factors, including (1) the length of tow required to sample a target volume of 400 m^3 (ranging from about 400 m in the epibenthos to about 1.4 km in the neuston), (2) the bottom topography (rocky reefs precluded epibenthic sampling upcoast near SONGS, as did construction activity within 1 km downcoast during the early preoperational period), and (3) the desire to sample as near the SONGS diffusers as could prudently be done. The Impact site 1 km downcoast was the nearest that samples could be taken. The Control site 18.5 km downcoast was selected to be near (within 1 km) the University of California at Santa Barbara (UCSB) Adult Fish program's Control site. This site represented a habitat that was similar to the SONGS area and could be sampled, but that was far enough away to allow a reasonable expectation of independence from SONGS effects. After the completion of preoperational monitoring, tests of cross-shelf abundance and distributional patterns of ichthyoplankton at the Impact and Control sites revealed significant differences only for the bay goby, Lepidogobius lepidus, and for total larvae (neither was used in the BACI analysis). Thus the Control site appears to have been a good Control. The Impact and Control sites selected at the beginning of preoperational monitoring were maintained throughout the subsequent study.

In each of the five offshore sampling blocks at each site, a depth contour was randomly selected for sampling the surface (neustonic), midwater, and near-bottom (epibenthic) layers of the water column (Appendix B, Section B.1.1). At the SONGS transect, parts of blocks B and C were located within the San Onofre Kelp (SOK) bed (Figure 3-1). Since towed net samples could not be successfully completed in these parts of Blocks B and C, when the kelp bed depths were randomly selected, sampling was shifted 2.5 km downcoast of the other blocks (Figure 3-1) in order to avoid this area. This was considered more desirable than shifting the entire SONGS transect farther from the diffusers, to 3.5 km downcoast. However, the presence of the kelp bed between the Impact sampling site and the diffusers did raise the question of whether the kelp bed would affect our ability to measure any SONGS effects in the portions of Blocks B and C that were shifted downcoast. For example, it was speculated that SOK might act as a filter, or as a barrier to the discharge plume. Erdman (1987) reported that SOK shows evidence of both properties, diverting the discharge plume around the inner boundary of the kelp bed when downcoast currents exceed about 3 cm/sec, but also passing some fraction of the water through the kelp bed at a slower rate than in the adjacent open water.

In an attempt to determine whether the kelp bed would affect the results of the monitoring study, during the preoperational period we compared ichthyoplankton abundances between samples taken in Blocks B and C along the SONGS transect and those shifted downcoast. No statistically-significant differences were detected (Barnett et al., 1984). A second analysis using the full preoperational and operational data sets was done at the end of the monitoring studies (Table 3-3). In this analysis, the concentration in the water column (number/400 m^3) of each taxon utilized for BACI testing was compared (two-tailed t-test, evaluated at $\alpha = 0.05$) between Block B and Block B offset, and between Block C and Block C offset. Since ichthyoplankton are known to have seasonal abundance cycles (e.g., Walker et al., 1987), the data were analyzed separately for the warm-water and cool-water periods (as defined in Section 3.7.3). A total of 86 separate t-tests were performed; these would be expected to yield four or five significant results by chance alone. In fact, only one significant result was obtained, for California halibut, Paralichthys californicus, in the summer and fall of the After period (fewer larvae in Block B offset). A nearly-significant result was obtained for northern anchovy, Engraulis mordax, in the summer and fall of the After period as well (p=0.054). These results suggest that the presence of the kelp bed did not have a general impact on the monitoring studies, although the result for P. californicus does suggest caution in interpreting the BACI analysis results for this species.

Transect lines were sampled at night to reduce the problem of avoidance of the sampling gear by larval fish (Barnett et al., 1978). Lights on land provided visual reference for locating transect lines, and a fathometer was used to locate the selected depth contour within each of the 5 offshore blocks. During each sampling period, the transect off SONGS was sampled on the first night of a survey and the Control transect was sampled from 1-3 nights later. If weather conditions prevented completion of the survey, then both the Control and Impact transects were sampled within the next possible 4-night period.

Samples of about 400 m^3 were taken in each of the three depth strata using specially designed sampling gear. All samplers were fitted with 0.333 mm mesh Nitex nets and calibrated flowmeters (Appendix B, Section B.1.1). Samplers were launched, towed, and recovered with the vessel underway at about 1 m/sec. Ichthyoplankton tows were made parallel to shore and each offshore block was usually sampled in the same direction (downcoast at SONGS to avoid towing nets into the construction area during the early preoperational period and into the diffusers subsequently, upcoast at Control to avoid towing nets into the area directly off the Santa Margarita River). If sampling took longer than usual (e.g., if weather conditions were poor), the extra transit time required to sample each block in the same direction was not always taken, and contiguous blocks were sampled in opposite directions (this occurred only rarely). The neustonic and epibenthic strata were sampled concurrently; midwater samples were collected after all the neuston and epibenthic samples were taken for a transect line.

A Brown Manta net (Brown and Cheng, 1981) was used to sample the neuston (Figure 3-2). The sampler consisted of a 0.333 mm mesh net attached to a plywood-covered aluminum frame with side-mounted floats made of fiberglass-covered styrofoam. The sampler was launched and recovered off the side of the vessel by means of a tag line. A 3 m spar and asymmetrical bridle kept the gear outboard of the bow wave. A weight (32 kg) suspended from the end of the wire held the bridle below the sea-surface, out of the path of the net. The net had an 88 cm wide mouth (total mouth area = 0.14 m^2) and fished to a depth of 16 cm. The filtering ratio (R = filtering area/mouth area) of the net was 8.0. Both a Tsurami-Seiki (TSK) flowmeter and a General Oceanics (GO) flowmeter were mounted in the mouth of the net. The GO flowmeter served as a back-up for the TSK, which at times fouled with kelp and eelgrass. Two Manta nets were towed simultaneously, off port and starboard, for 20 minutes (about 1.4 km) to obtain a sample of about 400 m^3. Deck lighting of the vessel was minimized during the neuston tows.

For midwater sampling, an opening-closing 71 cm Brown-McGowan bongo net was used (Figure 3-2). The bongo net consisted of 0.333 mm mesh nets attached to two circular aluminum frames connected to each other. A GO flowmeter was mounted to the starboard frame. The bongo net was deployed and retrieved from the stern of the vessel by means of a hydraulic winch. A 60 kg weight suspended below the frame maintained the proper wire angle (about 45°). Wire was paid out (scope about 2:1) until the weight bumped the bottom. Dacron doors fitted to the front of the frames were then opened by wire messenger, and a stepped-oblique tow consisting of 18, 30-sec steps was made. The twin nets of the bongo, with a total mouth area of 0.79 m^2 and filtering ratio of 5.6, provided a sample of about 425 m^3.

The Auriga net*, used to sample the epibenthos, consisted of a 0.333 mm mesh net attached to a rectangular, galvanized, metal frame

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* Designed by Marine Biological Consultants, Inc., 947 Newhall Street, Costa Mesa, California.

(0.5 m high and 2 m wide) equipped with a pair of side-mounted, 2 m diameter wheels (Figure 3-2). The sampler was launched and recovered from the stern of the vessel by means of a hydraulic winch. A wire scope of 3:1 ensured that the sampler rolled along the bottom when it was towed at a vessel speed of about 1 m/sec. A 90 kg weight mounted atop the frame maintained the orientation (mouth of net oriented towards direction of tow) of the sampler on the bottom and a series of plastic rollers (12 cm diameter) attached to the chasis below the mouth of the frame helped prevent the sampler from digging into the bottom. During sampling, the mouth of the net was about 17 cm above the bottom. A series of rectangular dacron flaps protected the bottom of the net without restricting the flow of water through the net. Both TSK and GO flowmeters were suspended within the net. The Auriga net, with a mouth area of 1 m^2 and filtering ratio of 5.9, provided a sample of about 400 m^3 after being towed on the bottom for 6.6 minutes.

Although the Auriga net is not an opening-closing sampler, contamination from the midwater was considered minimal. Divers have observed that the mouth of the net assumes a horizontal attitude when off the bottom (M. Sowby, pers. comm.: Southern California Regional Water Quality Control Board - Los Angeles Region). Therefore, the main component of water movement is across rather than through the net during launch and recovery.

Upon recovery, all nets were washed down with a hose to condense the sample into the removable cod-end of the net. The contents of the cod-end were then rinsed into a sample jar(s), which was labeled inside the jar and outside on the lid, and preserved with 5-10% Formalin-seawater.

3.1.2 Laboratory Analysis

Samples were sorted for fish larvae and eggs to obtain counts of at least 100 larvae other than Engraulis mordax (northern anchovy) and 100 eggs (Appendix B, Section B.1.2). Samples with large numbers of fish larvae were split with a Folsom plankton splitter to yield subsamples of 1/2 to 1/32 fractions. At least 1/32 of the sample was examined and additional subsamples, as necessary, were sorted to obtain the specified number of fish larvae. Samples with fewer than 100 non-engraulid larvae were examined in their entirety. Subsampling in this way yields acceptable estimates of the abundances of the more common taxa, but is likely to result in higher variability in the estimates for rarer taxa. However, searching a larger fraction of the sample for the rarer taxa would involve a substantial increase in effort and cost, and it was concluded that on balance the potential information gain would probably not offset this increased cost.

Fractions were sorted at 6-12X magnification using a dissecting microscope and all fish larvae were removed for subsequent identification and curation. A second technician checked 10% of the sorted fraction to ensure that at least 90% of all fish larvae were removed (Appendix B, Subsection B.1.2.B). On those rare occasions when fewer than 90% of the larvae were removed, the sample was resorted, and rechecked until a 90% efficiency was attained.

Fish eggs were sorted from the same fraction examined for fish larvae. Depending on their abundance, eggs were counted and removed from 1%, 5% or 10% aliquots of the sorted fraction. A minimum of 100 eggs was sorted from the aliquots, if possible. A Hensen-Stemple pipette was used for subsampling fish eggs.

Sorting of Auriga net samples was sometimes hindered by large amounts of sand and detritus. When this was the case, organisms were removed from the sand by a swirl and decant technique and the sample was cleaned of the debris before sorting by using a flotation technique adapted from Ladell (1936). Large fish and debris were rinsed and removed from the sample, then ichthyoplankton were floated out of the sample using a solution of 40% $MgSO_4$ (specific gravity = 1.2). The flotation procedure involved a series of steps whereby a small volume (about 100 ml) of the sample was thoroughly mixed with about 3,500 - 4,000 ml of the $MgSO_4$ solution, the heavy material was allowed to sink, and the lighter-weight plankton was poured from the top of the solution. After the entire sample was processed, the flotation procedure was repeated to ensure adequate separation of the plankton from the sample. The floated sample was rinsed of $MgSO_4$, rehydrated, sorted, and the volume of the debris recorded. A portion of the debris from each floated sample was examined to ensure the success of the separation.

Fish larvae were identified to the lowest practicable taxon. Eggs were identified as Engraulis mordax or "other". All counts for larvae and eggs and subsample information were entered into the MRC data base and standardized to number per 100 m^3 by using the flowmeter information. Operational samples from Block E were not analyzed with the exception of 20 midwater samples which were analyzed for anchovy larvae only. Consequently, the samples used in the analyses for SONGS effects were those collected from Blocks A-D, between the 6 and 45 m isobaths.

Samples were curated and stored by MEC for the MRC. The samples were inventoried in the MRC Curation Bottle Inventory data base. Sorted and unsorted portions of samples, which had been split by Folsom plankton splitter, were stored separately. Fish eggs and larvae that had been counted and identified were stored in poly-seal capped vials. Periodic checks of the samples ensured that the 10% buffered (sodium borate) Formalin-seawater remained within acceptable pH limits (5.5 - 7.8).

Representative specimens of each ichthyoplankton taxon were separately curated in a documented reference collection (Barnett et al., 1982). The taxonomic quality of the reference collection has been assured by MEC's active participation in the 1978-1980 Taxonomic Quality Assurance Program (TQAP) of ichthyologists performing work on Southern California Edison projects in southern California.

As part of the MEC quality assurance program, the precision associated with subsampling ichthyoplankton samples was investigated. The mean coefficient of variation associated with dividing 12 ichthyoplankton samples in half with the Folsom plankton splitter was less than 5% (Appendix B, Section B.1.2). The mean coefficient of variation associated with counting 90 1% Hensen-Stemple pipette subsamples from a sample (with replacement) was 5%.

3.1.3 Frequency of Sampling

The ichthyoplankton preoperational monitoring data base consists of 5 surveys from July to September 1979, 30 surveys taken at weekly intervals from 10 March to 16 October 1980, and 3 surveys taken in July, September, and November 1981 (Table 3-1). The interim data base consists of 5 surveys taken in the months of March, July, August and November 1982, and March 1983. The operational period is considered to have begun in July 1983 when pumping operations at SONGS Units 2 and 3 increased to a total of eight pumps (see Figure 1-3) and at least one of the two units was operating during most of the period. Generally, if neither unit was operating, a scheduled survey was postponed until operations restarted. The operational data base consists of 27 surveys; three taken in July, August, and December 1983, eight surveys taken in 1984, nine surveys taken in 1985, and seven surveys taken in 1986 (Table 3-1).

The close spacing of the 1980 surveys was dictated by the requirement for close-interval observations on the length-frequency distributions of larval queenfish and white croaker, to be used in the UCSB Adult Fish program's adult-equivalents loss calculations (DeMartini and Larson, 1980). The 1980 samples were intended to serve the dual purposes of supplying this length-frequency data as well as forming a large part of the preoperational period BACI data base. The operational surveys were taken at longer intervals partly dictated by the operational status of Units 2 and 3, but based mainly on a calculated (from the preoperational data: see Barnett et al., 1983b, 1985) minimum three-week interval between surveys to avoid potential problems with serial correlations of the SONGS-Control Deltas.

Power of test analyses based on the preoperational data indicated that 38 surveys from each of the preoperational and operational phases of monitoring were necessary to attain an 0.80 probability of detecting a 50% reduction in relative cross-shelf abundance with a Type 1 error of 5% for 5 of 23 ichthyoplankton taxa (Table 3-4). Approximately 130 other taxa were identified during the monitoring studies; most of these occurred infrequently and the remaining, more common, taxa were found predominantly well seaward of the SONGS offshore cooling structures. It was thus considered most unlikely that a SONGS effect could be identified for any of these other taxa, and they were not utilized in the analyses for reductions in relative cross-shelf abundance.

3.2 Zooplankton Monitoring

3.2.1 Field Sampling

Zooplankton were collected along two transect lines: an Impact line directly offshore of SONGS and a Control line approximately 12 km downcoast of SONGS (Figure 3-3). The location of the Impact study site off Unit 1 was dictated by the desire to sample as near the Units 2 and 3 diffusers as could prudently be done, while at the same time avoiding the offshore diffuser construction activity during the early preoperational period. The Control site was placed about 12 km downcoast on the basis of a SONGS discharge plume simulation study made by TRW, Inc. for MEC in 1978. This study indicated that sites farther than 10 km downcoast would have less than a 1% chance of being influenced by the plume. Thus the Control site 12 km downcoast was considered far enough away to allow a reasonable expectation of independence from SONGS effects. Sampling sites selected at the beginning of preoperational monitoring were maintained throughout the subsequent monitoring studies. At the end of the preoperational monitoring period, a comparison of macrozooplankton abundances and abundance patterns at the Impact and Control sites indicated that for the 15 most abundant taxa (including all the taxa utilized in BACI testing, except the cladoceran Podon polyphemoides) the two areas were not significantly different (Barnett et al., 1981). Comparison of physical and chemical data from the two transects also failed to reveal marked differences (Reitzel and Zabloudil, 1983).

Five stations, located on the 8 m, 13 m, 18 m, 30 m, and 100 m depth contours, were sampled at the Impact and Control transect lines. The stations were located by a combination of depth contour, permanent buoys, landmarks, and compass headings (Appendix B, Section B.2.1).

The 8 m stations corresponded to the isobath midway between the intake and discharge locations of SONGS Unit 1, the 13 m stations corresponded to the midpoint of the diffuser lines, the 18 m stations were 500 m offshore of the end of the diffuser lines, the 30 m stations corresponded to the faunal break between inshore and coastal plankton assemblages (Barnett and Sertic, 1978), and plankton captured at the 100 m stations were used to help define the offshore boundary of the Inner Nearshore populations. Since the 18 m stations were not sampled on some of the surveys prior to 1983, data from the 18 m stations were not included in the final analyses for SONGS effects.

Three strata corresponding to subsurface, midwater, and epibenthic depths were sampled at each station (Appendix B, Section B.2.1). The subsurface samples were collected one meter below the sea surface. One or two midwater depths were collected depending on the station. At the 8 m station, one midwater depth at about 4 m was collected. At the remaining stations, two midwater depths were selected in an attempt to sample above and below the thermocline. The epibenthic samples were collected from 0.5 m or 1 m above the ocean bottom depending on whether the bottom was silty. One exception was the 100 m stations: instead of sampling the epibenthos, samples were collected to a depth of 30 m, which generally corresponds to the lower limit of the euphotic zone.

A temperature profile of the water column was taken prior to sampling a station to determine the presence/absence and depth of the thermocline. The sea surface temperature was measured with a temperature probe and calibrated bucket thermometer, then the water temperature was measured at one meter intervals from the surface to the bottom, or to at least 30 m, with a temperature probe (Appendix B, Section B.2.1). Non-thermocline conditions existed when the temperature changed less than 1.0°C per meter over the entire water column. The midwater depths sampled during non-thermocline conditions were as follows: 8 m station - 4 m depth; 13 m station - 4 m and 8 m depths; 18 m station - 8 m and 12 m depths; 30 m station - 8 m and 20 m depths; and 100 m station - 8 m and 20 m depths. During thermocline conditions, midwater depths were generally moved five meters or less (usually 1-2 meters) from the standard non-thermocline depths.

Usually three replicate macrozooplankton samples and one microzooplankton sample were taken at each of the surface, midwater, and epibenthic depths specified above for each station. However, the number of replicate macrozooplankton samples varied from the above mode during the preoperational period in the following ways: ten were taken between August 1976 and June 1977, five were taken between November 1977 and January 1979, and three were taken after October 1979. One microzooplankton sample per sampling location was collected on most of the preoperational surveys and on the February 1984 survey.

Surveys were conducted during daylight hours and both Impact and Control stations were sampled the same day. Samples were taken with a centrifugal pump with a 7.5 cm diameter hose (Figure 3-4); a 68 kg weight held the hose in the vertical position. Samples were pumped at a rate of approximately 1.0 m^3/min for one minute; the flow rate was calibrated prior to sampling each station (Appendix B, Section B.2.1). Macrozooplankton samples were collected and filtered through 0.202 mm mesh Nitex nets. After the sample was taken, the net was washed down with a hose to condense the sample into the removable cod-end of the net. The contents of the cod-end were rinsed into a sample jar, which was labeled inside the jar, and preserved with 5-10% buffered Formalin-seawater.

3.2.2 Laboratory Analysis

A composite sample consisting of one-half of each of the three replicate macrozooplankton samples from each depth stratum from each sampling station was analyzed (Appendix B, Section B.2.2). An exception was the operational period samples from the 100 m stations, which were placed in storage and not analyzed. Samples used in the final analyses for SONGS effects thus were those collected at the 8, 13, and 30 m isobaths. Replicate samples were split with a Folsom plankton splitter and one half of each was randomly selected for the composite sample. The three replicate halves selected for the composite sample were combined into one sample jar. The non-selected halves were stored separately in jars with sodium borate-buffered (pH 7.0) 5-10% Formalin-seawater. During the early part of the preoperational period (1976-1979), replicate samples were analyzed separately; the mean of those replicates were used for the combined data analysis.

The composite sample was analyzed to obtain counts of 40 individuals in each of 27 key species or taxa (Appendix B, Section B.2.2). The abundant taxa were counted from at least two subsamples taken with a Hensen-Stemple pipette. The coefficient of variation associated with this subsampling technique was 18% for the more abundant taxa (Appendix B, Section B.2.2). The entire composite sample was counted for rarer taxa. Samples were analyzed at 12X magnification using a dissecting microscope.

All counts for identified taxa and subsample information were entered into the MRC data base and standardized to number per m^3 using the flow rate and length of sample information.

Samples were curated and stored by MEC for the MRC. The samples were inventoried in the MRC Curation Bottle Inventory data base. Annual checks of the samples ensured that the 5-10% Formalin-seawater remained at proper strength and pH (5.5-8.0 for macrozooplankton and 7.8-9.0 for microzooplankton samples).

As part of the MEC quality assurance program, representative specimens of each zooplankton taxon were separately curated in a documented reference collection (Barnett et al., 1982). The taxonomic quality of the reference collection has been assured through verification of voucher specimens by A. Fleminger of Scripps Institution of Oceanography.

3.2.3 Frequency of Sampling

The zooplankton preoperational data base consists of 32 surveys from August 1976 to November 1981 (Table 3-1). The interim data base consists of 6 surveys, which were taken from January 1982 to June 1983. The operational period was considered to have begun July 1, 1983, corresponding to the beginning of fairly consistent operations of Units 2 and 3 (see Figure 1-3). The operational data base consists of 23 surveys: two were taken in August and December 1983, seven surveys were taken in 1984, eight in 1985, and the remaining six surveys were taken in 1986.

Power of test analyses based on preoperational data (Barnett et al., 1981) indicated that 29 surveys from the operational phase of monitoring would be sufficient for detecting a 50% change in the abundance of nine taxa with an 80% probability and Type 1 error of 5% (Table 3-5).

3.3 Phytoplankton Monitoring

Water samples taken for the purpose of making phytoplankton cell counts were collected in both the preoperational and operational monitoring periods. Since, however, they were only analyzed during the preoperational period, they are not discussed in this report. Other samples were collected for the determination of chlorophyll-a concentration, an indirect measure of phytoplankton standing crop. These samples were collected during each zooplankton monitoring survey (see Section 3.2.1) and analyzed by MEC during the preoperational period and by the MRC physical/chemical contractor (Ecosystems Management Associates, Inc.) subsequently.

3.3.1 Field Sampling

The locations and frequency of chlorophyll-a water sampling were the same as those described for zooplankton monitoring (Section 3.2.1). Depths to 35 m were sampled for chlorophyll-a using a cleaned and purged pumping system (Little Giant Submersible Pump). Samples taken below 35 m depth were obtained with clean Van Dorn bottles or a large volume water pump. All samples were passed through clean 0.202 mm mesh netting before further shipboard treatment. Chlorophyll-a and phaeopigment samples were filtered aboard ship onto either glass fiber (Whatman GF/C) or membrane filters (Millipore Type AA) and frozen instantly in dry ice. Samples were kept frozen (-20°C) until analyzed in the laboratory.

3.3.2 Laboratory Analysis

Chlorophyll-a and phaeopigment were analyzed fluorometically as described in Strickland and Parsons (1972) during the preoperational period, and by a modification of the method described by Holm-Hansen et al. (1965) during the operational period (e.g., Reitzel and Zabloudil, 1982).

3.4 Longshore Anchovy Gradient Survey

At the request of the MRC, MEC conducted one longshore midwater survey in March 1986. This was designed to detect a gradient in anchovy larval abundance with distance from SONGS.

3.4.1 Field Sampling

Four replicate midwater bongo samples were taken at each of seven longshore locations located along the 18 m isobath. The sampling stations were located downcoast of SONGS at 0-1 km, 1-2 km, 4 km, 6 km, 8 km, 12 km, and 18.5 km.

These midwater samples were collected using the same techniques and gear as described above for the ichthyoplankton midwater monitoring field sampling (see Section 3.1.1). At each site, replicates 1 and 3 were taken towing upcoast, replicates 2 and 4 were taken towing downcoast.

3.4.2 Laboratory Analysis

The longshore gradient samples were sorted for Engraulis mordax (northern anchovy) larvae only. The samples were analyzed to obtain counts of at least 100 larvae following the techniques described above for ichthyoplankton monitoring laboratory analysis (see Section 3.1.2).

3.5 Intake - Diffuser Survey

To determine through-plant macrozooplankton losses of Units 2 and 3, and to confirm results obtained from similar studies done in 1979 on Unit 1, MEC conducted one intake-diffuser sampling survey. (It was assumed that ichthyoplankton losses could only be greater than zooplankton losses, and would need study only if zooplankton losses were small). In order to document these transit loss processes, macrozooplankton and chemistry samples were collected from the intakes and one diffuser port from each Unit to estimate (1) the amount and kinds of macrozooplankton that are altered in transit through SONGS intake-diffuser system, (2) in what phase (dissolved, particulate, living or dead) material exits the diffusers relative to how it enters the intakes and (3) how the material exiting the diffuser alters the ambient water conditions near the diffusers.

3.5.1 Field Sampling

Samples were collected on 5 December 1986 from stations near the intakes of Units 2 and 3, from within a diffuser port of each unit, at a downcurrent station within the discharge plume and at an ambient station 2 km downcoast of the diffuser lines. This last location was upcurrent of the diffusers at the time of sampling.

The intake sampling locations were positioned at mid-depth about 5 meters or less away from the intake structures and within the influence of the intakes. The diffuser samples were collected from within a diffuser port. Contamination of diffuser water by ambient water was shown to be negligible as measured by a Turner Fluorometer during a preliminary trial when rhodamine dye, released by divers around the diffuser port, was not observed in the pumped sample water. The plume station was selected to be 0.5 km downcurrent (downcoast) of the Unit 2 discharge line at about the 12 m depth contour which was the inshore-offshore midpoint of the full lengths of both diffusers. Visual observations by the sampling crew of current direction, high turbidity at the plume station and low turbidity upcoast of the diffuser lines at the same isobath were used to ensure the station was in the diffuser plume. The plume was sampled at the depth of 1 m. Previous dye studies performed by ECO-M in May, 1986, demonstrated that plume water was generally confined to the upper 4 meters of the water column. Each Unit was sampled separately for intake/diffuser sampling. Because Units 2 and 3 are multiple port diffuser systems, through-plant lag times for a parcel of water can vary with Unit and port. Therefore the lag times were determined empirically for the port in question on the dates of sampling by injecting rhodamine dye into the intake and timing its appearance at the selected diffuser port as detected by a Turner Fluorometer. The lag times, determined for Unit 2 was 40 minutes; for Unit 3, 33 minutes.

Total organic carbon (TOC), seston dry weight, particulate organic carbon (POC), dissolved organic carbon (DOC), and adenosine triphosphate (ATP) were taken at the following four stations: 1) Unit 3 Intake, 2) Unit 3 Diffuser, 3) Plume, and 4) Ambient.

At these stations, water was pumped continuously from depth into a seawater receiving trough. At 10-minute intervals, for a total of 10 samples, an unfiltered, 4-gallon sample was removed by clean plastic bucket from the trough. From this bucket, a 4-liter sample was immediately removed using a 4-liter graduated cylinder. This sample was mixed before removing any subsamples by pouring it into another 4-liter graduated cylinder and then back again. A 1-liter subsample was then removed for TOC analysis and transferred into an acid cleaned nalgene sample bottle. Twenty drops of concentrated sulfuric acid were added, the bottle sealed, and inverted several times to thoroughly mix and acidify the sample. A second 1-liter subsample was removed for seston dry weight and filtered through a pre-weighed GF/C filter. After filtration the funnel and filter were rinsed with deionized water to flush all residual seston to the filter and remove any inorganic salts. The filter was removed and placed in a labeled petri dish and frozen on dry ice. A third 1-liter subsample was removed for POC analysis and treated exactly like the seston dry weight subsample with the exception that a pre-combusted GF/C filter was used in place of a pre-weighed GF/C filter. A 250 ml subsample of the filtrate collected from the POC sample was removed for DOC analysis. This subsample was placed in a nalgene bottle, acidified with 5 drops of sulfuric acid, sealed and inverted several times to mix.

Macrozooplankton samples were taken at five stations: 1) Unit 2 intake, 2) Unit 2 diffuser, 3) Unit 3 intake, 4) Unit 3 diffuser, and 5) plume. These samples were collected (between samplings for chemistry at chemistry stations) using a centrifugal pump with delivery flowrates of 0.85 to 1.33 m^3/minute. Flowrates were determined by measuring the times necessary to fill known volumes. Twenty 1-minute macrozooplankton samples were collected, one every 5 minutes at Unit 3 intake and diffuser locations; ten 1-minute samples, one every 2 minutes, were taken at Unit 2 intake and diffuser locations; and ten 1-minute samples were taken every 2.5 minutes at the plume location. Samples were filtered through a 0.202 mm mesh net. Collected plankton were preserved in 5% formalin seawater. Formalin solutions were buffered to pH 7.0 prior to use.

3.5.2 Laboratory Analysis

Ten individual samples from each location were analyzed for zooplankton in the same manner as described for monitoring samples (see Section 3.2.2) with the following exceptions. An average of twenty individuals from a minimum of two subsamples were used for the estimates. Taxa not meeting this criterion were considered rare and were counted in the entire sample. Raw counts were converted to numbers per cubic meter.

TOC, POC and DOC samples were analyzed by non-dispersive infrared analyses on an Oceanography International Corporation Model 524B Carbon System following recommended methods of the manufacturer as outlined in MRC's Data Standards document (in prep.). The only modification to these procedures was to divide the POC filters into thirds for analysis. Filter blanks were also divided into thirds to obtain an average blank value for a third of a filter. POC values for each third, after subtracting out the average carbon value for a third of a filter, were summed to obtain the total POC value for the whole filter.

Seston dry weight was determined by drying the filters and seston samples to a constant weight at 65°C, weighing the samples and then subtracting the filter weight.

3.6 Intake Loss Surveys

Intake withdrawal was expected to be one of the major effects of SONGS. From October 1985 through January 1986 when monitoring surveys for ichthyoplankton and zooplankton were not conducted, MEC collected samples specifically for intake losses.

3.6.1 Frequency of Sampling

The intake loss surveys were conducted on a triweekly basis, following the schedule used for ichthyoplankton monitoring surveys (Table 3-1).

3.6.2 Field Sampling

Collection techniques were identical to those utilized in the monitoring surveys. The stations sampled were those SONGS monitoring stations closest to the intake depth (9 m). Epibenthos, midwater, and neuston ichthyoplankton samples were collected on the SONGS transect line 1 km downcoast of SONGS in either Block A or Block B, whichever had a randomly selected sampling isobath closest to 9 m (see Figure 3-1). Epibenthos, midwater, and surface zooplankton samples (macrozooplankton and microzooplankton) were collected on the SONGS line directly offshore of SONGS at the 8 m sampling station (see Figure 3-3).

3.6.3 Sample Analysis

The laboratory analysis techniques were identical to those described above for the monitoring samples.

3.7 Analytical Methodology

We utilized three approaches to identify SONGS effects on the ichthyoplankton and macrozooplankton. These were:

(1) Application of the BACI procedure, which determines changes in the relative cross-shelf abundance of a species with respect to location and SONGS operation;

(2) Analyses of cross-shelf abundance patterns to investigate whether shifts in a species' distribution occurred after SONGS operation began; and

(3) The calculation of intake withdrawal losses during the After period to provide an estimate of minimum SONGS effects which may be qualitatively linked with the results of BACI analyses. Additionally, potential but unproven losses that could result from diffuser activity were calculated.

3.7.1 BACI

To determine whether there were changes in plankton abundances that could be associated with SONGS operations, the monitoring studies were conducted according to the requirements of an analytical design called BACI, an acronym for Before-After/Control-Impact. The rationale and framework of the BACI procedure is presented in the next sections.

3.7.1.1 BACI Model Description

The philosophy of the BACI procedure is simple. Synoptic observations are made on a number of species at both an "Impact" location close to the power plant intakes and diffusers and at a "Control" location far enough away from the power plant to not be influenced by it, but close enough to represent a similar habitat with similar populations of organisms. Abundance observations are taken a number of times "Before" the power plant is operational, and again a number of times "After" the power plant is operating. Plant start-up time and independence of observations determine the number of surveys in the Before period; i.e., measurements cannot be too close together because they are then essentially duplicate observations. At the end of the Before period the number of surveys required in the After period to yield the desired power of the statistical test is calculated (and hence "fixed"). This is discussed further below. Control locations are chosen with care to mimic, as nearly as possible, natural changes occurring in populations at the Impact site in the Before period. Thus, any differences in the Control/Impact relationship in the After period compared to the Before period can be attributed to SONGS unless plausible alternative explanations are available. Impact minus Control differences, called Deltas, estimate the difference in population sizes between the two sites at the times observed. The average Delta in the Before or After period estimates the mean difference in population size for that period. A significant difference between the average Delta in the Before time period and the average Delta in the After time period would suggest that the power plant is having an effect on the population at the Impact site.

For many species in the studies the average Delta in the Before time period was zero, indicating the populations at the two sites were of the same size. If the populations were not of the same size in the Before period, we looked for a continuation of the same relative difference in the After period. If the average Delta in the After period were more negative than the Before Delta, this would indicate that the population near the power plant had decreased in size relative to the Control site population.

Note that since BACI analysis is performed on the Deltas, which are a measure of the relationship between population sizes at the Impact and Control locations, variations in population sizes in response to natural phenomona that act equally at both locations do not affect the analysis. Theoretically then, the design allows SONGS effects to be

Species often do not react in an additive way to an event, but instead behave multiplicatively, for example, by doubling or halving. In this case the BACI model must be expressed in the multiplicative form as follows:

	Impact	Control
Before	$\mu \times L$	μ
After	$\mu \times L \times T \times S$	$\mu \times T$

Notice that this model replaces the plus signs of the additive model with multiplication signs. In the multiplicative model the parameters L, T, and S are all proportional changes rather than differences. For example, L = 1.2 indicates that abundances at the Impact location are 120% of abundances at the Control site (i.e., Impact abundance exceeds Control abundance by 20%).

To perform statistical analyses on a multiplicative model, it must be linearized (i.e., made additive). Linearization is accomplished by taking logarithms of the observations. Since $\log(\mu \times L \times T \times S) = \log(\mu) + \log(L) + \log(T) + \log(S)$, we now have the additive model already described, with the parameters replaced by log (parameter).

In the multiplicative model, averages of the observations are averages of log-transformed observations and estimates of the parameters as given in the additive model become estimates of log-transformed parameters. Thus, for the multiplicative model, estimates of the parameters are given by:

$L = \text{antilog}\ (Y_{IB} - Y_{CB})$

$T = \text{antilog}\ (Y_{CA} - Y_{CB})$

$S = \text{antilog}\ ((Y_{IA} - Y_{CA}) - (Y_{IB} - Y_{CB}))$

$S = \text{antilog}\ (\text{DELTA}_A - \text{DELTA}_B)$

where the Y's are averages of log-transformed data and the Deltas are differences of averages of log-transformed data. S, the SONGS effect parameter, represents a proportion applied to the mean abundance that would have been found at the Impact location if the power plant were not there. For example, if S = .6 it means that the abundance of organisms at the Impact location with SONGS present was 60% of the level that would have been measured there if the power plant were not present. Or, stated differently, the power plant has caused a (1 - S) = 40% reduction in the abundance of organisms.

We wish to emphasize that when a multiplicative model is invoked all analyses are performed on log-transformed data. Results from log-transformed data analyses can sometimes be different from what one would expect by looking at the untransformed data. We discuss below both how we decided whether to use an additive or a multiplicative model, and how we attempted to reconcile the differences between these two ways of looking at the data.

The BACI test reduces to a t-test of the null hypothesis,

H_o: $\mathrm{DELTA}_A - \mathrm{DELTA}_B = 0$.

The alternative hypothesis can be either H_a: $\mathrm{DELTA}_A \neq \mathrm{DELTA}_B$, which is a two-tailed test (used for macrozooplankton and chlorophyll), or H_a: $\mathrm{DELTA}_A < \mathrm{DELTA}_B$, which is a one-tailed test (used for ichthyoplankton). A one-tailed test was used to test for decreases in ichthyoplankton abundance because no mechanism could be envisioned, a priori, by which SONGS could cause increases in abundance. In the end, only one taxon showed increases that would have been significant had a two-tailed test been used. A two-tailed test was used for zooplankton and chlorophyll because of the possibility that SONGS-induced hydrographic changes could stimulate, as well as depress, phytoplankton production, and hence zooplankton population growth. In both tests, a t-statistic is calculated, equal to the difference between the two Deltas divided by an estimate of the pooled standard error of that difference. Degrees of freedom for this t-test are 2 less than the total number of surveys taken.

Any survey that yielded an observation of zero abundance at both sites for a particular taxon was dropped from the analysis for that taxon. This was done because no useful information is added (some organisms could have been present but their abundances were below our threshhold of detection) while the variance of the Deltas is artifically reduced, by keeping the zero-zero observation.

Before the t-statistic was calculated, the variance of the Before Deltas was compared to the variance of the After Deltas by use of an F-test evaluated at $\alpha=0.05$. If the variances were equal, then the t-statistic was calculated. However, if the variances were unequal, then an approximate t-statistic and Satterthwaite's degrees of freedom were used. This t-statistic uses the sum of variances of the means rather than the pooled variance, and Satterthwaite adjusts the degrees of freedom depending on the values of the two estimated variances.

A p-value was calculated (the p-value is the probability, under the null hypothesis of no difference, of getting a t-statistic at least as large as the one obtained by chance alone) and a significance level was chosen (either 0.05 or 0.10; see Section 3.7.1.4 for choice rationales). If the p-value was less than or equal to the significance level, the null hypothesis was rejected and a SONGS effect was indicated. Performing the BACI test thusly means that there was a 0.05 (or 0.10) Type I error rate; i.e., a 0.05 (or 0.10) chance that the null hypothesis would be incorrectly rejected.

The power of a test is the probability of correctly rejecting the null hypothesis. The MEC monitoring plan was designed, using a select group of species, to attain a power (probability) of 0.80 to detect a 50% change (or decrease) with a significance level of 0.05. Whether or not this level of power is attained depends on the magnitude of the difference between the mean of the Before Deltas and the mean of the After Deltas and on the amount of variability in the Before and After periods. The power of each BACI test was calculated and reported.

In order for the stated Type I error and power to be close to the true error and power, certain assumptions must be met. The next section briefly discusses these assumptions, how they were tested, how their absence could affect the test results, and how this could be corrected for. For a more complete exposition of the BACI model and assumptions see Stewart-Oaten (1986).

3.7.1.2 BACI Assumptions Description

In order that the BACI hypothesis of $\mathrm{DELTA}_A = \mathrm{DELTA}_B$ is meaningful and that the Type I error and power are valid, the following assumptions on the Deltas must be met:

- additivity in the Before time period,
- lack of trends with time in the Before time period,
- lack of serial correlation in both time periods, and
- normally distributed errors in both time periods.

Each of these assumptions will be discussed below. Appendix C presents the protocol developed to examine the assumptions tests in order to minimize subjective interpretations.

The Additivity Assumption

A fundamental assumption in framing the BACI hypothesis is that the Deltas within each time period are observations from the same distribution; in particular, the mean Delta must be constant over all surveys within a period. This is a restatement of the assumption for a t-test that the observations, in this case Deltas, must be independent and identically distributed.

How is this assumption violated? Consider a species that responds to events in a multiplicative manner; e.g., in response to an event, the population size either halves or doubles. For the first survey, the true population size at Control is 100 and at Impact it is 400, yielding a Delta of 300. Suppose that an upwelling event occurs before the second survey and the populations double; now there are 200 at Control and 800 at Impact for a Delta of 600. The "true" mean Delta of the second survey does not equal the "true" mean Delta of the first survey. In a multiplicative response, the mean Delta will be large when the abundances are large and the mean Delta will be small when the abundances are small. There is not a single mean Delta on which to base a hypothesis. For an additive response, the 100 at Control would increase to 400, say, and the 400 at Impact would increase to 700, yielding a Delta of 300, the same as the earlier survey. Note that when abundances, or concentrations, are low it is difficult to distinguish between additive and multiplicative responses. For example, if initial abundances are less than 10, a 20% decrease is approximately the same as a decrease of 1.5 organisms.

The test for a constant mean Delta over time is the additivity test. In essence, we look to see whether the observed Deltas are of the same size for small and large abundances. The sum of Control + Impact is used as an indication of abundance. A regression is fit on Delta versus the sum; if the regression line has zero slope, then the Deltas are additive, otherwise they are non-additive, except in certain circumstances described below.

Lack of additivity indicates that we do not have a testable hypothesis. Two possible solutions to this problem are described here. One is to check the additivity regression test for problems such as influence points or zeros which may lead to an incorrect interpretation. An influence point is an outlier, usually at either end of the regression line, whose presence or absence causes a large change in the value of the slope. In addition, if the abundances of a species contain many zeroes at one location, then the Delta (SONGS minus Control) versus sum (SONGS plus Control) line approximately equals ± 45 degrees. In this case, the result is an artifact of the additivity test structure and the test is not appropriate.

The other solution is to invoke the multiplicative model and log-transform the abundance data. If abundances are multiplicative (e.g., 2x), then taking the log linearizes them (e.g., log (2x) = log (2) + log (x)). The Deltas are then the differences between the log-transformed abundances. Note that we refer later in the text to log-transformed Deltas, by which we mean Deltas of the log-transformed abundances.

Using a log transformation introduces a new problem: the abundance data often include many zeroes, and since the log of zero is undefined, zero observations do not fit the multiplicative model. Two solutions to this problem are (1) to eliminate the surveys containing a zero observation and perform analyses on the smaller data set; or (2) to force a multiplicative model by adding a small constant amount to all observations before log-transforming. Since the most appropriate size of the constant to be added is unknown, a number of different constants were tried and tested for all BACI assumptions.

In the situation where one cell of observations (e.g., Before SONGS) contains a preponderance of zero abundance values, the size of the constant added to all observations before log-transforming can control the results of the BACI test. We used a Chi^2 test to identify these cases. When such circumstances were shown to exist, the BACI analyses were not used as the primary tests, and were only used as corroborative tests when more than one log(x+constant) transformation passed all assumption tests.

In general, we found that the results of the BACI t-test and calculation of percent change obtained by using log-transformed Deltas depended on the size of the constant added to the abundances. There are no unambiguous criteria for selecting a constant; rather, a range of constants can be found which satisfy all necessary assumptions. However, the order of surveys arranged from smallest to largest untransformed Delta changed radically when the abundances were log-transformed, in a way that depended on the constant. This, in turn, sometimes led to different results in BACI testing and even to different directions of effects; i.e., a decrease in the relative abundance using untransformed data sometimes became an increase when we used log-transformed data.

Taking differences of log-transformed data causes this difficulty. Figure 3-5 shows how this can happen. In this figure, the horizontal axis is untransformed abundance and the vertical axis is log-transformed abundance. The curve is a logarithm curve which crosses the horizontal axis at 1 (log (1) = 0 for all bases), is negative and very steep for abundances less than 1, and is positive and less steep for abundances greater than 1. Abundances A_1 and A_2 are both less than 1, and the Δ of log-transformed data, called log Δ_1 on the figure, is much larger than the Δ of the untransformed data, Δ_1. On the other hand, when abundances are larger than 1, as in A_3 and A_4, then the Δ of the log-transformed abundances, called log Δ_2, is smaller than the Δ of the untransformed abundances, Δ_2. For this situation, Δ_2 minus Δ_1 is positive, indicating that Δ_2 is larger than Δ_1, but log Δ_2 minus log Δ_1 is negative. If most of the Before abundances were less than 1 (a situation which can happen in cross-shelf data since these "abundances" are expressed as number/400 m^3 for ichthyoplankton and number/1 m^3 for zooplankton) and most of the After abundances were greater than 1, our results would reflect this graph. Note that adding a constant before taking a log shifts the abundances right or left on the horizontal axis and thus can maximize or minimize this effect but can never get rid of it because of the shape of the logarithm curve. We found situations in which the untransformed data appear to indicate a change in one direction, but BACI results on log-transformed data showed a change in the opposite direction (e.g., Ilypnus gilberti preflexion stage larvae). In such situations, the direction of the change indicated by the BACI test was the direction we discussed in our results.

Because log-transformed results are more difficult to interpret and understand, we preferred to perform BACI testing on untransformed data whenever possible, and to use log transformations only when necessary to meet the requisite BACI assumptions. We also discussed untransformed species abundance whether or not BACI testing was performed on log transformations. The percent relative change in abundance values in our discussions are, however, based on transformed data when BACI testing was performed on transformed data. Percent relative changes based on both transformed and untransformed data are given in Appendix D.

Trends in the Before Time Period Assumption

For a testable hypothesis the Deltas cannot exhibit a trend with time in the Before time period. If the Deltas did trend with time, for example if they were increasing, then the Control site population would not be mimicking the Impact site population changes. In other words, the Control site would not be a good match for the Impact site in the Before period. If the two sites did not match in the Before period, any change in the After period could not be attributed to SONGS.

To test for trends we performed a regression on the Deltas with time and looked for a non-zero slope. As with additivity, an outlier at either end of the regression line can cause a non-zero slope. Also, note that non-additivity with increasing (or decreasing) abundances over time could also appear as a trend with time; therefore, a linearizing transformation (log(x), log (x + C), inverse, square root) may detrend a data set. In general, very few species had the problem of trends with time once the data were transformed. When trends persisted after transformation, the BACI t-test could not be performed.

Trends in the After time period could be the result of a slow response to SONGS. Therefore, trends in the After time period were looked for and noted as a possible SONGS effect.

Serial Correlation Assumption

A necessary assumption to perform a t-test is that the data be independently distributed. If the data are serially correlated, then, in effect, the investigator has observed too frequently. The process being observed has not had enough time to change. The result is that the variance is underestimated, causing the t-statistic to be inflated and thereby rejecting the null hypothesis too often. Serial correlation was detected by use of the von Neumann test for serial correlation in deviations from the mean. Tables of significance were taken from Anderson (1970: Table 6.3).

The solution to this problem is to incorporate the serial correlation into the model; instead of independent errors, the errors are autoregressive. The difference can most easily be seen in a statement of the models involved. For the independent errors BACI t-test the model is:

$$\text{Delta}_{jk} = \mu + D_k S + \varepsilon_{jk}$$

where k = 1 for observations in the Before period
2 for observations in the After period
j = survey number within a period
μ = Before time period mean Delta
D_k = 0 for $k = 1$, Before period observations
1 for $k = 2$, After period observations
S = SONGS effect
ε_{jk} = independent, normal $(0,\sigma^2)$ random errors

For serially correlated data, only the error term in the above model changes, incorporating autoregressive terms:

$$\varepsilon_{jk} = A_1 \varepsilon_{j-1,k} + A_2 \varepsilon_{j-2,k} + \nu_{jk}$$

where A_1 = coefficient of first order autoregressive term
A_2 = coefficient of second order autoregressive term
ν_{jk} = independent, normal $(0, \sigma^2)$ random errors

Maximum likelihood techniques are used to estimate all the coefficients in the autoregressive errors model. With 2 extra terms in the model, A_1 and A_2, the degrees of freedom now decrease by 2. However, the trade off is that we have ν, an estimate of error free of autoregressive correlation, to be used as the error term (MSE) in the BACI t-test. The p-value from the autoregressive t-test for the BACI effects is asymptotically correct, with valid results for sample sizes greater than 30 when correlations are small (Fuller, 1976).

Fitting observations unequally spaced in time to a correlated errors model as if they were equally spaced can generate correlations in the residuals. For example, consider observations closely spaced at the beginning of a series, and widely spaced at the end of the series, with correlations at the beginning and independence at the end. Fitting a correlated model to this data could yield residuals which are uncorrelated for the closely spaced observations, but could introduce a correlation which did not exist in the residuals for the observations that are truly farther apart. We looked for this phenomenon by performing a Durbin-Watson test on the residuals from the autocorrelated errors model. In all cases, these residuals were independent.

For serially-correlated data, models were originally overfit with three autoregressive terms in the error model. The third order model was rarely significant and thus the final model adopted typically contained only two autoregressive terms. We chose between the significant models on the basis of minimizing the MSE, AIC (Akaike Information Criterion) and SBC (Schwartz Information Criterion) terms of the model. The single most appropriate model was used in the BACI test.

There were times when the autoregressive errors procedure indicated that serial correlation was not present in the full data set (i.e., none of the models was significant). When this occurred, we used the results of the BACI t-test.

Normally Distributed Errors

Along with independent, identically distributed observations, a t-test assumes that the observations are normally, or Gaussian, distributed. Since the t-test is known to be robust against this assumption, meaning the error levels are still accurate even if the data are non-normal, we did not explicitly test for normality. However, as an aid in choosing a constant with the log-transformation, we performed Gupta's test for symmetry (Antille et al., 1982) whenever a transformation was necessary. This test was used to avoid the very skewed distributions that the log $(x + c)$ transformation can produce.

3.7.1.3 Secondary Tests

In place of, or as a confirmation of, the BACI t-tests, several other analyses were performed. These procedures, all of which are discussed below, were: Wilcoxon rank sum tests, a SONGS versus Control regression procedure, and a binomial SONGS effect test. In addition, the BACI t-tests or Wilcoxon rank sum tests were performed on two subsets of the After data, representing surveys taken when the Impact site was estimated to be under the influence of the discharge plume (plume dates) and surveys taken when it was not (non-plume dates). These tests were used to aid in the interpretation of the primary BACI test based on the full After data set.

Wilcoxon Rank Sum Test

We used the results of the nonparametric BACI Wilcoxon rank sum test as a substitute for the BACI t-test when influence points (violating the additivity assumption) were found. Because averages are sensitive to outliers, their presence could strongly affect the BACI t-test results. The Wilcoxon rank sum test was used for corroboration of BACI t-test results when no outliers were present.

We applied the Wilcoxon rank sum test to the Deltas. Assuming the distributions of the Deltas in the two time periods were identical except for a possible shift in their median positioning, L, the null hypothesis is that $L_A - L_B = 0$, with either a two-tailed alternative hypothesis, $L_A - L_B \neq 0$ (for macrozooplankton), or a one-tailed alternative hypothesis, $L_A - L_B < 0$ (for ichthyoplankton). All the Deltas were ordered and ranked. Under the null hypothesis, the ranks should be randomly distributed between the two periods. We computed the sum of the ranks of the Deltas within the time period with the smallest number of surveys. We then calculated the p-level, which indicated the probability, under the null hypothesis, of obtaining the sum of ranks observed or a sum indicating a less random distribution of ranks.

Occasionally the Wilcoxon rank sum test and the BACI t-test gave different results (e.g., Evadne nordmanni). These divergences can be explained in terms of the size of the numbers and their variabilities. For example, suppose that the Before Deltas were mostly positive with a few large positive Deltas and some negative Deltas, and the After Deltas were all negative but very small in magnitude. As a result of the large variability, the BACI t-test would find no significant differences, but the Wilcoxon test would find a significant change from mostly positive Deltas to all negative Deltas. Conversely, one extremely large positive

Delta in the Before period and another extremely large negative Delta in the After period (both outliers) could cause the BACI t-test to find significant differences because it is influenced by the size of the outliers. The Wilcoxon test, however, looks only at the ranks of the Deltas and, not being influenced by the size of the outliers, may find no differences. We encountered both of these situations.

SONGS versus Control Regressions

Plots of SONGS versus Control values provide a visual aid in understanding possible SONGS effects. This analysis was used to interpret conflicting additivity test results, to look for non-linear SONGS effects, and as a corroboration of BACI and binomial (see below) test results. SONGS effects can be tested by fitting various functions to the SONGS/Control relationship and testing for non-zero coefficients.

If the SONGS-Control Deltas are additive, then $S - C = d$ or $S = d + (1 \times C)$. In other words, the SONGS versus Control graph will be a 45 degree line (slope = 1) with an intercept at d. The SONGS/Control relationship in the After period with a SONGS effect would also be a 45 degree line with a different intercept, d_1, which would be less than d. This graph would consist of two parallel, 45 degree lines separated by a constant amount equal to $d - d_1$, the SONGS effect.

We fit a straight line regression model to the SONGS/Control data for each period separately. We then looked for equality of slopes and intercepts. If the slopes were equal but the intercepts were not, that was taken as evidence of a SONGS effect equal to the change in intercepts. If the slopes of the Before and After regressions were not equal, then SONGS may have had a more complicated effect. Note that slopes not equal to one imply a multiplicative model in the Deltas.

We also fit curved lines to the SONGS versus Control data. Data to which curved lines could be fit exhibit a more complicated form of multiplicativity. If the regression fit two parallel curved lines to the data, then the interpretation was that the relationship between SONGS and Control abundances was the same in both time periods, but the level of abundance changed in the After time period. If two different curved lines were fit to the data, then the SONGS/Control relationship in the Before time period differed from that in the After time period.

This regression procedure, like all regression analyses, was sensitive to influence points. Very occasionally we deleted one or two such points to see results without their influence.

Binomial SONGS Effect Test

A binomial-form test was developed for those species that were not amenable to BACI t-testing as a result of lack of additivity or trends in the Before data (e.g., Hypsopsetta guttulata preflexion stage larvae). Linear trends with time imply that the Control site is inadequate for a given species, but serial correlation can be incorporated into a binomial model. If the SONGS minus Control differences do not have a constant mean (non-additivity of the untransformed Deltas), or if the SONGS/Control ratio does not have a constant mean (non-additivity of log-transformed Deltas), perhaps the proportion of organisms at SONGS relative to the sum of SONGS and Control is constant. Following this line of thought led to development of the binomial test on the estimated proportions. The binomial test examined whether the proportion of the abundance of an organism at SONGS relative to its abundances at SONGS and Control was constant. We made two fundamental assumptions for this binomial test: (1) For each individual organism found at either SONGS or Control on a given date, the probability that this organism came from SONGS was independent of the same probability for all other individuals, and (2) the probability that an organism came from the SONGS site was constant over time. Incorporating these two assumptions into standard binomial tests lead to a modified binomial test on $Z = S/(S + C)$ where S equals the sum of abundances found over all surveys at the Impact location within one time period, and C equals the sum of all abundances found over all surveys at the Control site within the same time period. The binomial test compares this estimated Z in the Before period to the estimated Z in the After period and is evaluated at $\alpha=0.05$.

Plume/Non-plume Analyses

BACI analyses were made on subsets of the operational data classified by the presence or absence of plume water (plume/non-plume). The rationale for doing this was that the principal SONGS effects on ichthyoplankton and zooplankton were thought to be intake withdrawal and entrainment in the discharge plume. Since both of these should be detectable as abundance changes in the plume, limitation of the BACI analysis to After surveys when the plume was present should yield an estimate of the worst-case scenario. These analyses were conducted in order to help interpret the principal BACI test results.

The determination of whether or not a survey was a "plume" survey was based upon the percentage of the past 48 hours that plume waters were present at the SONGS sampling stations (Blocks A-D for ichthyoplankton, and the 8, 13, and 30 m zooplankton stations). If the sum of the values at all stations equalled or exceeded 50%, then the survey was a plume survey. The summation criterion was used because the plume could either retain its integrity and stay near one station, or spread out and occur at several stations. The percentage of time that plume water was at a station was determined by the use of a model (Reitzel et al., 1987) that used current speed, current direction, pump operating level (from the MRC databases DBUVT and BSONGS), and eddy diffusion to backtrack the water that was at the sampling station. Water at the station was classified as plume water if it had left the diffusers within the previous 48 hours. The model determines presence or absence of plume water for each hour. The percentage of time that the plume was present can be calculated by adding up the number of hours during which the plume was present and dividing by the length of the period. For our criterion, the presence/absence record for the previous 48 hours was used.

This classification does not distinguish between water that crossed the diffusers more recently, and that which crossed less recently, within the previous 48 hours. Between the diffusers and the SONGS station, plume water mixes with ambient water; the longer the transit time, the more mixing will occur. If the cut-off age were taken as 24 hours instead of 48, the fraction of hours classified as plume should be smaller, but the strength of the plume in those hours should be greater. The 48 hour cut-off may lead to inclusion of some very dilute plume waters in the plume category, but this will not generally result in overestimating either the magnitude or the statistical significance of any plume effects detected (Reitzel et al., 1987). The classification also does not distinguish the location of the plume in the water column at any site. Since we intended to use the classification only as an index of plume presence or absence, this was not considered a serious drawback.

All surveys taken when plume water (as defined above) was present at the SONGS transect were tagged as plume surveys; other surveys were considered non-plume surveys. Separate BACI analyses were performed on both the plume and non-plume collections of surveys. In the plume group, we have in some sense maximized the plume effect with a concomitant decrease of degrees of freedom. In this group we expect to find at the least those SONGS effects seen in the full data base, and may find others not seen in the full data base. On the other hand, SONGS effects associated with the plume should be difficult to detect with the non-plume set of surveys.

The plume and non-plume analyses are used in interpreting the results of the principal BACI tests on the full data set. For example, if tests on the full data set and the plume subset reveal an effect, this is considered to be a SONGS effect unless a plausible alternative explanation is available. An effect detected in the plume subset but not in the full data set is interpreted as a SONGS effect below the detection level of the principal test on the full data set. This may reflect a small effect, or low power of the principal test, or both. If an effect is detected in both the full data set and the non-plume subset, this is not considered a SONGS effect.

3.7.1.4 MEC's Application of the BACI Procedure

The BACI procedure is a major approach to assess whether SONGS effects occur. Over the course of MEC's monitoring of San Onofre for the MRC, the general approach, assumptions, and procedure of BACI have received intensive critical scrutiny. The BACI procedure that has evolved out of these discussions includes both testing and descriptive applications. The descriptive applications include examining the data for conformity with BACI assumptions, and comparing t-test results and non-parametric test results for consistency among several transformations of the data. However, at the core of the BACI approach is a single test per species, or developmental stage of a species, for the significance of differences between Before and After Deltas.

Since the multiple testing used in the a posteriori descriptive examinations may invalidate the results of the BACI test, we developed a protocol (Appendix C) to separate the BACI testing from the further description. First, BACI results were reported for one selected data treatment (untransformed data whenever appropriate). Second, the results for other transformations were examined to gain insight into consistency among transformations, for corroboration of the primary statistical test, and for any further information that might be contained in the data.

Whenever possible we preferred to use the untransformed data. The low absolute values of most of our data suggest that additive models are appropriate; in fact, extensive trials with other transformtions (e.g., log(x), log(x+c), inverse, and square root) did not substantially improve the degree to which the data were amenable to statistical analysis or our ability to interpret the data. Finally, in most cases where there were zero observations, the log(x + c) transformations, initially thought to be most desirable, were too sensitive to the value of the constant, c. Thus, we did all that we reasonably could in our analytical protocol to accept untransformed data before resorting to the imposition of a transformation.

Description of Change

The number of surveys to be taken in the After time period was calculated on the basis of the requirement that the power (probability) to detect a 50% change in abundance be at least 80%. The 50% change in abundance was estimated by assuming that abundance levels at the Control site would remain constant and that abundance levels at the SONGS site would double or decrease by half. For this report we wished to retain this perspective and therefore calculated a percent change which could be compared to that used in estimating sample size.

As discussed in Section 3.7.1.1, within an additive model, Delta_A estimates the location effect, and Delta_B estimates the location effect and the SONGS effect. Thus, Delta_A - Delta_B estimates only the SONGS effect, S, or the number of organisms lost due to the presence of the plant. We have taken this number and expressed it as a percent relative to the average number of organisms found at SONGS in the Before time period. It is reported as the percent change in abundance of the organism.

When the multiplicative model was invoked, it became more difficult to estimate percent change. BACI testing for the multiplicative model is performed on Deltas of log-transformed data, a transformation which is non-linear and non-monotonic. Thus, it is not surprising that (1 - S), which estimates the proportional loss due to SONGS relative to the abundance which would have been at SONGS if the power plant were not there, cannot be easily related to the untransformed data. If a measure of the abundance at the Impact site in the After time period without the presence of SONGS were available, we could simply multiply this abundance by (S - 1) to estimate the number of organisms lost and then divide by the average at SONGS in the Before time period to obtain a percent change comparable to that of the additive model. However, since this could not be done, as an alternative, we estimated the abundance at the After Impact site in the absence of the power plant, and the number of organisms lost to the SONGS effect, in the following manner. Mean abundances in the four location/period cells of the BACI model, Y_{IB}, Y_{CB}, Y_{IA}, and Y_{CA} as in Section 3.7.1.1, were estimated using untransformed data. Using a multiplicative model, we estimated the parameters L (location effect), T (time effect), and S (SONGS effect: see Section 3.7.1.1) as:

$T = Y_{CA} / Y_{CB}$

$L = Y_{IB} / Y_{CB}$

$S \times T = Y_{IA} / Y_{IB}$

$S = (S \times T) / T = (Y_{IA} / Y_{IB}) / (Y_{CA} / Y_{CB})$

$S - 1$ = SONGS change factor

$Y_{CB} \times T \times L$ = abundance at the Impact Site in the After time period without the power plant

$Y_{CB} \times T \times L \times (S - 1)$ = abundance lost at the Impact Site in the After period due to SONGS

% Relative Change = $100 (Y_{CB} \times T \times L \times (S - 1)) / Y_{IB}$.

Once T, L, and S have been estimated, S - 1 represents the estimated proportion of organisms at SONGS lost due to the presence of the power plant. This proportion is relative to the number of organisms that would have been found at the Impact site if the power plant were not present. Thus, to estimate the number of organisms lost due to the presence of the power plant, we need to estimate the number of organisms that would have been observed in the absence of the power plant. This number is estimated as the average abundance at the Control site in the Before period, times the proportional increase (or decrease) due to location, times the proportional change due to time, or Y_{CB} x L x T. Multiplying Y_{CB} x L x T by (S - 1) yields the number of organisms lost due to the presence of the power plant. Dividing this number by the average abundance at the Impact site in the Before time period yields a percent change comparable to that calculated with the additive model.

Because this estimate of percent change is based on arithmetic means applied to a multiplicative model, the percentage found may differ in sign from that found using geometric means (i.e., means of log-transformed data), which is what the fully multiplicative model uses. Furthermore, this method often yields relative decreases of more than 100%. Although this seems counterintuitive, what these large decreases mean is that measured abundance decreased at the Impact site whereas in the absence of the power plant it would have been expected to increase.

BACI Testing

The level of significance (α-level) for the BACI test was selected to be either 0.05 or 0.10; the power of the BACI t-test was used as the selection criterion (recall that the power of the BACI test is the probability of detecting a 50% decrease or increase when such a change has truly occurred). When the sampling plan for monitoring was established, the number of surveys to be taken in the After Period was based on power analyses of the Before data. The number of After Surveys for zooplankton and ichthyoplankton were selected to attain a power of 80% to detect a 50% relative change (decrease for ichthyoplankton) in the populations of some of the most abundant species and some of the other taxa (Tables 3-4, 3-5). The remaining species were more variable than this group and as a result the powers of their BACI t-tests were lower than 80%. For these remaining species, we felt that a significance level of 0.10 was appropriate. Additionally, some of the species that we predicted would have sufficient power on the basis of the Before period data, did not because the SONGS-Control Deltas in the After Period data were more variable than anticipated. Therefore, for a given level of effort either a lower power could be accepted or the α-level could be increased to retain some, if not all, the desired power. We chose to do the latter. For species or taxa with power of less than 80% we used the 0.10 significance level. This increased our chance of recognizing an effect if one had occurred, but at the same time it increased the likelihood (to 10%) that we would declare an effect when in fact there was none.

Once the significance level was selected and the p-level for the BACI t-test was produced, a p-level less than or equal to the selected significance level caused rejection of the null hypothesis of no relative change in Deltas. All other p-levels, regardless of how near to the selected significance level, did not allow us to reject the null hypothesis. This p-level criterion was also applied to the Wilcoxon rank sum tests and to the autoregressive errors t-test. For the linear regressions and binomial tests, the significance level was set at $\alpha=0.05$.

3.7.2 Pattern Analyses

Three analyses were performed to search for changes in the spatial distribution of abundance that could be attributed to SONGS operations. The first was a Multivariate Analysis of Variance (MANOVA), followed by an Analysis of Variance (ANOVA) on ranks, and finally a Bonferroni t-test.

To review briefly, samples used in the final analyses for SONGS effects were taken in four Blocks (A-D) for ichthyoplankton; A-block was closest to shore and D-block farthest from shore (See Section 3.1 for detail). Within each block, three parts of the water column were sampled: neuston, midwater, and epibenthos. Each survey thus consisted of samples taken in twelve strata (4 blocks x 3 depth intervals per block) at SONGS and at Control. For macrozooplankton, data were from three stations: at the 8 m, 13 m, and 30 m isobaths (see Section 3.2 for detail). At 8 m, three depths were sampled: surface, midwater, near-bottom. At the remaining stations, high and low midwater samples (above and below the thermocline, when it was present) were collected as well as the surface and near-bottom samples.

For the pattern analysis, all Before observations, (both SONGS and Control) and the After-Control observations were combined into one group (hereafter called "Before-or-Control") to be compared with the After-SONGS group. Combining Before-SONGS with Before-Control and After-Control groups simplifies the analysis while putting any differences between those three categories into the error variance. This in turn causes the analysis to be more conservative (i.e., makes it harder to find differences), but it has the virtue of building a standard based on all conditions unaffected by SONGS Units 2 and 3 operations.

If the MANOVA was performed on untransformed abundance data, the technique might be sensitive to an overall change in abundance. That is, significant differences might be found at all strata due to a change in abundance everywhere in the After-SONGS group. Therefore, the pattern analysis was performed using abundance ranks for each stratum within each survey as a vector variable. In this analysis only the relative changes between the strata were important.

The MANOVA procedure for ichthyoplankton considers the rank for each stratum within the cross-shelf to be an observation on a component of a twelve-dimensional vector. For zooplankton the vector is eleven-dimensional. These vectors have been observed in the Before-or-Control and After-SONGS time/location periods. The null hypothesis that there was no difference between the vector of means (of ranks) in the two time/location groups was tested versus an alternative hypothesis that there were differences. If the MANOVA revealed significant differences, then a univariate ANOVA test for each stratum was used to identify the strata that had changed.

For this ANOVA, 24 levels (12 strata each for the two time/location groups) were tested for significant differences in ranks by a one-way model. Multiple comparison testing (Bonferroni t-test) was used to see how the time/location levels grouped. For macrozooplankton the number of strata were 11 or 15 (as discussed above) in the MANOVA and ANOVA procedures.

Pattern analyses were performed on all taxa and developmental stages regardless of BACI outcomes. A shift in spatial distribution as demonstrated by a change in abundance ranks might occur without changes in total abundance, or changes in total abundance could occur equally in all strata, resulting in no spatial changes. For these reasons, we considered the results of both analyses.

The pattern analysis results illustrated in Section 4 (Figures 4-4 through 3-6) show the ANOVA results (arrows indicate the direction of change in strata where significant or nearly-significant results were obtained) for those taxa having significant MANOVA results. This presentation differs from the pattern analysis results illustrated in Appendix D. The latter show schematic representations of cross-shelf abundance patterns in the After-SONGS and Before-or-Control data sets for all taxa and stages. These patterns are represented by shading; the shading is based on a subjective interpretation of the Bonferroni t-test results, which are given below each figure for the convenience of the reader who wishes to make an independent interpretation of the patterns. The value shown for each stratum on each figure is the mean abundance in that stratum. Mean abundances do not always reflect the patterns based on the tests on abundance ranks.

3.7.3 Intake Withdrawal Losses and Potential Diffuser Induced Losses

Intake withdrawal losses and diffuser induced losses were estimated and used in our a priori assessment of possible effects due to SONGS operations. Losses of taxa, species, and developmental stages of species were considered relative to each other and relative to the size of changes the monitoring program was designed to detect. High estimated loss values (e.g., 50%) would suggest that organisms are more likely to exhibit a significant relative changes in abundance levels (i.e., BACI effects, as described in Section 3.7.1).

Estimated intake withdrawal loss analytical methodology, results, and discussions presented in this section are different than those presented in a later section (Section 5.0). The purpose of the latter was to project future annual intake losses, with confidence limits. Consequently, those projections were based on data from long term abundance records from 1976-1980 and from 1982-1986. In the former analysis we were interested in estimating the losses that actually occurred during the period when field monitoring for effects was underway. Therefore the losses were based on abundance records for the operational monitoring period alone.

Samples used for this analysis of intake losses were collected from July 1983 to September 1986. Since macrozooplankton and ichthyoplankton are known to have seasonal abundance cycles (e.g., Barnett and Jahn, 1986; Walker et al., 1987), losses were first calculated on a seasonal basis and then averaged over seasons and years. This procedure reflected more precisely the match of cooling system operation levels (volume of water circulated) and plankton abundances. For ichthyoplankton, the warm season was taken as June - November while the cool season was December - May (Walker et al., 1987); for zooplankton the respective seasons were March - August and September - February (Barnett and Jahn, 1986).

The data used for the loss estimates were based on samples taken at the Control transect on all operational monitoring period surveys. We assumed that data from the Control area more closely reflected source water conditions than would data from the SONGS transect during the operational period, which would have reflected biotic conditions after being subjected to SONGS cooling operations. However, use of Control data ignores longshore current reversals and the possibility of multiple exposure of a water parcel and its organisms to withdrawal, and the estimates presented in Section 3 may thus be slightly too high.

Estimated losses due to intake withdrawal were calculated as a percentage of the numbers found in the cross-shelf (blocks A through D). To calculate the cross-shelf area affected by intake withdrawal, we followed a methodology, described below, provided by J. Reitzel of Eco-M (personal comm.).

The mean cross-section area exposed to the intakes and diffusers was modeled as the mean of Q/S^*, in which Q was the intake and entrainment rate, and S^* was some measure of ambient longshore current.

Neither the current speed nor its velocity was a fully satisfactory measure: taking the speed essentially treated each current reversal as a completely fresh exposure of a population, while taking velocity canceled out all current reversals. As an intermediate measure, we took S^* to be the excursion-speed, defined as the distance between extremes of longshore displacement in a time interval T, divided by T. This S^* fell off a little with increasing T: its mean from July 1983 to September 1986 fell smoothly from 2,275 m at T = 12 hours to 2,000 m at T = 120 hours.

To find a measure of the excursion speed, we actually computed the mean of $1/S^*$ for successive periods of T = 12 hours. The inverse of this mean was 3.1 cm/sec or 2,702 m/day. For the same period July 1983 through September 1986 the mean speed was 5,561 m/day and the mean velocity was 1746 m/day. The average intake volume in cubic meters per day was calculated using the volumes in the MRC database DBSONGS, for the July 1983 through September 1986 operational period. The total number of plankters withdrawn from a one meter wide (longshore) band was then calculated as follows:

$$\# \text{ Withdrawn} = \sum_{i=1}^{N} (V/L) \times (Z_i/H) \times (D_i)$$

where V = average intake volume in cubic meters per day calculated from the DBSONGS data base

L = average longshore flow in meters per day (2702 m/day)

Z_i = depth in meters of the sampling stratum i

D_i = density as number of animals per cubic meter in stratum i

N = number of strata in the block containing the intakes or diffusers (3 for ichthyoplankton; for zooplankton, 4 at the diffusers and 3 at the intakes)

H = Average height in meters of the water column (9 m for intakes, 11 m for Unit 3 diffuser, 13 m for Unit 2 diffuser).

Each sampling date withdrawal estimate was assigned to a season category, the seasonal mean number withdrawn was calculated, and finally the mean over seasons was computed. This mean over seasons represented the mean loss during the operational period.

The number of organisms in the cross-shelf plane (the plane normal to both the surface and the coastline) was calculated by multiplying the density per stratum by the cross-shelf area per stratum and summing these products for all strata on each date. The seasonal means and mean over seasons were then calculated to give a mean cross-shelf number during the operational period.

The percentage of plankters in the cross-shelf plane that was lost to intake withdrawal during the operational period was then calculated by:

$$\% \text{ loss} = 100 \times (\text{mean loss}) / (\text{mean cross-shelf number})$$

For intake losses, ichthyoplankton densities from surface, midwater, and near-bottom samples from Block A were used. For zooplankton, densities from the three water column levels from the 8 m station were used. It was assumed that organisms in all three strata were equally susceptible to withdrawal and would thus be lost in proportion to the volume of water withdrawn from each stratum. This might have resulted in an overestimate of unknown magnitude of the losses of the strongly epibenthic older larval stages of a few fish species (e.g., the gobies).

The potential losses to diffuser induced entrainment were calculated in a similar manner, except that 9 times the average intake volume was used as the estimate of the water volume entrained by the discharges (MRC, 1983). For ichthyoplankton, densities in sampling block C were used to estimate the number of larvae entrained by the discharge of Unit 2 and densities in block B were used to estimate those entrained by the discharge of Unit 3. For zooplankton, the 13 m station was used to estimate entrained numbers for both units. Three estimates of potential diffuser losses were made: 10%, 25%, and 50% of those entrained. Each of these loss estimates was added to the intake losses and the percentage loss of the cross-shelf numbers was calculated as above.

Table 3-1. List of survey dates and descriptions applied to them in this report. Definitions of descriptive terms can be found in Section 3.1 through 3.6.

ICHTHYOPLANKTON	ZOOPLANKTON	DESCRIPTIONS
24 Jul 1979	25 Aug 1976	Preoperational surveys
22 Aug 1979	26 Aug 1976	
23 Aug 1979	15 Sep 1976	
20 Sep 1979	17 Sep 1976	
21 Sep 1979	04 Nov 1976	
10 Mar 1980	11 Jan 1977	
17 Mar 1980	13 Jan 1977	
24 Mar 1980	23 Mar 1977	
04 Apr 1980	07 Jun 1977	
14 Apr 1980	09 Jun 1977	
23 Apr 1980	02 Nov 1977	
05 May 1980	20 Jan 1978	
12 May 1980	31 May 1978	
19 May 1980	27 Jul 1978	
26 May 1980	24 Aug 1978	
02 Jun 1980	15 Sep 1978	
09 Jun 1980	10 Jan 1979	
17 Jun 1980	27 Nov 1979	
24 Jun 1980	20 Dec 1979	
30 Jun 1980	24 Jan 1980	
07 Jul 1980	25 Feb 1980	
14 Jul 1980	23 Mar 1980	
21 Jul 1980	29 Apr 1980	
28 Jul 1980	29 May 1980	
04 Aug 1980	29 Jun 1980	
11 Aug 1980	31 Jul 1980	
18 Aug 1980	31 Aug 1980	
25 Aug 1980	25 Sep 1980	
01 Sep 1980	29 Oct 1980	
08 Sep 1980	24 Jun 1981	
22 Sep 1980	05 Aug 1981	
26 Sep 1980	05 Nov 1981	
29 Sep 1980		
06 Oct 1980		
13 Oct 1980		
07 Jul 1981		
15 Sep 1981		
17 Nov 1981		

Table 3-1 (cont'd). List of survey dates and descriptions applied to them in this report.

ICHTHYOPLANKTON	ZOOPLANKTON	DESCRIPTIONS
09 Mar 1982	27 Jan 1982	Interim surveys
13 Jul 1982	18 Jun 1982	
26 Aug 1982	24 Aug 1982	
10 Dec 1982	21 Dec 1982	
12 Mar 1983	15 Feb 1983	
	21 Jun 1983	
19 Jul 1983		Operational surveys
23 Aug 1983	18 Aug 1983	
13 Dec 1983	05 Dec 1983	
13 Mar 1984	07 Feb 1984	
07 May 1984	11 May 1984	
30 May 1984	08 Jun 1984	
19 Jun 1984	31 Aug 1984	
23 Aug 1984	28 Sep 1984	
13 Sep 1984	18 Oct 1984	
4 Oct 1984	14 Dec 1984	
20 Dec 1984	18 Jan 1985	
21 Jan 1985	26 Mar 1985	
22 Apr 1985	19 Apr 1985	
13 May 1985	16 May 1985	
4 Jun 1985	7 Jun 1985	
25 Jun 1985	2 Jul 1985	
19 Jul 1985	30 Jul 1985	
6 Aug 1985	30 Aug 1985	
26 Aug 1985	11 Feb 1986	
12 Sep 1985	9 Mar 1986	
17 Feb 1986	9 May 1986	
5 Mar 1986	3 Jun 1986	
1 Apr 1986	3 Jul 1986	
30 Apr 1986	11 Sep 1986	
21 Jul 1986		
3 Sep 1986		
25 Sep 1986		
11 Oct 1985	11 Oct 1985	Intake Loss Surveys
1 Nov 1985	1 Nov 1985	
21 Nov 1985	22 Nov 1985	
13 Dec 1985	14 Dec 1985	
2 Jan 1986	3 Jan 1986	
21 Jan 1986	22 Jan 1986	
7 Mar 1986		Anchovy Gradient Survey
	5 Dec 1986	Intake Diffuser Survey

Table 3-2. Results of MANOVA and t-tests on ichthyoplankton cross-shelf abundance and abundance patterns. Taxa are grouped by their abundance patterns (Barnett et al., 1984). Values of $p > 0.05$ indicate no difference between SONGS and the Control area.

	MANOVA *p*	t-test *p*
Inner nearshore taxa		
Atherinidae	.52	.94
Genyonemus lineatus	.11	.07
Gibbonsia type A	.25	.20
Gobiesox rhessodon	<.01	.10
Heterostichus rostratus	.26	.07
Seriphus politus	.44	.28
Total larvae minus *Engraulis mordax*	.01	.06
Transitional taxa		
Engraulis mordax	.21	.17
Hypsoblennius spp.	<.01	.82
Lepidogobius lepidus	.003	<.01
Paralichthys californicus	.59	.75
Total larvae	<.01	.05
Total fish eggs	.25	.32
Unidentified (round) eggs	.43	.22
Outer nearshore taxa		
Pleuronichthys ritteri	.29	.70
P. verticalis	.76	.49
Offshore taxa		
Citharichthys spp.	.67	.31
Stenobrachius leucopsaurus	.45	.88
"Coastal" taxon		
Engraulis mordax eggs	.35	.60

Table 3-3. Results of t-tests on mean concentration (number/400 m^3) in the water column. Comparisons were between Block B and Block B offset, and between Block C and Block C offset. The null hypothesis of no difference between the Block and the offset (vs. H_a: a difference) was evaluated at $\alpha=0.05$. During the Before period, Block B was sampled on 23 surveys and B offset on 15 surveys (33 and 5, respectively for Block C and C offset); during the After period Block B was sampled on 10 surveys and B offset on 22 surveys (22 and 10, respectively, for Block C and C offset). Seasons are: S-F=summer and fall; W-S=winter and spring. N=number of occurrences of a taxon; Mean=mean number/400 m^3 in the water column; S.D.=one standard deviation from the mean; p>T is the p level of the t-test (p>0.05 indicates a nonsignificant result).

			B			B offset				C			C offset			
Species	Season	Period	N	Mean	S.D.	N	Mean	S.D.	p>T	N	Mean	S.D.	N	Mean	S.D.	p>T
Clevelandia ios	S-F	BEFORE	15	0.53	0.76	6	0.26	0.44	0.42	3	1.36	2.28	2	0.51	0.54	0.65
	S-F	AFTER	3	0.68	0.50	9	0.34	0.36	0.23	1	2.06	.	1	0.03	.	.
	W-S	BEFORE	4	2.71	1.99	0	.	.	.	1	1.11	.	0	.	.	.
	W-S	AFTER	3	1.64	1.29	4	0.17	0.14	0.19	1	0.56	.	0	.	.	.
Quietula y-cauda	S-F	BEFORE	6	0.51	1.01	1	0.37	.	.	1	0.08	.	0	.	.	.
	S-F	AFTER	4	0.37	0.28	7	0.34	0.52	0.92	1	0.06	.	4	0.18	0.24	.
	W-S	BEFORE	2	0.86	0.07	1	2.20	.	.	1	0.03	.	0	.	.	.
	W-S	AFTER	3	0.99	0.51	4	0.40	0.36	0.13	4	0.53	0.57	0	.	.	.
Ilypnus gilberti	S-F	BEFORE	14	0.81	1.59	6	2.68	4.35	0.35	4	0.45	0.55	1	0.17	.	.
	S-F	AFTER	4	2.92	2.61	10	2.38	3.27	0.78	6	0.30	0.28	4	0.50	0.42	0.40
	W-S	BEFORE	4	0.39	0.37	2	0.96	0.04	0.11	2	0.54	0.71	0	.	.	.
	W-S	AFTER	4	4.55	2.21	6	6.19	5.17	0.57	5	5.66	7.01	1	0.46	.	.
Gobiesox rhessodon	S-F	BEFORE	11	0.46	0.69	6	1.61	2.10	0.24	6	0.36	0.70	2	0.08	0.05	0.62
	S-F	AFTER	3	2.19	1.95	9	1.95	4.43	0.93	6	0.42	0.47	4	0.64	0.34	0.46
	W-S	BEFORE	5	2.66	3.51	3	0.85	1.28	0.43	0	.	.	2	0.65	0.70	.
	W-S	AFTER	1	0.50	.	2	0.21	0.24	.	2	0.39	0.48	0	.	.	.
Paraclinus integripinnis	S-F	BEFORE	7	0.88	1.03	3	1.97	2.96	0.59	6	1.30	0.93	0	.	.	.
	S-F	AFTER	4	0.69	0.71	3	6.28	10.77	0.46	2	0.20	0.25	3	0.98	1.19	0.45
Gibbonsia type a	S-F	BEFORE	7	0.56	0.51	3	1.06	0.77	0.25	3	0.74	0.89	0	.	.	.
	S-F	AFTER	3	4.82	6.98	5	0.63	0.47	0.41	2	0.04	0.01	1	0.46	.	.
	W-S	BEFORE	3	9.26	13.18	1	0.05	.	.	2	1.03	1.42	0	.	.	.
	W-S	AFTER	2	0.37	0.00	4	2.01	1.72	0.15	2	1.07	0.76	0	.	.	.
Heterostichus rostratus	S-F	BEFORE	9	0.37	0.42	4	0.36	0.37	0.99	1	0.03	.	1	0.10	.	.
	S-F	AFTER	2	0.79	1.06	4	0.66	0.73	0.86	1	0.39	.	3	0.42	0.70	.
	W-S	BEFORE	4	0.44	0.75	1	1.03	.	.	0	.	.	1	0.90	.	.
	W-S	AFTER	1	0.24	.	4	0.48	0.34	.	.	.	.	.	.	.	.
Seriphus politus	S-F	BEFORE	17	15.20	25.13	9	50.84	139.6	0.47	22	12.01	22.57	3	17.94	27.68	0.68
	S-F	AFTER	5	19.98	16.22	9	8.71	13.39	0.19	8	9.08	9.04	5	13.99	20.00	0.55
	W-S	BEFORE	6	36.65	34.92	4	65.66	35.81	0.24	8	53.84	35.33	2	23.06	14.55	0.28
	W-S	AFTER	3	13.77	19.97	5	2.54	1.76	0.43	4	36.34	66.62	3	0.91	0.05	0.37
Genyonemus lineatus	S-F	BEFORE	11	0.85	0.66	8	3.96	8.99	0.36	17	1.27	1.55	2	0.65	0.75	0.59
	S-F	AFTER	3	2.63	4.49	4	0.66	0.56	0.53	4	0.06	0.05	1	4.19	.	.
	W-S	BEFORE	6	101.9	98.99	4	243.3	218.6	0.20	8	150.4	93.86	2	22.49	11.22	0.10
	W-S	AFTER	4	19.45	35.65	8	36.84	38.10	0.47	8	26.82	44.62	3	3.41	4.82	0.19
Cheilotrema saturnum	S-F	BEFORE	5	1.39	1.05	3	0.88	0.62	0.48	3	6.32	5.83	1	1.08	.	.
	S-F	AFTER	1	0.61	.	3	0.54	0.49	.	2	0.56	0.79	2	0.01	0.00	0.50
	W-S	BEFORE	2	0.46	0.63	0	.	.	.	0	.	.	1	1.14	.	.
	W-S	AFTER	1	0.38	.	0	.	.	.	2	3.57	4.00	0	.	.	.

Table 3-3. (Cont.)

Species	Season	Period	B N	B Mean	B S.D.	B offset N	B offset Mean	B offset S.D.	B offset p>T	C N	C Mean	C S.D.	C offset N	C offset Mean	C offset S.D.	C offset p>T
Menticirrhus undulatus	S-F	BEFORE	7	3.59	4.10	1	0.00	.	.	6	4.76	6.97	1	4.51	.	.
	S-F	AFTER	3	0.13	0.07	0	.	.	.	5	2.20	2.63	2	2.69	3.79	0.85
	W-S	AFTER	1	1.52	.	0	.	.	.	1	0.76	.	0	.	.	.
Paralabrax spp	S-F	BEFORE	7	5.41	10.58	3	0.34	0.29	0.25	10	25.57	66.27	1	41.17	.	.
	S-F	AFTER	2	17.27	16.69	6	2.52	3.98	0.43	7	11.23	11.75	4	15.34	19.14	0.67
Hypsopsetta guttulata	S-F	BEFORE	6	1.34	2.16	2	0.91	1.28	0.80	2	1.10	0.95	1	1.08	.	.
	S-F	AFTER	0	.	.	2	0.30	0.39	.	0	.	.	1	0.60	.	.
	W-S	BEFORE	3	2.16	2.42	2	1.83	2.58	0.89	3	1.87	1.67	0	.	.	.
	W-S	AFTER	0	.	.	2	0.80	1.12	.	1	0.33	.	1	0.77	.	.
Paralichthys californicus	S-F	BEFORE	10	0.60	0.86	9	1.44	1.47	0.14	17	7.86	13.55	3	12.73	21.96	0.60
	S-F	AFTER	3	9.34	4.88	5	1.49	1.61	0.01	4	3.61	6.45	5	8.52	10.48	0.44
	W-S	BEFORE	4	16.55	25.22	4	14.07	15.32	0.87	8	15.80	16.44	2	1.17	1.57	0.26
	W-S	AFTER	3	0.10	0.07	2	13.50	3.22	0.11	5	7.18	5.58	3	1.46	1.57	0.14
Atherinopsis californiensis	S-F	BEFORE	6	0.25	0.20	2	0.02	0.02	0.18	4	0.29	0.51	0	.	.	.
	S-F	AFTER	0	.	.	1	0.58	.	.	1	0.19	.	0	.	.	.
	W-S	BEFORE	6	15.53	8.24	4	7.55	8.27	0.17	8	6.45	13.18	2	21.23	24.79	0.25
	W-S	AFTER	3	0.65	0.54	8	2.24	3.17	0.42	6	1.13	1.49	4	0.63	0.43	0.54
Leuresthes tenuis	S-F	BEFORE	14	0.35	0.85	6	0.30	0.13	0.85	16	0.11	0.13	2	0.71	0.76	0.47
	S-F	AFTER	3	0.38	0.52	5	1.46	1.28	0.22	5	0.89	1.66	3	0.42	0.05	0.56
	W-S	BEFORE	4	0.96	0.70	3	0.26	0.34	0.18	5	0.23	0.21	2	0.62	0.63	0.23
	W-S	AFTER	3	5.29	4.48	4	0.52	0.76	0.20	3	1.22	1.27	2	0.08	0.04	0.26
Engraulis mordax	S-F	BEFORE	17	17.04	25.68	11	20.80	35.34	0.75	24	24.13	24.21	3	38.35	54.80	0.70
	S-F	AFTER	5	29.78	58.34	10	22.52	24.16	0.80	10	96.90	133.2	5	3.85	3.33	0.05
	W-S	BEFORE	6	283.2	357	4	870.7	671.5	0.11	8	568.3	539.1	2	89.18	43.47	0.26
	W-S	AFTER	4	64.79	97.63	8	154.8	135.5	0.27	8	143.5	148.3	4	134.6	247.9	0.94
Citharichthys spp	S-F	BEFORE	1	2.20	.	2	1.21	1.66	.	4	0.47	0.37	0	.	.	.
	S-F	AFTER	2	1.68	2.35	2	0.66	0.93	0.62	3	0.91	1.16	1	1.01	.	.
	W-S	BEFORE	1	0.02	.	0	.	.	.	2	0.94	1.29	0	.	.	.
	W-S	AFTER	2	0.39	0.52	1	0.01	.	.	4	3.66	6.71	2	0.40	0.55	0.55
Hypsoblennius spp	S-F	BEFORE	16	4.06	5.14	10	6.76	13.34	0.55	23	8.33	11.55	3	1.58	1.94	0.33
	S-F	AFTER	5	1.73	1.61	10	4.68	4.63	0.20	9	6.03	5.14	5	2.03	1.92	0.12
	W-S	BEFORE	6	0.98	1.30	4	1.32	1.01	0.68	8	2.73	5.32	2	4.45	2.37	0.68
	W-S	AFTER	4	1.57	1.61	5	2.17	3.01	0.73	7	2.29	5.88	3	2.92	3.86	0.87

Table 3-4. Summary of results of BACI power testing on ichthyoplankton taxa. Except as noted under the column entitled "Before n", power tests were run on the 38 preoperational surveys (n) or a subset of these surveys, and an assumed 38 operational surveys (N).

Taxon	Before n	N for power	Power at α=.05
Total larvae	21	21	>.99
Engraulis mordax	38	38	>.99
Non-engraulid larvae	21	21	.97
Unidentified egg	38	38	.89
Seriphus politus	38	38	.85
Hypsoblennius spp.	38	38	.85
Genyonemus lineatus	38	38	.81
Paralabrax spp.	23	23	.69
Atherinidae	38	38	.67
Menticirrhus undulatus	16	16	.53
Paralichthys californicus	38	38	.50
Engraulis mordax egg	38	38	.46
Pleuronichthys verticalis	38	38	.38
Gobiesox rhessodon	38	38	.36
Hypsopsetta guttulata	38	38	.36
Medialuna californiensis	38	38	.33
Pleuronichthys ritteri	38	38	.31
Citharichthys spp.	38	38	.30
Gobiidae type a	38	38	.30
Gibbonsia sp. A	38	38	.28
Sebastes spp.	38	38	.26
Stenobrachius leucopsarus	38	38	.25
Sphyraena argentea	23	23	.24
Parophrys vetulus	20	20	.15
Girella nigricans	38	38	<.11

Table 3-5. Summary of results of BACI power testing on zooplankton taxa. Tests were based on the 32 preoperational surveys (n) and an assumed 29 operational surveys (N).

Taxon	Before n	N for power	Power at $\alpha = .05$
Corycaeus anglicus	32	29	>.99
Sagitta euneritica	32	29	.99
Paracalanus parvus	32	29	.96
Penilia avirostris	32	29	.94
Oithona plumifera	32	29	.94
Evadne nordmanni	32	29	.93
Cyphonautes larvae	32	29	.90
Acartia tonsa	32	29	.86
Unidentified fish eggs	32	29	.84
Cypris larvae	32	29	.75
Evadne spinifera	32	29	.73
Labidocera trispinosa	32	29	.68
Calanus spp.	25	25	.65
Podon polyphemoides	32	29	.59
Acartia clausi	32	29	.44
Oithona oculata	32	29	.41
Engraulis mordax eggs	32	29	.21

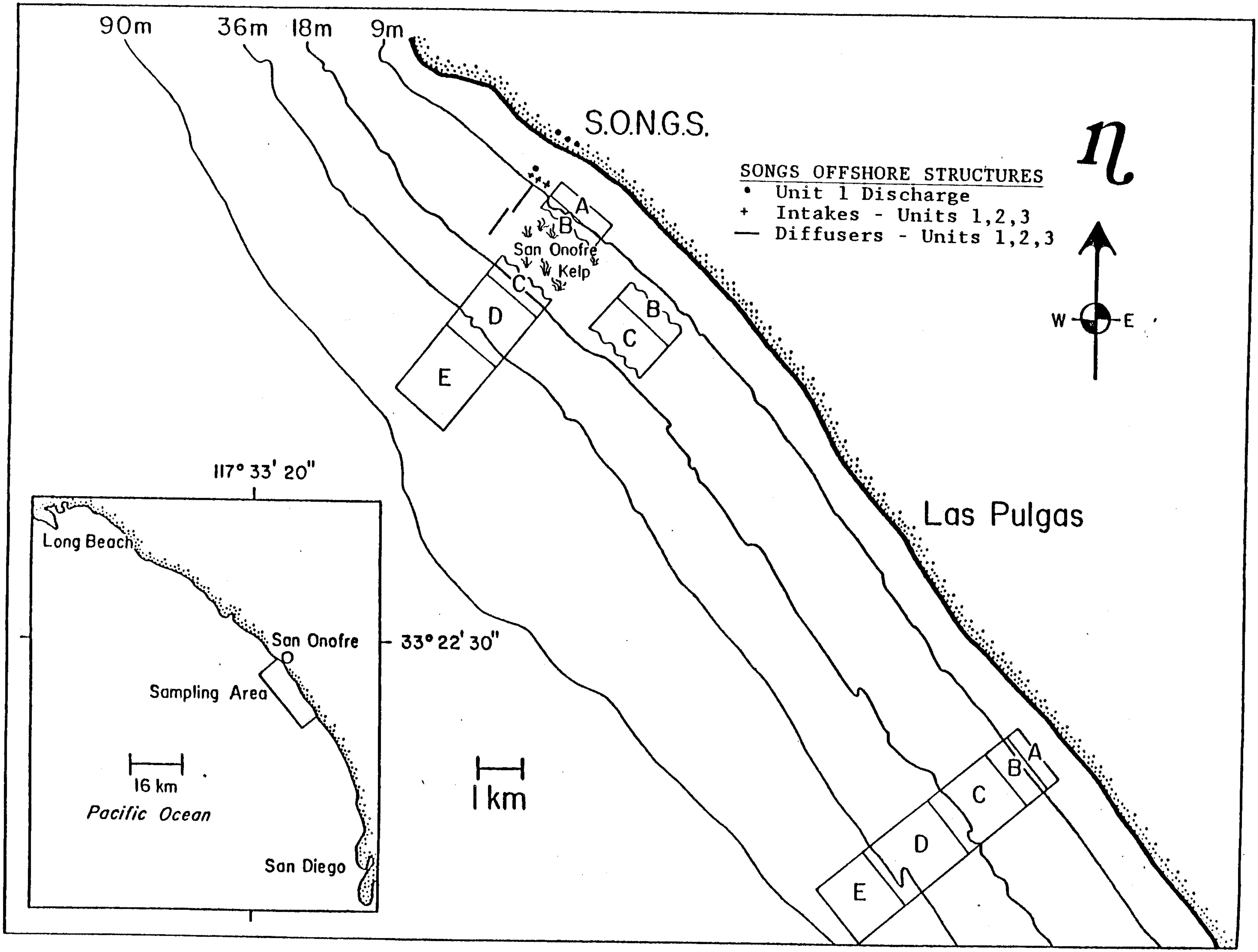

Figure 3-1. Locations of monitoring sampling blocks for ichthyoplankton. Samples are collected at a randomly selected isobath within each block during each survey.

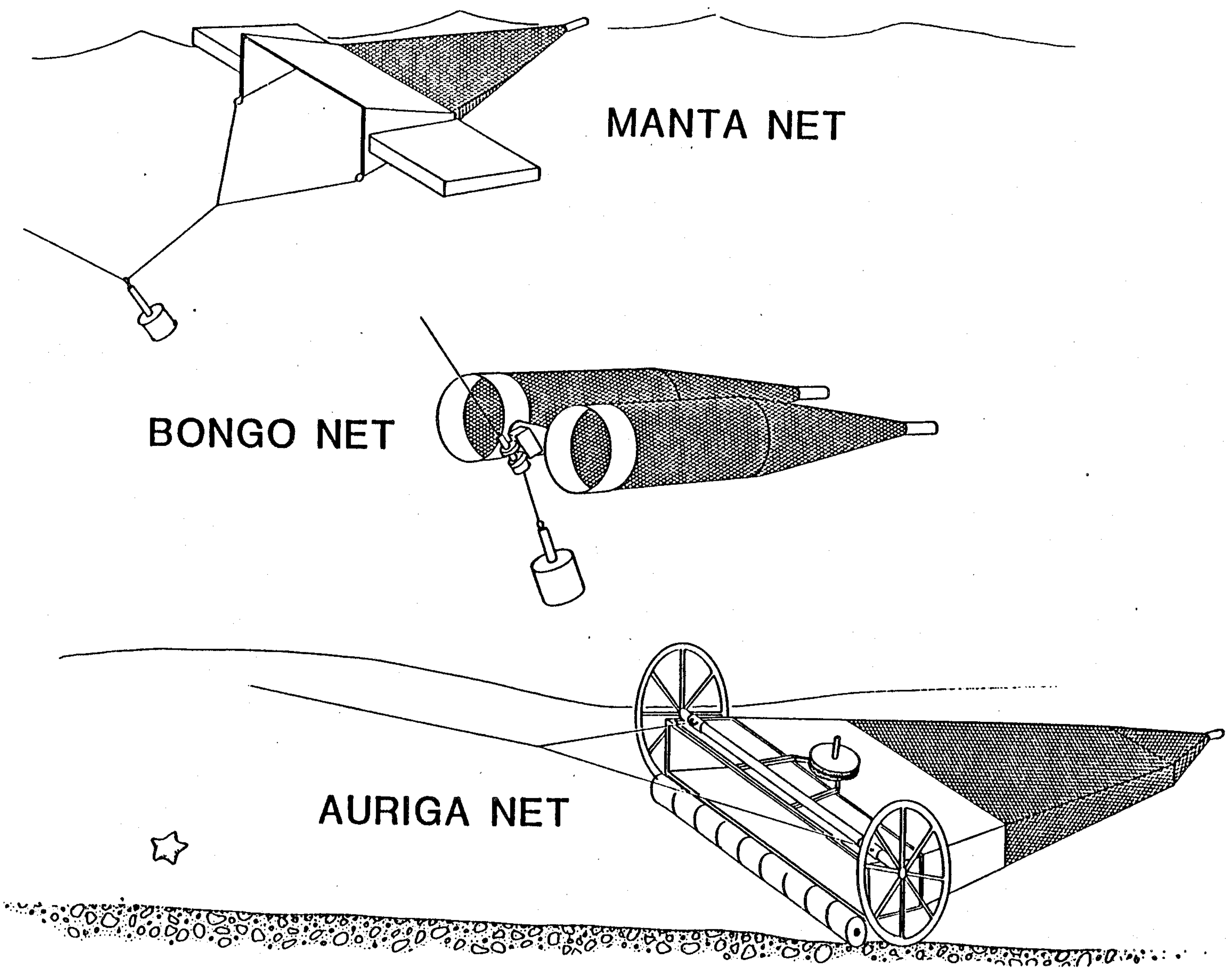

Figure 3-2. Configuration of the gear used to sample the neustonic, midwater, and epibenthic strata.

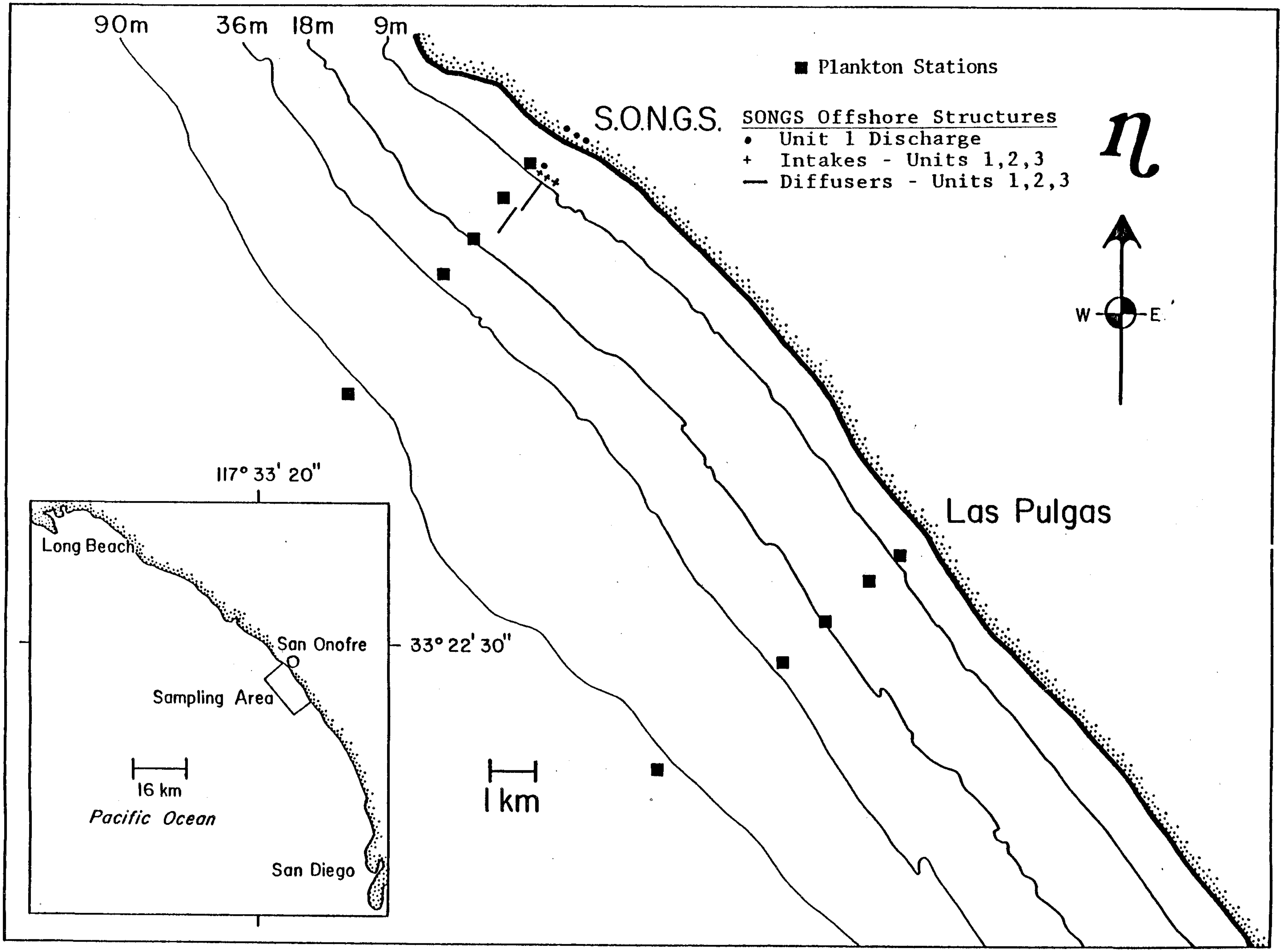

Figure 3-3. Locations of monitoring stations sampled for plankton.

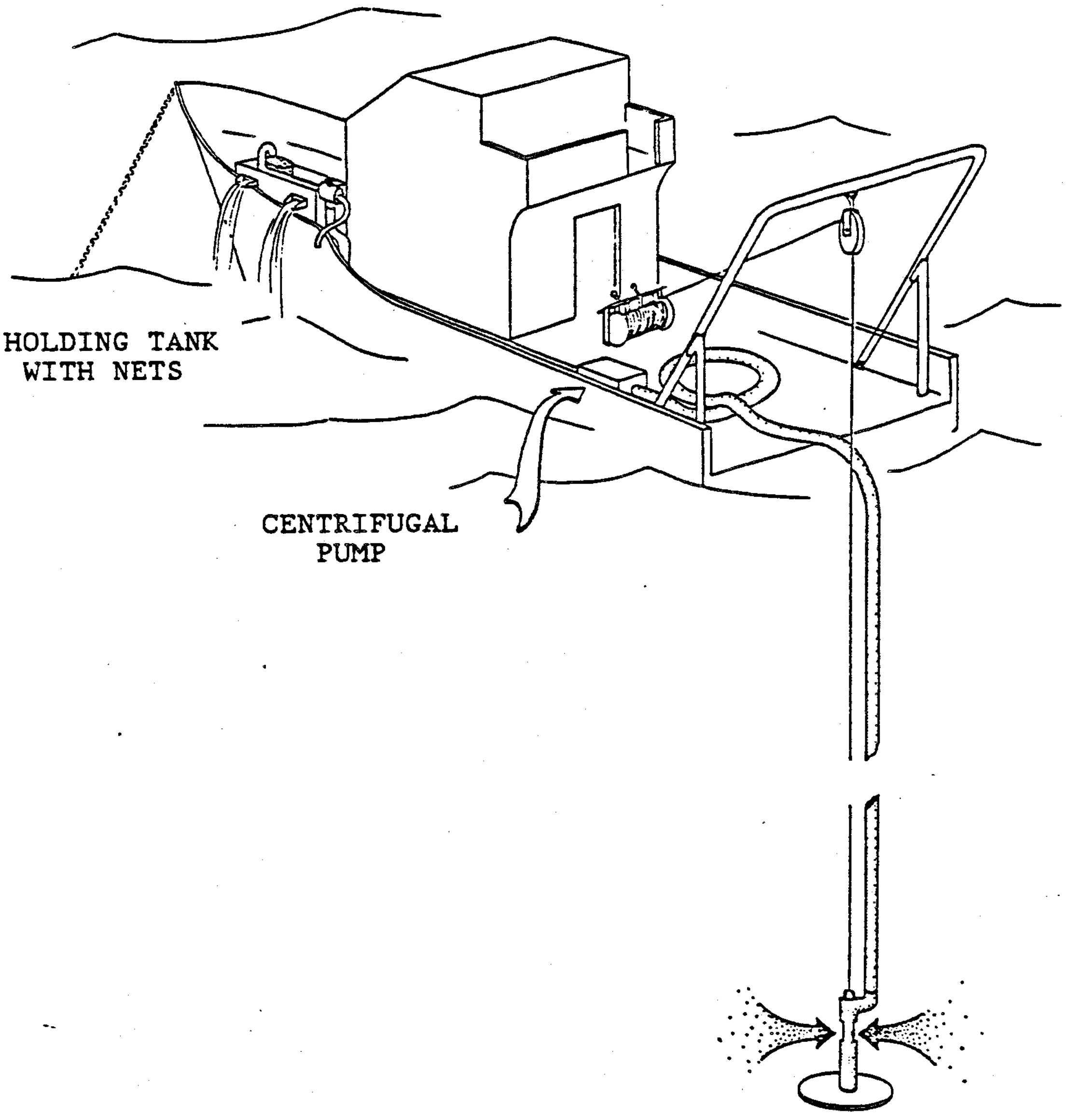

Figure 3-4. Configuration of the gear used to sample plankton.

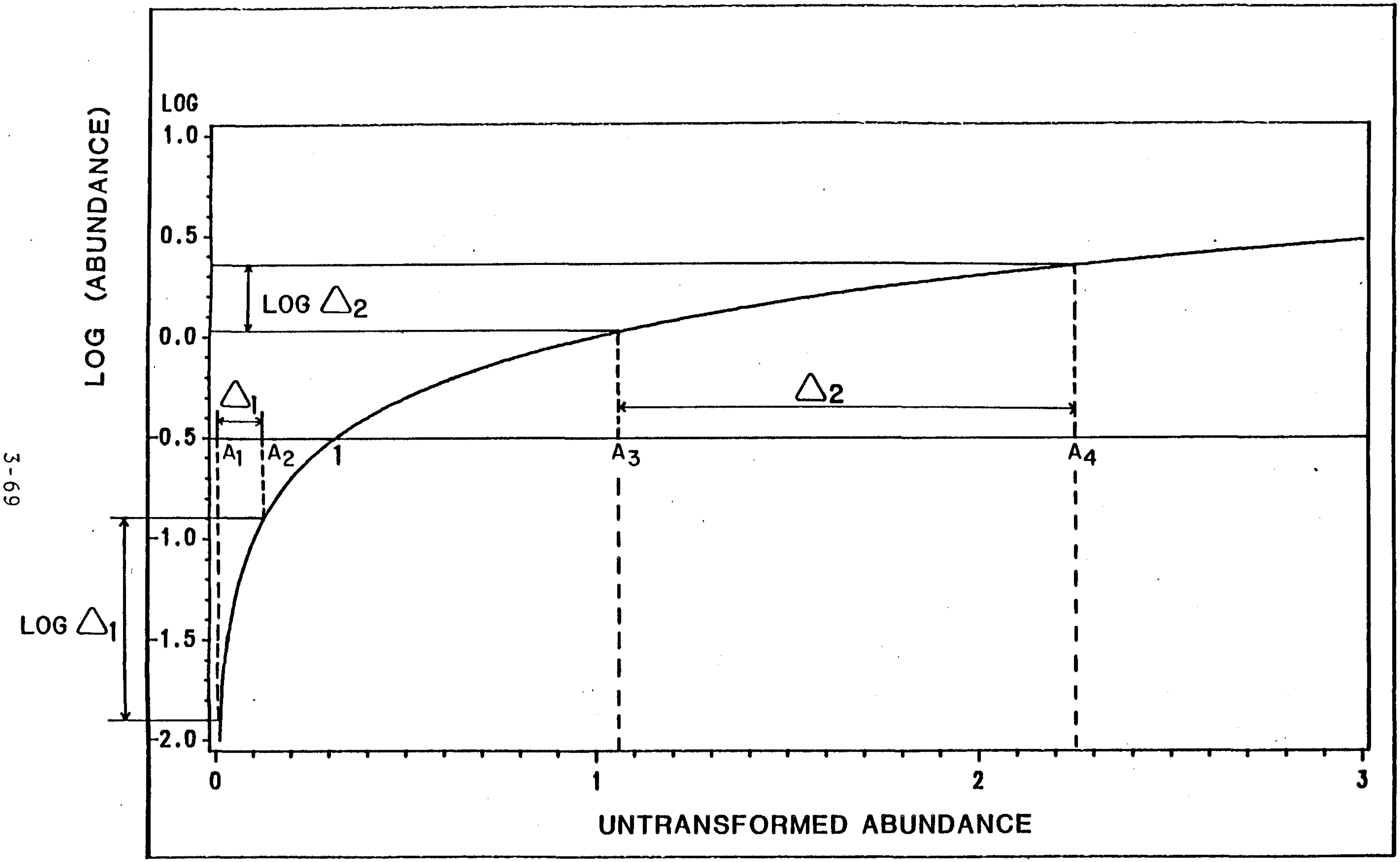

Figure 3-5. Influence of adding a constant (1) to a value to be log transformed. The A's are untransformed values; the Δ's are for untransformed values; logΔ's are for log transformed values.

4.0 ASSESSMENT OF SONGS EFFECTS

4.1 Synopsis

MEC's primary goals in this final analysis of the ichthyoplankton and macrozooplankton were:

(1) to determine if the abundances of the ichthyoplankton and macrozooplankton taxa or life stages of taxa were significantly different (lower, for ichthyoplankton) at SONGS during the operational period from what would have been expected on the basis of abundances observed at the Control area; this determination was based on the BACI analysis;

(2) to determine if the cross-shelf pattern of distribution of any taxon or life stage was different at SONGS during the operational period relative to the pattern established by combining preoperational distributions at SONGS and Control with the operational distribution at Control; this was the MANOVA/ANOVA/Bonferroni pattern analysis on ranks of abundance in the cross-shelf strata; and

(3) to determine if changes detected in the abundance of a taxon at SONGS could be related to a known SONGS mechanism -- intake withdrawal; this was a qualitative comparison of calculated losses with relative changes in SONGS-Control abundances (Deltas).

Nineteen of the approximately 150 types of larval fish identified during the SONGS studies, and seventeen of the 20 macrozooplankton taxa and composite groups enumerated during these studies were utilized in the final analyses. These taxa were categorized into four broad groups based on their onshore-offshore distributions: inner nearshore (seven ichthyoplankton and 2 macrozooplankton taxa), nearshore/transitional (nine ichthyoplankton and four macrozooplankton taxa), broadly distributed (three ichthyoplankton and nine macrozooplankton taxa), and offshore (one macrozooplankton species). The risk of intake withdrawal losses (and thus depletion near SONGS) was expected to be highest for the inner nearshore taxa. The nearshore/transitional zone taxa and the broadly-distributed taxa with abundance centers nearer shore were expected to be susceptible to both intake withdrawal and to entrainment in the discharge plume (resulting in pattern shifts, and possibly in depletion near SONGS), while the offshore taxa and the broadly-distributed taxa with abundance centers farther from shore were expected to be relatively immune to both mechanisms.

For the ichthyoplankton, the abundance of all larval stages of a species combined (total larvae) and of three larval stages separately (preflexion, flexion, and postflexion) were tested. The results for the inner nearshore ichthyoplankton taxa were:

- Statistically significant changes were detected among three of the inner nearshore species. The BACI tests showed that relative abundances of total and flexion-stage larvae of all three species of gobies in this group, of the postflexion stage of the arrow goby (Clevelandia ios), and of the preflexion stage of the shadow goby (Quietula y-cauda), were significantly lower near SONGS than at Control during the operational period. The plume/non-plume analysis corroborated these results. None of the four other inner nearshore taxa exhibited statistically significant changes in relative abundance in the full After data set.
- These relative decreases were due to smaller increases in absolute abundance at SONGS than at Control for the shadow

goby and cheekspot goby (Ilypnus gilberti); the arrow goby declined in absolute abundance at SONGS while increasing at Control. Five of the seven inner nearshore species increased in absolute abundance at SONGS and Control between the two monitoring periods.

- Pattern analysis indicated statistically significant shifts in cross-shelf distributions near SONGS for one or more stages, including total larvae, of six of the seven inner nearshore species, but the shifts were all small and did not constitute clear evidence of redistribution due to entrainment in the SONGS discharge plume.
- Calculated losses due to withdrawal in the Units 2 and 3 intakes and entrainment in the discharge plume were large enough to have produced the observed relative decreases; the nature of the changes in abundances at SONGS and Control could be interpreted as cropping of larval production by intake and entrainment mortality, but since equally plausible alternative mechanisms could be postulated, the changes could not be ascribed solely to SONGS operation.

The results for the nearshore/transitional ichthyoplankton taxa were:

- Significant changes in relative abundance were detected among three of the nine nearshore/transitional taxa.
- Most of the taxa decreased in absolute abundance at both SONGS and Control between the two monitoring periods. The exceptions were black croaker (Cheilotrema saturnum), which increased at both sites, kelp and sand basses (Paralabrax

spp.), which increased at Control, and California grunion (Leuresthes tenuis), which increased at SONGS.

- BACI testing showed that total, preflexion, and flexion larvae of jacksmelt (Atherinopsis californiensis), preflexion and flexion-stage larvae of the kelp and sand basses, and preflexion-stage larvae of queenfish (Seriphus politus) decreased significantly in relative abundance between the preoperational and operational periods. Analysis of the plume dates and non-plume dates data sets corroborated the results of the primary tests for total and preflexion jacksmelt larvae and preflexion queenfish larvae, but not for Paralabrax larvae. SONGS operation could have contributed to all of these changes.
- Pattern analyses detected small redistributions near SONGS of two white croaker (Genyonemus lineatus) stages and flexion-stage larvae of queenfish, but these changes were not considered to be ecologically important because they involved relatively few larvae.
- Estimates of intake and entrainment losses suggest that the changes in relative abundance could not be due solely to cooling water withdrawal, but had to include the effects of a suite of other, unknown, mechanisms operating simultaneously.

Results for the broadly distributed ichthyoplankton taxa were:

- The most abundant ichthyoplankton species in the study area --northern anchovy (Engraulis mordax) -- decreased 55% in relative abundance near SONGS. This was statistically significant. The plume dates analysis indicated that in addition to total northern anchovy larvae, postflexion-stage larvae also declined significantly in relative abundance.

- The absolute abundance of total northern anchovy larvae decreased by 35% at SONGS and increased by 20% at Control between the two monitoring periods; postflexion-stage larvae decreased by 57% at SONGS and by 37% at Control.
- No statistically significant changes in relative abundance were detected for the remaining broadly-distributed taxa--sanddabs (*Citharichthys* sp.) and blennies (*Hypsoblennius* sp.).
- The pattern analyses did not detect any redistributions among the broadly distributed taxa.
- Calculated intake and entrainment mortality was clearly insufficient to result in detectable changes in the abundance of any of the three taxa; SONGS operation apparently acted on anchovies in a manner not fully identified by the monitoring program.

The results for the inner nearshore macrozooplankton were:

- BACI tests did not identify statistically significant changes in relative abundance.
- Both taxa --*Oithona oculata* and *Acartia clausi* -- decreased in absolute abundance at both SONGS and Control; the decline of *Acartia clausi* was especially marked (84-94%).
- Pattern analyses did not identify statistically significant redistributions of either species.

- Although calculations of intake and entrainment mortality suggested that SONGS operation could have produced an effect detectable by BACI testing, the large regional decline in abundance and the high variability of the data prevented such effects, if they occurred, from being detected.

The results for the nearshore/transitional macrozooplankton taxa were:

- BACI testing identified a relative increase in the abundance of barnacle nauplii at SONGS as statistically significant; the plume/non-plume analyses corroborated this result.
- The relative changes for the remaining three taxa -- barnacle cyprid larvae, _Acartia tonsa_, and _Podon polyphemoides_ -- were not statistically significant.
- The most abundant macrozooplankter in the study area, _Acartia tonsa_, as well as barnacle cyprid larvae, changed little in absolute abundance at both SONGS and Control between the two monitoring periods. The cladoceran _Podon polyphemoides_ and, especially, barnacle nauplii decreased in abundance at both locations.
- Although the abundance of _Acartia tonsa_ did not change significantly, pattern analysis indicated that the species decreased in the epibenthos at the 8 m station and increased in the midwater strata at the 13 m station. These changes are attributed to SONGS-induced changes in local patterns of water circulation.
- Calculated intake and entrainment losses were not sufficient to have caused statistically detectable decreases in abundance at SONGS, which conforms to the results of the BACI tests.

Results for the cross-shelf macrozooplankton taxa were:

- The changes in relative abundance for the nine cross-shelf taxa ranged from -49% to +104%. The principal BACI tests did not identify any of these changes as statistically significant. The analysis of plume dates, however, showed that the relative increases in the abundances of Evadne nordmanni and cyphonautes larvae were statistically significant, suggesting a possible SONGS effect smaller than expected detection levels. Mechanisms by which SONGS could cause these changes could not be postulated.
- Four of the nine cross-shelf taxa increased in absolute abundance at both SONGS and Control, and three decreased at both locations. The cladoceran Penilia avirostris essentially disappeared from the study area between the two monitoring periods. Cyphonautes larvae nearly doubled in abundance at SONGS while declining somewhat at Control.
- Pattern analyses indicated statistically significant changes in the cross-shelf distributions of cyphonautes larvae and the copepods Corycaeus anglicus and Oithona plumifera. These changes are attributed to SONGS-induced changes in local patterns of water circulation.
- Calculated losses from intake and entrainment were insufficient to cause detectable changes in abundance, which conforms to the results of the BACI analyses.

The results of the other macrozooplankton categories were:

- The offshore copepod Calanus pacificus showed no statistically significant changes in relative abundance or cross-shelf distribution, indicating that there were no detectable SONGS effects on that species.

- The relative abundance of total zooplankton did not change significantly. The pattern analysis detected a shift in distribution similar to, and probably largely driven by, that of *Acartia tonsa*. This redistribution was probably attributable to SONGS-induced changes in local circulation.

The results for the phytoplankton were:

- Chlorophyll at the 30 m station and average cross-shelf chlorophyll concentration showed no statistically significant changes, indicating that there was no detectable SONGS effect.

4.2 Ichthyoplankton Results and Discussion

As a way of organizing the presentation of the results of the final BACI and MANOVA analyses on the ichthyoplankton, MEC grouped the taxa analyzed into three categories corresponding to the cross-shelf distributions of their larvae. These categories, the inner nearshore taxa (Section 4.2.1), the inner nearshore/transitional zone taxa (Section 4.2.2), and the broadly distributed taxa (Section 4.2.3) were established independently of any ecological criteria other than cross-shelf larval distribution because our *a priori* expectation was that the strength of any effects resulting from SONGS Units 2 and 3 cooling operations would largely be a function of larval proximity to the offshore cooling structures. The taxa analyzed were chosen because they had high BACI power (*Hypsoblennius*, *Seriphus*, *Engraulis*, *Genyonemus*), or because they were commercially valuable (*Menticirrhus*, Paralabrax, Paralichthys), or because they were abundant in the study area (the remainder).

Each of the following three sections starts with a brief introduction to the taxa (more detailed synopses of the biology for each taxon are given in Appendix A.1), followed by a short discussion of some of the ways SONGS operations might have affected them during the operational period. This is followed by more detailed taxon-by-taxon accounts of the test results. The first paragraph of each individual account summarizes MEC's results. After the individual accounts, we recapitulate the significant results for each group and, where possible, attempt to interpret them in terms of potential contributing mechanisms.

Values of mean abundance are presented in Table 4-1, test results in Tables 4-2, 4-3, and 4-4, percent changes in abundance in Table 4-5, and intake losses in Table 4-6. The protocol for examining assumption testing and BACI testing is presented in a separate volume as Appendix C.1. Examples applying the protocol to a species showing a significant effect (Clevelandia ios) and a species showing no effect (Gobiesox rhessodon) form Appendices C.2 and C.3, respectively. The main body of figures supporting this chapter are provided in Appendix D. For each taxon and developmental stage discussed, there are six kinds of figures: (1) a figure summarizing the BACI assumptions test results; (2) a figure summarizing the BACI test results and giving the percent change in mean abundance at SONGS and Control and the percent change in relative abundance; (3) a figure showing preoperational and operational period Delta values plotted together on a one-year time scale to facilitate between-period comparison; (4) a figure showing Delta values through time; (5) a figure showing abundance values at SONGS and at

Control plotted through time; and (6) a figure summarizing the pattern analysis results and giving schematic representations of cross-shelf abundance patterns at SONGS in the operational period and in a "Before-or-Control" data set.

4.2.1 Inner Nearshore Taxa

In a previous analysis of ichthyoplankton cross-shelf distribution patterns near SONGS, Barnett et al. (1985) identified eleven species as inner nearshore taxa. These were species largely restricted to the zone within about 3.8 km from shore (to a depth of 21 m) and occurring in greatest abundance within about 2 km from shore (to a depth of 12 m). Nine of the eleven inner nearshore taxa were selected for this final BACI analysis; the remaining two, an unidentified clingfish and the California tonguefish, were not analyzed because their larvae were rare near SONGS. Two of the nine taxa (queenfish and white croaker) are treated in this report along with the nearshore/transitional zone ichthyoplankton because although their older larval stages are largely restricted to the very nearshore zone, their younger stages have a broader cross-shelf distribution.

The remaining seven taxa are treated in this section, since they all maintain inner nearshore distributions throughout larval life. These taxa include three gobies: Clevelandia ios (arrow goby), Quietula y-cauda (shadow goby), and Ilypnus gilberti (cheekspot goby); three clinids: Paraclinus integripinnis (reef finspot), Gibbonsia spp. (kelpfish), and Heterostichus rostratus (giant kelpfish); and one clingfish, Gobiesox rhessodon (California clingfish). All seven species share life history characteristics in addition to larval distribution; for example, all spawn adhesive eggs in nests guarded by a parent (usually the male), all have a long incubation period ($\geq$ one week), and the larvae of all are relatively large and well developed at hatching.

4.2.1.1 Potential SONGS Effects

These inner nearshore taxa were expected, *a priori*, to form the group most likely to show effects of SONGS Units 2 and 3 operations because their cross-shelf location roughly coincided with that of the SONGS Units 2 and 3 intakes and diffusers, and the SONGS effects on fish larvae were expected to result largely from intake withdrawal and entrainment in the discharge plume. These effects were expected to be negative, because most larvae withdrawn at the intakes will die in passage through the cooling systems and those entrained in the diffuser discharge plume may be subject to increased predation and/or may be transported seaward, beyond their normal range, where survival may be reduced.

Because these fishes are nearshore, mainly demersal species, SONGS Units 2 and 3 operations might be expected to affect the adults as well as the larvae. Effects could be positive or negative: for example, the discharge of dead or injured organisms (zooplankton, mysids, fish larvae, etc.) could provide a food resource near the diffusers that might directly or indirectly support larger populations of these fishes. Alternatively, the turbid discharge plume might reduce the local benthic algal cover as a result of reduced light transmittance, thus rendering the habitat suboptimal for those species strongly associated with algal cover (for example, shadow goby and spotted kelpfish). Such effects, however, should occur on a relatively small spatial scale around SONGS. Because the habitats of the adults cover a much larger area in the San Onofre region, local decreases or increases in larval production would probably not be attributable to adult losses or immigration alone. Any such local change in larval production would tend to be obscured as a result of the broad dispersion of the younger larvae by coastal currents. Similarly, a significant impact on local larval production as a result of adult losses via impingement or entrapment is also unlikely. The benthic habitat of the adults of these nearshore species should make them relatively immune to such effects, and in fact they are rare in inplant samples (e.g., DeMartini et al., 1987).

Thus, significant changes in larval abundance near SONGS in the After period would presumably have resulted mainly from larval withdrawal and entrainment and, perhaps, from increased predation if planktivorous fishes were attracted to the vicinity of the discharge plume; the BACI tests should have identified these as negative effects.

MEC estimated the percentages of larvae in the cross-shelf plane that were killed as a result of withdrawal and entrainment during the operational period to determine whether these effects could have produced significant BACI results. Intake withdrawal alone probably killed about 10-36% of the inner nearshore larvae in the cross-shelf plane, depending on the species (Table 4-6). Estimated losses of individual stages ranged from as low as 2% of the postflexion-stage giant kelpfish larvae to as high as 67% of the postflexion-stage larvae of <u>Gibbonsia</u> sp. A. In general, however, intake withdrawal alone probably did not kill enough larvae to have produced a 50% decrease in cross-shelf abundance, which is the level of effect the BACI analyses were intended to detect. If larvae secondarily entrained in the discharge plume were subject to additional mortality as a result of less even if it did occur. We did not test for relative increases and see no compelling reason to suppose that the increase noted above represents a real effect. T-tests and Wilcoxon rank sum tests of the other acceptable data treatments (all log (x + C) transformations) also yielded nonsignificant results (Table 4-2), and the binomial test indicated that the proportion of _G_. _rhessodon_ larvae at SONGS in the operational period did not differ from the proportion in the preoperational period (Table 4-4).

Results of the principal BACI t-test on untransformed stage-specific data were also nonsignificant in relative abundance, and acceptable data treatments confirmed the principal test results (Table 4-2, Figures D-71, D-76, D-81). The binomial test for each stage indicated that the proportion of larvae at SONGS in the operational period was not different from the proportion in the preoperational period (all values of $p > 0.10$; Table 4-4). Preflexion and flexion stages increased in mean abundance at both SONGS and Control (Table 4-1), but mean abundances were always higher at SONGS in both monitoring periods. Mean abundances of postflexion larvae, on the other hand, were essentially the same at both locations in both periods (a single very large catch on 23 August 1984 translated into a large increase in mean abundance at SONGS in the operational period; without this date, mean abundance at SONGS differed little from mean abundance at Control). The ratios of postflexion to preflexion-stage abundances differed little between monitoring periods at both locations (when the 23 August 1984 datum was excluded); the ratio at Control was larger than that at SONGS in both periods, suggesting that an appreciable fraction of the larvae in the Control area could have drifted there from the rockier areas to the north, while those at SONGS may have been produced locally (i.e., in the San Mateo - San Onofre region).

If the larvae at SONGS were of local origin, and if withdrawal and entrainment effects were actually important for this species, we might expect to see significant reductions in relative abundance during plume dates. Results of the t-tests on untransformed plume dates data (Table 4-3) were nonsignificant ($p > 0.10$) except for preflexion-stage larvae ($p = 0.10$). Preflexion-stage larvae declined in mean abundance at SONGS while increasing at Control on the plume dates; the older developmental stages and total _G. rhessodon_ larvae increased at both locations. On non-plume dates, t-test results were all nonsignificant ($p > 0.10$). The plume dates result for preflexion-stage larvae, coupled with the changes in mean abundance, are what would be expected from SONGS withdrawal and entrainment effects; we may not have obtained similar results for the other stages because they may be capable of oriented behavior that allows them to resist transport effects. Their more epibenthic nighttime distribution should also tend to reduce entrainment effects. Alternatively, the lack of effects for flexion and postflexion-stage larvae may imply that the significant plume dates result for preflexion-stage larvae was just a chance occurrence. We cannot separate these possibilities on the basis of the existing data.

Distributional patterns also were compared between monitoring locations and periods. This pattern analysis showed a significant shift in cross-shelf distributions of flexion-stage larvae during the operational period at SONGS. These larvae experienced a relative increase in the Block C epibenthos (Figure D-69); the center of abundance did not shift.

4.2.1.2.5 <u>Paraclinus</u> <u>integripinnis</u> (Reef finspot)

All stages of reef finspot except preflexion larvae increased in abundance at both locations, but more at Control. Preflexion larvae decreased at both locations. BACI tests of the abundance of total larvae and of all stages were nonsignificant, as were all but one of the secondary tests. The plume/non-plume analysis and the pattern analyses also failed to yield clear evidence of a SONGS effect. When one date on which unusually large numbers of larvae were caught at SONGS was deleted from the data set, the BACI tests of total and preflexion larvae were significant. However, since those data reflect natural variability, there is no valid justification for deleting that date. We conclude, therefore, that SONGS operations had no detectable effect on the reef finspot population.

The BACI results of all of the t-tests (using untransformed data for total larvae preflexion, and postflexion-stage larvae, and the log $(x + 0.1)$ transformation for flexion-stage larvae) were nonsignificant (Table 4-2; all values of $p > 0.10$). The binomial test (Table 4-4) showed that the proportions of <u>P</u>. <u>integripinnis</u> larvae (total larvae and all three stages) at SONGS in the operational period were not different from the expected proportions based on preoperational period data (all values of $p > 0.10$). Secondary BACI tests (transformations, Wilcoxon rank sum test) confirmed the results of the primary tests, except that the t-test on log $(x + 1)$ and log $(x + 0.1)$-transformed total <u>P</u>. <u>integripinnis</u> larvae data indicated a significant ($p < 0.10$) decrease in relative abundance. This lack of agreement occurred because the analysis of untransformed data was controlled by a single very large collection.

The power of the BACI procedure to detect a change in relative abundance was low (all ≤ 0.36 at $\alpha = 0.10$), so that a real change would have had to be very large to be statistically recognized. The relative changes of total and flexion-stage larvae were rather large (Table 4-5), although not as large as the decreases recognized as significant for the gobies. Postflexion-stage larvae decreased in mean abundance at both SONGS and Control; all others increased at both locations. The percentage increases were much larger at Control than at SONGS (> 130% at Control vs. < 60% at SONGS), although abundances of all three larval stages remained generally higher at SONGS than at Control in both monitoring periods.

The nonsignificant BACI results for total larvae and for the preflexion-stage larvae were attributable to a single survey made on 19 July 1983, when large numbers of young reef finspot larvae were collected in the midwater and epibenthos near shore at SONGS. These collections legitimately reflected the natural high variability of the open coastal system, and the BACI results that include this survey should be regarded as the best estimator of any overall effect. However, it is interesting to note that excluding this survey yielded significant ($p < 0.10$) BACI results both for total larvae and for preflexion-stage larvae. The mean abundance of total larvae at SONGS declined about 50% (rather than increasing about 27% with the 19 July 1983 datum), but the increase at Control remained larger than 100%.

The BACI analysis of the plume date data (Table 4-3) yielded significant results ($p = 0.05$; t-test on untransformed data) for total P. integripinnis larvae, probably because the 19 July 1983 datum was not included in this subset. However, results for the three developmental stages all remained nonsignificant (all values of p >

0.10). Since withdrawal and entrainment effects should have been most visible in this data subset, the lack of significant results suggests either that these effects were not important for larval P. integripinnis during the 1983 - 1986 operational period, or that the variability of the catch data was too high to allow detection of such effects, or both.

The pattern analysis results (Figure D-90) could be interpreted as agreeing with the BACI results of the tests run without the 19 July 1983 datum in that significant ($p \leq 0.05$) shifts in cross-shelf distributions were recognized for both total larvae and the preflexion-stage larvae. Inspection of the abundance patterns did not reveal a striking shift in distribution, although total larvae did show a relative increase in the Block A epibenthos and a relative decrease in the Block B midwater at SONGS in the operational period relative to the Before-or-Control data set. The preflexion-stage larvae showed a relative increase in the Block A epibenthos. These relative changes may indicate a SONGS-induced redistribution.

4.2.1.2.6 Gibbonsia sp. A (Kelpfish)

The abundances of Gibbonsia sp. A (probably G. elegans, the spotted kelp fish; see Appendix A.1) changed very little at both sites. The BACI tests were nonsignificant and were corroborated by the secondary tests. The pattern analysis failed to identify a clear redistribution of kelpfish larvae. Thus, SONGS operations had no detectable effect on the kelpfish population near SONGS.

The Wilcoxon rank sum test (the t-test was inappropriate because an influence date was delected to obtain additivity) on the untransformed data for total Gibbonsia sp. A larvae was nonsignificant

(Table 4-2; $p > 0.10$). This was due to the fact that relative abundance (Table 4-5) increased only slightly (15%), reflecting a slight increase in mean abundance at SONGS (12%) together with a slight decrease at Control (11%). Corroborative t-tests on transformed data likewise yielded nonsignificant results. Time plots of cross-shelf abundances (Figure D-110) and Deltas (Figure D-109) showed considerable variability and overlapping of values, but no evidence of an effect. Regressions of SONGS abundance on Control abundance did not differ between monitoring periods, strengthening the interpretation of "no effect". The binomial test (Table 4-4) indicated that the proportion of larvae at SONGS in the operational period did not differ from the proportion at SONGS in the preoperational period ($p = 0.63$). BACI and binomial analyses of the developmental stages (Table 4-2) gave nonsignificant results (all $p > 0.10$) as well, and, as in the case of total larvae, showed no evidence of a shift in abundance relationships between monitoring periods in the various plots of abundance and Delta values.

The plume/non-plume BACI analyses (Table 4-3) gave nonsignificant results for total Gibbonsia larvae and all three stages (all values of $p > 0.10$), supporting the primary test result.

The pattern analysis (Figure D-111) confirmed that larvae were most abundant near shore, but did not distinguish between abundance patterns in the SONGS operational and Before-or-Control data sets, except for flexion-stage larvae. Inspection of the patterns for flexion-stage larvae did not show a striking shift, and we do not regard this result as evidence of an effect of SONGS operation.

4.2.1.2.7 Heterostichus rostratus (Giant kelpfish)

The relative abundance of all but the preflexion larvae of giant kelpfish increased at SONGS. The BACI tests and the corroborative tests were all nonsignificant. Pattern analysis suggested a redistribution of flexion-stage larvae away from the block closest to shore. The consistently nonsignificant results of the BACI tests, however, means that SONGS operations had no detectable effect on the giant kelpfish population.

The t-tests on the untransformed data for total H. rostratus larvae and the three larval stages yielded nonsignificant results (Table 4-2; all values of $p > 0.10$). Relative abundance of all but the preflexion-stage larvae increased (Table 4-5). Preflexion larvae showed a nonsignificant ($p > 0.10$) decrease. The secondary BACI tests were also nonsignificant. Mean abundance of total larvae and preflexion-stage larvae increased at both SONGS and Control, the mean abundance of flexion-stage larvae decreased at both locations, and the mean abundance of postflexion-stage larvae increased at SONGS but decreased at Control (Table 4-1). The binomial test (Table 4-4) indicated that the proportions of total larvae and of all developmental stages at SONGS in the operational period were not different from the proportions in the preoperational period (all values of $p > 0.05$).

Analyses of the plume dates and the non-plume dates (Table 4-3) yielded nonsignificant (all values of $p > 0.10$) results for the plume dates subset, when a withdrawal/entrainment effect would be expected to be most apparent, but a significant ($p = 0.09$) reduction in the relative abundance of flexion-stage larvae in the non-plume dates subset, when a withdrawal/entrainment effect should have been least apparent. Since there were only four non-plume observations for flexion-stage larvae, we are inclined to discount this result.

The pattern analysis (Figure D-132) indicated a significant ($p < 0.01$) shift of flexion-stage larvae at SONGS in the operational period. Inspection of the distributional patterns showed a relative decrease in the Block A (most nearshore) epibenthos at SONGS in the operational period. Because this was an area of high larval abundance in the Before-or-Control data set, the MANOVA suggests an important redistribution. However, even if this redistribution did represent withdrawal/entrainment effects, those effects were not large enough to have produced significant reductions in relative abundance.

The BACI and pattern analysis results for postflexion-stage larvae should probably be discounted, since, owing to their behavior (i.e., schooling around giant kelp plants), these larvae were probably not adequately sampled, especially at the Control site, which is about 8 km downcoast from the nearest kelp bed (Barn Kelp). The more planktonic younger larvae could drift to the Control site from the vicinity of the Barn Kelp within about 2-5 days (assuming a mean southward drift in the range of 2-5 cm/s, Reitzel et al., 1987), so for these the Control site may represent a more adequate control, although the demise of Barn Kelp makes that assumption questionable as well. Both the abundance and resulting Delta values were quite variable for the preflexion-stage larvae (Figures D-116, D-114) and, to a lesser extent for the flexion-stage larvae (Figure D-119); consequently the power to detect a real change in relative abundance was low for both stages (Table 4-2). Nevertheless, we see no reason to discount the BACI and pattern analysis results and we therefore conclude that for H. rostratus there was no detectable effect of SONGS operation, or at most only a minor redistribution in cross-shelf position at SONGS in the 1983-1986 operational period.

4.2.1.2.8 Inner Nearshore Taxa: Discussion

The general pattern for the inner nearshore taxa was, with two exceptions, an increase in abundance during the operational period at both the Impact and Control sites. Increases were smaller at SONGS for four species, but Gobiesox rhessodon increased more at SONGS. Only the arrow goby, Clevelandia ios, declined in abundance at SONGS, and only the kelpfish, Gibbonsia sp. A, declined at Control. Changes in abundance were somewhat more variable for the individual developmental stages of each species although these, too, tended to follow the general pattern of increases in abundance at both sites. These changes in abundance were identified as effects for one or more of the developmental stages of all three goby species, but not for any of the other inner nearshore demersal taxa. The plume/non-plume analysis suggested an effect smaller than the detection level of the tests on the full After data set for the preflexion-stage larvae of California clingfish (Gobiesox rhessodon).

This lack of significant BACI results in the full operational data set for four of the seven species thought, *a priori*, to be most likely to show an effect if there was one, may reflect the highly variable nature of the data, may suggest that any "effects" were minor, or both. All of the inner nearshore taxa were quite variable in occurrence, with the result that the variances of the Deltas used in the BACI testing procedure were high and the tests had too little power to recognize any but very large changes in relative abundance as significant. It is not certain that we could ever statistically identify a change in relative abundance for some of these species, even if a real change did occur.

On the other hand, since effects in the inner nearshore group occurred only among the gobies, three questions immediately come to mind: "how do the gobies differ ecologically from the other inner nearshore taxa?"; "how do these differences result in effects?"; and "are these important SONGS effects?". We can provide straightforward answers only to the first question, but we can use those answers to form a basis for speculations on the other two questions.

In answer to the first question, although we previously stressed the general similarity in the natural histories of the inner nearshore demersal taxa, another broad generalization is that the gobies differ from the others in habitat preference. The gobies are thought to reside principally on intertidal mudflats and on the mud and sand bottom in shallow waters of bays, estuaries, and harbors (little is known of their distribution or abundance in open coastal waters; to date only _Ilypnus gilberti_ has been reported to have populations along the open coast, although the others probably do occur there as well). The other inner nearshore demersal taxa occur principally on rocky reefs and around kelp beds along the open coast. Larval distributions are similar for all the inner nearshore demersal taxa, except that the goby larvae tend to be centered a little nearer shore and nearer the bottom than the others.

We suggest that the answer to the second question lies in the more benthic habit of goby larvae. The three principal ways we imagined that SONGS might produce a detectable change in the relative abundance of the inner nearshore fish larvae were: (1) directly, by withdrawal and/or entrainment of the planktonic larvae; (2) indirectly, by increased predation if planktivorous fishes were attracted to the vicinity of the discharge plume, and (3) indirectly, by producing some habitat change that would lead to a change in the size or condition of the spawning populations. If any of these "mechanisms" are important, the facts that goby larvae are found closer to shore than the other nearshore taxa and that the adults have different habitat preferences from the other nearshore taxa might expected to result in a different intensities of SONGS effects than would be the case with for the other inner nearshore taxa.

In Section 4.3 of this report we describe a conceptual model of SONGS-induced circulation, based principally on the results of the macrozooplankton pattern analyses, by which withdrawal and entrainment around the Units 2 and 3 offshore cooling structures might produce significant effects on the plankton, especially for the inner nearshore taxa. Briefly, the major components of this model are:

(1) planktonic organisms entrained at the intakes are consumed by the intake conduit fouling community or are killed during passage through the condenser and sink shortly after discharge;

(2) water withdrawn at the intakes is replaced (conservation of mass requires this) by water that comes predominantly from seaward; and

(3) some fraction of the water in the vicinity of the diffusers is entrained by the diffuser plume and transported surfaceward and seaward, perhaps with some associated mortality to the plankton in that water resulting from turbulent shear or predation.

According to this model, during periods of continuous plant operation individuals of the inner nearshore taxa would be withdrawn at the intakes and lost to the system (except as detritus); at the same time the fraction of the water that was drawn from farther offshore to replace the withdrawn water would, to some degree, dilute the concentration of the remaining inner nearshore taxa (since these taxa are less abundant in the "offshore water"). Organisms entrained and transported seaward by the diffuser plume might suffer some additional losses of unknown magnitude, particularly if they are unable to survive offshore or to return to the nearshore environment (whether either would occur is unknown). On the other hand, improved larval survival near the diffuser plume might be anticipated for fish larvae able to avoid being entrained (probably the larger, better-developed postflexion-stage larvae), provided that other organisms discharged and entrained are suitable as food for those larvae and are perceived as such. However, any such improvement in local larval feeding condition might be counterbalanced by increased predation if mobile predators are attracted to the discharge area. In fact, there is some evidence that such predators have been attracted to the discharge area: the atherinids have increased significantly in relative abundance at the UCSB Fish Project Far Impact Site, which is near the MRC Ichthyoplankton Impact Site, during the operational period (DeMartini et al., 1987). These planktivores probably do consume fish larvae, and may have contributed to the observed effects by cropping larvae in the SONGS vicinity.

The observed effect for the nearshore taxa resulting from withdrawal/entrainment and local predation on larvae would be a relative depletion at SONGS. If such mechanisms actually operate, the withdrawal/entrainment aspects of the effect should be most apparent for planktonic taxa with the most nearshore distributions; i.e., the gobies. Our estimates of most likely intake losses of goby larvae did tend to be somewhat larger than the estimated losses for most of the other inner nearshore taxa (Table 4-6), but did not, in general, seem large enough to have alone produced a BACI effect. If as many as half the larvae at risk to secondary entrainment in the discharge plume were also killed, the most likely total losses of goby larvae could have become substantial, exceeding 50% of the total number in the cross-shelf plane. However, these estimated losses were also not large enough to have alone produced the observed significant relative changes, all of which were at least four times larger than the estimated withdrawal/entrainment losses.

Since the goby larvae (as well as those of all the other inner nearshore taxa) are well-developed at hatching, they may develop the ability to resist transport effects early in larval life. Certainly, this must be true of the postflexion-stage. In our loss estimates we assumed that all larvae of all stages are strictly planktonic and have no ability to make oriented movements that would reduce such effects. This was probably a fair assumption to make for the younger larvae of the planktonic spawners, but may well have been unrealistic for the inner nearshore taxa. The assumption was made for two reasons: (1) young larvae do have rather limited swimming ability and cannot effectively resist currents of centimeters per second except by adjusting their vertical position to levels where current speeds are lower; and (2) no data were available that would allow us to quantify the ability of the inner nearshore larvae to make oriented movements such that transport effects would be reduced. Hunter (1972) estimated that late preflexion-stage anchovy larvae can cruise on the order of one-half body length per second. This might be a reasonable estimate to apply to preflexion-stage goby larvae, but would undoubtedly underestimate the swimming ability of older larvae. Swimming at an average of one-half body length per second (roughly 1-3 mm/s), preflexion-stage goby larvae would have little ability to resist transport by coastal currents moving on the order of a few centimeters per second, except by moving toward the bottom, where current speeds are lower and where transport effects are thus reduced. The largely epibenthic distribution of the goby larvae should serve to reduce longshore transport effects, and these larvae might therefore have a longer residence time in the vicinity of the SONGS intake and discharge structures than would be expected for strictly planktonic organisms moving with the mean current. If goby residence time actually is longer, SONGS withdrawal and entrainment effects might have had longer to work on these larvae, and it is at least conceivable that larger cumulative effects than we predicted could have resulted. On the other hand, the presumed greater ability of the older larvae to resist transport effects should work just as well, if not better, in the vertical and offshore directions as in the alongshore direction, and this may serve to reduce their susceptibility to withdrawal and entrainment. We cannot estimate the relative contributions of potentially reduced susceptibility and increased exposure to these effects.

However, the reduced abundance of Clevelandia ios larvae at SONGS, and the smaller increases at SONGS of the other larval gobies (and of reef finspot and, possibly, giant kelpfish larvae) may well reflect some contribution from these withdrawal/entrainment effects. The lack of relative reductions of the other kelpfish and of California clingfish larvae at SONGS may be attributable to inputs of larvae from the rocky areas off San Mateo Point, just to the north of SONGS. Clingfish and kelpfish larvae were shown to be most abundant near rocky bottom in the MEC special habitats study (Barnett and Sertic, 1979b), and on a single date when both the San Mateo and San Onofre areas were surveyed, both kelpfish and clingfish larvae were much more abundant off San Mateo than off San Onofre. It is conceivable that inputs from the area of higher abundance to the north may have masked any cropping at SONGS.

In addition to the expected negative BACI effect, it follows from the circulation model that a seaward shift in distribution should be observed at SONGS during the operational period. For the most part, centers of abundance did not shift at all for the inner nearshore taxa; instead, rather subtle shifts, not always seaward or surfaceward, were detected in strata where larvae tend to occur less often and in lower numbers.

As noted above, the inner nearshore taxa may develop the ability to resist transport effects relatively early in larval life, certainly by the postflexion-stage. Their principally epibenthic distributions should also serve to minimize transport effects, particularly if the larvae actively select the epibenthic area. If these larvae are capable of such oriented behavior, then we would not necessarily expect to see the kinds of pattern shifts that more planktonic organisms should show.

The third question we posed was whether the effects on the gobies were important SONGS effects. The facts that the projected pattern shifts were not particularly evident and that the expected BACI results were observed only for the most nearshore, epibenthic species among the inner nearshore taxa does not mean that withdrawal and entrainment effects were absent, but it does imply that withdrawal, entrainment, and dilution formed only one component of a suite of mechanisms that must have been operating for this group. For example, in addition to any intake withdrawal effect for the most nearshore species, SONGS Units 2 and 3 operations might have been expected to have localized, probably small, effects on the adults and juveniles of all the inner nearshore demersal taxa. Such effects could have been positive or negative, depending upon the juvenile/adult habitat and the nature of the habitat change near SONGS. For the rocky reef species (mainly reef finspot and California clingfish) the rip rap around the intakes and diffusers may have provided a small amount of new habitat. However, since any resulting increase in the spawning populations would have been small and very localized, and their newly hatched larvae highly susceptible to entrainment effects, it is difficult to imagine this resulting in a detectable increase in larval abundance.

The inner nearshore demersal taxa strongly associated with kelp and benthic algae (the kelpfishes and shadow goby) could have been negatively affected by SONGS Units 2 and 3 operations if the turbid discharge plume caused a reduction in the local macrophyte cover via shading (decreased light transmittance). In fact the San Onofre Kelp bed did become smaller during the operational period, suggesting the possibility of a reduction in attached macrophyte cover. The rip rap around the intakes and discharges might have compensated somewhat for such a potential habitat loss for the kelpfishes (Gibbonsia) and shadow goby (Quietula), although this would probably have been of rather limited importance, and the increased abundance of benthic algae such as Acrosorium during El Nino might also have temporarily compensated for any such loss for these two species. Even if shading did ultimately render the area in the vicinity of the discharge suboptimal for Gibbonsia and Quietula, the effect would be localized, and any resulting decline in the spawning populations probably would not produce a statistically detectable local reduction in larval abundance.

Reduction of the San Onofre Kelp bed due to shading might have more important negative effects on the giant kelpfish, since a large part of the life cycle of that fish is intimately involved with giant kelp and the algal understory. If the San Onofre Kelp bed, which in the late 1970s accounted for roughly one-third of the kelp area between Dana Point and the Santa Margarita River (e.g., Dean, 1979), were to be significantly reduced as a result of SONGS operations (e.g., MRC, 1980), the loss of habitat might translate into a smaller spawning population and a local reduction in the production of giant kelpfish larvae. As noted above, the San Onofre Kelp bed did decrease in size during the operational period, but at the same time the nearby San Mateo Kelp bed expanded, probably compensating for any habitat loss in the San Onofre Kelp. Thus, a detectable reduction in giant kelpfish larval abundance near SONGS should not have been expected in the 1984-1986 operational period as a result of alteration of the adult habitat.

For the soft-bottom inner nearshore demersal species (the gobies), habitat alterations around the intakes and/or diffusers resulting from SONGS operations (e.g., a change in grain size resulting from discharge of shells of fouling organisms, suspended sediment entrained at the intakes, terrestrial material discharged through the plant cooling system, etc.) could have had either positive or negative effects on the resident adult population and/or local recruitment of juveniles, depending on the nature of the changes. Such effects should have been localized near SONGS, but probably were small and would not necessarily be expected to be detectable via an ichthyoplankton survey.

For all the inner nearshore demersal taxa (larvae through adults, except perhaps the juveniles and adults of giant kelpfish), the discharge of injured or dead organisms (e.g., mysids, macrozooplankton) that passed through the Units 2 and 3 cooling systems may have had a direct positive effect by providing a supplemental food resource. Juveniles and adults could have further benefited if the increased organic input resulted in increased local production of benthic epifauna (e.g., mysids) or infauna. In fact, standing stocks of epifauna and some components of the infauna did appear to increase during the After period, although these changes were not clearly linked with SONGS operations (Barnett et al., 1987). Any increase in larval production resulting from a local increase in the spawning population or improvement in spawner condition would not necessarily be expected to be seen in an ichthyoplankton monitoring survey.

Adult entrapment and impingement effects should have been unimportant for the inner nearshore taxa since their benthic habitat should have rendered them relatively immune to such effects. They occur only rarely in impingement/entrapment sampling (e.g., DeMartini et al., 1985, 1987).

The operational period began during the 1982-1984 El Nino, and it is quite possible that the increases in abundance noted for most of the inner nearshore demersal taxa were related to this phenomenon. For example, the mean abundance of shadow goby (Quietula y-cauda) larvae at SONGS differed little between the El Nino and non-El Nino operational surveys, but increased substantially at Control during El Nino (Table 4-7). This is suggestive of an El Nino effect that operated more strongly at Control than at SONGS. If an effect did occur, such localization would suggest that the effect operated most strongly on the relatively stationary adult population (increased larval production) or juveniles (increased local recruitment). The larger increases in abundance of preflexion and flexion shadow goby larvae during El Nino might be taken to mean that larval production increased more than local recruitment.

A way in which El Nino might have had a stronger effect at Control than at SONGS is most easily visualized for <u>Clevelandia</u> <u>ios</u>, whose principal sources of larvae in coastal waters may be to the north and south of SONGS in estuaries and bays, where adults are known to be abundant. The nearest such sites to SONGS are the Santa Margarita River and Oceanside Harbor to the south, and Dana Harbor and Newport Bay to the north. The Control site is about 1 km north of the Santa Margarita River, and SONGS is another 18 km farther north. As a result, increased production near the Santa Margarita River should be more apparent at Control than at SONGS, since the longshore flow near shore in the San Onofre region alternates in the upcoast and downcoast directions, but with a net downcoast motion. The upcoast motion would have to be maintained on the order of one-half to one tidal cycle for larvae produced at the Santa Margarita River to reach the Control site (assuming a current of 2-5 cm/s). At the same mean current speed of 2-5 cm/s (Reitzel et al., 1987), planktonic larvae traveling south from Newport Bay would require on the order of 10-30 days to reach SONGS (perhaps longer, since their largely epibenthic distribution should serve to minimize transport effects); ten to thirty day-old larvae should have developed to the flexion and postflexion-stages. Larvae transported south from Dana Harbor would arrive at a younger stage, possibly late preflexion or flexion (about 4-10 days travelling at 2-5 cm/s). If the principal larval sources are indeed estuaries, bays, and harbors, then relatively few larvae, on average, and those mostly older stages, might be expected to reach SONGS from these areas as a result of transport by coastal currents. At least some local reproduction must occur near San Onofre as well, since young preflexion-stage larvae do occur there in modest numbers.

The large increases in larval abundance at Control could reflect an El Nino effect, for example if the increased runoff resulting from the El Nino period storms altered the bottom type in the vicinity of the Santa Margarita River mouth in a way that favored C. ios, and if that change persisted at least through 1986 (the silt fraction of the bottom sediment could have increased as a result of terrestrial runoff; no data are available to evaluate this). Since C. ios is a colonizing species, it should be capable of rapidly exploiting any suitable new habitat (e.g., silt or silty-sand bottom). The increased larval abundance could thus reflect a larger local population of spawners and/or preferential recruitment to the Control area if the increase in silt and clay was larger and sooner there, or if C. ios is indeed restricted to estuarine, harbor and bay habitats as reported in the literature. Increased spawning near the Control site would suggest higher abundances of preflexion-stage larvae, which was not observed for C. ios. A sizeable fraction of these larvae could have been excluded from the analysis because they were classified with the "Gobiidae" and "Ilypnus/Clevelandia" categories owing to the difficulty of distinguishing preflexion C. ios from Ilypnus gilberti. However, even if all the larvae in the "Gobiidae" and "Ilypnus/Clevelandia" categories were assumed to be C. ios, there would still be far too few preflexion-stage larvae at the Control site to account for the number of flexion and postflexion-stage larvae. Therefore, if changes at the Control site were important in producing the BACI results, these must have consisted largely of immigration of older postflexion larvae and/or preferential settling of younger (flexion and postflexion) larvae in the Control vicinity. Brothers (1975) pointed out that older C. ios larvae tend to localize near the areas where they will subsequently recruit as juveniles. At San Onofre, the combination of increased local predation and intake withdrawal losses may have exceeded the combination of limited local reproduction plus larval transport from the more important areas to the north and south during this time, resulting in the observed decrease in abundance during the operational period.

If increased settling and/or immigration of larval Clevelandia ios near the Santa Margarita River during and following El Nino actually occurred, the initial high negative SONGS-Control Delta values might have appeared as early as the spring and summer of 1983; Delta values in July and August of 1983 were negative but not especially large. The large negative Deltas were first observed one (fish) generation later, in 1984. An El Nino effect at Control, coupled with cropping of larvae at SONGS, would be consistent with many, but not all, of the life history characteristics and BACI results observed for C. ios, but cannot be unequivocally demonstrated on the basis of the available data alone.

The above explanation also does not account for the large increases in abundance of most of the other inner nearshore taxa at the Control site. For example, larval abundance of all three goby species increased substantially at the Control site during the operational period. We have shown one way that this could happen for C.ios; however, for Q. y-cauda and I. gilberti also to increase via a similar mechanism, one would predict that the amounts of both open sandy bottom and algae cover increased in the Control vicinity (in fact, the red algae Acrosorium did increase substantially near the SONGS and Control sites in 1984). Owing to the somewhat different microhabitat preferences of the two species, the ratios of postflexion-stage goby larvae might suggest whether a shift in bottom type did occur, since these larvae should be moving into areas where they will subsequently recruit to the benthic juvenile-adult habitat (Brothers, 1975). Presumably, recruitment will be to a preferred habitat whenever possible. The ratios of postflexion-stage *C. ios* to *I. gilberti* larvae were similar at SONGS and Control during the preoperational period, and at Control during the operational period (range 0.7-0.9), but were very much lower at SONGS in the operational period (0.2). This suggests that rather than a change at Control, it was SONGS that became an unfavorable location for older larvae of *C. ios*, relative to *I. gilberti*. The ratio of the abundance of postflexion *C. ios* larvae to the abundance of postflexion *Quietula y-cauda* larvae likewise showed little change at Control between monitoring periods (6.2 preoperational, 7.3 operational period), but an order of magnitude decline at SONGS (from 24.0 - 2.1), again suggesting that there was little change at Control, but that SONGS became less favorable to *C. ios* than to *Q. y-cauda*. If the postflexion-stage ratios are actually some measure of subsequent recruitment to a preferred habitat, the inference would be that the SONGS habitat, rather than the Control habitat, changed during the operational period.

In summary, MEC detected significant BACI effects for the three most nearshore, epibenthic species. These resulted from large abundance increases at Control, and much smaller increases, or in the case of *C. ios* a decrease, at SONGS. The overall pattern of change for the inner nearshore taxa was a general increase in abundance during the operational period, particularly at the Control site. We have identified a number of mechanisms that could have contributed to these observed changes; however, we do not believe that any one mechanism alone could have produced the observed significant results. The significant changes that we identified as effects may be associated with withdrawal at the Units 2 and 3 intakes and/or entrainment near the diffusers, with predation at San Onofre, with El Nino effects, with SONGS-related local habitat alterations, or with other, unidentified, mechanisms. These other mechanisms could include such things as direct mortality or debilitation (and therefore increased susceptibility to predation or starvation) of fish larvae in the discharge receiving water resulting, for example, from chlorination or the release of other biocides or of radionuclides. We have no way to evaluate the potential contributions of such mechanisms to the observed results, and thus merely note that they might exist. The nature of the monitoring survey data are such that operative mechanisms cannot be unequivocally identified, nor even unequivocally located, at SONGS or Control. There are also plausible explanations of why most non-goby larvae failed to show significant relative decreases at SONGS in the After period. These are related to adult habitat changes away from SONGS, for example at the San Mateo Kelp bed, during the operational period.

4.2.2 Inner Nearshore/Transitional Zone Taxa

The nine taxa categorized as nearshore/transitional zone species are characterized by broad cross-shelf larval distributions, but with highest abundance during at least part of their larval life nearshore, within the depth zone encompassing the SONGS Units 2 and 3 intakes and diffusers. Barnett et al. (1985) identified the larvae of these taxa as being components of four different spatial groups distinguished by the vertical and cross-shelf locations of their highest abundance within the nearshore zone. Two of the species included in the nearshore/transitional zone, queenfish and white croaker, were originally classified with the inner nearshore group (Barnett et al., 1985), owing largely to the very nearshore epibenthic habitat of their later larval stages. However, their younger larval stages have a broader cross-shelf distribution, extending seaward beyond the Units 2 and 3 diffusers. Two other croakers, the black croaker and the California corbina, also are abundant in the nearshore epibenthos, but are more abundant in the midwater strata seaward of the Units 2 and 3 diffusers. These two, together with the similarly distributed larvae of the California halibut and diamond turbot, were classified in a nearshore/transitional zone group by Barnett et al. (1985). Kelp and sand bass larvae were classified as transitional zone species, with highest abundance in the neuston and midwater seaward of the 12 m isobath (Barnett et al., 1985), while larvae of the California grunion and jacksmelt were not characterized. Both species occupy an almost exclusively neustonic habitat that is not shared by any other nearshore taxon.

The taxa included in the nearshore/transitional zone category are a heterogeneous group as adults, ranging from the largely epibenthic and solitary flatfishes to the neustonic, schooling atherinids. Adults range in size from only a few centimeters to tens of centimeters; feeding habits range from benthic generalists to piscivores. Several of these taxa, including the California grunion, white croaker, California corbina, kelp and sand basses, and California halibut, are of moderate to considerable sport or commercial fishery value. All but the atherinids (grunion and jacksmelt) are united in spawning small planktonic eggs that hatch relatively soon (about 1 - 3 days) after spawning. All except the atherinids begin larval life as small, poorly-developed, largely inactive yolksac stage larvae that are little more than planktonic embryos. The atherinids, on the other hand, spawn large, attached or buried eggs that hatch as large, active, well-developed larvae following a relatively long incubation period. Most of the nearshore/transitional zone taxa move to shallow nearshore waters by the late larval or early juvenile stage.

4.2.2.1 Potential SONGS Effects

SONGS Units 2 and 3 operations could be expected to affect both the adults and larvae of the taxa in this group. Direct negative effects on the adults would have been principally entrapment and impingement; the magnitude of these effects is a function of adult size, behavior, and "robustness," and of the efficacy of the SONGS fish return system. Some of the species in the nearshore/transitional zone group, for example queenfish and white croaker, are clearly at considerable risk to these effects (e.g., DeMartini et al., 1985, 1987). The discharge of dead or injured macrozooplankton may have provided a food resource near the diffusers that could have directly benefited fishes such as the planktivorous atherinids and queenfish, or indirectly benefited benthic generalists such as white croaker, if the increased organic input resulted in locally increased production of benthos. Of the various potential SONGS effects on adult fishes, we did not expect any to have caused large enough changes in reproduction to have been detected via the BACI procedure as a local reduction of larval abundance during the operational period. On the other hand, if planktivorous fishes were attracted to the vicinity of the discharge plume (and there is some evidence that this happened, since atherinids have become relatively more abundant 2-3 km downcoast of SONGS in the operational period: DeMartini et al., 1987), increased local predation could have resulted in a local depression of larval abundance. We have not measured and therefore cannot estimate the magnitude of such an indirect effect on the ichthyoplankton.

Owing to the cross-shelf distributions of the larvae, Barnett et al. (1985) predicted that discharge plume entrainment effects (i.e., seaward transport) would probably be relatively minor but that intake withdrawal could be important, except perhaps for the atherinids. Estimates of the magnitudes of these effects based on the standing stocks of the larvae during the 1983 - 1986 operational period are now available (Table 4-6). Estimated intake withdrawal losses were small for all nine species. For only three species--diamond turbot (20%), jacksmelt (13%), and California grunion (10%)--were the losses equivalent to more than 3% of the total number in the cross-shelf plane. If larvae at risk of secondary entrainment in the discharge plume were subject to any additional mortality as a result of having been entrained, estimated losses could have increased considerably. For example, if half the larvae at risk to entrainment were killed, the combined withdrawal and entrainment losses would have been equivalent to more than 20% of the total number in the cross-shelf plane for five of the nine taxa: queenfish (21%), California corbina (23%), diamond turbot (67%), jacksmelt (41%), and California grunion (31%). The older larvae of some of the species could have been more at risk of withdrawal and/or entrainment effects than the younger larvae. For example, withdrawal of queenfish larvae may have killed the equivalent of at least 34% of the postflexion-stage larvae in the cross-shelf plane, but only about 3% of the preflexion-stage larvae in the cross-shelf plane (Table 4-2). The largest estimated losses for the inner nearshore/transitional zone taxa were mainly among the postflexion-stages, which is the most valuable stage in terms of subsequent recruitment. The estimated combined withdrawal/entrainment losses, assuming that half of the larvae entrained were killed, could have exceeded half the total number of larvae in the cross-shelf plane for jacksmelt and all of the croaker species except California corbina (Table 4-6). However, it is possible that these are overestimates for the postflexion-stage larvae, since we made no allowance for their ability to resist transport effects. The magnitudes of the estimated losses were such that we would not necessarily expect significant BACI results attributable solely to withdrawal, but if 50% losses of entrained larvae also occurred, then at least the older larvae of several species would be reduced by the 50% level that the BACI was intended to detect.

4.2.2.2 Test Results

Significant decreases in relative abundance were detected for total, preflexion, and flexion-stage jacksmelt larvae, for the preflexion-stage larvae of queenfish, and for the preflexion and flexion-stage larvae of the kelp and sand basses. A significant reduction in relative abundance was detected for preflexion stage white croaker larvae when the BACI analysis was limited to the plume dates subset of the operational data, in which any withdrawal and entrainment effects should have been most apparent. The plume/non-plume analysis for kelp and sandbass larvae yielded nonsignificant results for preflexion-stage larvae, casting doubt on the results obtained from the full data set. Thus, of these various BACI results, only those for the total and preflexion-stage jacksmelt larvae and preflexion queenfish larvae provided clear indications of an effect of SONGS operations. Pattern shifts were detected only for total and preflexion-stage white croaker larvae and the flexion-stage larvae of queenfish. Although these shifts within strata were consistent with the circulation model described in Section 4.3 of this report, they were relatively minor in extent.

Unlike the results for the inner nearshore taxa, the nearshore/transitional zone taxa generally declined in abundance at both SONGS and Control. In the few cases where mean abundance did increase, the increase usually occurred only at Control, or was much larger at at Control than at SONGS (Table 4-5). A notable exception to this pattern was the California grunion, which increased substantially at SONGS while decreasing a little at Control (a two-tailed BACI test would have revealed this as a significant relative increase).

In summary, there is evidence of a general decline in abundance for most of the nearshore/transitional zone taxa, but significant decreases in relative abundance for only four and a shift in cross-shelf pattern for only two of those four. Our estimates of withdrawal and potential entrainment losses during the operational period suggest that the BACI effects were not attributable to these mechanisms alone, but instead probably resulted from a suite of mechanisms operating simultaneously.

Taxon-by-taxon descriptions of results of the BACI, binomial, and pattern analyses follow. The first paragraph of each individual account summarizes MEC's results and conclusion for that taxon. Readers interested only in general summaries of results should skip to Section 4.2.3, where the broadly-distributed taxa are presented.

4.2.2.2.1 Seriphus politus (Queenfish)

BACI results for preflexion larvae showed a significant relative decrease (not confirmed by secondary tests), but results for total, flexion, and postflexion queenfish larvae showed no significant effects (Table 4-2). The plume/non-plume analysis (Table 4-3) revealed significant decreases of total and preflexion larvae on plume dates. The pattern analysis showed that only flexion-stage larvae were redistributed, but since that stage was not abundant, it is unlikely that the results were meaningful. Thus, SONGS operations may have had an effect on the youngest larvae that was near the limit of detection of the BACI testing on the full After data set; the high variability of the data, and the consequent low power of the tests, prevented clear detection of an effect.

At both SONGS and Control, the abundance of queenfish larvae decreased in the operational period by 47% at SONGS and 16% at Control, yielding a relative decrease of 32% (Table 4-5). This relative decrease was smaller than the level of change that the study was designed to detect, and result of the t-test on untransformed data was not significant ($p = 0.29$). Secondary tests concurred with the primary test. In contrast, the binomial test result (Table 4-4) indicated that the proportion of total queenfish larvae at SONGS in the operational period was lower than the proportion in the preoperational period ($p < 0.01$). Examination of the time plot of Delta values (Figure D-150) revealed considerable overlap in Before and After Delta values and no striking shift in Deltas between monitoring periods. The large negative Deltas observed during the operational period in the summer of 1985 were not repeated in 1986 (Figure D-151). Tests on the untransformed plume data did indicate a significant relative reduction, while the non-plume test results were not significant (Table 4-3). This suggests that there was an effect, but one that was smaller than the detection level of the test on the full data set.

Queenfish larvae were present in high concentrations, with large variabilities that masked possible real differences in relative abundance (Table 4-1). Also, since queenfish larvae move inshore and toward the bottom with age, the potential magnitude of any SONGS effects would differ among the different life stages. This difference would confound the effects of the other stages and thereby increase both the variance of the number of total larvae and the difficulty of finding effects even if they did occur. For these reasons, it was of interest to investigate whether SONGS had an effect on the individual larval stages.

The youngest (preflexion-stage) larvae were found in all blocks in all parts of the water column, but were most abundant in the epibenthos and midwater of inshore A and B Blocks. Although the mean abundance of preflexion-stage larvae increased slightly at the Control site (8%), the mean abundance at SONGS decreased 41%, yielding a significant relative decrease of 48% ($p = 0.06$, at $\alpha = 0.10$, and power = 0.58). The BACI testing was performed on the untransformed data, which met all requisite assumptions of the BACI model. The secondary tests, on log-transformed data, all showed no significant changes between Before Deltas and After Deltas, thus failing to confirm the results of the primary test. Inspection of the time plot of Delta values (Figure D-156) revealed that although there was considerable overlap in values between monintoring periods, the high positive values obtained during the preoperational period were not repeated in the operational period. Probably as a result of this, the binomial test (Table 4-4) indicated that the proportion of total preflexion-stage larvae at SONGS during the operational period was significantly lower than during the preoperational period (p < 0.01).

As the *Seriphus* preflexion larvae matured to the flexion-stage, the large abundances in the inshore A and B Blocks epibenthos became more pronounced, possibly increasing the susceptibility of the larvae to intake withdrawal and diffuser entrainment effects. The flexion-stage larvae declined in mean abundance by 73% at SONGS and 70% at Control between the preoperational and the operational time periods (Tables 4-1, 4-5). The resulting 17% decline in relative abundance was not significant by the BACI t-test on untransformed data (Table 4-2). The results were corroborated by the results of secondary tests on log-transformed data, and the Wilcoxon rank sum test. The time plot of Delta values (Figure D-161) revealed no clear difference between monitoring periods, and the binomial test (Table 4-4) indicated that the proportion of flexion-stage queenfish larvae at SONGS in the operational period was not lower than the proportion at SONGS in the preoperational period (p = 0.35).

The BACI analysis on untransformed data for postflexion-stage larvae was nonsignificant (Table 4-2). Mean abundance decreased by 27% at the Control site but by only 2% at SONGS, yielding a 44% relative increase (Table 4-5). Again, the time plot of Delta values (Figure D-166) showed considerable variability but no difference between monitoring periods. The binomial test (Table 4-4) likewise indicated no decrease in the proportion of postflexion-stage queenfish larvae at SONGS in the operational period (p = 0.77).

The plume/non-plume BACI analyses yielded no significant BACI results for any of the larval stages in the non-plume dates group.

Analysis of plume dates using untransformed data yielded significant BACI results (p = 0.05) for total queenfish larvae as noted above and for preflexion-stage larvae. High (positive) preoperational period Delta values were not repeated in the operational period.

The pattern analysis on total queenfish larvae (Figure D-153) revealed no cross-shelf shifts in larval location at SONGS, suggesting no detectable offshore transport as a result of entrainment in the discharge plume. Queenfish larvae were found in all parts of the water column at all depths, although they were more abundant in the inshore epibenthos and less abundant in the offshore epibenthos. The MANOVA revealed no changes in spatial distributions for preflexion larvae, indicating that the After-SONGS decrease noted in the BACI testing occurred equally in all the cross-shelf strata. Interestingly, the pattern analysis indicated a significant (p = 0.01) shift in the spatial distribution of the flexion-stage larvae (Figure D-153): in the operational period the relative abundance decreased in the midwater of Block A--the block closest to shore and near the intakes--perhaps indicating an intake withdrawal effect on this larval stage. We also detected a significant relative increase in the A- and B-Block neuston. However, the number of organisms found in these locations was very small compared to the midwater and epibenthic parts of the water column; an increase from $0.40/m^3$ to $0.43/m^3$ occurred in the neuston whereas the mean abundance decreased from 12.59 to $4.77/m^3$ in the A-block midwater. Although this difference in the neuston was statistically significant, it probably was not ecologically important.

Postflexion-stage larvae occurred predominantly in the A and B Block epibenthos, with only an occasional individual farther from shore or nearer the surface. The spatial pattern did not differ between the set of "Before-or-Control" and the "After-SONGS" data (Figure D-153).

4.2.2.2.2 Genyonemus lineatus (White croaker)

BACI analyses of white croaker larval abundances did not reveal any significant changes except for preflexion larvae on plume dates. This was partly due to the fact that since relatively few surveys were conducted during the winter-spring spawning season, the power of the tests to detect changes was low. Pattern analysis suggested an entrainment effect on preflexion larvae. The weight of evidence suggests, but does not confirm, that SONGS operations affected the abundance and distribution of young white croaker larvae.

The BACI analysis on untransformed cross-shelf abundance (Table 4-2) of white croaker larvae showed a nonsignificant 44% decrease in relative abundance associated with a larger decrease in mean abundance at SONGS (69%) than at Control (30%; Table 4-5). The secondary tests likewise failed to distinguish the decrease in mean Delta from zero. The analyses on plume and non-plume data sets both yielded nonsignificant results (Table 4-3).

The preoperational period sampling was largely directed toward queenfish, and secondarily toward some of the more abundant nearshore planktonic spawners of sport or commercial value. Most of these species are summer spawners, whereas white croaker are winter-spring spawners. Thus the timing of sampling in the preoperational period was not particularly appropriate for white croaker: about 19% of the preoperational surveys and 38% of the operational surveys were taken during the major part of the white croaker spawning season, During the spawning season, larval abundance often was orders of magnitude higher than it was when most of the preoperational and operational surveys were conducted (e.g., Figure D-173).

When relatively few larvae are available for analysis, it is not too surprising to find no effect. On the other hand, the high variability during spawning season (e.g., Figure D-171) served to reduce BACI power so that even if an effect did occur it might not be statistically recognizable via the BACI procedure; the powers of all primary BACI analyses of white croaker were less than 0.50 (Tables 4-2, 4-3). The regional decrease in abundance of white croaker noted earlier was small compared to the difference between "spawning season" surveys and "off season" surveys (less than an order of magnitude for the regional decline vs. roughly two orders of magnitude for the seasonal difference), and is, therefore, unlikely to have accounted for the nonsignificant BACI results.

Although the BACI testing procedures failed to detect a significant effect, the binomial test (Table 4-4) indicated that the proportion of white croaker larvae at SONGS in the operational period was significantly lower than expected.

When the BACI analyses were applied to the larval stages, the results were nonsignificant for all three stages (Table 4-2). Time plots of Delta values (Figures D-177, D-182, D-187) of the three stages revealed high variability during spawning season and little variability during the off season, when very few larvae were taken, but no obvious differences between monitoring periods. Mean abundance declined from the preoperational to the operational period for all three stages at both SONGS and Control (Table 4-1). The decline was much larger at SONGS for preflexion larvae, a little larger at SONGS for flexion-stage larvae, and essentially the same at both locations for postflexion-stage larvae. Accordingly, relative abundance decreased 55% for preflexion-stage larvae, increased 5% for flexion-stage larvae, and increased 41% for postflexion-stage larvae (Table 4-5). Preflexion-stage and flexion-stage larvae also showed a significantly lower proportion than expected at SONGS in the operational period ($p < 0.01$ and $p = 0.02$, respectively). The relative decrease for preflexion-stage larvae was about the level of change that the study was intended to detect, but since the power of the t-test was moderately low, the likelihood of statistically recognizing a 50% decrease as significant was also low.

The plume/non-plume BACI analyses (Table 4-3) yielded nonsignificant ($p > 0.10$) results for all but the preflexion-stage larvae on plume dates, which declined significantly ($p = 0.10$) in relative abundance. Mean abundance of preflexion-stage larvae declined 57% at SONGS while increasing 49% at Control in this subset of the operational period data. Thus, there was some suggestion of an effect, but one below the detection level of the test on the full data set, for this stage. Such a minor effect, if it truely occurred, is unlikely to have been of importance to the white croaker population since the probability that a larva will survive to recruitment from the preflexion-stage is very low, even under purely natural conditions.

The pattern analysis on total larvae (Figure D-174) indicated a significant shift in pattern at SONGS in the operational period relative to the pattern in the Before-or-Control data set. However, examination of the abundance pattern did not reveal a striking change: larvae may have been shifted away from the midwater shoreward of the intakes and slightly upward into the water column in the depth range corresponding approximately to the Unit 3 diffuser. The MANOVA also showed a significant, but not striking, pattern shift (Figure D-174) for the preflexion-stage larvae. The location of highest abundance did not change, but the region of secondary abundance at SONGS shifted upward into the neuston in the depth zone encompassing the Units 2 and 3 diffusers during the operational period. This could be interpreted as reflecting a diffuser entrainment effect, with larvae transported upward from a preferred habitat lower in the water column. Such an effect should have been most apparent for preflexion-stage larvae, since these have the most limited swimming abilities. If the young larvae were entrained in the discharge plume, they do not appear to have been transported seaward to any appreciable degree and, owing to their broad cross-shelf distribution, probably would not be severely adversely affected by such transport even if they had been. Losses of larvae in the discharge plume probably did occur as a result of turbulent shear stress (this effect is thought to be of minor importance; e.g., MRC, 1980) and predation (resulting perhaps from disorientation of the entrained larvae, or increased predator abundance in the vicinity of the discharge plume, or both) but these effects did not result in a large enough decline in relative abundance to have been statistically recognized in the BACI testing.

4.2.2.2.3 Cheilotrema saturnum (Black croaker)

Later-stage black croaker larvae were very rarely collected (Table 4-1), so only total and preflexion larvae were tested. Primary and secondary BACI tests and plume/non-plume BACI tests were nonsignificant. Pattern analyses failed to reveal any evidence of redistribution. Therefore, SONGS operation had no detectable effect on black croaker larvae.

The BACI results (Table 4-2) based on untransformed data were nonsignificant for total and preflexion-stage larvae (too few flexion and postflexion-stage larvae were collected to analyze statistically). Time plots of Delta values for total black croaker larvae and preflexion stage larvae (Figures D-192, D-198) showed no obvious differences between periods. Mean abundance of larvae increased at both SONGS and Control during the operational period, as did relative abundance (Table 4-5). The increase in abundance at Control was larger (about 160%) than the increase at SONGS (about 94%) owing to especially high abundance on the 24-24 August 1983 survey (Figure D-194). The secondary BACI tests (Figures D-192, D-197) and the binomial test (Table 4-4) confirmed the primary BACI test in showing no significant differences in the abundances or proportions of total or preflexion-stage larvae at SONGS between the preoperational and operational periods. Results of the BACI analysis of the plume dates subset of operational data were also nonsignificant. The pattern analysis (Figure D-195) showed no evidence of a shift in cross-shelf distribution at SONGS during the operational period, supporting the BACI and binomial test results.

Since most of the C. saturnum taken during the ichthyoplankton monitoring study were preflexion-stage larvae, it is not surprising that BACI, binomial, and pattern analysis results for the preflexion-stage larvae mirrored those shown for total larvae. Neither flexion nor postflexion-stage larvae occurred at both monitoring locations on the same date, and given this variability the power to detect an effect would have been very low even if enough non-zero observations were available to warrant analysis. Mean abundance of flexion-stage larvae declined at both SONGS and Control, while postflexion-stage larvae declined only at SONGS (Table 4-1). However, because so few individuals were involved, these changes may not reflect actual population changes. Instead, the results of the analyses lead us to conclude that there was no effect of SONGS operation on Cheilotrema saturnum larvae.

4.2.2.2.4 Menticirrhus undulatus (California corbina)

BACI tests, the binomial test, plume/non-plume tests and pattern analysis for all yielded nonsignificant results. This indicates that SONGS operation had no detectable effect on the larvae of California corbina.

The BACI t-tests on untransformed data yielded nonsignificant results for total corbina larvae and for the preflexion and flexion stages (Table 4-2). Postflexion-stage larvae occurred too infrequently (only once in the operational period) to allow statistical analysis. The secondary tests corroborated the primary test for total and preflexion-stage larvae, and the time plots of Delta values revealed no striking differences between monitoring periods (Figures D-203, D-209). For the flexion-stage larvae, however, secondary tests (t-test on log-transformed data and the Wilcoxon rank sum test on untransformed data) gave significant ($p < 0.10$) results, contradicting the primary test. This discrepancy was probably due to the very small sample size (seven preoperational and four operational surveys), which suggests that this BACI result is more reflective of natural variability than of a SONGS effect. The plume/non-plume analyses yielded nonsignificant results for both subsets (Table 4-3), supporting the interpretation of no effect.

The mean abundance of total corbina larvae and of the preflexion and flexion-stages decreased at Control in the operational period (about 70%); the abundances of total and preflexion-stage larval decreased to a smaller degree at SONGS (about 30%) while the abundance of flexion-stage larvae increased at SONGS by 86% (Tables 4-1, 4-5). Consequently, relative abundance increased for total larvae and both stages (Table 4-5). The proportion of each of these categories at SONGS in the operational period was not significantly lower than its respective proportion at SONGS in the preoperational period (Table 4-4).

The interpretation of no effect is supported by the nonsignificant results of BACI t-tests of untransformed data noted above for total larvae, and for preflexion-stage corbina larvae, on plume dates (Table 4-3). The pattern analysis (Figure D-206) indicated no significant overall shifts in cross-shelf pattern (all values of $p > 0.05$ for total larvae, preflexion, and flexion-stages).

4.2.2.2.5 Paralabrax Species (Kelp Bass and Sandbasses)

Results of the BACI tests of the abundance of total larvae were not significant. Significant results for preflexion and flexion-stage larvae were attributed to the effects of two very large collections in the operational period, but could not be entirely dismissed. The pattern analyses revealed no significant redistributions. Because of the equivocal results of the analyses, MEC can neither accept nor reject the conclusion that SONGS had an effect on preflexion and flexion-stage larvae, but we conclude that SONGS operation had no detectable effect on total and postflexion larvae.

The powers of all of the tests were low (Table 4-2), so that only very large changes in the abundance of Paralabrax larvae could be detected. The primary BACI test of untransformed data on total larvae (Table 4-2) indicated that the 110% decrease in relative abundance (Table 4-5) was not significant. The secondary tests (t-tests on log (x + C) - transformed data) likewise yielded nonsignificant results (Figure D-213), confirming the primary test result. The binomial test, on the other hand, gave a significant result (Table 4-4), suggesting that the proportion of total Paralabrax spp. larvae at SONGS in the operational period was lower than the proportion at SONGS in the preoperational period. Examination of a time plot of Delta values (Figure D-214), however, cast doubt on the result of the binomial test: all but four values of Delta were grouped around a mean of zero, and showed no obvious difference between monitoring periods. The plume date analysis yielded a nonsignificant result (Table 4-3), supporting the interpretation of no effect.

The analyses were rerun on the larval stages because the older stages are distributed somewhat nearer shore than the younger larvae and consequently may have been more likely to show effects. Surprisingly, the BACI t-test on untransformed data for preflexion-stage larvae (Table 4-2) indicated that the 101% decrease in relative abundance was significant, despite the broad distribution of the larvae and the low power of the test. Some secondary tests confirmed the principal result, others did not. Inspection of the time plot of Delta values (Figure D-221) certainly did not suggest a strong effect, but did suggest that the significant results based on untransformed data stemmed largely from two surveys in the operational period, on 23 August 1983 and 12 September 1985, when very large collections were made at the Control site. These represent valid data, and although they are outliers there is no reason to discount them. Mean abundance declined by 36% at SONGS but increased by 70% at Control (Table 4-5). Such a pattern of changes in abundance might be expected if a true SONGS effect had occurred; however, mean abundance exclusive of the 23 August 1983 and 12 September 1985 dates decreased at Control by an amount comparable to the decline at SONGS, so this pattern, too, resulted from only two surveys.

BACI t-test results for flexion-stage larvae (Table 4-2) were significant, and were corroborated by the secondary tests (Figure D-224). The binomial test indicated that a smaller than expected proportion of the flexion-stage larvae occurred at SONGS during the operational period (Table 4-4). Mean abundance decreased 42% at SONGS while increasing 374% at Control, and relative abundance decreased by 416% (Table 4-5; see Section 3.7.1.4 for an explanation of why relative abundance can differ from the values that one would expect on the basis of absolute abundance). Concordance of a suite of results might be taken as stronger evidence of an effect than in the case of the preflexion larvae. Inspection of the time plot of Delta values (Figure D-226), however, revealed that this result, too, was driven by two surveys, this time with a much larger catch at SONGS in the preoperational period on 7 July 1981 (yielding a large positive Delta) and a much larger catch at Control during the operational period on 23 August 1983 (yielding a large negative Delta value). Exclusive of those two dates, mean abundance declined at both SONGS and Control, but much more so at SONGS (-98% at SONGS vs. -34% at Control). Again, those two dates are valid data points, and there is no valid reason, apart from their status as outliers, to discard them.

The primary BACI test of data on postflexion-stage larvae yielded a nonsignificant result (Table 4-2) that was corroborated by the secondary tests (Figure D-229). The binomial test did indicate that the proportion of postflexion-stage larvae at SONGS in the operational period was significantly lower than the preoperational period proportion (Table 4-4). However, inspection of the time plot of Delta values (Figure D-230) again showed that the only marked difference between periods was the very large positive preoperational period value resulting from a large collection at SONGS on 7 July 1981 and the large negative Delta during the operational period resulting from a large collection at Control on 23 August 1983. Since inclusion of these points should have increased the likelihood of finding an effect, it is reasonable to accept the nonsignificant BACI result.

The BACI test of data on total larvae on the plume dates, as noted above, gave a nonsignificant result (Table 4-3), suggesting that there was no effect of SONGS. Mean abundance decreased by 67% at SONGS and 38% at Control in this subset. The tests of the data on preflexion and postflexion-stage larvae also yielded nonsignificant results. The plume dates subset of operational data contained only a single observation for flexion-stage larvae and could not be analyzed. Although significant results were obtained for the non-plume dates, such results do not indicate a SONGS effect (Section 3.7.1.3).

Finally, the MANOVA for changes in abundance pattern (Figure D-217) indicated no significant shifts in cross-shelf distribution at SONGS during the operational period for total larvae and all three stages, in conformance with the bulk of the other results on _Paralabrax_ larvae.

4.2.2.2.6 _Hypsopsetta_ _guttulata_ (Diamond turbot)

MEC's analyses detected no effects of SONGS operations on diamond turbot larvae. The primary BACI test (incorporating an autoregressive errors model) of total larvae indicated that the 4% decline in relative abundance was nonsignificant (Table 4-2). This result was supported by the nonsignificant results of the secondary tests (Figure D-234). A trend in the preoperational period Delta values of preflexion-stage larvae disappeared when a single date was deleted, permitting the use of the t-test. The autoregressive errors BACI t-test of data on preflexion-stage larvae that did not include this date yielded a nonsignificant result (Table 4-2), which was confirmed by the binomial test result (Table 4-4).

Flexion and postflexion-stage diamond turbot larvae occurred too rarely in the operational period (in 3 surveys and 1 survey, respectively) to warrant statistical analysis (Table 4-1). Both of these stages, like preflexion and total diamond turbot larvae, declined in abundance at both SONGS and Control from the preoperational to the operational period. These declines at both locations were on the order of 80% for total and preflexion-stage larvae and 50-100% for the older larvae (Table 4-5).

The plume/non-plume analysis yielded a nonsignificant result for total larvae (Table 4-3). Insufficient data were available for the analysis of other stages.

The analysis of cross-shelf pattern of distribution revealed no shifts at SONGS in the operational period (Figure D-237) and no changes in relative abundance within any stratum, supporting the negative results of the BACI and binomial tests.

The lack of significant results for diamond turbot larvae was related, at least in part, to the small sample sizes, high variability, and trends in the data. Since, however, inspection of the plots of Delta values over time (Figures D-235, D-241, D-246) revealed no obvious differences between monitoring periods, the nonsignificant results appear to be valid.

4.2.2.2.7 Paralichthys californicus (California halibut)

The relative abundance of California halibut larvae at SONGS decreased by 20% between the two monitoring periods. However, the primary BACI test and most of the secondary tests yielded nonsignificant results. Results of the plume/non-plume analysis were also nonsignificant. The pattern analysis revealed no significant redistributions. MEC concludes that SONGS operation had no detectable effect on the abundance and distribution of halibut larvae.

Serially correlated untransformed Delta values in the preoperational period mandated the use of the autoregressive errors procedure instead of the standard BACI t-test. With the second order autocorrelation modeled, a nonsignificant decrease (20%) in relative abundance was revealed (Tables 4-2, 4-5). The results of the secondary tests confirmed the primary test result (Figure D-250). Mean abundance decreased a little more at SONGS (-60%) than at Control (-49%) from the preoperational to the operational period, and the binomial test identified this as a significant decrease in the proportion of total halibut larvae at SONGS during the operational period (Table 4-4). Examination of the time plot of Delta values (Figure D-251) revealed much higher variability in the preoperational period when abundances were higher, but no other obvious differences between monitoring periods.

The older larvae were of particular interest in the analyses of SONGS effects because they tend to concentrate near shore and thus may be more susceptible to withdrawal and entrainment. The primary BACI results for all stages were nonsignificant (Table 4-2). Of the secondary tests, only the binomial test results for preflexion and postflexion-stage larvae were significant (Table 4-4; Figures D-256, D261, D-266), indicating that for both stages the proportion at SONGS in the operational period was lower than the respective proportion at SONGS during the preoperational period (both values of $p < 0.01$). Inspection of the time plot of Delta values (Figure D-257) suggested that the significant binomial for preflexion larvae was caused by only very few preoperational surveys when particularly large catches were made at Control.

The BACI analysis on the plume dates subset of operational data, yielded a nonsignificant result for total larvae (Table 4-3), confirming that for total California halibut larvae there was no SONGS effect during the operational monitoring period. The BACI t-tests on data from all three larval stages also yielded nonsignificant results (Table 4-3).

The MANOVA showed no significant shifts in cross-shelf distribution and no relative changes in any stratum for total larvae and all three stages at SONGS during the operational period relative to the pattern in the Before-or-Control data set (Figure D-254).

4.2.2.2.8 Atherinopsis californiensis (Jacksmelt)

Jacksmelt larvae declined in relative abundance at SONGS by 43% between the two monitoring periods. BACI analyses showed that this change was significant, and also showed significant changes in the abundances of the preflexion and flexion stages, although the latter was uncorroborated by secondary tests. These results all seem to have had a seasonal component, with a larger difference between monitoring periods during the spawning season, when larvae were more abundant, than during the "off season". The pattern analysis did not reveal a shift in cross-shelf distribution for any stage. SONGS operations appear to have affected preflexion and total larvae, may have affected flexion-stage larvae, and did not affect post-flexion larvae.

The autoregressive errors procedure on log (x + 0.1)-transformed data for total jacksmelt larvae (required because the operational period Delta values were serially correlated) indicated a third order autocorrelation, and yielded a significant BACI result (Table 4-2). This could not be corroborated by secondary t-tests because all other data treatments except the log (x) transformation (use of which would have resulted in deletion of about 33% of the Before surveys and 20% of the After surveys) were nonadditive.

The binomial test indicated that the proportion of total jacksmelt larvae at SONGS in the operational period was lower than the proportion in the preoperational period (Table 4-4), and the plume/non-plume analyses yielded a significant result on the plume dates, but not for the non-plume subset (Table 4-3). Thus an effect is suggested. The mean abundance of jacksmelt larvae declined more at SONGS (-79%) than at Control (-36%), yielding a 43% decline in relative abundance (Table 4-5).

Inspection of the time plot of Delta values (Figure D-272) suggests that during the spawning season, Delta values may have been higher in the preoperational period, but there was little difference between periods in the "off season," when fewer larvae occurred and when the majority of surveys were taken. Larval abundance was nearly always much higher during "spawning season" surveys than during "off season" surveys, except in the spring of 1980 (Figure D-274), when both cool water and high abundances of jacksmelt larvae persisted longer than usual.

For the stage analyses, yolksac and preflexion-stage larvae were pooled as "preflexion" stage. Since yolksac stage larvae are large and vigorous, have essentially the same distribution as preflexion-stage larvae, and are frequently difficult to distinguish from preflexion-stage larvae, this seems justified. The autoregressive errors BACI t-test on the preflexion-stage data indicated that the 48% decline in relative abundance was significant (Table 4-2). The binomial test also indicated that the proportion of total preflexion-stage jacksmelt larvae at SONGS in the operational period was lower than the preoperational proportion (Table 4-4). The autoregressive errors t-test on plume dates yielded a significant result, while that on non-plume dates did not (Table 4-4), supporting the interpretation of an effect. Mean abundance declined at both SONGS and Control, but more so at SONGS (-81% vs. -32% at Control).

Inspection of the time plot of Delta values (Figure D-278) for preflexion-stage larvae revealed a broad zone of overlap between preoperational and operational period Deltas during spawning season, but with a tendency for the preoperational period values to be higher (mean untransformed Delta +9.44) than the operational period values (mean untransformed Delta -1.07). During the "off season," the preoperational values were smaller for the most part (mean untransformed Delta +3.12), but remained higher than operational period values (mean untranformed Delta -0.01).

Results of the primary BACI test on data for flexion stage larvae, like the result for preflexion larvae, was significant (Table 4-2), even though the decline in relative abundance was only 7%. The decline in mean abundance differed little between SONGS and Control (-67% at SONGS, -59% at Control). The secondary tests were divided: the other t-tests and the binomial yielded nonsignificant results, but the Wilcoxon rank sum tests yielded significant results (Table 4-4, Figure D-282). The plume/non-plume results were both nonsignificant (Table 4-

3). Examination of the time plot of Delta values (Figure D-283) did little to resolve these conflicting results. Delta values from the spawning season did appear to be generally lower during the operational period than during the preoperational period, but the difference in values between spawning season and the "off season" was much smaller than in the case of the younger larvae.

The primary BACI test for postflexion-stage larvae yielded a nonsignificant result (Table 4-2), and was corroborated by the secondary tests (Figure D-287). The decline in mean abundance was nearly identical at both SONGS and Control (-90% at SONGS, -92% at Control), but yielded an increase in relative abundance (Table 4-5). Examination of the time plot of Delta values (Figure D-288) likewise revealed no difference between monitoring periods aside from lower variability during the operational period, when abundance was substantially reduced at both SONGS and Control. SONGS clearly had no detectable effect on postflexion-stage jacksmelt larvae. The plume/non-plume dates analyses were nonsignificant.

The pattern analysis (Figure D-275) did not reveal a shift in cross-shelf distribution at SONGS in the operational period for total jacksmelt larvae or any of the larval stages (all values of $p > 0.05$). Barnett et al. (1986) speculated that a relative increase of atherinid larvae in the seaward sampling blocks at SONGS might occur during the operational period as a result of seaward transport in the discharge plume, but such an effect was not apparent in the pattern analysis on jacksmelt larvae.

4.2.2.2.9 Leuresthes tenuis (California grunion)

Grunion larvae showed a relative increase of nearly 300%. All BACI tests of all stages and of the plume/non-plume data subsets yielded nonsignificant results, and the pattern analysis revealed no significant changes in the distribution of grunion larvae. SONGS operation clearly had no detectable effect on the abundance (i.e., there was no reduction in abundance) or distribution of larval Leuresthes tenuis.

The BACI t-test on total larvae data yielded a nonsignificant result (Table 4-2), reflecting the increase in mean abundance (241%) at SONGS and concurrent decrease (41%) at Control, which produced a large increase in relative abundance (282%; Table 4-5). This increase would have been statistically significant had it been tested for, which indicates that for this species use of a one-tailed test was inappropriate. The secondary tests also yielded nonsignificant ($p > 0.10$) results, confirming the principal test result (Figure D-292). The binomial test indicated that the proportion of total California grunion larvae at SONGS in the operational period was not lower than the proportion in the preoperational period (Table 4-4). Examination of the time plot of Delta values (Figure D-293) revealed little difference between monitoring periods, or perhaps a tendency for operational period values to be a little higher than preoperational values during spawning season. In either case there was clearly no indication of a decrease in relative abundance during the operational period and thus no effect. In view of the abundance decrease at Control and the very similar larval life histories of the grunion and jacksmelt (which decreased everywhere: Section 4.2.2.2.8), it is difficult to understand how the grunion larvae could have increased in abundance near SONGS except by assuming increased spawning along the San Onofre beaches.

The nonsignificant results for total California grunion larvae were reflected in the nonsignificant results for the developmental stages, all of which increased in relative abundance during the operational period (Tables 4-1, 4-4). In these analyses the yolksac and preflexion-stages were combined as "preflexion" for the same reasons as in the analyses of _Atherinopsis_. Both the primary and secondary BACI tests and the binomial tests were nonsignificant for all stages (Tables 4-2, 4-4, Figures D-298, D-303, D-308).

The plume/non-plume analyses of all stages yielded nonsignificant results (Table 4-3).

The MANOVA did not show a shift in cross-shelf distribution (Figure D-296) at SONGS during the operational period for total California grunion larvae or for any of the stages (all values of $p > 0.05$), nor did it indicate relative changes in any particular strata.

4.2.2.2.10 Inner Nearshore/Transitional Zone Taxa: Discussion

The general pattern observed among the inner nearshore/ transitional zone taxa was, with few exceptions, a decrease in abundance during the operational period at both the Impact and Control sites (Table 4-4). These decreases tended to be of similar magnitude at both sites, or larger at SONGS. Only California corbina decreased more at the Control site than at the Impact site. Only black croaker larvae increased in mean abundance at both sites (more so at Control). California grunion larvae increased at SONGS while decreasing at Control, and larval kelp and sand basses showed exactly the opposite pattern, decreasing in mean abundance at SONGS while increasing at Control.

Few of these changes in abundance were large enough to have produced significant BACI results, which is not very surprising given the generally low power of the BACI tests for these taxa (Tables 4-2 and 4-3). The fact that significant changes were detected for one or more larval stages of only three of these taxa in the full operational data set and for only one additional species in the plume dates suggests that the overall effect of SONGS was minor, although these results undoubtedly also reflect the highly variable nature of the catch data. The effect for total queenfish larvae appears to have been largely driven by the preflexion-stage result. This, together with the possible minor effect for preflexion-stage white croaker (detected only in the plume dates analysis), is probably of little importance to the respective populations as a whole since the probability that a larval fish will survive from the preflexion-stage to recruitment is very small.

It is difficult to imagine a single mechanism that could account for both the significant and nonsignificant results for the inner nearshore/transitional zone taxa; certainly no single SONGS mechanism (e.g., entrapment/impingement of adults or withdrawal/entrainment of larvae) nor any single ecological mechanism (e.g., local predation, local changes in larval production, growth, or survival, etc.) can be invoked that, operating uniformly, would have accounted for all results. The location of larvae very nearshore in the epibenthos seemed to be important for recognizing which of the inner nearshore taxa would show an effect; however, this was not the case for the inner nearshore/transitional zone taxa. Among the four taxa showing effects, two (queenfish and white croaker) tend to be predominantly epibenthic, but the other two (jacksmelt and Paralabrax) occur largely in the upper water column. The older, more nearshore larvae of several of the inner nearshore/transitional zone taxa were either too rare to test statistically or else showed no evidence of an effect.

Two species pairs included in the inner nearshore/transitional zone group differed in terms of BACI test results. Both members of one pair, queenfish and white croaker, showed some evidence of an effect, at least during the preflexion-stage when, owing to their small size and weak swimming ability, they should have been most at risk to withdrawal and/or entrainment effects. The other species pair, jacksmelt and California grunion, showed opposing results: jacksmelt declined in relative abundance, whereas grunion would have shown a significant increase had a two-tailed test been used. Both are similarly distributed, both are essentially neustonic and both decreased in mean abundance similarly at Control. The declines at Control may represent a general decline in atherinid abundance during the operational period and the additional decrease of jacksmelt larvae near SONGS was thought to include a SONGS influence, perhaps related to predation in the vicinity of the plume, or to a reduction of adult spawning habitat (e.g., the reduction of the San Onofre Kelp bed), for example. However, the very large increase of grunion larvae near SONGS is difficult to understand except by invoking increased spawning along the beaches in the San Onofre vicinity.

In short, MEC did detect evidence of a BACI effect for four of the nine inner nearshore/transitional zone taxa. The mechanisms that would account for these results, however, are not known.

4.2.3 Broadly-Distributed Taxa

Three taxa are included here in a group whose larvae occur throughout the cross-shelf plane from very near shore to well seaward of the 75 m isobath. These three taxa, the northern anchovy (Engraulis mordax), sanddabs (Citharichthys spp.), and blennies (Hypsoblennius spp.), were classified by Barnett et al. (1985) into two groups distinguished mainly by their vertical position in the water column: the northern anchovy group (which also included four of the nine taxa treated in the inner nearshore/transitional zone group) was characterized by highest abundance in midwater throughout the cross-shelf plane and in the epibenthos nearshore, while the sanddab/blenny group was characterized by highest abundance in the neuston and midwater across the cross-shelf plane.

The broad cross-shelf distributions of their larvae is the only feature that unites the broadly-distributed taxa. The adults form a very heterogeneous group, ranging from the small, schooling planktivorous northern anchovy to the solitary, benthic generalist sanddabs. Adults of all three species typically are most abundant in the coastal zone (blennies are restricted to the shallow waters along the coast and around the offshore islands), but the sanddabs and, especially, the anchovies may range far out to sea as well. Anchovies and sanddabs spawn small planktonic eggs from which small, poorly developed, and largely inactive yolksac stage larvae hatch, while the blennies spawn adhesive eggs in nests guarded by an adult, and hatch as small but relatively well-developed and active larvae.

4.2.3.1 Potential SONGS Effects

SONGS effects on adults of this group vary depending on the species considered. For example, large numbers of northern anchovies are lost to impingement (DeMartini et al., 1985), but adult sanddabs and blennies are largely immune to impingement effects because of their benthic habit.

Because most northern anchovy larvae near San Onofre appear to come from outside the local area (Barnett et al., 1984), it is unlikely that any reduction in local production resulting from the large numbers of adults impinged (e.g., DeMartini et al., 1985) would have resulted in any detectable change in local larval abundance during the operational period. On the other hand, the planktivorous adults may be attracted to the vicinity of the discharge plume; if so, they could have locally reduced the abundance of eggs and/or larvae via predation. Such an effect would not necessarily be distinguishable from a local reduction caused, for example, by intake withdrawal.

Any effects detectable as decreases in the relative abundance of larvae should have been those that acted upon the larvae alone. These may have included the direct effects of withdrawal and entrainment, as well as the indirect effect of predation caused by planktivorous fishes. Although the magnitude of such potential predation effects cannot be directly estimated, withdrawal and entrainment effects have been estimated. Losses of larvae caused by withdrawal at the intakes during the operational period were probably equivalent to less than 2% of the respective totals in the cross-shelf plane for each of the taxa considered here (Table 4-6), reflecting their broad cross-shelf distributions. If larvae at risk of entrainment in the discharge plume were subject to added mortality as a result of being entrained, the total losses for this group of taxa would still have remained small: MEC's estimates showed that if as many as half the larvae at risk of entrainment during the operational period were killed, the combined entrainment and withdrawal mortality would not have exceeded about 13% of the total in the cross-shelf plane for any of these taxa. The older larvae of blennies and northern anchovy may have been at greater risk to both withdrawal and entrainment effects (Table 4-6) owing to their tendency to be more concentrated nearer shore (e.g., Barnett et al., 1984), but the largest estimated losses for this stage still barely exceeded the equivalent of 26% of the respective total postflexion-stage larvae in the cross-shelf plane. Thus, these estimates suggest that withdrawal or entrainment alone would not have caused significant BACI results.

4.2.3.2 Test Results

The final analysis of data revealed no general patterns of changes in abundance among the broadly-distributed group; the three taxa displayed three different patterns (Table 4-5). The final BACI analyses failed to yield significant results for the blennies and sanddabs, but did reveal an effect in the case of total anchovy larvae (Table 4-2), which declined in abundance at SONGS while increasing at Control. The plume/non-plume analysis confirmed that result and indicated an effect for postflexion larvae as well. The northern anchovy was the only ichthyoplankton taxon for which the power of the BACI test reached the desired 0.80 level. None of the pattern analyses were significant, indicating that no redistributions occurred in the operational period.

In summary, an effect was observed for one of the three broadly-distributed taxa, even though we did not particularly expect to detect an effect for any of them. This effect may have been related, at least in part, to the operation of SONGS Units 2 and 3.

Species-by-species synopses of the BACI and associated analyses for the broadly distributed taxa are presented in the next three sections, followed by a summary discussion. The first paragraph of each individual account summarizes MEC's results and conclusion for that taxon. The reader interested only in the general summaries of results may wish to skip to Section 4.3.

4.2.3.2.1 Engraulis mordax (Northern anchovy)

The relative abundance of total northern anchovy larvae decreased at SONGS by 55%; all stages decreased in relative abundance as well. BACI tests showed that these decreases were statistically significant for total larvae, but not for any stage. The power of the test for total larvae exceeded 0.80. Plume/non-plume analysis showed a significant effect for total and postflexion larvae, and no effect for the other two stages. MEC concludes that SONGS operation affected the abundance of total and postflexion anchovy larvae but not of preflexion and flexion-stage larvae.

The primary BACI test on data for total northern anchovy larvae yielded a significant result (Table 4-2). Unlike the BACI tests for all other ichthyoplankton taxa, this test had high power (0.97 at $\alpha = 0.05$). The secondary tests--Wilcoxon rank sum tests using other valid transformations ($\log(x + 0.1)$, $\log(x + 1)$)--also had high power (both 0.97 at $\alpha = 0.05$) and yielded significant results, confirming the principal result (Figure D-313). The mean abundance of anchovy larvae decreased 35% at SONGS while increasing 20% at Control (yielding a 55% relative decrease; Table 4-5), and as one might predict, the binomial test indicated that the proportion of northern anchovy larvae at SONGS in the operational period was significantly lower than the proportion at SONGS in the preoperational period (Table 4-4). Examination of the time plot of Delta values (Figure D-314) revealed a broad zone of overlap between operational and preoperational Deltas, with a possible tendency for operational period values to be slightly lower than preoperational values. There was also a small group of much higher preoperational values during the principal spawning season. As an exercise, the BACI test was run on the log(x)-transformed data exclusive of the 17 March 1980 survey to see whether the large catches at SONGS on that date forced the significant test results described above. They appear to have been influential: the t-test gave a nonsignificant result ($p = 0.06$), although the Wilcoxon rank sum test result remained significant ($p = 0.02$). Exclusive of the 17 March 1980 survey, mean abundance declined 13% at SONGS while increasing 46% at Control. Aside from its outlier status, there was no reason to delete the 17 March 1980 survey, and the BACI result using the full preoperational data set is, therefore, valid. The analyses on the plume/non-plume data sets yielded a significant result on plume dates and a nonsignificant result on non-plume dates (Table 4-3), supporting the primary test on all dates.

The BACI t-test on preflexion-stage data had much lower power (0.59 at $\alpha = 0.10$) than did the test for total anchovy larvae, and it yielded a nonsignificant result (Table 4-2) that was corroborated by the secondary tests (Figure D-318). Mean abundance declined 36% at SONGS but increased 4% at Control. Exclusive of the 17 March 1980 data point, mean abundance declined only 7% at SONGS but increased 38% at Control. The binomial test indicated that the proportion of total preflexion-stage larvae at SONGS in the operational period was significantly lower than the proportion at SONGS in the preoperational period (Table 4-4), but the analysis on plume dates yielded a nonsignificant result (Table 4-3), supporting the primary BACI test on all dates. Inspection of the time plot of Delta values (Figure D-320) did not reveal a striking difference between monitoring periods except for a small group of very high preoperational Delta values during the major spawning season.

The untransformed data for flexion-stage larvae did not fit the additive model; however, the log (x) transformation did result in additivity, requiring the deletion of only a single preoperational survey when no flexion-stage larvae were taken at Control. The BACI t-test yielded a nonsignificant result (Table 4-2). However, unlike the results for preflexion-stage and total northern anchovy larvae, the Wilcoxon rank sum test gave a significant result, contradicting the principal t-test result. Other secondary tests using valid data treatments (log (x + C) transformations) yielded variable results, showing that the results of the t-test were controlled by the constant applied in the log transformation, and that the more consistent Wilcoxon rank sum test results may have been more reliable. The BACI plume dates t-test for flexion-stage larvae yielded a nonsignificant result (Table 4-3). However, some of the secondary plume dates tests were significant and thus failed to corroborate the primary test result. The conflicting results are difficult to interpret; the different t-test and Wilcoxon rank sum test results indicate that changing the constant selected for use with the log (x + C) transformations by an order of magnitude could change the outcome of the test, which calls into question the nonsignificant results of the primary tests. On the other hand, the changes in mean abundance on plume dates differed little between SONGS and Control, supporting the nonsignificant results of the primary tests. The non-plume dates analysis yielded nonsignificant results (Table 4-3). Mean abundance of flexion-stage larvae in the full data set declined 37% at SONGS while increasing 83% at Control, yielding a 112% relative decrease (Table 4-5). Inspection of the time plot of Delta values (Figure D-325) showed a pattern much like that of total anchovy larvae, with a band of Delta values ranging between about ± 100 that contained most of the preoperational and operational values (with no obvious difference between periods), together with a small group of high preoperational values and a small group of low operational values during the principal spawning season. The binomial test indicated that the proportion of flexion-stage larvae at SONGS in the operational period was significantly lower than the proportion at SONGS in the preoperational period (Table 4-4), which agreed with the BACI Wilcoxon rank sum tests results but conflicted with the principal t-test and plume dates test results.

The BACI t-test on untransformed data for postflexion-stage larvae yielded a nonsignificant result (Table 4-2) that was confirmed by all of the secondary tests (Figure D-329). Mean abundance of postflexion-stage larvae declined at both SONGS and Control, but more so at SONGS (-57% vs. -37% at Control), resulting in a 17% decline in relative abundance (Table 4-5). Inspection of the time plot of Delta values (Figure D-330) revealed considerable variability in both monitoring periods, but no obvious difference between periods. The binomial test did indicate a significantly lower proportion of total postflexion-stage larvae at SONGS in the operational period than in the preoperational period (Table 4-4), but aside from one especially large preoperational period Delta value on 14 April 1980, the plot of Delta values did not show why this result was obtained.

Results of the BACI test on the plume dates for postflexion larvae were significant (Table 4-3), and were corroborated by the other tests. Mean abundance of postflexion larvae on plume dates declined by 62% at SONGS and by 17% at Control. Results of the BACI analysis of the non-plume data subset were nonsignificant (Table 4-3), suggesting that SONGS operations may have been involved in the significant results obtained for postflexion-stage larvae.

The MANOVA did not reveal a shift in abundance pattern (Figure D-317) at SONGS during the operational period for total northern anchovy larvae or for any of the larval stages.

A single preliminary survey was made during the operational period on 7 March 1986 to assess whether the alongshore spatial scale of the significant effects on the total and postflexion-stage larvae could be determined. The regressions of larval abundance on distance downcoast from SONGS were nonsignificant owing to high variability and small sample size; however, the plot of abundance vs. distance (Figure 4-1) for total northern anchovy larvae indicated that abundances were lowest 6-8 km downcoast. Among the multitude of plausible (and entirely speculative) scenarios that might account for this pattern, one is a SONGS effect, with depressed abundances extending up to 8 km downcoast, but not as far as 12 km downcoast.

Conflicting BACI results were obtained for preflexion and flexion-stage larvae; accepting the principal BACI test results at face value suggests that these stages showed no evidence of an effect. However, since the data treatment for both of these stages seems to have controlled the outcome of the tests, the principal results should be accepted with some reservations.

4.2.3.2.2 Citharichthys spp. (Sanddabs)

Young sanddab larvae showed large relative increases at SONGS; older larvae were rarely collected (Table 4-1). BACI tests of the whole data set and of the plume/non-plume subsets had very low power (<0.25) to detect changes. Results of all tests were nonsignificant, indicating that SONGS operation had no detectable effect on the abundance and distribution of sanddab larvae.

The BACI t-tests on total and preflexion Citharichthys spp. larvae revealed nonsignificant changes in relative abundance (Table 4-2); they had very little power to detect a change even if one had occurred. The secondary tests likewise yielded nonsignificant results, confirming the principal test result (Figures D-334, D-339).

Citharichthys spp. larvae collected during the MRC study were predominantly yolksac and preflexion-stages; too few flexion and postflexion-stage larvae were taken to analyze separately. The results of the analyses on total sanddab larvae thus largely reflected the results from the preflexion-stage larvae.

Mean abundance of total larvae increased at both SONGS and Control, but much more so at SONGS (268%) than at Control (3%), resulting in a relative increase of 265% (Table 4-5). Preflexion larvae showed a relative increase of 337%. Inspection of the time plot of cross-shelf abundance (Figure D-337) revealed that these large increases at SONGS were attributable to two very large catches at SONGS in the operational period. Exclusive of these two dates, mean abundance during the operational period was virtually identical at both SONGS and Control, supporting the interpretation of no difference between monitoring periods. The time plot of Delta values (Figure D-335) revealed considerable variability, but no obvious difference between the preoperational and operational periods. The binomial test yielded a nonsignificant result (Table 4-4), as expected given that abundance increased more at SONGS than at Control.

The BACI t-tests on plume/non-plume abundance data yielded nonsignificant results. The MANOVA did not reveal an overall shift in cross-shelf abundance patterns (Figure D-338) at SONGS during the operational period.

4.2.3.2.3 Hypsoblennius spp. (Blennies)

None of the tests of the abundance or distribution of blenny larvae yielded significant results, indicating that SONGS operation had no detectable effects on larvae of Hypsoblennius spp.

The BACI t-test on untransformed data for total Hypsoblennius spp. larvae yielded a nonsignificant result (Table 4-2), as did the tests on log (x)-transformed data for preflexion-stage larvae, untransformed data for the flexion-stage larvae, and log (x + 0.1) transformed data for the postflexion-stage larvae (Table 4-2). Secondary tests confirmed the principal BACI test results. Time plots of Delta values (Figures D-346, D-352, D-357, D-362) revealed considerable variability for preflexion and flexion-stage larvae, but little evidence of a difference between monitoring periods for total larvae or any of the stages. The binomial tests confirmed this lack of a difference between periods (Table 4-4). The results of the plume/non-plume BACI analyses also did not show any significant changes in relative abundance.

The MANOVA did not reveal a pattern shift at SONGS in the operational period relative to the Before-or-Control data set for total larvae or any of the stages (Figure D-94).

4.2.3.2.4 Broadly-Distributed Taxa: Discussion

BACI effects were not particularly anticipated for the broadly-distributed taxa, except perhaps northern anchovy, owing to their cross-shelf distributions and the relative immunity of the adults to SONGS effects. Adult northern anchovy are highly susceptible to impingement mortality at SONGS Units 2 and 3, but any resulting local reduction in spawning stock should not have led to a detectable local reduction in larval standing stock because most larvae at San Onofre apparently do not originate in the local vicinity (Barnett et al., 1984). However, since larvae apparently do move into the nearshore San Onofre area, and the older larvae seem to concentrate near the bottom in the very nearshore zone encompassing the Units 2 and 3 offshore cooling structures, it was possible that losses of larvae near SONGS (e.g., withdrawal, increased local predation, etc.) might have resulted in a detectable effect. Northern anchovy larvae were the only ichthyoplankton taxon with high BACI power; this enhanced MEC's ability to recognize the moderate decrease in relative abundance as a significant effect. The possible effect on the postflexion-stage larvae seen in the analysis on plume dates in noteworthy because these older larvae should have a relatively high likelihood of surviving to recruitment under purely natural conditions. Additional losses here could be important, although given the vast range over which northern anchovies occur such losses probably are inconsequential.

The estimate of the most likely losses of anchovy larvae due to withdrawal during the operational period was very small, even for the larger, more nearshore larvae. The estimate was based on the assumption that all larvae are strictly planktonic and move with the water. However, physiological and behavioral changes in the anchovy larvae during the late flexion and early postflexion-stages improve their ability to regulate position to the extent that they become functionally schooling micronekton rather than ichthyoplankton. It is at least conceivable that such schooling micronekton might be able to remain selectively in the vicinity of SONGS, for example if the discharged dead or injured macroplankton in the plume were perceived as a patch of food. Schooling would serve to increase the volume of water searched for food and thus increase the likelihood that the outfall from the plume or the plume itself could be perceived as a "patch" of food. If the residence time of the older larvae near SONGS actually did increase, SONGS withdrawal would have more time to work on these larvae than was allowed in our loss model, and resulting losses could have been larger, although by how much would be very difficult to estimate. Predation by larger planktivorous fishes attracted to the plume (e.g., atherinids, which did show a relative increase 2-3 km downcoast of SONGS, near the ichthyoplankton Impact site) could also act to reduce the local abundance of anchovy (and presumably all other) larvae whether the larvae remained near SONGS or simply passed by. If, however, the older larvae actually did remain near SONGS a relative depletion might be more likely to occur. The different BACI results using plume dates (significant) and non-plume dates (nonsignificant) subsets of the operational data for northern anchovy might be taken to suggest that direct SONGS effects (e.g., withdrawal) were more important than secondary effects such as increased predation, unless the planktivorous fishes were very closely associated with the plume rather than simply relatively more abundant in the general area. Planktivorous fishes (e.g., blacksmith) associated with kelp beds have been observed to concentrate near the upstream end of their kelp bed, and to move to the other end when the alongshore current reverses, so it may be possible that planktivorous fishes do follow the plume.

Preflexion-stage and early flexion-stage northern anchovy larvae presumably would not be able to remain near SONGS, selectively and our estimates of losses might be more applicable for them. However, these larvae should be at least as susceptible to planktivores as the older, schooling larvae, and thus they may still suffer substantial mortality. Because anchovy larvae are relatively large in the late preflexion and early flexion-stages (about 5-10 mm, a size range where most of the other taxa considered in this report pass through the flexion-stage to the postflexion stage or beyond, and thus gain the benefits of improved perceptive and swimming ability, as well as in many cases entering a new habitat), they may be selectively taken by planktivorous fishes.

Our discussion of the BACI results for northern anchovy larvae is largely a series of suppositions, each one of which is at least plausible, and which in total at least do not refute the observed BACI results. However, whether the mechanisms we have suggested are actually in force cannot be demonstrated from the monitoring survey results, but must be measured directly.

In summary, among the broadly-distributed taxa, only northern anchovy, which was also the only ichthyoplankton taxon with high power, showed an effect. This effect may have been associated either directly or indirectly with SONGS operations.

4.3 Macrozooplankton Results and Discussion

4.3.1 Summary of Results and Description of a Possible SONGS Mechanism

In their original predictions of SONGS effects on the plankton, Barnett et al. (1979a) stated that the macrozooplankton were expected to be depleted in the nearshore zone as a result of withdrawal by the SONGS Units 2 and 3 cooling systems, while the offshore surface waters were expected to be enriched with nearshore bottom waters via the discharge plumes. The enrichment of offshore surface water was predicted to induce a net increase in primary production off San Onofre. In general, these predicted effects were not observed: there was no evidence for a depletion of the macrozooplankton and no indication of an increase in the phytoplankton standing crop (production rates were not studied). There were, however, shifts in the distributions of a few taxa, which we interpreted as SONGS effects.

We estimated the percentage of the cross-shelf abundance of each taxon that was lost during the operational monitoring period as a result of (1) withdrawal at the intakes, and (2) secondary entrainment by the Units 2 and 3 discharge plumes. Mechanism (1) is known to operate; mechanism (2) has not been demonstrated, but could potentially cause large losses of some taxa if it did operate. Estimated intake withdrawal losses alone generally accounted for less than 4% of the cross-shelf abundance of any taxon, well below the level that the monitoring program was designed to detect. When the additional potential mortality resulting from secondary entrainment (e.g., shear stress, predation in the discharge plume) was also included, the total loss estimates generally remained below the 50% level of effect that the BACI analyses were intended to detect. Only Acartia clausi and Oithona oculata were estimated to suffer substantial losses, but both taxa experienced regional declines in abundance that began before the operational period. Thus, even though the declines continued through the operational period, they could not be shown to be associated with SONGS operations.

The BACI test results on the full monitoring data bases confirmed that substantial decreases in relative abundance did not occur. There was some evidence of significant increases in the relative abundances of cirriped nauplii, cyphonautes larvae, and the cladoceran Evadne nordmanni. MEC considered these to be minor SONGS effects, but could not postulate the operative mechanism(s).

MANOVA and ANOVA techniques were used to detect significant shifts within some of the cross-shelf strata in the distribution of total zooplankton and of four individual taxa: cyphonautes larvae and the copepods Acartia tonsa, Corycaeus anglicus, and Oithona plumifera. These shifts were considered to be SONGS effects, albeit minor ones since they were not associated with significant reductions in relative cross-shelf abundance. The distributional shifts did form a reasonably coherent pattern, from which a conceptual (and hydrodynamically plausible) model of SONGS-induced circulation was derived. We propose this model as a possible SONGS mechanism, but remind the reader that it is strictly an empirical model based on a combination of zooplankton (and to a lesser extent, ichthyoplankton) results and a general description of the probable SONGS-induced flow field (Reitzel, 1980); the model has not been tested.

In this model, macrozooplankters (including ichthyoplankton) are withdrawn by the SONGS intakes and "strained" from the cooling water (e.g., animals are consumed by the intake conduit fouling community, or are killed during passage through the plant and sink quickly after being discharged), so that the discharged water is relatively empty of planktonic organisms (see Section 5.1). Conservation of mass requires that the water withdrawn by the intakes be replaced; this replacement water is drawn inward toward SONGS from all directions, but predominantly from offshore in the absence of an alongshore current. Both the SONGS-induced shoreward flow and the seaward-directed discharge are superimposed on the alongshore current regime (e.g., Figure 4-2). Because the replacement water has some offshore component, it should contain fewer inner nearshore organisms, on average, than "pure" nearshore water (i.e., the inner nearshore plankton concentration should be diluted). In addition, some fraction of the discharge plume water, also containing few nearshore organisms, is likely to be recirculated into the inner nearshore zone, contribution to the dilution of the nearshore plankton concentration. Thus, during periods of continuous plant operation, the taxa with the most restricted nearshore distributions should become relatively depleted inshore near SONGS.

Since the offshore fraction of the replacement water will contain offshore taxa, for these a relative enrichment near shore at SONGS should occur during periods of continuous plant operation. Taxa with broad cross-shelf distributions, on the other hand, would be transported from an area of one level of abundance (high or low) to an area of probably similar abundance, and a pattern shift might thus be difficult to detect.

Planktonic organisms in the water column over the diffusers should be secondarily entrained in the discharge plume and on average moved upward and seaward (note that during periods of strong thermal stratification the plume may remain in the lower 5 m of the water column and during periods of strong downcoast flow it may be retained nearshore: Erdman, 1987), resulting in relative offshore enrichment of nearshore group taxa and a relative depletion (dilution) of more offshore taxa.

MEC lacked the data necessary to quantify the relative contributions to the nearshore replacement water from its various potential sources, but we could generalize as follows about water movements, based on the significant changes seen in the spatial distributions of taxa:

(1) abundance ranks decreased throughout the water column at 30 m, but more so in the upper water column as water from farther offshore (and containing fewer of the coastal zooplankters) was drawn shoreward to replace 30 m water that had been drawn farther inshore. The plankton-depleted discharge plume water should have contributed to the observed abundance rank decreases.

(2) abundance ranks increased in the 13 m midwater strata for some of the cross-shelf and more offshore taxa as water was drawn from upcurrent and offshore regions having higher concentrations, to replace the secondarily entrained nearer-shore midwater.

(3) abundance ranks increased for some taxa in the 13 m midwater strata as 8 m and 13 m epibenthic water was secondarily entrained and, together with its higher abundances of those taxa, mixed upward into the 13 m midwater strata.

(4) abundance ranks decreased in the 8 m epibenthos as the epibenthic water was withdrawn at the intakes, perhaps secondarily entrained to some extent and transported

seaward, and was replaced by a mixture of 13 m epibenthic water, 8 m midwater and perhaps shallower epibenthic water and recycled discharge plume water. The complex hydrodynamic regime of the very nearshore zone made this region most difficult to model.

Although no single taxon showed all of these relative shifts within strata, the composite of all significant changes exhibited a reasonably complete picture of the model (Figure 4-3). Nearly-significant changes ($0.05 < p \leq 0.10$) were generally in accord with the significant changes (Figure 4-3). Various parts of the pattern were demonstrated for a nearshore/transitional zone taxon (Acartia tonsa), for three cross-shelf taxa (the copepods Corycaeus anglicus and Oithona plumifera, and the bryozoan cyphonautes larvae), and for total zooplankton (Figure 4-4).

The results for the most abundant zooplankter, Acartia tonsa, provide an example of the derivation of the circulation model from the pattern analysis results. A. tonsa displayed a significant relative decrease in mean abundance rank in the 8 m epibenthic stratum; this could have resulted if the high abundance water from this stratum was withdrawn by the intakes and replaced with water drawn in part from lower abundance strata seaward (13 m epibenthos and midwater) and surfaceward (8 m midwater). These contributions should have served to "dilute" the 8 m epibenthos stratum with respect to A. tonsa, yielding the observed decrease. The significant increases in ranks of abundance that were detected in the 13 m lower midwater and high midwater strata could be interpreted as resulting from secondary entrainment and upward transport in the discharge plume from the nearshore epibenthos and lower midwater where abundance was higher, into the 13 m midwater strata where abundance was somewhat lower (see Figures 4-4, D-382). In this case, inputs into the midwater from secondary entrainment would have been larger than the contributions from the presumably empty pure plume water and the lower abundance offshore replacement water, in order to have produced the observed results.

The nearshore pattern changes demonstrated for total zooplankton probably were strongly influenced by A. tonsa, since it was the dominant taxon. These changes for total zooplankton included a decrease in mean rank of abundance in the 8 m epibenthos, which we interpreted as resulting from withdrawal at the intakes and replacement from adjacent epibenthic waters containing fewer organisms, on average (e.g., Figure 4-4). Increased predation might also have contributed to the decrease in the 8 m epibenthic stratum. Total zooplankton showed a relative increase in mean abundance rank in the lower midwater stratum at 13 m; this was interpreted as reflecting replacement from the more seaward zone of higher abundance, and possibly some contribution from secondary entrainment from the higher abundance 8 m epibenthos. The decrease detected in the upper midwater stratum at 30 m was thought to reflect movement into the 30 m block by water (containing fewer macrozooplankters) drawn from farther offshore.

Cyphonautes larvae showed a significant relative increase in mean rank of abundance in the 8 m midwater and, along with the copepods Corycaeus anglicus and Oithona plumifera, increases in the 13 m midwater. These increases were interpreted as resulting from the shoreward movement of replacement water drawn from the higher abundance area farther seaward. Relative decreases in mean ranks of abundance were detected in various strata at 30 m for cyphonautes and O. plumifera (Figure 4-4); these were interpreted as resulting from the shoreward movement of water drawn into the 30 m block to replace water drawn farther shoreward from that block. Water drawn from seaward of the 30 m isobath is assumed to contain fewer of these taxa.

Corycaeus anglicus also showed a significant relative decrease in mean rank of abundance in the nearshore epibenthos. Since C. anglicus had lower ranks of abundance in the nearshore epibenthos than in the more seaward midwater regions, according to our circulation model it might have been expected to display a relative increase in the nearshore epibenthos. However, if the replacement water came from shoreward (presumably lower abundance) regions, as well as from the seaward epibenthos, and if this copepod experienced increased predation (for example, from ichthyoplankters such as gobies or clinids, which increased in mean abundance in this area), we could perhaps account for the observed decrease in the nearshore epibenthos. As noted above, the most nearshore zone is complex, and not all pattern analysis results from this zone can be fit comfortably into a simple circulation model. This does not necessarily invalidate the model, but it does serve to demonstrate that the model is no more than a first order approximation. Validation and refinement of the model would require directed physical oceanographic studies.

4.3.2 Individual Taxa

The macrozooplankton taxa are organized into four broad categories corresponding to their cross-shelf distributions in the following sections. These categories are: the inner nearshore taxa (Section 4.2.2.1), the nearshore/transitional taxa (Section 4.2.2.2), the cross-shelf taxa (Section 4.2.2.3), and the offshore taxa (Section 4.2.2.4). In each of these four sections, we give a brief introduction to the taxa (more detailed synopses of the biology for each taxon are given in Appendix A.1), followed by a brief statement of our a priori expectation of SONGS effects. This is followed by more detailed taxon-by-taxon accounts of test results. These tests were performed for the full set of Units 2 and 3 preoperational (= Before) and operational (= After) monitoring data; ancillary BACI tests were performed on the plume and non-plume (Section 3.7.1) subsets of the After data as well. The data tested were cross-shelf abundances and Deltas for each taxonomic category and developmental stage.

In addition to the tests for changes in cross-shelf abundance, we present results of the pattern analysis used to detect changes in cross-shelf distribution. The pattern analyses were performed on the full set of Before and After data using abundance values for each taxonomic category and developmental stage collected at three to four levels in the water column (see Section 3.2.1) at stations located at 8 m, 13 m, and 30 m depths.

The mean cross-shelf abundances and standard deviations for each taxon at SONGS and Control in each monitoring period are given in Table 4-8. Results of the BACI tests are shown in Tables 4-9 and 4-10. Binomial test results are given in Table 4-11. Table 4-12 presents the percent relative change in abundances (i.e., the changes in cross-shelf abundances at SONGS relative to the cross-shelf abundances that would have been seen if SONGS did not exist). Estimates of withdrawal and entrainment losses during the After period are presented in Table 4-13. Results of the assumption tests and the BACI test results for all transformations are presented in Appendix D. Also presented in Appendix D are figures of preoperational and operational Deltas plotted on a 1-year time scale as well as through time, abundance values at SONGS and Control plotted through time, and cross-shelf distributions.

4.3.2.1 Inner Nearshore Taxa

Inner nearshore taxa are those generally found in highest abundance around the 8 m isobath (Barnett and Jahn, 1987). Only two of the macrozooplankton taxa included in this analysis for SONGS effects, the copepods *Acartia clausi* and *Oithona oculata*, are inner nearshore taxa.

Owing to their nearshore distributions, these taxa were considered the most likely to be affected by SONGS operations. For example, estimates of intake withdrawal losses indicated that about 65% of *A. clausi* and 28% of *O. oculata* in the cross-shelf plane at SONGS would be killed by this mechanism alone (Table 4-13). Losses of this magnitude, for *A. clausi* at least, might reasonably be expected to have resulted in a BACI effect. However, neither species demonstrated changes in abundance that could be considered related to SONGS operations, owing to a combination of regional decreases in abundance, high variability, and sporadic occurrence. Results for each species are briefly described below. The first paragraph in each account summarizes our interpretation of the test results for that species. The reader interested only in summaries of results for each group may wish to turn to Section 4.3.2.2 Nearshore/Transitional Taxa.

4.3.2.1.1 *Acartia clausi*

A. clausi nearly disappeared from both SONGS and Control, beginning before the operational monitoring period. This regional decline was not attributed to SONGS activities. The bases for these statements are as follows.

Abundance at SONGS declined 84%, from a mean of 34/m^3 in the Before period to 6/m^3 in the After period. Control abundance simultaneously underwent a 94% decline, from a mean of $12/m^3$ to less than $1/m^3$, yielding a 4% relative increase (Table 4-12). This widespread abundance decline actually began prior to the After period: occurrences were relatively rare after April 1980 (Figure D-369). During the 23 After surveys, A. clausi occurred at both SONGS and Control locations on only 3 dates; on an additional 11 surveys it was found at only one of the sites.

It thus appears that A. clausi declined regionally, beginning before the After period, and that this decline was more noticeable at SONGS where abundances were much higher in the early preoperational period than they were at Control.

Reflecting this regional decline in abundance, the Before Deltas ranged from $-75/m^3$ to $+250/m^3$ while the After Deltas (based on generally low to zero abundances at both locations) were close to zero except for three positive Deltas ranging from $15/m^3$ to $25/m^3$. The nonsignificant ($p = 0.33$; $\alpha = 0.10$) primary BACI t-test result was confirmed by all secondary test results based on other valid data treatments (log transformations, Wilcoxon rank sum test, SONGS vs. Control regressions) and by the analysis on plume dates alone (Table 4-10). No significant shifts in the spatial distribution of A. clausi were found with the pattern analyses.

4.3.2.1.2 Oithona oculata

No evidence of a SONGS effect was detected for O. oculata. Results of all tests on cross-shelf abundance were non-significant, and the pattern analysis showed no significant change in distribution.

At SONGS, average cross-shelf abundance decreased from $7.63/m^3$ (Before) to $6.45/m^3$ (After), a 16% loss; Control abundance simultaneously declined 87% from $4.62/m^3$ to $0.63/m^3$. This larger decline at Control resulted in a 36% relative increase (Table 4-12); however, the results of the primary BACI test on untransformed data and the secondary tests (log transformations, Wilcoxon rank sum test) were all nonsignificant (Figure D-372). Tests on the plume and non-plume subsets of the After data likewise yielded nonsignificant results (Table 4-10). The power of the primary BACI test was low (Table 4-9), indicating high variability in the Oithona oculata Deltas.

SONGS versus Control regressions fit one line with a slope less than one to data from both monitoring periods. This agreed with the nonsignificant BACI results, but also indicated a possible problem with nonadditivity of the untransformed data.

Pattern analysis results agreed with all other analyses: no differences were detected between the After/SONGS spatial distribution and the "all others" spatial distribution.

4.3.2.2 Nearshore/Transitional Taxa

The nearshore/transitional taxa are considered to be those that occur predominantly between the 8 m and the 30 m isobaths (Barnett and Jahn, 1987). At San Onofre, these included one cosmopolitan copepod, Acartia tonsa, the two larval forms (nauplii and cypris) of barnacles, and the cladoceran Podon polyphemoides.

SONGS was expected to directly and indirectly affect these organisms through withdrawal and secondary entrainment. Estimated losses due to intake withdrawal alone were generally low (< 4%: Table 4-13), reflecting the broad cross-shelf distributions of these taxa. The high abundance of the pre-settlement cypris stage barnacle larvae in the nearshore epibenthos yielded higher withdrawal loss estimates: about 20% of the numbers in the cross-shelf. Loss estimates for the nearshore/transitional taxa increased to about 14-38% if a 50% mortality from secondary entrainment in the discharge plume was assumed (Table 4-13).

Because these estimated losses were rather modest, MEC did not expect to detect significant reductions in relative cross-shelf abundance resulting from withdrawal and entrainment alone, and in fact none were detected. However, a significant relative increase was detected for barnacle nauplii (note that the Deltas values tested by the BACI procedure -- see Figure D-384 -- indicated a relative increase even though the calculation based on log-transformed abundances -- see Table 4-12 -- showed a relative decrease of 0.10%; Section 3.7.1.4 explains how such a discrepance can occur).

A change in cross-shelf distribution, perhaps reflecting SONGS-induced circulation, was noted for *Acartia tonsa*. This change included a relative decrease in the mean rank of abundance in the epibenthos at 8 m and relative increases in mean ranks of abundance in in the two midwater strata at 13 m. Although we consider this redistribution to be a SONGS effect, it probably is of little importance to *A. tonsa* since it represents only a small-scale shift within the zone normally occupied by this species.

Results of analyses for each taxon are briefly described below. The first paragraph in each account gives our interpretation of the test results for that species. The reader interested only in summaries of results for each group may wish to turn to Section 4.3.2.3 Cross-Shelf Taxa.

4.3.2.2.1 Acartia tonsa

The relative cross-shelf abundance of *A. tonsa* did not change significantly as a result of SONGS operations. However, the cross-shelf distribution of the species did change significantly in the After period, and this change was considered a SONGS effect, possibly reflecting SONGS-induced circulation. The bases for these statements are given below.

At San Onofre, *Acartia tonsa* cross-shelf abundances varied from a minimum of $10/m^3$ to a maximum of $7581/m^3$. Generally, low abundances occurred from October through February (Figure D-381). Cross-shelf abundances increased regionally in the After period, with a slightly larger increase at Control (Table 4-12): SONGS abundance increased 11% from $1605/m^3$ to $1779/m^3$ whereas abundance at Control went up 30% from $1{,}189/m^3$ to $1{,}545/m^3$. This yielded a relative decrease of 19%, which was not statistically significant ($p = 0.96$; $\alpha = 0.05$), as shown by the primary BACI t-test on log (x)-transformed data (Table 4-9). Other appropriate BACI t-tests on log (x + C)-transformed data, Wilcoxon rank sum tests, and SONGS versus Control regressions agreed with the primary BACI result (Figure D-378). Separating the operational data into plume dates and non-plume dates subsets again confirmed the nonsignificant results based on cross-shelf abundance (Table 4-10).

The pattern analysis showed a significant ($p = 0.01$) difference between the SONGS-After pattern and the Before-or-Control pattern of ranks of abundance. The mean rank of abundance in the 8 m epibenthic stratum decreased, while in the 13 m midwater strata mean ranks increased. This change in pattern was interpreted as a SONGS effect consisting of: (1) intake withdrawal and dilution by replacement water decreasing the abundance in the 8 m epibenthic stratum, and (2) secondary entrainment and upward transport in the SONGS discharge plume leading to increases in the 13 m midwater strata. Since these changes represent redistributions within strata normally occupied by A. tonsa, it is not surprising that they failed to produce a significant change in cross-shelf abundance. Note, however, that the 19% relative decrease observed is similar to the estimated 22% loss assuming 50% mortality of entrained O. tonsa (Table 4-13).

4.3.2.2.2 Cirriped Nauplii

A significant relative increase in cross-shelf abundance and a nearly-significant ($p = 0.06$) pattern shift were detected for the barnacle nauplii. The relative increase was considered a SONGS effect, although the mechanism could not be identified. The possible redistribution could be interpreted as resulting from SONGS-induced circulation, but an effect could not be declared since the p-level of the test was larger than the α level at which it was evaluated.

Cirriped nauplii were found off San Onofre on all surveys, predominantly in the midwater areas of the 13 m, 18 m, and 30 m stations (Figure D-388). They occurred only rarely in the 18 m or 30 m epibenthos.

Average abundance at SONGS declined 58%, from $30/m^3$ in the Before period to $13/m^3$ in the After period. A 58% reduction also occurred at Control, from $18/m^3$ to $7/m^3$, yielding a relative decrease of 0.1% (Table 4-12). Very high abundance on one date, 23 March 1980, strongly influenced the Before mean abundances. exclusion of this date resulted in an average Before abundance at SONGS of $16/m^3$ and at Control of $14/m^3$, which yielded a relative increase because SONGS abundance then decreased only 19% while Control abundance decreased by 43%.

BACI t-test results on log (x)-transformed data showed a significant ($p = 0.05$; $\alpha = 0.10$) relative increase. Although Table 4-12 identified a slight decrease, the t-test actually uses values of Delta, which showed a relative increase in abundance. This was corroborated by the Wilcoxon rank sum test and the SONGS versus Control regressions. Tests using the plume and non-plume subsets of the operational data yielded significant results for the plume dates alone (Table 4-10), which suggested that the main test did indeed indicate a SONGS effect. Examination of the Deltas plotted against time (Figure D-385) did not reveal a clear Before-After difference, but did show that the Before Deltas tended to be lower than the After Deltas during the summer.

The pattern analysis yielded a nearly-significant result ($p = 0.06$) in the comparison of the SONGS-After pattern of ranks of abundance with the Before-or-Control pattern of ranks. This nearly-significant shift had two components: (1) a decrease in the 13 m epibenthos, and (2) an increase in the 13 m upper midwater. Although an effect could not be declared on the basis of the test result, it is conceivable that there was a pattern change, and if so this might have been interpreted as a SONGS effect consisting of: (1) secondary (diffuser) entrainment from the 13 m epibenthos, with dilution proportional to the fraction of the replacement water drawn from near the bottom seaward of the nearshore zone (resulting in decreased abundance in the 13 m epibenthos), and (2) relative enrichment of the 13 m upper midwater resulting from inputs of secondarily-entrained nauplii and additions from the replacement water drawn shoreward from the upper water column farther offshore, and containing higher abundances of nauplii (see Figure D-388).

The significant increase in relative cross-shelf abundance of cirriped nauplii, which resulted from a greater decrease at Control than at SONGS, met our criteria for declaring a SONGS effect (i.e., a significant relative change in the full operational data set, corroborated by secondary test results, and also detected in the plume dates operational subset but not in the non-plume subset). The operative mechanism(s) is unknown. There should have been a local increase in available habitat for adult barnacles in the form of the Units 2 and 3 intakes and surrounding rip rap. If more barnacles did settle locally, and if they survived long enough to reproduce, this could have contributed to the observed effect.

4.3.2.2.3 Cypris Larvae

SONGS operations had no detectable effects on the cypris stage of barnacle larvae. Cypris larvae, the older pre-settlement stage of barnacles, were found on every survey. Highest abundances were in the 8 m and 13 m epibenthos and secondarily in the 8 m midwater (Figure D-394).

SONGS and Control sites had identical average cross-shelf abundances of $9.42/m^3$ in the Before period (Table 4-8). Control abundance decreased by 35% to $6.69/m^3$ in the After period while SONGS abundance remained relatively constant at $9.62/m^3$. The percent relative increase was thus 34% (Table 4-12). The BACI t-test result on untransformed data was not significant ($p = 0.42$; $\alpha = 0.10$). This result was confirmed by tests on all log transformations (Figure D-390) and by the SONGS vs. Control regressions. However, the BACI testing of the plume dates subset did yield significant results for both the t-test ($p = 0.01$) and the Wilcoxon rank sum test ($p = 0.01$), while the non-plume dates test results were nonsignificant (Table 4-10). This could indicate an effect below the detection level of the tests on the full

After data set, although inspection of the plot of Delta values (Figure D-391) suggests that there was no effect. The pattern analysis yielded a nonsignificant result (Table 4-9, Figure D-390).

4.3.2.2.4 Podon polyphemoides

SONGS effects were not detected for Podon polyphemoides. P. polyphemoides was temporally patchy with many zero occurrences throughout the SONGS study (Figure D-399). Cross-shelf abundances typically were below $150/m^3$, and most were below $10/m^3$. The maximum cross-shelf abundance of $5970/m^3$ occurred on 29 May 1980. At SONGS the cross-shelf average abundance declined 20%, from $297/m^3$ in the Before period to $238/m^3$ in the After period. Control station averages simultaneously fell 21%, from $304/m^3$ to $237/m^3$. The percent relative change was thus +2% (Table 4-12).

BACI t-testing on untransformed data yielded a nonsignificant result ($p = 0.97$; $\alpha = .10$), as did the Wilcoxon rank sum test on untransformed data ($p = 0.64$; $\alpha = .10$). These nonsignificant results were corroborated by the tests on log-transformed data (Figure D-396). Tests on both the plume and non-plume subsets of the After data likewise yielded nonsignificant results (Table 4-10).

Although the SONGS vs. Control regression fit two straight lines to the Before and After data, these regressions were undoubtedly influenced by four surveys when abundances were extremely high, and thus we do not consider this result an indication of a SONGS effect.

The pattern analysis yielded no statistically significant results. MEC concluded, therefore, that there was no SONGS effect for P. polyphemoides.

4.3.2.3 Cross-shelf Taxa

Cross-shelf taxa are defined as those taxa that are abundant across the coastal zone, out to 100 m depth. At San Onofre these taxa included the copepods Corycaeus anglicus, Labidocera trispinosa, Oithona plumifera, and Paracalanus parvus, the arrow worm Sagitta euneritica, the cladocerans Evadne nordmanni, E. spinifera, and Penilia avirostris, and the cyphonautes larval stages of bryozoans. Except for the meroplanktonic cyphonautes, all of these taxa are widely-distributed holoplankters.

Given the broad cross-shelf distributions of these taxa, we did not expect to detect effects of SONGS operations. In fact, the calculated losses from intake withdrawal were less than 4% for all members of this group; even with the addition of the maximum estimated losses due to secondary entrainment, the total loss estimates remained well below the 50% level that the BACI analyses were intended to detect (Table 4-13). As expected, we did not detect significant reductions with the BACI analyses (Table 4-9). On the other hand, the secondary BACI analyses did detect a significant relative increase in the abundance of Evadne nordmanni. Based on the weight of evidence, we considered this increase to be a minor SONGS effect. We do not know why this significant relative increase occurred. A significant relative increase in cyphonautes abundance was detected in the analysis on the plume dates subset of the operational data (Table 4-10), but not in the full After data set (Table 4-9). This was also considered a minor effect, below the level of detection for the tests on the full After data set. The operative mechanism(s) could not be postulated.

We noted significant changes in cross-shelf distributions, which we interpreted as probably reflecting SONGS-induced circulation, for three of the eight taxa: Corycaeus anglicus, cyphonautes larvae, and Oithona plumifera. These were considered SONGS effects.

Results of the analyses for each of the cross-shelf taxa are described below. Our interpretation of the test results is summarized in the first paragraph of each species account. Readers interested only in general summaries of results for each group may wish to turn to Section 4.3.2.4 Offshore Taxa.

4.3.2.3.1 Evadne nordmanni

Evadne nordmanni displayed a significant relative increase in most of the secondary tests on cross-shelf abundance, but not in the main BACI t-test. Based on the weight of evidence, we interpreted these various results as indicating a SONGS effect. No significant changes in cross-shelf pattern were detected.

E. nordmanni was present on most surveys, usually in low numbers, and mostly in the 13 m and 18 m midwater and surface strata (Figure D-406). Cross-shelf abundances ranged from 0 to 1600/m^3; the occasional very high abundances occurred in spring. Cross-shelf abundances generally increased from the Before to the After time period. SONGS abundance increased 108%, from 50/m^3 to 106/m^3, while Control abundance went up 157%, from 76/m^3 to 199/m^3. This yielded a relative decrease of 49% (Table 4-12). However, the number of surveys on which the SONGS cross-shelf abundance exceeded the Control abundance (positive Deltas) increased from 37% in the Before period to 64% in the After period (Figure D-404).

The BACI t-test on log (x)-transformed data did not yield a significant result ($p = 0.12$; $\alpha = 0.10$), probably because of the large variability in the data. On the other hand, the Wilcoxon rank sum test on log (x)-transformed data did indicate a significant increase ($p = 0.037$). Most secondary tests based on other log transformations agreed with these results: Wilcoxon rank sum test results were significant (except log (x + 10)), BACI t-test results were nonsignificant (Figure D-402).

The regressions of SONGS versus Control abundances fit one line to data from both monitoring periods, indicating no SONGS effect. The slope of this line was not equal to one, confirming the nonadditivity of the untransformed Deltas.

When the plume dates and non-plume dates subsets of After data were tested separately using the log (x)-transformed data, both the BACI t-test and the Wilcoxon rank sum test results for the plume surveys indicated a significant increase ($p = 0.07$ and 0.006, respectively; $\alpha = 0.10$). The tests on non-plume surveys showed no significant results (Table 4-10). The plume/non-plume analyses may be viewed as supporting the Wilcoxon rank sum test result on the full After data set.

Based on the weight of evidence, we interpreted the results of the various tests on cross-shelf abundance as marginal evidence of a SONGS effect. We cannot postulate the operative mechanism(s).

No significant change in spatial distribution was found in the pattern analysis (MANOVA $p = 0.11$).

4.3.2.3.2 Evadne spinifera

We detected no SONGS effects on Evadne spinifera. E. spinifera occurred sporadically (Figure D-411), principally above the bottom at 13 m, 18 m, and 30 m. They were rarely found at 8 m or in epibenthic samples at any depth (Figure D-412).

Cross-shelf abundances ranged from 0 to as high as $215/m^3$. Average cross-shelf abundance at SONGS fell from $18/m^3$ in the Before period to $11/m^3$ in the After period, a 37% decline. At Control average cross-shelf abundance simultaneously decreased 44% from $41/m^3$ to $23/m^3$. This yielded a relative increase of 6% (Table 4-12).

The BACI t-test on log (x)-transformed data (only the log (x) and Log (x + 0.1) transformations satisfied all BACI assumptions) yielded a nonsignificant result ($p = 0.18$; $\alpha = 0.10$), but the Wilcoxon rank sum test using the same transformation indicated a significant relative increase ($p = 0.07$) (Figure D-408). Both the t-test and Wilcoxon rank sum test on log (x + 0.1)-transformed data also yielded significant results ($p = 0.03$ and 0.07, respectively; $\alpha = 0.10$). However, results of tests on the plume dates subset of log (x-transformed data were nonsignificant ($p = 0.19$ and $p = 0.15$ for the t-test and Wilcoxon rank sum test, respectively; $\alpha = 0.10$), while the non-plume surveys did show significant differences between monitoring periods ($p = 0.005$ and 0.05, respectively, for the t-test and Wilcoxon rank sum test on log (x)-transformed data; $\alpha = 0.10$). We interpret significant results on non-plume dates, and nonsignificant results on plume dates, as indicating no SONGS effect. The marginal indication of an effect detected in the full After data set is thus not considered a SONGS effect.

The SONGS versus Control regression fit one straight line to both monitoring periods, supporting the interpretation of no effect. Nonadditivity of the untransformed data was confirmed by the slope of the regression line not equalling one.

The pattern analysis indicated that the spatial distribution did not change ($p = 0.53$).

4.3.2.3.3 *Penilia avirostris*

Penilia avirostris experienced a marked regional decline in abundance, beginning before the After period. Results of statistical tests were considered to be of doubtful validity and were not evaluated with respect to possible SONGS effects.

P. avirostris was most abundant in summer and fall, especially in 1976 and 1981. Abundances were low from 1977 through 1979. In 1980, and during the entire After period, only a few were found (Figure D-417). Mean cross-shelf abundance at SONGS thus plummeted from $308/m^3$ in the Before period to $0.31/m^3$ in the After period. Abundances at Control likewise fell from $482/m^3$ in the Before period to $0.31/m^3$ in the After period (Table 4-8). During the After period, *P. avirostris* occurred at both SONGS and Control only twice, and at one site or the other only three additional times. This apparent regional decline in *P. avirostris* abundance was Bight-wide in extent, as shown by an examination of samples collected at the 8 m and 36 m isobaths in 1981 and 1983 from San Onofre, Seal Beach, Oxnard Beach, and Playa del Ray (these samples were provided by the Los Angeles County Museum of Natural History). Because so few animals were collected in the After period, the results of statistical analyses were considered to be of doubtful validity and are not discussed.

4.3.2.3.4 *Corycaeus anglicus*

MEC detected no SONGS-related changes in the relative cross-shelf abundance of *Corycaeus anglicus*. There were changes in the spatial pattern that were considered to be largely a SONGS-induced redistribution.

Corycaeus anglicus occurred in all strata on every monitoring survey. More were found in the 13 m, 18 m, and 30 m midwater strata than in the surface or bottom strata of those areas or at 8 m (Figure D-424). Abundance varied seasonally, particularly in the Before period, with higher abundances during summer and lowest abundances from November through January (Figure D-423). Abundance generally increased at both the SONGS and the Control sites in the After period (Table 4-8). Cross-shelf abundances varied from a minimum of $10/m^3$ to as high as $1993/m^3$, but ranged mainly between about $100/m^3$ and $500/m^3$. Exceptionally high abundances that strongly influenced the statistical test results occurred on two dates: 31 July 1980, when very large collections were made at SONGS, and 9 May 1986, when the large collections were made at Control.

Mean cross-shelf abundance at SONGS increased 72%, from $241/m^3$ in the Before period to $413/m^3$ in the After period. At the same time, abundance at Control increased 140%, from $206/m^3$ to $495/m^3$. This yielded a relative decrease of 48% (Table 4-12). The Wilcoxon rank sum test on untransformed data (the test of preference because an influence date was deleted to obtain additivity) and all tests on log-transformed data indicated that this was not a significant change (all t-test values of $p > 0.16$, all Wilcoxon rank sum test values of $p > 0.70$; $\alpha = 0.10$: see Figure D-420). Both the t-test and Wilcoxon rank sum test on untransformed data from the plume dates and non-plume dates subsets likewise yielded nonsignificant results (all $p \geq 0.30$; $\alpha = 0.10$).

The regressions of SONGS abundance on Control abundance fit two different straight lines for the two monitoring periods; neither had a slope of one. These two lines, however, were strongly influenced by the 31 July 1980 and 9 May 1986 outliers. Without these two points, the analysis would probably have fit one straight line with a slope of one, indicating additivity and no SONGS effect.

The pattern analysis indicated a significant shift ($p = 0.03$) consisting of a decrease in mean rank of abundance in the 8 m epibenthos and an increase in 13 m lower midwater (Figure 4-5). Nearly significant ($0.05 < p < 0.10$) changes also occurred in other strata, including an increase in the 8 m midwater and decreases in the 30 m epibenthos and surface strata. The significant pattern changes were interpreted as reflecting, at least in part, SONGS-induced redistribution. The nearly-significant shifts could be similarly interpreted. For example, the significant increase in mean rank of abundance in the 13 m lower midwater stratum and the nearly-significant decreases in the 30 m epibenthos and surface strata could result from replacement water being drawn towards SONGS from seaward and upcurrent. Water drawn into the 13 m area would contain higher numbers of C. anglicus, while the water drawn into the 30 m area from farther offshore would contain fewer C. anglicus. The significant decrease in mean rank of abundance in the 8 m epibenthos apparently cannot be fully accounted for in terms of SONGS-induced redistribution, but may reflect increased predation from ichthyoplankters as well as replacement from low abundance epibenthic waters shoreward. The nearly-significant increase in mean rank of abundance in the 8 m midwater stratum might have reflected replacement water drawn from seaward and upstream, and containing higher numbers of C. anglicus (e.g., Figure 4-4).

4.3.2.3.5 Cyphonautes Larvae

A possible SONGS effect was detected in the analysis of plume dates cross-shelf abundance on plume dates. MEC interpreted this as a minor effect below the detection level of the tests on the full After data set. The operative mechanism(s) could not be postulated. A significant pattern shift was also detected; this was interpreted as reflecting SONGS-induced redistribution.

At San Onofre, cyphonautes larvae were found in all strata on all surveys. The highest abundances were consistently in the 30 m midwater strata, with slightly lower abundance in the 13 m and 18 m midwater strata (Figure D-430). The 8 m epibenthos at SONGS in the Before period had high mean abundance due to a few extremely large collections in winter and spring of 1977. Contrary to Yoshioka's (1973) finding that abundance was highest in winter, the cyphonautes larvae in the SONGS study did not show winter peaks of abundance (Figure D-429). In fact, the highest abundances occurred in the summer of 1985.

Cross-shelf abundances ranged from $7/m^3$ to $670/m^3$. At SONGS, mean cross-shelf abundance increased 83% from $82/m^3$ in the Before period to $151/m^3$ in the After period. Control abundances change little, declining only 4% from $113/m^3$ to $108/m^3$. This yielded an 87% relative increase (Table 4-12). During the Before period 13 of 31 surveys (42%) had positive Deltas, whereas 14 of the 23 After surveys (61%) had positive Deltas (Figure D-428). This would suggest that a significant relative increase had, in fact, occurred. However, the primary BACI t-test on log (x)-transformed data indicated that this was not a significant change ($p = 0.20$; $\alpha = 0.05$). Similarly, the Wilcoxon rank sum test also yielded a nonsignificant result ($p = 0.10$; $\alpha = 0.05$).

All t-test results using other log transformations were nonsignificant ($p = 0.12$ to 0.20; $\alpha = 0.05$), as were the Wilcoxon rank sum test results ($p = 0.06$ to 0.10; $\alpha = 0.05$). These results all concurred with the primary BACI test results (Figure D-426).

SONGS versus Control regressions fit two straight lines, one for the Before period with a slope not equal to one, and another for the After period with a slope that was not different from one. The slope different from one indicated nonadditivity of the untransformed Before data, and thus confirmed the result of the additivity test. The slope for the After regression line was significantly different from the slope for the Before line, indicating a difference between periods, and the sign of the difference was positive, indicating that SONGS abundance increased relative to Control abundance in the After period, contrary to the BACI test results.

BACI t-test and Wilcoxon rank sum test results using the log (x)-transformed data from the plume dates subset were both significant ($p = 0.05$ and 0.04, respectively; $\alpha = 0.10$), but they were not significant for the non-plume dates subset surveys ($p = 0.86$ and 0.75, respectively; $\alpha = 0.10$). This suggests the possibility of a SONGS effect, but one below the detection level of the BACI tests on the full After data set. The mechanism for such an effect is unknown.

In the Before period San Onofre and San Mateo Kelp were major sources of Membranipora cyphonautes larvae in the SONGS area, and Barn Kelp was a source for the Control area. Barn Kelp declined substantially during the study, leaving San Onofre and San Mateo Kelp as the only major local sources of Membranipora cyphonautes larvae. San Onofre kelp declined during the After period while San Mateo Kelp prospered; thus if the cyphonautes BACI results reflected only Membranipora production we should have seen significant results on non-plume dates and nonsignificant results on plume dates, opposite the results obtained.

Cyphonautes larvae exhibited a significant ($p = 0.03$) change in the spatial pattern of ranks of abundance in the SONGS-After data set. Relative increases in the 8 m and 13 m midwater strata (above the diffusers) were accompanied by a decrease in the lower midwater stratum at 30 m. These inshore increases and the offshore decrease were interpreted as a SONGS effect. A possible mechanism for this effect is a SONGS-induced circulation pattern in which water withdrawn at the intakes and secondarily entrained and transported seaward is replaced by water drawn toward SONGS from seaward. The observed pattern shift could thus have resulted from replacement water containing higher concentrations of larvae being drawn into the 8 and 13 m blocks from seaward (recall that abundance was highest in the 30 m midwater strata), while the decrease at 30 m could have resulted from water containing lower concentrations of larvae being drawn into that block from farther seaward.

4.3.2.3.6 Labidocera trispinosa

No evidence of a SONGS effect was detected for Labidocera trispinosa.

At San Onofre, L. trispinosa adults and late copepodids were found predominantly at the surface at the 8 m isobath, and lower in the water column farther offshore in the Before period (Figure D-436). In the After period, abundances were generally lower everywhere (e.g., Table 4-8), but with relatively higher numbers of organisms found near the bottom at the 8 m isobath. At SONGS, abundances were generally higher than at the Control site. Cross-shelf abundances varied from a low of less than $1/m^3$, with highest abundances in the summer and fall of 1981 (Figure D-435). Mean cross-shelf abundance at the Control site dropped

36%, from $33/m^3$ in the Before period to $21/m^3$ in the After period. The mean cross-shelf abundance at SONGS simultaneously dropped 26% from $64/m^3$ to $47/m^3$, yielding a relative percent increase of 10% (Table 4-12). The plots of the Before and After Deltas vs. time (Figure D-433, D-434) revealed no striking shifts between the monitoring periods.

BACI tests were performed on log (x)-transformed data, which met all the requisite assumptions (untransformed data were not additive and thus could not be tested). The t-test results were nonsignificant ($p = 0.36$; $\alpha = 0.10$). The Wilcoxon rank sum test result confirmed the primary t-test result ($p = 0.50$; $\alpha = 0.10$). All log (x + C)-transformed data testing likewise yielded nonsignificant results (Figure D-432), again confirming the principal test result. BACI t-test results for the analyses on plume dates and non-plume dates were also nonsignificant ($p = 0.42$ and 0.36, respectively; $\alpha = 0.10$) as were the Wilcoxon rank sum test results ($p = 0.44$ and 0.66, respectively; $\alpha = 0.10$). We thus concluded, on the basis of the nonsignificant primary test result and confirmation by all secondary tests, that there was no SONGS effect measurable as a change in cross-shelf abundance.

SONGS versus Control regressions fit two curved lines, indicating both nonadditivity of the untransformed data and suggesting a SONGS effect. However, the analyses appeared to be dominated by 3 outliers: 24 June 1981, 5 November 1981 and 31 August 1984. Deleting these 3 points and rerunning the regressions yielded a single with a slope of 1 fit to both the Before and After data sets.

The analysis of spatial distributions showed no difference ($p = 0.24$) between the pattern of ranks of abundance at SONGS in the After period and the Before-or-Control pattern of ranks.

4.3.2.3.7 _Oithona plumifera_

The relative abundance of _Oithona plumifera_ did not change significantly as a result of SONGS operations. However, the cross-shelf distribution of _O. plumifera_ did change significantly, and this change was interpreted as a SONGS effect, possibly reflecting a pattern of SONGS-induced circulation.

Oithona plumifera was present in all surveys, predominantly at the 30 m isobath in the midwater strata (Figure D-442). Cross-shelf abundances ranged from $<1/m^3$ to $1,200/m^3$, with most Before observations $<100/m^3$. Abundances generally increased in the After period (Figure D-441), so that many cross-shelf abundances were between $100/m^3$ and $350/m^3$. The average cross-shelf abundance at SONGS increased 133%, from $64/m^3$ in the Before period to $149/m^3$ in the After period. At Control, the increase was only 28%, from $88/m^3$ to $113/m^3$. The relative increase was thus 104% (Table 4-12). However, examination of time plots of Delta values (Figure D-439, D-440) revealed that most Deltas were close to zero, indicating considerable similarity between the two areas in both time periods.

The BACI t-test, performed on log (x)-transformed Deltas (untransformed data were not additive and thus could not be used), showed a nonsignificant result ($p = 0.49$; $\alpha = 0.05$). Although the Before Deltas were serially correlated, when the BACI t-test was modeled with autoregressive errors, we noted that the full data set did not have any auto-correlation. We thus used the t-test without autoregressive errors. The nonsignificant Wilcoxon rank sum test result ($p = 0.61$; $\alpha = 0.05$) confirmed the primary t-test result, as did all tests on log (x + C)-transformed data that met the BACI assumptions (Figure D-438). Nonsignificant results were also obtained for the t-tests on the log (x)-transformed plume and non-plume data ($p = 0.58$ and 0.88, respectively; $\alpha = 0.05$). The results of the Wilcoxon rank sum tests were similarly nonsignificant ($p = 0.51$ and 0.99, respectively). We thus interpreted the BACI test results as indicating no effect.

Two different straight lines were fit to the SONGS versus Control regressions. The slope in the Before period did not equal one, confirming nonadditivity of the untransformed data. The slope in the After period was significantly larger than the slope in the Before period, indicating an increase at SONGS compared to Control. A change in the relationship between SONGS and Control in the different monitoring periods (i.e., two different straight lines) could be an indication of a SONGS effect, but we did not interpret it as one since the BACI tests were not significant.

Pattern analyses revealed a significant ($p = 0.03$) change between the SONGS-After and Before-or-Control ranks of abundance. Univariate ANOVAs for each stratum indicated the following changes: (1) a nearly-significant ($0.05 < p < 0.10$) decrease in mean rank of abundance in the 8 m epibenthos, (2) a significant increase in mean rank in the 13 m high midwater stratum, and (3) significant decreases in the 30 m high midwater and 30 m surface strata. These changes were considered SONGS effects, possibly reflecting a SONGS-induced circulation pattern (see Section 4.3.1). Thus, the significant increase in mean rank of abundance in the 13 m high midwater stratum may have reflected the incursion of more offshore water containing a higher abundance of _O. plumifera_ (e.g., Figure 4-4) drawn shoreward to replace the secondarily-entrained nearshore midwater. The significant decreases in mean ranks at 30 m may have reflected incursions of plankton-depleted water from the plume, and water containing fewer _O. plumifera_ drawn into the 30 m block from farther offshore. The nearly-significant decrease in mean rank in the 8 m epibenthos could have reflected, at least in part, a combination of dilution from replacement water drawn from the more seaward epibenthos (which contains fewer _O_. _plumifera_, on average), and possibly recirculation of plume water depleted of plankton.

4.3.2.3.8 _Paracalanus_ _parvus_

Neither the relative abundance nor the cross-shelf distribution of _Paracalanus_ _parvus_ changed significantly as a result of SONGS operations.

_P_. _parvus_ occurred in all strata on all surveys, with slightly higher abundances in the high midwater stratum at 13 m and lower abundances in all 8 m strata (Figure D-448). Cross-shelf abundances were highly variable, ranging from 49/m^3 to 5,500/m^3. Cross-shelf abundance generally increased in the After period (e.g., Table 4-8). Abundance at SONGS increased 29%, from an average of 839/m^3 in the Before period to 1,078/m^3 in the After period. Abundance at Control simultaneously increased 69%, from an average of 636/m^3 in the Before period to 1,076/m^3 in the After period. This yielded a relative decrease of 41% (Table 4-12). The Deltas showed an indication of seasonality, but no difference between monitoring periods (Figure D-445).

The BACI t-test on log (x)-transformed Deltas (untransformed data were nonadditive and thus could not be used) yielded a nonsignificant result ($p = 0.91$; $\alpha = 0.05$). This principal test result was confirmed by the Wilcoxon rank sum test ($p = 0.86$; $\alpha = 0.05$). Tests on log $(x + 0.1)$, log $(x + 1)$, and log $(x + 10)$ transformations also all agreed with the primary BACI result (Figure D-444). Splitting the After data into plume dates and non-plume dates yielded similar results: the t-tests on log (x)-transformed data were not significant (p = 0.56 and 0.42, respectively; α = 0.10). The results of the Wilcoxon rank sums tests were likewise nonsignificant (p = 0.80 and 0.64, respectively; α = 0.10).

SONGS versus Control regressions fit two straight lines; the Before period line had a slope not different from 1, indicating that the untransformed data were additive, in contrast to the result of the specific test for additivity. The After regression line had a smaller slope than the Before line, indicating a different relationship between SONGS and Control abundances in the After period, in contrast to the BACI results. However, the presence of an influence point on 7 June 1977 controlled the fit of the Before line. A rerun of the regression analysis without this point resulted in only one straight line fit to the data from both monitoring periods.

The pattern analysis revealed no difference between the SONGS-After pattern of ranks of abundance and the Before-or-Control pattern of ranks (p = 0.89).

4.3.2.3.9 <u>Sagitta</u> <u>euneritica</u>

SONGS effects were not detected for <u>Sagitta</u> <u>euneritica</u>.

At San Onofre, <u>S</u>. <u>euneritica</u> were found in all strata on all surveys, predominantly in the epibenthos and midwater strata at the 13 and 30 m isobaths. Abundances were low at 8 m and on the surface throughout the study area (Figure D-454). A slight seasonality was apparent in that abundances were lower in January and higher from March through July.

Cross-shelf abundances ranged from a low of 10/m^3 to a high of 1232/m^3. Mean cross-shelf abundance at SONGS changed very little, remaining near 170/m^3 during both monitoring periods (Table 4-8). At the Control site the mean cross-shelf abundance increased 10%, from 159/m^3 in the Before period to 174/m^3 in the After period. These changes resulted in a relative decrease of 9% (Table 4-12).

The BACI t-test on untransformed data yielded nonsignificant results ($p = 0.73$; $\alpha = 0.10$). The untransformed Deltas were serially correlated in the After period, but when the autoregressive errors procedure was applied, serial correlation was not detected in the full data set. Therefore, BACI testing was performed on untransformed data using the standard t-test with independent errors. Results of the Wilcoxon rank sum test on untransformed data supported the t-test result ($p = 0.40$; $\alpha = 0.10$). Examination of the Deltas plotted against the time of year (Figure D-451) showed litte difference between the two monitoring periods, further supporting the nonsignificant BACI test result. Finally, tests using other log transformations (Figure D-405) and the ancillary tests on the plume dates and non-plume dates subsets all yielded nonsignificant results (Figure D-450; Table 4-10), confirming the conclusion of no effect.

The SONGS versus Control regressions fit two different curved lines, indicating nonadditivity in the untransformed Before data and a different relationship between SONGS and Control abundances in the two time periods. Given that these were the only significant results based on cross-shelf abundance, we accepted the primary BACI result which indicated that there was no significant relative change in abundance of *Sagitta euneritica* attributable to SONGS operations.

The pattern analysis revealed no significant shift in spatial pattern of ranks of abundance between the two data sets ($p = 0.13$)

4.3.2.4 Offshore Taxa

Offshore taxa are those that are most abundant seaward of the 30 m isobath and occur only infrequently or in much lower abundance nearer shore. One offshore taxon, Calanus pacificus, was utilized for the BACI analyses. Owing to its offshore distribution, SONGS effects were not anticipated for this species (e.g., maximum estimated intake and diffuser losses were less than 4% of average cross-shelf abundance: Table 4-13), and none were detected (e.g., Figures D-456, D-460), as described below.

4.3.2.4.1 Calanus pacificus

We detected no evidence of a SONGS effect on Calanus pacificus.

In this study C. pacificus were found primarily offshore, in the midwater strata at the 30 m isobath (Figure D-460). Abundance was low in late fall through early winter months and very high in May through July (Figure D-459). Every survey contained at least a few individuals. Cross-shelf abundances ranged from less than $1/m^3$ to $1052/m^3$, but typically were less than $200/m^3$. Large increases in cross-shelf abundances occurred at both SONGS and Control after April 1985, with values typically in the mid-hundreds (Figure D-459). Cross-shelf abundance at SONGS increased by 248%, from an average of $40/m^3$ in the Before period to an average of $140/m^3$ in the After period. At Control the increase was 159%, from $31/m^3$ to $81/m^3$. This yielded a relative increase of 125% (Table 4-12).

Although this seems like a large relative change, none of the statistical analyses identified it as significant (Figure D-456). The primary BACI t-test on untransformed Deltas, which had very low power (20% at $\alpha = 0.10$: Figure D-455), yielded a nonsignificant result ($p = 0.29$; $\alpha = 0.10$), as did the Wilcoxon rank sum test on untransformed Deltas ($p = 0.86$; $\alpha = 0.10$). Except for two very large After values, the Delta values for the two periods were similar (Figure D-457). Although the power of the BACI t-test increased to 77% ($\alpha = 0.10$) for log (x)-transformed Deltas, the test result remained nonsignificant ($p = 0.83$), as did the Wilcoxon rank sum test result ($p = 0.89$). Similarly, all log (x + C) transformations yielded higher power (Figure D-455) and nonsignificant test results (Figure D-456), confirming the primary result.

Regressions of SONGS abundance on Control abundance fit one straight line to the data from both monitoring periods, further confirming that there was no SONGS effect. The slope of the line was one, confirming additivity of the untransformed Deltas.

BACI t-tests on untransformed Deltas using the plume dates and non-plume dates revealed no significant differences between monitoring periods ($p = 0.24$ and 0.20, respectively; $\alpha = 0.10$). The Wilcoxon rank sum test results were similarly nonsignificant ($p = 0.51$ and 0.66, respectively; $\alpha = 0.10$). Thus all secondary tests on cross-shelf abundance confirmed the primary test result and the interpretation of no effect.

Spatial distributions did not differ significantly ($p = 0.11$) between the SONGS-After and the Before-or-Control data sets, further confirming that there was no effect.

4.3.2.5 Total Zooplankton

Little evidence of a SONGS effect was obtained in the BACI testing of cross-shelf abundances of individual taxa. However, before concluding that zooplankton cross-shelf abundances were largely unaffected by SONGS, we examined Total Zooplankton abundances to see whether there might have been an overall effect on the zooplankton community that we missed in the testing of its component parts. We found no evidence of an effect in the BACI testing, but did detect a pattern change largely reflective of the result obtained for the dominant zooplankter, <u>Acartia tonsa</u>. This was interpreted as a SONGS effect that might have resulted from a pattern of SONGS-induced circulation.

Cross-shelf abundances of total zooplankton were large and variable, ranging from 750/m^3 to 19,000/m^3 (Figure D-465). There were no surveys with counts of zero for total zooplankton. Cross-shelf abundance increased 15% at SONGS, from a mean of about 4,600/m^3 in the Before period to a mean of about 5,400/m^3 in the After period. Simultaneously, at Control cross-shelf abundance increased 17%, from about 4,200/m^3 to about 4,900/m^3 (Table 4-8).

Winter Deltas had a smaller range (-2,000/m^3 to +1,000/m^3) than summer (April through September) Deltas (-6,000/m^3 to +8,000/m^3, with most between -4,000/m^3 and +4,000/m^3) (Figure D-463). Although there was some indication of a seasonal pattern in the Deltas, the values for both monitoring periods generally showed a great deal of variability around a mean of zero (Figure D-463).

The BACI t-test on untransformed Deltas yielded a nonsignificant result ($p = 0.99$, $\alpha = 0.05$) indicating that the null hypothesis of no difference between Before and After Deltas could not be rejected (Table 4-9).

All secondary t-tests using log transformations agreed with the primary result based on untransformed data (all values of $p > 0.60$; $\alpha = 0.05$: see Figure D-462). The Wilcoxon rank sum test results also confirmed the primary BACI t-test result (all values of p between 0.59 and 0.86). Results of BACI tests using untransformed data from plume dates and non-plume dates also were nonsignificant (all values of $p > 0.20$; $\alpha = 0.05$).

SONGS versus Control regressions on the full data sets fit one straight line to both sets, with a slope of 1, indicating additivity of the untransformed data and no SONGS effect.

Pattern analyses revealed a significant change ($p = 0.01$) in the spatial distribution of abundance ranks of zooplankton in the SONGS-After data set as compared to the Before-or-Control set. Significant ($p < 0.05$) relative decreases in mean ranks of abundance were noted in the 8 m epibenthos and in the high midwater stratum at 30 m, with an accompanying increase in mean rank in the low midwater stratum at 13 m (Figure 4-5). We believe that these spatial changes represent a composite of the significant changes noted for the individual taxa, particularly the dominant taxon Acartia tonsa. We identified these shifts for the individual taxa as SONGS effects and suggested that a pattern of SONGS-induced circulation was a possible mechanism that could have largely accounted for the observed patterns. This interpretation applies to total zooplankton as well.

4.4 Phytoplankton

Although phytoplankton samples were collected on each zooplankton monitoring survey, cell counts were not made during the After period and thus BACI testing on cell counts was not possible. However, chlorophyll-a concentration, an index of phytoplankton standing crop, was also measured during the monitoring surveys, by MEC in the Before period (see Section 3.3), and by the MRC physical/chemical contractor (Ecosystems Management Associates, Inc.) subsequently. Chlorophyll-a concentrations were thus analyzed as a surrogate for phytoplankton cell counts.

The SONGS Units 2 and 3 discharges were originally predicted to cause a local upwelling which would result in a local increase in phytoplankton production (Barnett and Sertic, 1979a). However, if such an increase in production did occur, it was not measurable as a significant increase in phytoplankton standing crop. In other words, no evidence for a SONGS effect was detected in the chlorophyll-a data.

Cross-shelf chlorophyll-a concentrations ranged from about 0.18 µg/ℓ to as high as 27.50 µg/ℓ during the course of the monitoring studies. Average concentrations increased at both SONGS and Control from the Before to the After period (e.g., Table 4-14). The increase at SONGS was 122%, from a mean of 2.86 µg/ℓ in the Before period to 6.36 µg/ℓ in the After period. The increase at Control was smaller--62%, from 2.74 µg/ℓ to 4.43 µg/ℓ.

The BACI t-test on untransformed Deltas indicated that this relative increase was not significant ($p = 0.27$; $\alpha = 0.10$), and the secondary Wilcoxon rank sum test on untransformed Deltas ($p = 0.82$; $\alpha = 0.10$) and all tests on log-transformed data (all $p > 0.30$; $\alpha \leq 0.10$) confirmed the nonsignificant primary test result (Table 4-14). The regressions of SONGS cross-shelf chorophyll-a concentrations on Control concentrations indicated that a single straight line with a slope not different from one fit the data from both monitoring periods, confirming that the untransformed data were additive and that there was no evidence of a SONGS effect.

In order to determine whether a significant increase in standing crop might have occurred, but was masked by our use of average cross-shelf chlorophyll-*a* concentrations, we also tested data from the 30 m station alone, where we expected an effect to be most apparent if there was one. The t-test on log (x)-transformed data (untransformed data were not additive (Table 4-15) and could not be used in this case, again yielded a nonsignificant result ($p = 0.30$; $\alpha = 0.05$), which was confirmed by the secondary Wilcoxon rank sum test on log (x)-transformed data ($p = 0.25$; $\alpha = 0.05$) and the tests on log (x + 0.1)-transformed data ($p \geq 0.25$; $\alpha = 0.10$). The regressions of chlorophyll-*a* concentrations at the 30 m isobath at SONGS on concentrations at 30 m at Control indicated that a single straight line fit the data from both monitoring periods, again confirming that there was no evidence for a SONGS effect.

Table 4-1. Mean cross-shelf abundance (number/m^3) and one standard deviation from the mean for each ichthyoplankton taxon utilized in the BACI analyses. Values are given for each larval developmental stage and for total larvae for each taxon in each monitoring period (Before, After) at SONGS and at Control. N=number of surveys.

		SONGS						Control					
		Before			After			Before			After		
Species	Stage	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Clevelandia ios	larvae	38	0.79	2.14	27	0.49	0.82	38	0.90	1.08	27	3.04	3.85
	preflexion	25	0.32	1.01	16	0.20	0.65	25	0.40	0.53	16	0.20	0.36
	flexion	24	0.15	0.41	24	0.06	0.10	24	0.17	0.17	24	0.88	1.40
	post-flexion	36	0.48	1.63	27	0.32	0.61	36	0.56	0.69	27	2.13	2.75
Quietula y-cauda	larvae	35	0.14	0.32	27	0.40	0.49	35	0.27	0.38	27	1.33	1.54
	preflexion	26	0.09	0.23	24	0.22	0.29	26	0.21	0.28	24	0.57	0.69
	flexion	14	0.06	0.10	25	0.08	0.12	14	0.16	0.29	25	0.60	0.91
	post-flexion	15	0.02	0.04	24	0.15	0.24	15	0.09	0.12	24	0.29	0.42
Ilypnus gilberti	larvae	37	1.01	2.43	27	3.86	6.87	37	1.64	3.50	27	7.74	8.33
	preflexion	33	0.18	0.33	27	1.26	2.08	33	0.62	1.16	27	2.43	3.13
	flexion	29	0.37	1.04	27	0.69	0.90	29	0.48	1.56	27	2.61	3.37
	post-flexion	34	0.54	1.31	27	1.91	4.84	34	0.76	1.70	27	2.58	3.29
Gobiesox rhessodon	larvae	34	0.65	0.98	22	1.01	1.49	34	0.36	1.35	22	0.39	0.89
	preflexion	30	0.57	0.92	21	0.65	1.10	30	0.25	0.79	21	0.31	0.79
	flexion	22	0.17	0.27	15	0.31	0.48	22	0.03	0.08	15	0.10	0.28
	post-flexion	7	0.04	0.07	12	0.34	0.97	7	0.04	0.03	12	0.04	0.05
Paraclinus integripinnis	larvae	16	1.03	1.14	14	1.31	3.18	16	0.28	0.57	14	0.65	0.79
	preflexion	13	0.56	0.87	14	0.89	2.21	13	0.14	0.26	14	0.35	0.48
	flexion	8	0.23	0.39	11	0.33	0.84	8	0.08	0.12	11	0.26	0.33
	post-flexion	4	0.40	0.46	7	0.33	0.40	4	0.34	0.66	7	0.21	0.29
Gibbonsia type a	larvae	29	0.75	1.87	26	0.84	1.10	29	0.28	0.67	26	0.25	0.42
	preflexion	24	0.55	0.94	25	0.62	0.78	24	0.20	0.56	25	0.17	0.33
	flexion	13	0.63	1.58	12	0.44	0.35	13	0.21	0.68	12	0.17	0.34
	post-flexion	4	0.09	0.15	7	0.16	0.29	4	0.05	0.06	7	0.02	0.05
Heterostichus rostratus	larvae	27	0.22	0.29	21	0.34	0.36	27	0.07	0.27	21	0.16	0.32
	preflexion	24	0.16	0.19	15	0.29	0.28	24	0.01	0.04	15	0.18	0.36
	flexion	13	0.16	0.31	14	0.12	0.12	13	0.10	0.31	14	0.04	0.10
	post-flexion	3	0.03	0.04	6	0.17	0.27	3	0.06	0.10	6	0.02	0.02
Seriphus politus	larvae	38	72.13	92.17	24	38.39	96.06	38	65.67	78.96	24	54.94	102
	preflexion	36	62.85	86.33	23	37.20	94.77	36	50.25	62.98	23	54.47	102.4
	flexion	32	9.97	31.05	18	2.73	5.65	32	7.92	16.38	18	2.36	4.43
	post-flexion	32	0.94	1.69	18	0.92	1.40	32	1.61	2.25	18	1.18	1.82
Genyonemus lineatus	larvae	37	122.6	314	24	38.25	101.9	37	101	212.5	24	70.79	234
	preflexion	32	121.3	311.3	21	37.61	102.4	32	86.74	183.2	21	70.11	223
	flexion	28	13.17	39.07	17	5.55	7.92	28	18.81	38.95	17	10.50	24.81
	post-flexion	26	10.18	31.16	12	2.81	3.45	26	15.51	28.78	12	3.99	7.04

Table 4-1 (Cont.)

		SONGS						Control					
		Before			After			Before			After		
Species	Stage	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Cheilotrema saturnum	larvae	26	2.16	6.72	11	4.18	9.05	26	1.17	2.60	11	3.05	8.80
	preflexion	24	2.18	6.99	8	5.75	10.34	24	1.13	2.55	8	4.11	10.26
	flexion	3	0.50	0.77	3	0.00	0.01	3	0.19	0.33	3	0.13	0.21
	post-flexion	2	0.08	0.11	3	0.00	0.00	2	0.06	0.08	3	0.10	0.11
Menticirrhus undulatus	larvae	17	5.97	11.24	12	3.92	5.73	17	6.08	11.99	12	1.63	3.10
	preflexion	15	4.58	9.02	12	3.23	4.62	15	4.89	10.33	12	1.52	2.87
	flexion	7	1.11	2.63	4	2.06	2.35	7	1.60	2.48	4	0.33	0.62
	post-flexion	3	0.00	0.00	1	0.08	.	3	0.63	0.88	1	0.00	.
Paralabrax spp	larvae	20	51.40	113.3	16	30.02	50.91	20	41.11	67.46	16	76.05	155.6
	preflexion	16	42.05	81.51	16	26.90	41.89	16	38.71	68.61	16	65.93	133.8
	flexion	13	11.73	33.27	6	6.80	16.58	13	4.71	8.59	6	22.33	47.30
	post-flexion	13	3.79	8.43	8	1.13	2.32	13	1.92	4.79	8	1.74	4.21
Hypsopsetta guttulata	larvae	23	1.21	1.92	15	0.23	0.31	23	0.66	0.72	15	0.15	0.30
	preflexion	19	1.22	2.00	15	0.23	0.31	19	0.63	0.71	15	0.13	0.30
	flexion	10	0.21	0.38	3	0.00	0.00	10	0.16	0.35	3	0.08	0.13
	post-flexion	7	0.00	0.00	1	0.00	.	7	0.01	0.02	1	0.00	.
Paralichthys californicus	larvae	38	28.75	44.75	24	11.48	16.23	38	23.71	33.09	24	12.11	14.86
	preflexion	34	24.32	39.40	24	10.44	15.62	34	18.96	25.79	24	11.11	13.59
	flexion	17	5.63	12.68	12	1.84	3.24	17	2.64	3.26	12	0.60	1.12
	post-flexion	28	1.07	2.46	14	0.20	0.29	28	1.29	2.01	14	1.19	2.33
Atherinopsis californiensis	larvae	24	8.88	17.85	17	1.86	2.79	24	3.98	8.66	17	2.55	3.77
	preflexion	21	9.57	18.15	16	1.85	2.85	21	3.74	6.92	16	2.53	3.77
	flexion	17	0.38	0.55	13	0.13	0.13	17	0.52	1.50	13	0.21	0.21
	post-flexion	13	0.20	0.33	9	0.02	0.03	13	0.27	0.64	9	0.02	0.03
Leuresthes tenuis	larvae	34	0.64	0.99	21	2.19	3.83	34	1.59	4.40	21	0.93	2.30
	preflexion	29	0.53	0.88	19	1.95	3.50	29	1.40	4.46	19	0.63	1.65
	flexion	27	0.17	0.29	15	0.41	0.47	27	0.36	1.15	15	0.39	0.91
	post-flexion	27	0.06	0.08	16	0.18	0.31	27	0.11	0.15	16	0.10	0.19
Engraulis mordax	larvae	38	542.6	1165	27	353	477.9	38	396.1	685.5	27	475.5	587.5
	preflexion	34	391.9	937.8	27	252.2	365.7	34	287.8	614.9	27	299.6	424.6
	flexion	34	108.5	207.4	27	68.13	134.2	34	67.09	103.4	27	123	222.7
	post-flexion	36	67.31	72.37	27	29.05	33.01	36	73.02	70.72	27	46.17	49.32
Citharichthys spp	larvae	24	1.17	1.73	18	4.29	8.15	24	1.84	3.51	18	1.88	3.15
	preflexion	22	1.03	1.74	17	4.54	8.33	22	1.79	3.69	17	1.86	3.14
	post-flexion	2	1.08	1.51	1	0.00	.	2	0.00	0.00	1	2.33	.
Hypsoblennius spp	larvae	38	20.40	24.03	26	20.15	39.16	38	17.80	19.09	26	11.00	14.40
	preflexion	36	17.13	20.72	25	19.01	37.82	36	13.75	13.58	25	11.08	14.50
	flexion	23	3.35	4.99	13	3.53	6.55	23	2.33	4.91	13	0.55	1.30
	post-flexion	30	0.90	2.44	21	0.12	0.26	30	0.98	3.54	21	0.08	0.18

Table 4-2. Summary of results of BACI analysis and pattern analysis on the full operational data set for ichthyoplankton. The p level for the indicated test is given in the results columns. NS=BACI test result not significant; SIG=BACI test result significant; x=not tested. Lower case letters indicate test results in which we had less confidence for any number of reasons, for example, lack of confirmation by secondary test results, small sample size, etc. AUTOREG refers to the t-test modeled with autoregressive errors.

	PRINCIPAL BACI TEST					MANOVA RESULT
TAXON	FORM OF TEST	TRANSFORMATION	α	POWER	RESULT	(α=0.05)
Clevelandia ios						
total	Wilcoxon	None	0.10	0.24	0.05 SIG	0.09
preflexion	t-test	log (x + 1)	0.10	0.24	0.82 ns	0.86
flexion	Wilcoxon	None	0.10	<0.10	<0.01 SIG	0.18
postflexion	t-test (AUTOREG)	log (x + 0.1)	0.10	0.29	0.07 SIG	0.09
Quietula y-cauda						
total	t-test	None	0.10	<0.10	0.01 SIG	0.02
preflexion	t-test	None	0.10	<0.10	0.09 sig	0.02
flexion	t-test	None	0.10	<0.10	0.02 SIG	0.31
postflexion	t-test	None	0.10	<0.10	0.23 NS	0.24
Ilypnus gilberti						
total	t-test	None	0.10	<0.10	0.06 sig	0.09
preflexion	t-test	log (x + 0.1)	0.10	<0.10	0.38 ns	0.06
flexion	t-test	None	0.10	<0.10	<0.01 SIG	0.18
postflexion	t-test	None	0.10	<0.10	0.35 NS	0.02
Gobiesox rhessodon						
total	t-test	None	0.10	0.27	0.76 NS	0.11
preflexion	t-test	None	0.10	0.29	0.52 NS	0.55
flexion	t-test	None	0.10	0.24	0.65 NS	<0.01
postflexion	t-test	None	0.10	<0.10	0.85 NS	0.14
Paraclinus integripinnis						
total	t-test	None	0.10	0.25	0.46 ns	0.02
preflexion	t-test	None	0.10	0.20	0.58 ns	0.05
flexion	t-test	log (x + 0.1)	0.10	0.18	0.17 NS	0.63
postflexion	t-test	None	0.10	0.36	0.58 NS	0.40
Gibbonsia sp. A						
total	Wilcoxon	None	0.10	0.32	0.76 NS	0.34
preflexion	t-test	None	0.10	0.38	0.62 NS	0.23
flexion	t-test	log (x + 1)	0.10	0.20	0.56 NS	0.04
postflexion	t-test	None	0.10	0.17	0.74 NS	0.17
Heterostichus rostratus						
total	t-test	None	0.10	0.36	0.58 NS	0.30
preflexion	t-test	None	0.10	0.30	0.39 NS	0.14
flexion	t-test	None	0.10	0.25	0.58 NS	0.004
postflexion	t-test	None	0.10	<0.10	0.84 ns	0.41
Seriphus politus						
total	t-test	None	0.10	0.64	0.12 NS	0.64
preflexion	t-test	None	0.10	0.58	0.06 sig	0.38
flexion	t-test	None	0.10	0.47	0.30 NS	0.01
postflexion	t-test	None	0.10	0.32	0.80 NS	0.69

Table 4-2. (Cont.)

TAXON	PRINCIPAL BACI TEST					MANOVA RESULT (α=0.05)
	FORM OF TEST	TRANSFORMATION	α	POWER	RESULT	
Genyonemus lineatus						
total	t-test	None	0.10	0.49	0.14 ns	0.02
preflexion	Wilcoxon	None	0.10	0.46	0.63 ns	0.02
flexion	t-test	None	0.10	0.26	0.53 ns	0.58
postflexion	t-test	None	0.10	0.21	0.71 ns	0.07
Cheilotrema saturnum						
total	Wilcoxon	None	0.10	0.28	0.49 NS	0.14
preflexion	t-test	None	0.10	0.24	0.62 NS	0.07
flexion	X					X
postflexion	X					X
Menticirrhus undulatus						
total	t-test	None	0.10	0.68	0.92 NS	0.27
preflexion	t-test	None	0.10	0.66	0.92 NS	0.18
flexion	t-test	None	0.10	0.31	0.94 NS	0.18
postflexion	X					X
Paralabrax sp.						
total	Wilcoxon	None	0.10	0.33	0.11 NS	0.41
preflexion	t-test	None	0.10	0.30	0.06 sig	0.22
flexion	t-test	log (x + 1)	0.10	0.24	0.01 sig	0.38
postflexion	t-test	None	0.10	0.24	0.22 NS	0.28
Hypsopsetta guttulata						
total	t-test (AUTOREG)	log (x + 0.1)	0.10	0.33	0.58 NS	0.90
preflexion	t-test (AUTOREG)	log (x + 0.1)	0.10	0.30	0.25 NS	0.95
flexion	X					0.80
postflexion	X					X
Paralichthys californicus						
total	t-test (AUTOREG)	None	0.10	0.54	0.23 NS	0.75
preflexion	t-test	None	0.10	0.55	0.21 NS	0.45
flexion	t-test	log (x + 1)	0.10	0.24	0.61 NS	0.44
postflexion	t-test	None	0.10	0.24	0.20 NS	0.62
Atherinopsis californiensis						
total	t-test (AUTOREG)	log (x + 0.1)	0.10	0.60	<0.01 sig	0.17
preflexion	t-test (AUTOREG)	log (x + 0.1)	0.10	0.59	<0.01 sig	0.43
flexion	t-test	log (x + 0.1)	0.10	0.34	0.09 sig	0.94
postflexion	Wilcoxon	None	0.10	0.28	0.37 NS	0.77
Leuresthes tenuis						
total	t-test	log (x + 0.1)	0.10	0.47	>0.99 NS	0.08
preflexion	Wilcoxon	None	0.10	<0.10	>0.99 NS	0.35
flexion	Wilcoxon	None	0.10	<0.10	0.92 NS	0.64
postflexion	t-test	log (x + 0.1)	0.10	0.30	0.98 NS	0.51

Table 4-2. (Cont.)

TAXON	PRINCIPAL BACI TEST					MANOVA RESULT
	FORM OF TEST	TRANSFORMATION	α	POWER	RESULT	$(\alpha=0.05)$
Engraulis mordax						
total	Wilcoxon	log (x)	0.05	0.97	0.02 SIG	0.07
preflexion	t-test	log (x + 1)	0.10	0.59	0.14 NS	0.29
flexion	t-test	log (x)	0.10	0.74	0.30 ns	0.39
postflexion	t-test	None	0.10	0.76	0.24 NS	0.51
Citharichthys spp.						
total	t-test	log (x + 1)	0.10	0.23	0.89 NS	0.16
preflexion	t-test	log (x + 1)	0.10	0.20	0.91 NS	0.39
flexion	X					
postflexion	X					
Hypsoblennius spp.						
total	t-test	None	0.10	0.54	0.79 NS	0.44
preflexion	t-test	log (x)	0.10	0.56	0.35 NS	0.32
flexion	t-test	None	0.10	0.27	0.78 NS	0.72
postflexion	t-test	log (x + 0.1)	0.10	0.43	0.26 NS	0.61

Table 4-3. Summary results of principal BACI analyses on plume and non-plume subsets of the ichthyoplankton operational data. Plume surveys are those taken when the impact site was estimated to be under the influence of the discharge plume; non-plume surveys are those taken when the impact site was estimated to not be under the influence of the discharge plume. These BACI tests were used to aid in the interpretation of the principal BACI test result based on the full operational data set. NS=test result not significant; SIG=test result significant; x=not tested. Lower case letters indicate results in which we had less confidence for any number of reasons, for example lack of agreement between the t-test and Wilcoxon rank sum test results, small sample size, etc. AUTOREG refers to the t-test modeled with auto-regressive errors.

TAXON	FORM OF TEST	TRANSFORMATION	α	POWER		PRINCIPAL TEST RESULT	
				PLUME	NON-PLUME	PLUME	NON-PLUME
Clevelandia ios							
total	Wilcoxon	None	0.10	0.20	0.21	<0.01 SIG	0.53 NS
preflexion	t-test	log (x + 1)	0.10	0.20	0.16	0.77 ns	0.80 ns
flexion	Wilcoxon	None	0.10	<0.10	0.17	<0.01 SIG	0.51 NS
postflexion	t-test	log (x + 0.1)	0.10	0.25	0.23	<0.01 SIG	0.36 NS
Quietula y-cauda							
total	t-test	None	0.10	<0.10	<0.10	0.01 SIG	0.33 NS
preflexion	t-test	None	0.10	<0.10	<0.10	0.07 SIG	0.49 NS
flexion	t-test	None	0.10	<0.10	<0.10	0.03 SIG	0.25 NS
postflexion	t-test	None	0.10	<0.10	<0.10	0.05 SIG	0.78 NS
Ilypnus gilberti							
total	t-test	None	0.10	<0.10	<0.10	<0.01 SIG	0.25 NS
preflexion	t-test	log (x + 0.1)	0.10	0.26	0.20	0.18 ns	0.75 ns
flexion	t-test	None	0.10	<0.10	<0.10	<0.01 SIG	0.21 NS
postflexion	t-test	None	0.10	<0.10	0.18	0.02 SIG	0.60 NS
Gobiesox rhessodon							
total	t-test	None	0.10	0.24	0.19	0.41 NS	0.82 NS
preflexion	t-test	None	0.10	0.29	0.21	0.10 sig	0.68 NS
flexion	t-test	None	0.10	0.21	0.24	0.52 NS	0.42 NS
postflexion	t-test	None	0.10	<0.10	0.26	0.84 NS	X
Paraclinus integripinnis							
total	t-test	None	0.10	0.35	0.34	0.05 SIG	0.01 SIG
preflexion	t-test	None	0.10	0.26	0.26	0.15 NS	0.06 SIG
flexion	t-test	log (x + 0.1)	0.10	0.17	0.17	0.13 NS	0.14 NS
postflexion	t-test	None	0.10	0.32	0.66	0.36 ns	0.37 NS
Gibbonsia sp. A							
total	Wilcoxon	None	0.10	0.25	0.22	0.63 NS	0.71 NS
preflexion	t-test	None	0.10	0.30	0.25	0.56 NS	0.66 NS
flexion	t-test	log (x + 1)	0.10	0.17	0.16	0.54 NS	0.59 NS
postflexion	t-test	None	0.10	0.16	0.28	0.82 NS	0.28 NS
Heterostichus rostratus							
total	t-test	None	0.10	0.32	0.26	0.80 NS	0.18 NS
preflexion	t-test	None	0.10	0.31	0.28	0.90 NS	0.05 SIG
flexion	t-test	None	0.10	0.21	0.17	0.54 NS	0.65 ns
postflexion	t-test	None	0.10	0.16	<0.10	0.84 ns	0.85 ns
Seriphus politus							
total	t-test	None	0.10	0.50	0.39	0.05 SIG	0.40 NS
preflexion	t-test	None	0.10	0.46	0.33	0.05 SIG	0.29 NS
flexion	t-test	None	0.10	0.34	0.28	0.32 NS	0.22 NS
postflexion	t-test	None	0.10	0.25	0.21	0.70 NS	0.65 NS

Table 4-3. (Cont.)

TAXON	FORM OF TEST	TRANSFORMATION	α	POWER PLUME	POWER NON-PLUME	PRINCIPAL TEST RESULT PLUME	PRINCIPAL TEST RESULT NON-PLUME
Genyonemus lineatus							
total	Wilcoxon	None	0.10	0.36	0.32	0.23 ns	0.98 NS
preflexion	Wilcoxon	None	0.10	0.34	0.30	0.10 sig	0.96 NS
flexion	t-test	None	0.10	0.21	0.18	0.30 ns	0.90 NS
postflexion	t-test	None	0.10	0.17	0.16	0.54 ns	0.86 NS
Cheilotrema saturnum							
total	Wilcoxon	None	0.10	0.22	0.20	0.43 NS	0.46 NS
preflexion	Wilcoxon	None	0.10	0.20	0.20	0.31 NS	X
flexion	X						
postflexion	X						
Menticirrhus undulatus							
total	t-test	None	0.10	0.69	0.46	0.91 NS	X
preflexion	t-test	None	0.10	0.73	0.54	0.98 NS	X
flexion	X						
postflexion	X						
Paralabrax sp.							
total	Wilcoxon	None	0.10	0.29	0.33	0.37 NS	0.10 sig
preflexion	t-test	None	0.10	0.26	0.54	0.16 NS	0.07 sig
flexion	t-test	log (x + 1)	0.10	X	0.22	X	0.05 sig
postflexion	t-test	None	0.10	0.24	0.20	0.18 NS	0.58 NS
Hypsopsetta guttulata							
total	t-test (AUTOREG)	log (x + 0.1)	0.10	0.28	0.23	0.40 NS	0.47 NS
preflexion	X						
flexion	X						
postflexion	X						
Paralichthys californicus							
total	t-test (AUTOREG)	None	0.10	0.39	<0.10	0.31 NS	0.36 NS
preflexion	t-test	None	0.10	0.39	0.31	0.24 NS	0.24 NS
flexion	t-test	log (x + 1)	0.10	0.19	0.18	0.79 NS	0.51 NS
postflexion	t-test	None	0.10	0.18	0.18	0.12 NS	0.37 NS
Atherinopsis californiensis							
total	t-test	log (x + 0.1)	0.10	0.59	0.37	0.08 sig	0.22 NS
preflexion	t-test (AUTOREG)	log (x + 0.1)	0.10	0.59	0.37	0.02 SIG	0.14 NS
flexion	t-test	log (x + 0.1)	0.10	0.28	0.25	0.25 NS	0.17 NS
postflexion	Wilcoxon	None	0.10	0.24	0.22	0.38 NS	0.39 NS
Leuresthes tenuis							
total	t-test	log (x + 0.1)	0.10	0.38	0.32	>0.99 NS	>0.99 ns
preflexion	t-test	None	0.10	<0.10	<0.10	0.97 NS	0.94 ns
flexion	Wilcoxon	None	0.10	<0.10	<0.10	0.38 NS	0.92 ns
postflexion	t-test	log (x + 0.1)	0.10	0.26	0.22	0.88 NS	0.97 ns

Table 4-3. (Cont.)

TAXON	FORM OF TEST	TRANSFORMATION	α	POWER		PRINCIPAL TEST RESULT	
				PLUME	NON-PLUME	PLUME	NON-PLUME
Engraulis mordax							
total	Wilcoxon	log (x)	0.05	0.87	0.86	0.01 SIG	0.60 NS
preflexion	t-test	log (x + 1)	0.10	0.45	0.29	0.18 ns	0.56 NS
flexion	t-test	log (x)	0.10	0.57	0.55	0.46 ns	0.21 NS
postflexion	t-test	None	0.10	0.61	0.50	0.09 SIG	0.63 NS
Citharichthys spp.							
total	t-test	log (x + 1)	0.10	0.20	0.18	0.76 NS	0.72 NS
preflexion	t-test	log (x + 1)	0.10	0.18	0.17	0.76 NS	0.79 NS
flexion	X						
postflexion	X						
Hypsoblennius spp.							
total	t-test	None	0.10	0.43	0.48	0.87 NS	0.23 NS
preflexion	t-test	log (x + 1)	0.10	0.58	0.48	0.74 NS	0.33 NS
flexion	t-test	None	0.10	0.22	0.21	0.94 NS	0.05 sig
postflexion	X						

Table 4-4. Results of binomial tests on SONGS/(SONGS+Control) cross-shelf abundance ratios for ichthyoplankton. The tests were lower-tailed, evaluated at $\alpha=0.05$. Values of $p \leq 0.05$ are statistically significant.

TAXON	STAGE	TEST STATISTIC	P
Clevelandia ios	larvae	-4.573	0.000
	preflexion	0.285	0.612
	flexion	-2.203	0.014
	post-flexion	-3.663	0.000
Quietula y-cauda	larvae	-0.755	0.225
	preflexion	-0.161	0.436
	flexion	-0.515	0.303
	post-flexion	0.377	0.647
Ilypnus gilberti	larvae	-0.879	0.190
	preflexion	1.239	0.892
	flexion	-2.065	0.019
	post-flexion	0.136	0.554
Gobiesox rhessodon	larvae	0.726	0.766
	preflexion	-0.115	0.454
	flexion	-0.402	0.344
	post-flexion	0.610	0.729
Paraclinus integripinnis	larvae	-0.915	0.180
	preflexion	-0.467	0.320
	flexion	-0.564	0.286
	post-flexion	0.177	0.570
Gibbonsia type a	larvae	0.337	0.632
	preflexion	0.311	0.622
	flexion	-0.138	0.445
	post-flexion	0.384	0.650
Heterostichus rostratus	larvae	-0.384	0.350
	preflexion	-1.336	0.091
	flexion	0.425	0.665
	post-flexion	0.643	0.740
Seriphus politus	larvae	-8.984	0.000
	preflexion	-11.33	0.000
	flexion	-0.378	0.353
	post-flexion	0.731	0.768
Genyonemus lineatus	larvae	-18.26	0.000
	preflexion	-19.98	0.000
	flexion	-1.992	0.023
	post-flexion	0.282	0.611
Cheilotrema saturnum	larvae	-0.938	0.174
	preflexion	-0.986	0.162
	flexion	-1.746	0.040
	post-flexion	-0.593	0.277

Table 4-4. (Cont.)

TAXON	STAGE	TEST STATISTIC	P
Menticirrhus undulatus	larvae	3.208	0.999
	preflexion	2.630	0.996
	flexion	2.844	0.998
	post-flexion	.	.
Paralabrax spp	larvae	-17.13	0.000
	preflexion	-12.68	0.000
	flexion	-10.79	0.000
	post-flexion	-2.325	0.010
Hypsopsetta guttulata	larvae	-0.203	0.420
	preflexion	-0.131	0.448
	flexion	-2.191	0.014
	post-flexion	0.566	0.714
Paralichthys californicus	larvae	-2.579	0.005
	preflexion	-3.038	0.001
	flexion	0.809	0.791
	post-flexion	-3.090	0.001
Atherinopsis californiensis	larvae	-4.294	0.000
	preflexion	-4.565	0.000
	flexion	-0.192	0.424
	post-flexion	0.052	0.521
Leuresthes tenuis	larvae	5.392	1.000
	preflexion	5.611	1.000
	flexion	0.989	0.839
	post-flexion	0.949	0.829
Engraulis mordax	larvae	-36.04	0.000
	preflexion	-22.91	0.000
	flexion	-28.54	0.000
	post-flexion	-7.249	0.000
Citharichthys spp	larvae	4.245	1.000
	preflexion	4.586	1.000
	post-flexion	.	.
Hypsoblennius spp	larvae	5.297	1.000
	preflexion	3.339	1.000
	flexion	4.326	1.000
	post-flexion	0.484	0.686

Table 4-5. Percent change in mean abundance at SONGS and at Control, and percent change in relative abundance, (SONGS - Control) from the preoperational to the operational period for ichthyoplankton.
N = number of surveys in each period.

				Percent Change		
				Mean Abundance		
TAXON	Stage	N-Before	N-After	SONGS	Control	Relative Abundance
Clevelandia ios						
	All	38	37	- 38	+ 238	- 309
	Preflexion	25	16	- 36	- 51	+ 15
	Flexion	24	24	- 61	+ 432	- 535
	Postflexion	36	27	- 34	+ 281	- 316
Quietula y-cauda						
	All	35	27	+ 196	+ 400	- 589
	Preflexion	26	24	+ 137	+ 176	- 263
	Flexion	14	25	+ 48	+ 267	- 729
	Postflexion	15	24	+ 578	+ 245	- 365
Ilypnus gilberti						
	All	37	27	+ 281	+ 372	- 321
	Preflexion	33	27	+ 600	+ 292	- 308
	Flexion	29	27	+ 88	+ 444	- 491
	Postflexion	34	27	+ 256	+ 239	- 83
Gobiesox rhessodon						
	All	34	22	+ 56	+ 6	+ 53
	Preflexion	30	21	+ 14	+ 24	+ 4
	Flexion	22	15	+ 76	+ 230	+ 37
	Postflexion	7	12	+ 814	- 6	+ 820
Paraclinus integripinnis						
	All	16	14	+ 27	+ 132	- 8
	Preflexion	13	14	+ 59	+ 150	+ 21
	Flexion	8	11	+ 43	+ 225	- 195
	Postflexion	4	7	- 18	- 38	+ 14
Gibbonsia sp. A						
	All	29	26	+ 12	- 11	+ 15
	Preflexion	24	25	+ 12	- 12	+ 16
	Flexion	13	12	- 31	- 19	- 11
	Postflexion	4	7	+ 79	- 63	+ 118
Heterostichus rostratus						
	All	27	21	+ 55	+ 129	+ 11
	Preflexion	24	15	+ 81	+1170	- 22
	Flexion	13	14	- 26	- 66	+ 17
	Postflexion	3	6	+ 459	- 73	+ 615

Table 4-5. (Cont.)

				Percent Change		
				Mean Abundance		
TAXON	Stage	N-Before	N-After	SONGS	Control	Relative Abundance
<u>Seriphus</u> <u>politus</u>						
	All	38	24	- 47	- 16	- 32
	Preflexion	36	23	- 41	+ 8	- 48
	Flexion	32	18	- 73	- 70	- 17
	Postflexion	32	18	- 2	- 27	+ 44
<u>Genyonemus</u> <u>lineatus</u>						
	All	37	24	- 69	- 30	- 44
	Preflexion	32	21	- 69	- 19	- 55
	Flexion	28	17	- 58	- 44	+ 5
	Postflexion	26	12	- 72	- 74	+ 41
<u>Cheilotrema</u> <u>saturnum</u>						
	All	26	11	+ 94	+ 161	+ 6
	Preflexion	24	8	+ 164	+ 264	+ 27
	Flexion	3	3	- 99	- 34	- 86
	Postflexion	2	3	- 100	+ 74	- 158
<u>Menticirrhus</u> <u>undulatus</u>						
	All	17	12	- 34	- 73	+ 40
	Preflexion	15	12	- 29	- 69	+ 44
	Flexion	7	4	+ 86	- 79	+ 199
	Postflexion	3	1	X	- 100	
<u>Paralabrax</u> spp.						
	All	20	16	- 42	+ 85	- 110
	Preflexion	16	16	- 36	+ 70	- 101
	Flexion	13	6	- 42	+ 374	- 417
	Postflexion	13	8	- 70	- 9	- 65
<u>Hypsopsetta</u> <u>guttulata</u>						
	All	23	15	- 81	- 77	- 4
	Preflexion	19	15	- 81	- 79	- 3
	Flexion	10	3	- 100	- 50	- 62
	Postflexion	7	1	(0)	- 100	+ 525
<u>Paralichthys</u> <u>californicus</u>						
	All	38	24	- 60	- 49	- 20
	Preflexion	34	24	- 57	- 41	- 25
	Flexion	17	12	- 67	- 77	+ 10
	Postflexion	28	14	- 81	- 8	- 72

Table 4-5. (Cont.)

TAXON	Stage	N-Before	N-After	Percent Change: Mean Abundance: SONGS	Percent Change: Mean Abundance: Control	Percent Change: Relative Abundance
Atherinopsis californiensis	All	24	17	- 79	- 36	- 43
	Preflexion	21	16	- 81	- 32	- 48
	Flexion	17	13	- 67	- 59	- 8
	Postflexion	13	9	- 90	- 92	+ 34
Leuresthes tenuis	All	34	21	+ 241	- 41	+ 282
	Preflexion	28	19	+ 269	- 54	+ 413
	Flexion	27	15	+ 141	+ 10	+ 120
	Postflexion	27	16	+ 216	- 10	+ 226
Engraulis mordax	All	38	27	- 35	+ 20	- 55
	Preflexion	34	27	- 36	+ 4	- 40
	Flexion	34	27	- 37	+ 83	- 121
	Postflexion	36	27	- 57	- 37	- 17
Citharichthys spp.	All	24	18	+ 268	+ 3	+ 265
	Preflexion	22	17	+ 341	+ 4	+ 337
	Flexion	0	0	X	X	X
	Postflexion	2	1	- 100	X	X
Hypsoblennius spp.	All	38	26	- 1	- 38	+ 32
	Preflexion	36	25	+ 11	- 19	+ 30
	Flexion	23	13	+ 5	- 76	+ 59
	Postflexion	30	21	- 86	- 91	+ 5

Table 4-6. Average intake and diffuser loss estimates for ichthyoplankton: percent loss of numbers in cross-shelf is based on 100% intake loss and indicated diffuser loss.

SPECIES	STAGE	0%	10%	25%	50%
Clevelandia ios	larvae	35.82	40.65	47.90	59.98
	preflexion	40.09	44.16	50.26	60.43
	flexion	28.73	35.60	45.90	63.07
	post-flexion	38.03	42.19	48.45	58.87
Quietula y-cauda	larvae	31.48	37.54	46.64	61.80
	preflexion	42.93	46.07	50.78	58.63
	flexion	22.42	30.88	43.58	64.73
	post-flexion	26.50	33.67	44.42	62.33
Ilypnus gilberti	larvae	28.83	35.08	44.47	60.11
	preflexion	27.59	33.43	42.19	56.79
	flexion	28.16	34.84	44.85	61.53
	post-flexion	30.13	36.57	46.23	62.33
Gobiesox rhessodon	larvae	10.13	16.16	25.21	40.29
	preflexion	6.92	12.82	21.68	36.43
	flexion	26.18	32.73	42.55	58.92
	post-flexion	14.38	21.47	32.10	49.82
Paraclinus integripinnis	larvae	10.73	20.33	34.73	58.73
	preflexion	14.33	24.61	40.05	65.77
	flexion	7.10	16.36	30.24	53.37
	post-flexion	5.01	12.98	24.93	44.84
Gibbonsia type a	larvae	28.86	32.92	39.01	49.15
	preflexion	43.10	47.09	53.06	63.02
	flexion	11.59	15.92	22.40	33.20
	post-flexion	67.42	67.42	67.42	67.42
Heterostichus rostratus	larvae	15.60	21.19	29.56	43.51
	preflexion	9.40	15.60	24.90	40.40
	flexion	56.56	56.86	57.29	58.02
	post-flexion	1.84	13.82	31.80	61.77
Seriphus politus	larvae	3.16	6.68	11.95	20.74
	preflexion	1.57	5.04	10.24	18.92
	flexion	22.36	26.40	32.46	42.57
	post-flexion	33.62	38.28	45.28	56.95
Genyonemus lineatus	larvae	1.37	4.48	9.16	16.94
	preflexion	0.88	3.41	7.21	13.55
	flexion	4.03	10.35	19.84	35.65
	post-flexion	6.70	15.77	29.38	52.05
Cheilotrema saturnum	larvae	0.15	1.49	3.49	6.84
	preflexion	0.00	1.25	3.13	6.25
	flexion	1.72	14.82	34.48	67.23
	post-flexion	22.81	30.46	41.94	61.07

Table 4-6. (continued)

SPECIES	STAGE	0%	10%	25%	50%
Menticirrhus undulatus	larvae	1.41	5.82	12.45	23.48
	preflexion	0.62	5.14	11.92	23.22
	flexion	8.90	12.32	17.44	25.98
	post-flexion	.	.	.	.
Paralabrax spp	larvae	0.04	1.45	3.58	7.12
	preflexion	0.04	1.55	3.80	7.55
	flexion	0.00	1.07	2.67	5.33
	post-flexion	0.13	1.37	3.22	6.30
Hypsopsetta guttulata	larvae	20.44	29.80	43.83	67.21
	preflexion	15.66	25.98	41.45	67.23
	flexion	67.02	67.02	67.02	67.02
	post-flexion	.	.	.	.
Paralichthys californicus	larvae	1.06	3.26	6.58	12.09
	preflexion	1.12	3.33	6.65	12.17
	flexion	0.10	4.35	10.74	21.38
	post-flexion	0.41	1.29	2.61	4.82
Atherinopsis californiensis	larvae	12.80	18.37	26.72	40.63
	preflexion	12.29	17.76	25.95	39.61
	flexion	17.31	24.62	35.58	53.85
	post-flexion	48.16	49.52	51.57	54.98
Leuresthes tenuis	larvae	10.18	14.27	20.41	30.65
	preflexion	9.73	13.37	18.83	27.94
	flexion	10.81	14.60	20.29	29.77
	post-flexion	11.08	18.50	29.63	48.17
Engraulis mordax	larvae	1.49	3.48	6.46	11.42
	preflexion	0.70	2.52	5.24	9.77
	flexion	1.34	2.87	5.15	8.96
	post-flexion	6.59	10.51	16.41	26.23
Citharichthys spp	larvae	0.53	1.46	2.87	5.22
	preflexion	0.55	1.54	3.03	5.50
	flexion	.	.	.	.
	post-flexion	0.00	0.00	0.00	0.00
Hypsoblennius spp	larvae	0.60	3.10	6.86	13.11
	preflexion	0.59	3.10	6.86	13.14
	flexion	0.05	1.66	4.07	8.09
	post-flexion	4.62	8.96	15.49	26.36

Table 4-7. Mean cross-shelf abundance (number per 400 m^3) of *Quietula y-cauda* larvae.

Larval Stage	Time Period	SONGS	Control
Total Larvae	Preoperational	0.14	0.27
	Operational El Nino	0.50	2.18
	Non-El Nino	0.34	0.69
Preflexion	Preoperational	0.09	0.21
	Operational El Nino	0.23	0.78
	Non-El Nino	0.21	0.39
Flexion	Preoperational	0.06	0.16
	Operational El Nino	0.08	1.00
	Non-El Nino	0.08	0.28
Postflexion	Preoperational	0.02	0.09
	Operational El Nino	0.19	0.39
	Non-El Nino	0.12	0.21

Table 4-8. Mean cross-shelf abundance (number/m^3) and one standard deviation from the mean for each zooplankton taxon used in the BACI analyses. Values are given for each monitoring period (Before, After) at SONGS and at Control. Life stages are combined, except for the meroplanktonic taxa (cirriped nauplii and cypris, bryozoan cyphonautes larvae). N = number of surveys.

	SONGS						Control					
		Before			After			Before			After	
Species	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Acartia clausi	30	33.50	73.75	11	5.51	9.30	30	11.61	19.03	11	0.67	1.91
Oithona oculata	30	7.63	15.30	22	6.45	24.98	30	4.62	15.04	22	0.63	1.02
Acartia tonsa	31	1605.45	1568.59	23	1779.34	1941.00	31	1188.82	1021.14	23	1544.56	1758.92
Cirriped Nauplii	19	30.18	63.77	21	13.17	15.22	19	17.99	21.98	21	7.27	12.08
Cirriped Cypris	31	9.42	11.84	24	9.62	15.08	31	9.42	11.48	24	6.69	9.83
Podon polyphemoides	29	296.81	1008.93	16	237.60	907.63	29	303.85	1181.74	16	237.37	924.97
Evadne nordmanni	30	50.37	112.02	22	105.81	166.99	30	76.40	155.64	22	198.69	462.35
Evadne spinifera	26	17.55	21.94	15	11.06	24.47	26	40.77	67.09	15	22.71	43.38
Penilia avirostris	26	307.97	652.58	5	0.31	0.43	26	482.20	1052.75	5	0.31	0.49
Corycaeus anglicus	31	241.06	254.58	23	413.43	259.78	31	206.16	173.62	23	495.33	410.13
Cyphonautes Larvae	31	82.46	61.15	23	150.60	161.83	31	112.50	101.44	23	108.13	105.12
Labidocera trispinosa	31	63.64	121.53	23	47.40	97.43	31	32.52	34.73	23	20.95	23.08
Oithona plumifera	31	64.18	51.70	23	149.23	249.03	31	88.20	119.52	23	112.95	100.89
Paracalanus parvus	31	838.53	1049.62	23	1078.12	836.40	31	636.11	507.99	23	1076.40	773.10
Sagitta euneritica	31	170.36	225.41	23	169.85	245.73	31	158.76	189.10	23	174.24	262.46
Calanus pacificus	24	40.21	61.06	23	140.13	265.09	24	31.32	47.73	23	81.06	121.76
Total zooplankton	18	4632.54	3337.00	23	5337.95	3174.49	18	4227.97	2573.63	23	4926.11	3644.02

Table 4-9. Summary of results of BACI analysis and pattern analysis on the full operational data set for macrozooplankton. The p level for the indicated test is given in the result columns. NS = test result not significant; SIG = test result significant; X = not tested. Lower case letters indicate results in which we had less confidence for any number of reasons, for example, lack of confirmation by secondary test results, small sample size, etc. AUTOREG refers to the t-test modeled with autoregressive errors.

TAXON	PRINCIPAL BACI TEST					MANOVA RESULT
	FORM OF TEST	TRANSFORMATION	α	POWER	RESULT	(α=0.05)
Inner Nearshore Taxa						
Acartia clausi	t-test (AUTOREG)	log (x + 0.1)	0.10	0.30	0.33 NS	0.18
Oithona oculata	t-test	None	0.10	0.25	0.66 NS	0.56
Nearshore/Transitional Taxa						
Acartia tonsa	t-test	log (x)	0.05	0.87	0.96 NS	0.01
Cirriped Nauplii	t-test	log (x)	0.10	0.62	0.05 SIG	0.06
Cirriped Cypris	t-test	None	0.10	0.47	0.42 ns	0.39
Podon polyphemoides	t-test	None	0.10	0.22	0.97 NS	0.37
Cross-Shelf Taxa						
Evadne nordmanni	t-test	log (x)	0.10	0.77	0.12 ns	0.11
Evadne spinifera	t-test	log (x)	0.10	0.62	0.18 ns	0.53
Penilia avirostris	x	x	x	x	x	x
Corycaeus anglicus	Wilcoxon	None	0.10	0.63	0.92 NS	0.03
Cyphonautes Larvae	t-test	log (x)	0.05	0.88	0.20 ns	0.03
Labidocera trispinosa	t-test	log (x)	0.10	0.78	0.36 NS	0.24
Oithona plumifera	t-test	log (x)	0.05	0.95	0.49 NS	0.03
Paracalanus parvus	t-test	log (x)	0.05	0.92	0.91 NS	0.89
Sagitta euneritica	t-test	None	0.10	0.70	0.73 NS	0.13
Offshore Taxa						
Calanus pacificus	t-test	None	0.10	0.20	0.29 NS	0.11
Total Zooplankton	t-test	None	0.05	0.83	0.99 NS	0.01

Table 4-10. Summary results of principal BACI analyses on plume and non-plume subsets of the operational data. Plume surveys are those taken when the Impact site was estimated to be under the influence of the discharge plume; non-plume surveys are those taken when the Impact site was estimated to not be under the influence of the discharge plume. These BACI tests were used to aid in the interpretation of the principal BACI test result based on the full operational data set. NS = test result not significant; SIG = test result significant; X = not tested. Lower case letters indicate results in which we had less confidence for any number of reasons, for example lack of agreement between the t-test and Wilcoxon rank sum test results, small sample size, etc. AUTOREG refers to the t-test modeled with autoregressive errors.

TAXON	FORM OF TEST	TRANSFORMATION	α	POWER		PRINCIPAL TEST RESULT	
				Plume	Non-Plume	Plume	Non-Plume
Inner Nearshore Taxa							
Acartia clausi	t-test (AUTOREG)	log (x + 0.1)	0.10	0.17	0.15	0.26 NS	X
Oithona oculata	t-test	None	0.10	0.13	0.15	0.47 NS	0.46 NS
Nearshore/Transitional Taxa							
Acartia tonsa	t-test	log (x)	0.10	0.65	0.68	0.99 NS	0.99 NS
Cirriped Nauplii	t-test	log (x)	0.10	0.34	0.43	0.01 SIG	0.28 NS
Cirriped Cypris	t-test	None	0.10	0.26	0.28	0.01 SIG	0.20 NS
Podon polyphemoides	t-test	None	0.10	0.12	0.12	0.96 NS	0.99 NS
Cross-Shelf Taxa							
Evadne nordmanni	t-test	log (x)	0.10	0.53	0.55	0.07 SIG	0.88 NS
Evadne spinifera	t-test	log (x)	0.10	0.34	0.28	0.19 NS	0.01 SIG
Penilia avirostris	X	X	X	X	X	X	X
Corycaeus anglicus	Wilcoxon	None	0.10	0.65	0.32	0.75 NS	0.75 NS
Cyphonautes Larvae	t-test	log (x)	0.10	0.73	0.66	0.05 SIG	0.86 NS
Labidocera trispinosa	t-test	log (x)	0.10	0.43	0.48	0.75 NS	0.36 NS
Oithona plumifera	t-test	log (x)	0.10	0.79	0.83	0.58 NS	0.88 NS
Paracalanus parvus	t-test	log (x)	0.10	0.80	0.75	0.56 NS	0.42 NS
Sagitta euneritica	t-test (AUTOREG, plume dates only)	None	0.10	0.48	0.36	0.30 NS	0.17 NS
Offshore Taxa							
Calanus pacificus	t-test	None	0.10	0.35	0.12	0.24 NS	0.20 NS
Total Zooplankton	t-test	None	0.10	0.68	0.63	0.24 NS	0.36 NS

Table 4-11. Results of binomial tests on SONGS/(SONGS+Control) cross-shelf abundance ratios for macrozooplankton. The tests were two-tailed, evaluated at $\alpha = 0.05$. Values of $p \leq 0.05$ are statistically significant.

TAXON	TEST STATISTIC	P
Acartia clausi	3.773	0.000
Oithona oculata	8.465	0.000
Acartia tonsa	-15.92	0.000
Cirriped Nauplii	-0.022	0.982
Cirriped Cypris	3.083	0.002
Podon polyphemoides	0.887	0.375
Evadne nordmanni	-5.068	0.000
Evadne spinifera	1.114	0.265
Penilia avirostris	0.407	0.684
Corycaeus anglicus	-15.41	0.000
Cyphonautes Larvae	17.651	0.000
Labidocera trispinosa	2.184	0.029
Oithona plumifera	15.409	0.000
Paracalanus parvus	-21.15	0.000
Sagitta euneritica	-3.206	0.001
Calanus pacificus	5.189	0.000
Total zooplankton	-1.709	0.087

Table 4-12. Percent change in mean abundance at SONGS and at Control, and percent change in relative abundance (SONGS-Control) from the preoperational (Before) to the operational (After) period for macrozooplankton. The percent change in mean abundance was calculated from untransformed data; the percent relative change was based on log-transformed data in cases where the primary BACI test was done on log-transformed data (see Table 3-9). Percent relative changes based on both transformed and untransformed data are given in Appendix D. N = number of surveys in each period.

TAXON	N		PERCENT CHANGE		
			MEAN ABUNDANCE		
	BEFORE	AFTER	SONGS	CONTROL	RELATIVE ABUNDANCE
Inner Nearshore Taxa					
Acartia clausi	30	11	-92	-97	+5
Oithona oculata	30	22	-16	-87	+36
Nearshore/Transitional Taxa					
Acartia tonsa	31	23	+10	+30	-19
Cirriped Nauplii	19	23	-58	-58	-0.1
Cirriped Cypris	31	23	-1	-35	+34
Podon polyphemoides	29	16	-40	-42	+2
Cross-Shelf Taxa					
Evadne nordmanni	30	22	+108	+157	-49
Evadne spinifera	26	15	-37	-44	+6
Penilia avirostris	26	5	-99.9	-99.9	<+0.1
Corycaeus anglicus	31	23	+72	+140	-48
Cyphonautes Larvae	31	23	+83	-4	+87
Labidocera trispinosa	31	23	-26	-36	+10
Oithona plumifera	31	23	+133	+28	+104
Paracalanus parvus	31	23	+29	+69	-41
Sagitta euneritica	31	23	-0.3	+10	-9
Offshore Taxa					
Calanus pacificus	24	23	+248	+159	+125
Total Zooplankton	18	23	+15	+17	+0.2

Table 4-13. Average intake and diffuser loss estimates for zooplankton: percent loss of numbers in cross-shelf is based on 100% intake loss and indicated diffuser loss.

TAXON	Stage	0%	10%	25%	50%
Acartia clausi	A/J	65.12	66.98	69.77	74.41
Oithona oculata	A/J	28.05	31.23	36.00	43.95
Acartia tonsa	A/J	3.74	7.46	13.05	22.36
Cirriped Nauplii	nauplius	0.52	3.20	7.23	13.94
Cirriped Cypris	larvae	19.81	23.53	29.10	38.40
Podon polyphemoides	A/J	1.20	7.12	15.99	30.78
Evadne nordmanni	A/J	1.55	8.46	18.84	36.12
Evadne spinifera	A/J	1.64	3.73	6.86	12.08
Penilia avirostris	A/J	1.22	2.03	3.25	5.29
Corycaeus anglicus	A/J	0.66	4.00	9.02	17.39
Cyphonautes Larvae	larva	2.64	4.87	8.21	13.77
Labidocera trispinosa	A/J	3.57	7.78	14.10	24.64
Oithona plumifera	A/J	1.09	2.43	4.45	7.82
Paracalanus parvus	A/J	1.80	5.81	11.83	21.86
Sagitta euneritica	A/J	1.08	5.60	12.38	23.69
Calanus pacificus	A/J	0.06	0.74	1.76	3.46
Total zooplankton	A/J	1.99	5.61	11.05	20.12

Table 4-14. Results of assumption tests and BACI test results for chlorophyll in the cross-shelf transect.

TRANSFORMATION	NUMBER OF SURVEYS BEFORE	NUMBER OF SURVEYS AFTER	P-LEVEL FOR ADDITIVITY*	SERIAL CORREL. SIGNIFICANCE*** BEFORE	SERIAL CORREL. SIGNIFICANCE*** AFTER
INV(X+0.1)	25	15	0.362	NS	NS
INV(X+0)	25	15	0.100	NS	NS
INV(X+1)	25	15	0.834	NS	NS
INV(X+10)	25	15	0.910	NS	NS
LOG(X+0.1)	25	15	0.927	NS	NS
LOG(X+0)	25	15	0.894	NS	NS
LOG(X+1)	25	15	0.885	NS	NS
LOG(X+10)	25	15	0.403	NS	NS
NOTRANSFORM	25	15	0.077	NS	NS

TRANSFORMATION	P-LEVEL FOR TRENDS**** BEFORE	P-LEVEL FOR TRENDS**** AFTER	P-LEVEL FOR SYMMETRY**	POWER AT ALPHA .05	POWER AT ALPHA .10
INV(X+0.1)	0.506	0.980	0.500	.	.
INV(X+0)	0.459	0.866	0.703	.	.
INV(X+1)	0.227	0.783	0.834	.	.
INV(X+10)	0.168	0.908	0.669	47.2	60.9
LOG(X+0.1)	0.177	0.999	0.314	91.4	95.8
LOG(X+0)	0.181	0.994	0.264	95.4	98.1
LOG(X+1)	0.170	0.944	0.423	67.4	78.3
LOG(X+10)	0.286	0.771	0.314	29.9	42.5
NOTRANSFORM	0.464	0.673	0.331	17.9	27.7

Transformation	Before surveys	After surveys	Before mean Delta	After mean Delta	Delta After minus Delta Before	Percent Relative Change	Percent Change SONGS	Percent Change Control	BACI t-test prob>T	Wilcoxon rank sum prob>Z
INV(X+0.1)	25	15	-0.114	-0.115	-0.001	.	122.37	61.58	0.993	0.503
INV(X+0)	25	15	-0.152	-0.169	-0.016	.	122.37	61.58	0.950	0.357
INV(X+1)	25	15	-0.035	-0.050	-0.015	.	122.37	61.58	0.678	0.737
INV(X+10)	25	15	-0.002	-0.006	-0.004	.	122.37	61.58	0.371	0.823
LOG(X+0.1)	25	15	0.063	0.133	0.069	60.79	122.37	61.58	0.456	1.000
LOG(X+0)	25	15	0.069	0.139	0.070	60.79	122.37	61.58	0.475	0.955
LOG(X+1)	25	15	0.040	0.105	0.066	60.79	122.37	61.58	0.383	0.801
LOG(X+10)	25	15	0.009	0.043	0.034	60.79	122.37	61.58	0.317	0.780
NOTRANSFORM	25	15	0.122	1.937	1.815	.	122.37	61.58	0.268	0.823

* If <.05 then the transformation is non-additive.
** If <.05 then the transformation is not symmetrical.
*** SIG indicates that the transformation has significant serial correlation at the .05 p-level using Von Neumann's test.
**** If <.05 then the transformation has a linear trend with time.

Table 4-15. Results of assumption tests and BACI test results for chlorophyll in the surface of the 30 m stations.

TRANSFORMATION	NUMBER OF SURVEYS BEFORE	NUMBER OF SURVEYS AFTER	P-LEVEL FOR ADDITIVITY*	SERIAL CORREL. SIGNIFICANCE*** BEFORE	SERIAL CORREL. SIGNIFICANCE*** AFTER
INV(X+0.1)	25	14	0.644	NS	NS
INV(X+0)	25	14	0.778	NS	NS
INV(X+1)	25	14	0.109	NS	NS
INV(X+10)	25	14	0.000	NS	NS
LOG(X+0.1)	25	14	0.086	NS	NS
LOG(X+0)	25	14	0.150	NS	NS
LOG(X+1)	25	14	0.005	NS	NS
LOG(X+10)	25	14	0.000	NS	NS
NOTRANSFORM	25	15	0.000	NS	NS

TRANSFORMATION	P-LEVEL FOR TRENDS**** BEFORE	P-LEVEL FOR TRENDS**** AFTER	P-LEVEL FOR SYMMETRY**	POWER AT ALPHA .05	POWER AT ALPHA .10
INV(X+0.1)	0.282	0.829	0.913	93.1	96.4
INV(X+0)	0.288	0.905	0.887	97.6	98.8
INV(X+1)	0.319	0.764	0.751	75.2	84.2
INV(X+10)	0.353	0.320	0.927	31.3	43.4
LOG(X+0.1)	0.287	0.547	0.154	73.7	83.1
LOG(X+0)	0.273	0.570	0.080	82.4	89.6
LOG(X+1)	0.329	0.423	0.205	48.6	62.0
LOG(X+10)	0.361	0.249	0.060	23.2	34.4
NOTRANSFORM	0.371	0.195	0.033	16.9	26.5

Transformation	Before surveys	After surveys	Before mean Delta	After mean Delta	Delta After minus Delta Before	Percent Relative Change	Percent Change SONGS	Percent Change Control	BACI t-test prob>T	Wilcoxon rank sum prob>Z
INV(X+0.1)	25	14	-0.391	-0.021	0.369	.	221.79	312.42	0.219	0.132
INV(X+0)	25	14	-0.572	-0.077	0.495	.	221.79	312.42	0.370	0.156
INV(X+1)	25	14	-0.078	-0.010	0.068	.	221.79	312.42	0.169	0.139
INV(X+10)	25	14	-0.003	-0.003	-0.000	.	221.79	312.42	0.984	0.285
LOG(X+0.1)	25	14	0.132	0.045	-0.087	-90.63	221.79	312.42	0.325	0.248
LOG(X+0)	25	14	0.153	0.047	-0.106	-90.63	221.79	312.42	0.302	0.248
LOG(X+1)	25	14	0.066	0.041	-0.025	-90.63	221.79	312.42	0.616	0.299
LOG(X+10)	25	14	0.013	0.020	0.007	-90.63	221.79	312.42	0.688	0.299
NOTRANSFORM	25	14	0.340	0.782	0.442	.	221.79	312.42	0.435	0.312

* If <.05 then the transformation is non-additive.
** If <.05 then the transformation is not symmetrical.
*** SIG indicates that the transformation has significant serial correlation at the .05 p-level using Von Neumann's test.
**** If <.05 then the transformation has a linear trend with time.

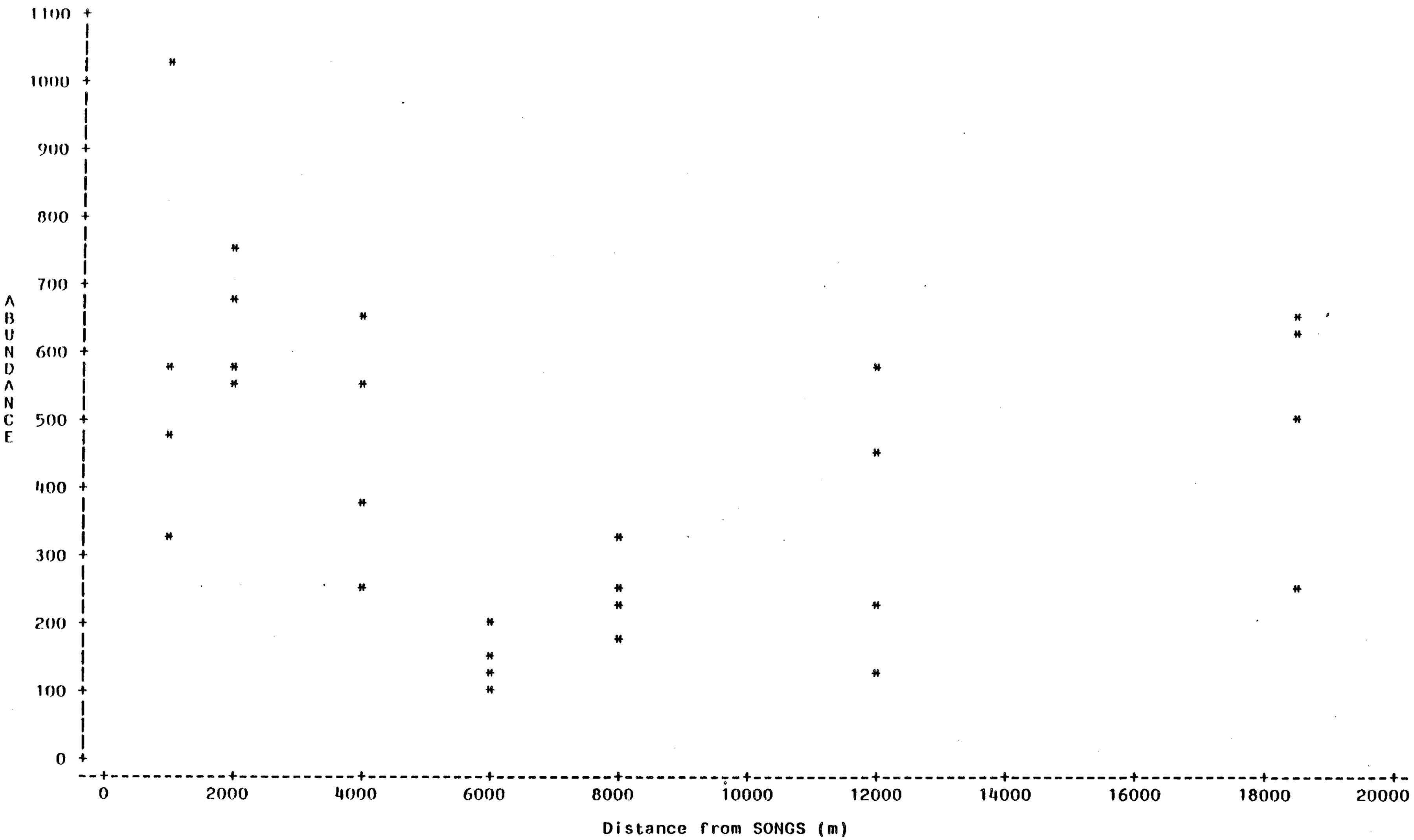

Figure 4-1. Abundance (number per 100 cubic meters) of northern anchovy larvae along the 18m isobath as a function of distance downcoast from SONGS. Data are from a single survey taken during the operational period on 7 March 1986.

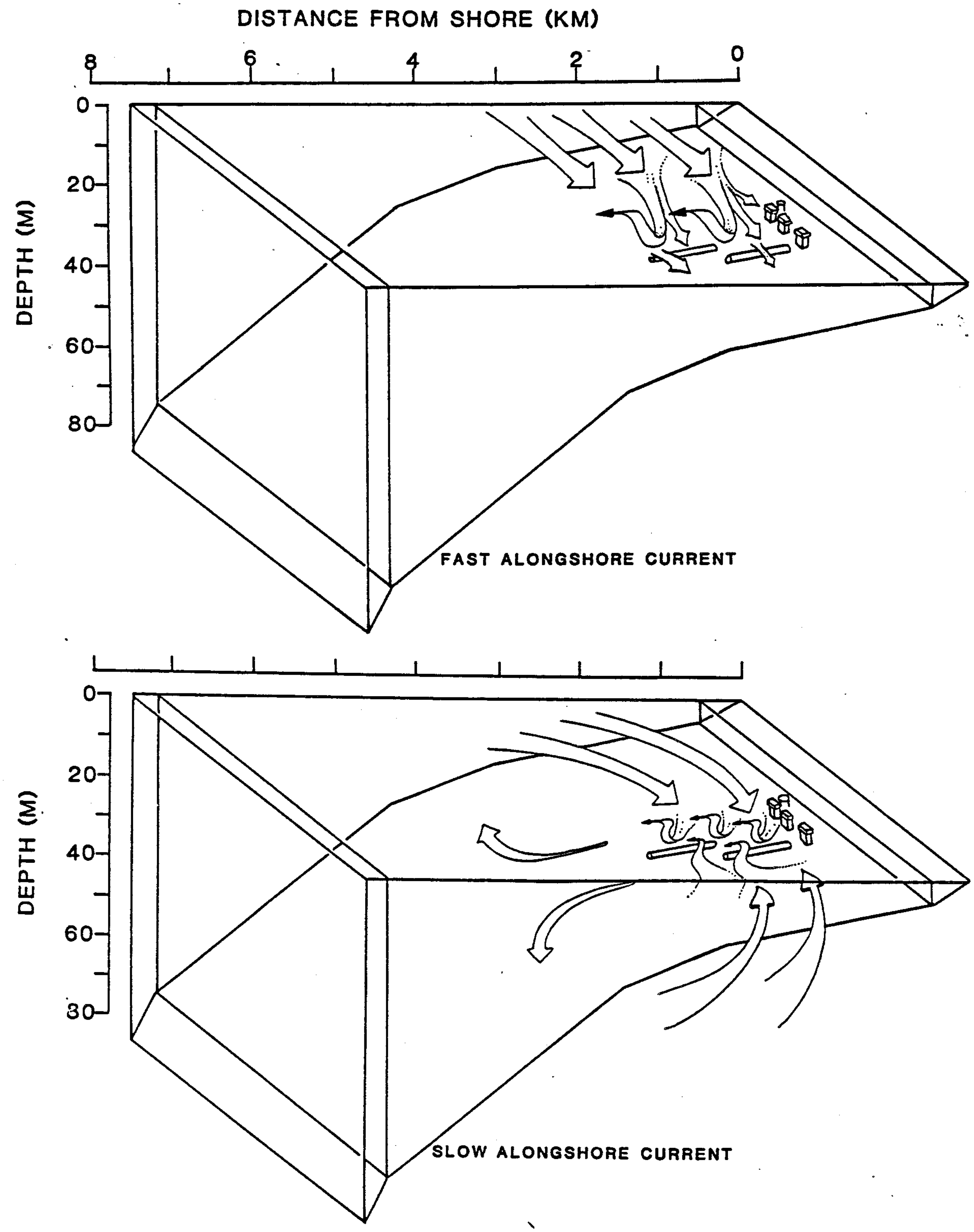

Figure 4-2. Schematic illustration of circulation pattern induced by SONGS. Adapted from Reitzel (1980).

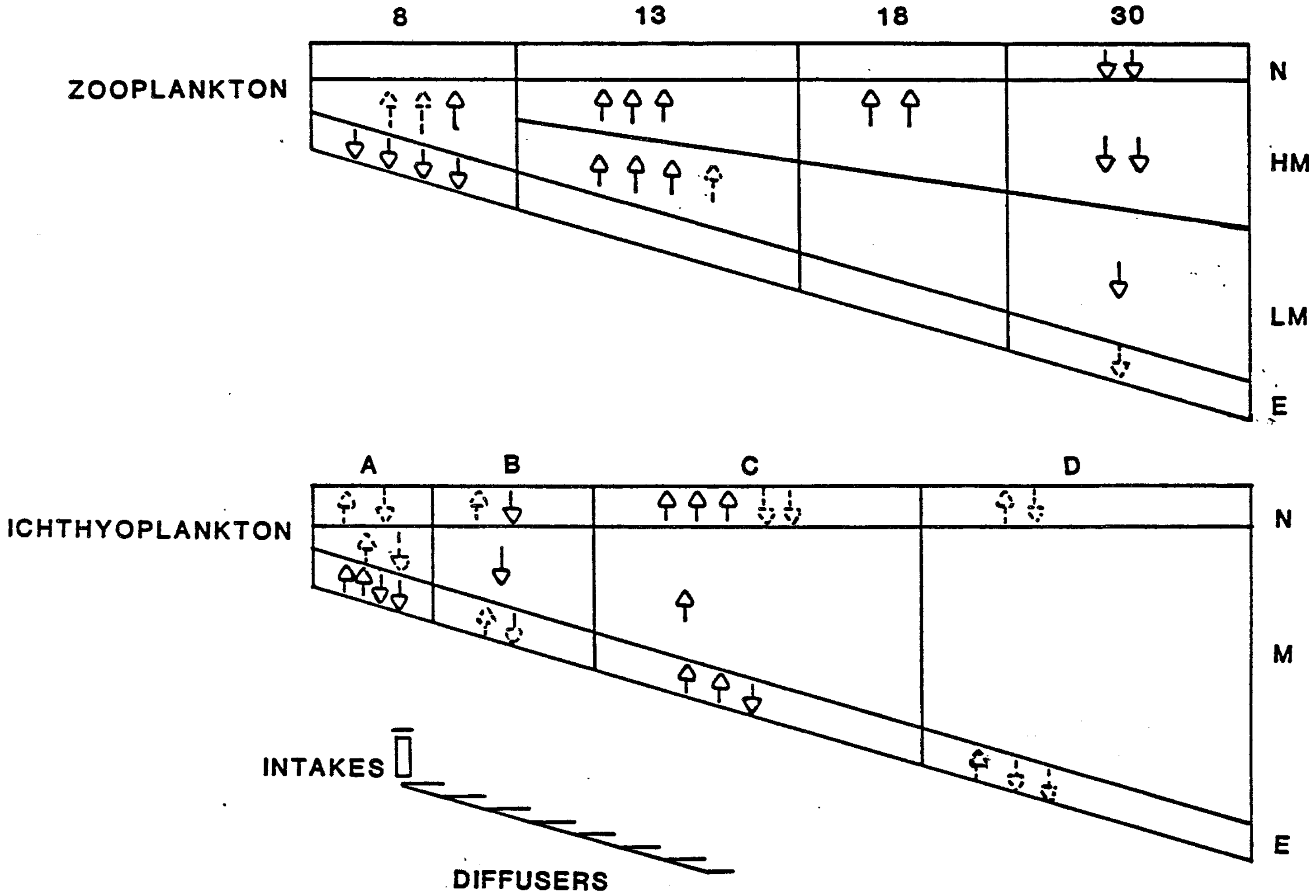

Figure 4-3. Composites of results of pattern analyses on all macrozooplankton and ichthyoplankton taxa. Arrows indicate direction of relative change in ranks of abundance. Solid arrows indicate $p \leq 0.05$; dotted arrows denote $0.05 < p \leq 0.10$. Sampling blocks are denoted by A, B, C, D (Ichthyoplankton) with A closest to shore; or 8, 13, 30 (Macrozooplankton: depth in meters); E = epibenthos, N = neuston, M = midwater, HM = high midwater, LM = low midwater.

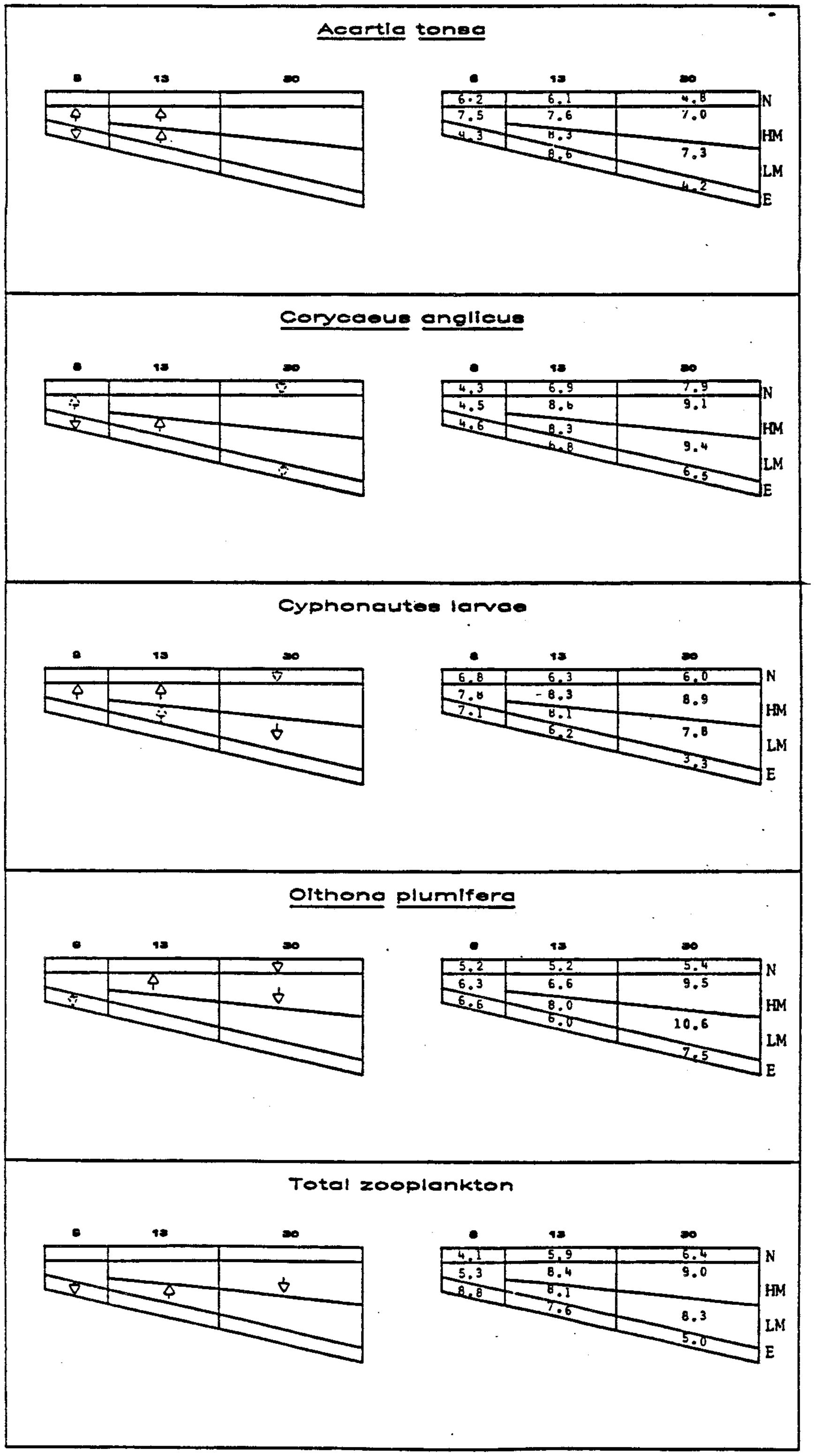

Figure 4-4. Results of pattern analyses on macrozooplankton taxa (left column) and the mean rank of each stratum at each depth based on abundances from SONGS in the Before period and Control from both periods (right column). Arrows indicate the direction of relative change in abundance. Solid arrow indicates $p \leq 0.05$, dotted arrow denotes $0.05 < p \leq 0.10$. Sampling blocks denoted by 8, 13, 30 (depth in meters); E = epibenthos, N= neuston, HM = high midwater, LM = low midwater.

5.0 INTAKE WITHDRAWAL

Projections of annual losses of ichthyoplankton and macrozooplankton to intake withdrawal by SONGS Units 2 and 3 were originally made in 1979 (MRC 1979a, b, 1980), based on an estimate of the volume of water that was expected to be circulated by the SONGS Units and on estimates of the abundance levels and distributions of planktonic organisms based on the relatively small data sets available at the time. Mortality was assumed to be 100% in passage through the SONGS cooling systems. In this report we provide the final projection of annual losses, which has been updated to utilize measurements of actual volumes of water circulated by Units 2 and 3 and ichthyoplankton and macrozooplankton abundance levels drawn from all monitoring data. These projections again utilize a 100% mortality rate of organisms passing through the Units 2 and 3 cooling systems, based on a measured 85-100% loss rate of macrozooplankton passing through the Unit 3 cooling system. Estimates of the biomass of withdrawn macrozooplankton discharged from the Units 2 and 3 cooling systems are provided in this section as well. Abundance declines detected in the final ichthyoplankton and zooplankton BACI analyses probably were related to numbers of organisms withdrawn; the relationship of the loss estimates to the BACI results is discussed in Section 4 of this report.

In this section, we first discuss the percentage losses of organisms withdrawn by the intakes and the fate of material passing through the Units 2 and 3 cooling systems (Section 5.1), followed by a discussion of the estimated annual losses of ichthyoplankton and macrozooplankton (Section 5.2).

5.1 Loss and Recovery Survey

In this section we address the percentage losses of organisms entering the intakes and the fate of material passing through the Units 2 and 3 cooling systems. Although the data were based on a single survey taken in December 1986 during which intake, diffuser port, plume and ambient stations were sampled, we have confidence in the results because they confirm results of earlier studies on Unit 1. It was found that nearly all of the macrozooplankton withdrawn by the intakes of Units 2 and 3 were killed in transit with a fraction of the numbers replaced by organisms emigrating from the cooling system biofouling community. No through-plant change in carbon was measured while seston analyses exhibited increased loads in diffuser waters relative to those found in intake waters.

Through-plant losses of macrozooplankton, including all meroplankton categories, ranged from 85-100% (except for biofouling organisms) at Unit 3 (Table 5-1). Losses were somewhat lower for several taxa at Unit 2, reflecting the relative maturity of the biofouling communities in the intake conduits at the time of sampling. Unit 3 had not undergone heat treatment for a long period -- eleven weeks -- while Unit 2 had undergone heat treatment just two weeks before the sampling date. Thus the loss levels confirmed the observations of Barnett and Sertic (1979a) that essentially all of the macrozooplankton (and by extrapolation, ichthyoplankton) entering the intakes are lost in the cooling water conduits primarily as a result of consumption by the biofouling community. This conclusion is further supported by the biofouling organisms category which showed large percentage increases in Unit 3 diffuser samples. This group of organisms comprised amphipods (>90% of the numbers), flatworms, mysids, isopods, and cumaceans: all organisms indicative of the fouling community inhabiting the system. A smaller abundance increase occurred for these organisms in samples from Unit 2, supporting the view of an incompletely re-established Unit 2 fouling community.

All samples were collected from the plume station within 1 hour of completion of sampling at the Unit 2 diffuser port. Therefore, the plume samples were representative of a combination of water discharged from the Unit 2 diffuser and ambient entrained water. The plume station sampling depth was located such that the sampled water should have undergone full initial mixing, resulting in about 10 parts ambient water to 1 part discharged water.

Comparisons of the plume samples with samples collected at the Unit 2 intake and with samples from the diffuser (Table 5-2) showed that macrozooplankton abundances in the plume were more like those found at the intake station than like those found in the diffuser water. This suggested that full mixing had occurred, although abundances of amphipods and others of the biofouling group remained significantly higher ($p < .05$, t-test; plume vs. intake samples) than would have been expected under 10:1 dilution. Plume abundances were higher than intake and discharge abundances for some taxa, suggesting that the entrained water contained higher abundances of those organisms than did intake waters.

Macrozooplankton losses and fouling organism gains were converted to equivalent carbon units. Volumes of organisms in each taxon and carbon (C) equivalents for those volumes were taken from Hirota (1972), Parsons and Takahashi (1973), and Barnett and Jahn (1987). Data used came from the results of Unit 3 (Table 5-1). We assumed that the results from Unit 3, which had not undergone heat treatment for a relatively long period, would be more representative of average conditions than would those of the recently-treated Unit 2. At Unit 1, earlier studies (Lockheed, 1977) showed that the mat-formed component of the fouling community (e.g., hydroids, sponges, Jassa falcata) reached a roughly steady-state coverage of about 50-75% within six weeks, although biomass (contributed principally by barnacles and mussels) generally continued to increase for 12 weeks or more.

The sum of [redacted] were calculated as [redacted] [redacted]. [redacted] in the biofouling group represent [redacted] or about 4.5% of the macrozooplankton losses. Thus, only about 5% of the withdrawn macrozooplankton biomass was returned to the ocean as live benthic or epibenthic biomass of about the same size range. This transfer efficiency is about half to a third of the 10-15% transfer efficiency usually cited for higher trophic levels of marine systems (see Parsons and Takahashi, 1973: p. 124). The difference between these estimated transfer efficiencies probably represents the amount of withdrawn macrozooplankton biomass utilized for growth of the attached biofouling community. This is not passed through as living biomass, but is returned to the sea in the form of dead organisms and dissolved organic carbon during heat treatments, for example. or broken off in stages or cleanings (i.e., Poisson-type discharge.)

Table 5-3 presents the results of the carbon and seston analyses. Carbon values are in units of mg C/liter. Seston concentration is given in units of mg seston dry weight/liter. We first note the linkage between the average particulate organic carbon (POC) values of 0.17 mg C/liter measured in the intake samples and the summed macrozooplankton losses described above. The macrozooplankton losses of 6,117 µg C/m^3 represented nearly 100% of the organisms withdrawn and therefore should represent the macrozooplankton fractions of the intake POC samples. In equivalent units, the total macrozooplankton losses were .0062 mg C/liter ($6{,}200\ \mu g\ C/m^3 * 10^{-3}\ m^3/liter * 10^{-3}\ mg/\mu g$) or only 4% of the 0.17 mg/liter POC found in the intake samples. The remainder of the POC material therefore must have comprised phytoplankton, bacteria and organic detritus. The POC values in the present study appear reasonable considering that Strickland et al. (1967) obtained average values of 0.05 - 0.50 mg C/liter over a year of sampling at a 25 m station in the La Jolla Bight.

Comparisons of diffuser and intake values show that there was no significant through-plant gain or loss of POC, dissolved organic carbon (DOC) or total organic carbon (TOC) ($p > .05$, t-tests). (The apparent significant gain in TOC between intake and diffuser is questionable because the mean value of the TOC at the intake was 24% less than the sum of the POC and DOC values; all three were taken from the same sample). Therefore, there appears to have been no net change of carbon material through the plant. As noted earlier, the macrozooplankton, whose changes were relatively large on their own scale, constituted only a small fraction of the total particulate carbon and consequently contributed little to potential changes in the latter.

It is clear that at the time of the loss and recovery survey diffuser water and plume water were enriched in seston as compared with intake and ambient water. In this case, because intake values were significantly lower than diffuser values ($p < .05$, t-test), it appears that the source of this increase was the power plant itself and not just a transport of sediment from inshore of the diffusers. One would expect, a priori, that the principal contributing source for this enhancement would be organisms living attached inside the intake and screen wells. However, because the organic fraction contributed little (.0062 mg

C/liter in withdrawn organisms and a non-significant 0.03 mg C/liter in POC), the gain of about 8.5 mg/liter or 150% in seston dry weight on passage through the plant must have been inorganic. If this represented a steady average output it would amount to about 75 metric tons of dry weight material per day, or over 25,000 tons per year. This could be, in part, the result of inorganic or low organic additions from organisms; for example mollusc and barnacle shells, chiton carapaces of crustaceans, and scales and bones of fishes. A qualitative examination of intake and diffuser plankton samples indicated that the diffuser samples did contain such things as amphipod tubes and exoskeletons, hydroid tubes, barnacle feet, empty mollusc shells, terrestrial plant seeds and small flakes of mica-like material that generally were not seen in intake samples. The diffuser samples contained a good deal more sand than the intake samples, as well. The exoskeletons, tubes and shells most likely were attributable to the biofouling community, but the sand and terrestrial plant seeds suggest additional inputs, perhaps from the auxiliary intakes (which are 1.3 m in diameter and located 100 m closer to shore than the primary intakes) or from sources at the plant itself. An alternative explanation for the excess seston might be that our seston data were not representative because they represented lagged or variable through-plant outputs.

The plume water appears to have retained the POC characteristics of the diffuser water. This, together with the point noted earlier that about 42% of the excess (over intake) numbers of biofouling organisms in the diffuser were found in the plume waters 0.5 km downcurrent (Table 5-2), indicates that less than a 10:1 dilution of diffuser water with ambient water had occurred when plume samples were taken.

Certain observations from this survey, such as gains by the cypris larvae of barnacles in the diffuser waters from Unit 2 (Table 5-1), remain unexplained. We would have expected any increases of this type to occur for the earliest larval stage -- cirriped nauplii -- rather than for the older cypris stage larvae. The discrepancy between TOC and the sum of POC and DOC also is unexplainable except by the 20% sampling and analytical error. However, neither of these unexplainable observations detracts from the main results of this survey --namely, that most organisms withdrawn by Units 2 and 3 are killed and replaced by loadings of seston and biofouling organisms.

5.2 Estimated Annual Losses of Ichthyoplankton and Zooplankton

The purpose of this section is to provide estimates of the numbers of ichthyoplankters and macrozooplankters annually withdrawn at the Units 2 and 3 intakes and killed in passage through the cooling systems. These estimates differ from the estimates presented in Section 4 in two important respects. First, here we used all appropriate data from all surveys taken during the various phases of the SONGS studies to generate average abundances of organisms susceptible to withdrawal, rather than the shorter operational period data bases used in Section 4. Use of the very long data bases (9-11 years) should provide better estimates of the average annual losses to be expected from year to year since they include abundances measured during a wide variety of oceanographic conditions, ranging from cool years to the 1982-1984 El Nino -- one of the strongest El Nino events of the century. Second, the average abundances that we used in this section are "regional means" which we generated by averaging abundances at the Impact and Control sites (there were a few surveys when Control data were not available, for example the intake loss surveys described in Section 3.6; in these cases the "regional mean" was simply the abundance at the Impact site). This was done to avoid underestimating losses as could happen by using Impact abundance alone (since the Impact collections were made at some distance from SONGS Units 2 and 3, and thus would have sampled water already subjected to withdrawal about half the time, on average), while at the same time avoiding the overestimate of losses that could occur by using Control abundance alone (since use of Control abundance would ignore the possibility of multiple exposure of water mass and its organisms to withdrawal, resulting from current reversals, for example). By averaging over the Impact and Control abundance values, which used alone would probably have yielded underestimates and overestimates of losses, respectively, we hoped to obtain a more realistic estimate of the actual losses to be expected.

The data bases and computations used to estimate the annual losses of planktonic organisms due to withdrawal at the Units 2 and 3 intakes require some description and are given below in Section 5.2.1. The results of the loss estimates are discussed in Sections 5.2.2 (ichthyoplankton) and 5.2.3 (macrozooplankton), and the loss estimates themselves are given on Tables 5-4 through 5-6 for ichthyoplankton and Tables 5-7 through 5-12 for macrozooplankton. These loss estimates are for intake withdrawal alone since this mechanism is known to operate. Estimates of potential losses due to secondary entrainment of organisms in the discharge plume are not included because these kinds of losses (e.g., mortality resulting from shear stress, losses due to increased susceptibility of entrained plankters to predation as a result of injury or disorientation) have not been demonstrated.

5.2.1 Methods

All samples collected at the Impact and Control sites near the depth of the SONGS intakes were used for this analysis of intake losses. These samples were collected from 1978-1980 and 1982-1986 for ichthyoplankton, and from 1976-1980 and 1982-1986 for macrozooplankton. Since ichthyoplankton and macrozooplankton are known to have seasonal abundance cycles (e.g., Barnett and Jahn, 1987; Walker et al., 1987) only years with at least two surveys in each of the two (warm and cool) seasons were used (for ichthyoplankton, the warm season was taken as June - November while the cool season was December - May: Walker et al., 1987; for macrozooplankton the respective seasons were March - August and September - February: Barnett and Jahn, 1987).

The ichthyoplankton data base included all surveys (excluding special studies such as the vertical/diel surveys) taken in the years listed above. For each survey, the Impact and Control ichthyoplankton sampling block (A or B: see Figure 3-1) nearest the 9 m isobath was selected. When the Block A and B locations were at equal depth intervals from the 9 m isobath (e.g., 8 m in Block A, 10 m in Block B), Block B was selected.

The zooplankton data base included all surveys for which discrete samples (i.e., discrete water column layers sampled separately) were collected near the intake depth (9 m). For surveys with more than one nearfield Impact sampling site close to the 9 m isobath, the Impact site nearest to the SONGS intakes was used. The discrete samples were collected from 1976-1978, in 1980, and again from 1982-1986. In addition to the discrete samples, oblique towed-net samples taken between October 1978 and September 1979 were included for loss estimates based on integrated water column abundances.

Taxa utilized in the intake loss estimates include all taxa utilized in the final BACI analyses, plus a number of others. For ichthyoplankton, the taxa include those that were the most abundant, as well as additional, less abundant, taxa of sport or commercial value. Composite groups of taxa having spatial affinities, groups that could be identified as having sport/commercial (Table 5-13), forage (Table 5-14), or fodder (a subset of "forage") value, and the total egg and larval categories also were treated. For macrozooplankton seventeen taxa, the composite groups total holoplankton, total meroplankton and total zooplankton, and two additional groups were included. Biomass estimates were made only for the macrozooplankton. All calculations were done separately for ichthyoplankton and for the macrozooplankton.

Estimated annual losses due to intake withdrawal were calculated by first averaging densities in the selected block at the Impact site and at Control to yield a regional mean density for each survey. Next, the regional means in each year were averaged within the warm season and within the cool season for that year. These seasonal averages within each year were then themselves averaged, generating a yearly average for each year. Lastly, an annual average density was calculated by averaging over all the yearly averages. This process can be expressed as follows:

$$C_{ys.} = \sum_{t=1}^{T_{ys}} C_{yst}/T_{ys}$$

$$C_{y..} = \sum_{s=1}^{2} C_{ys.}/2$$

$$C_{...} = \sum_{y=1}^{Y} C_{y..}/Y$$

where C_{yst} = regional average density from time t, season s, year y
T_{ys} = number of surveys within season s of year y
Y = number of years surveyed.

Note that a dot in place of a subscript indicates an average over that subscript.

The average density (c) at the Impact site and at Control was calculated in two ways. The first way assumed that organisms were withdrawn only from the midwater ("Mid Mean" on Tables 5-4 through 5-12); the second way assumed that organisms were withdrawn from the entire water column ("Water Mean" on Tables 5-4 through 5-12). Midwater samples provided the density values for the first method of calculation. Neuston, midwater and epibenthos samples (and the oblique macrozooplankton samples) provided the density values for the second method. For the second method, average density at each site (Impact and Control) was calculated as a weighted mean giving proportionate representation to the fraction of the water column depth sampled for each stratum. Thus, for macrozooplankton, where the numbers of vertical strata, sampling depths and total depth varied over time,

$$c = \frac{\sum_{i=1}^{S} (D_i \times \{Z_i - Z_{i-1}\})}{Z}$$

where c = the average density of zooplankton in the water column
D_i = the density of zooplankton in stratum i
Z_i = the lower depth limit of stratum i in meters, which is at the point midway between the depths of samples i and i+1 (note that when i=1, Z_{i-1} is set at 0)
Z = the depth of the water at the station in meters
S = the number of strata sampled,

and, for ichthyoplankton,

$$c = \frac{(D_N \times 0.16) + (D_M \times \{Z-1\}) + (D_E \times 0.5)}{Z}$$

where c = the average density of ichthyoplankton in the water column

D_N = the density of ichthyoplankton in the neuston sample

D_M = the density of ichthyoplankton in the midwater sample

D_E = the density of ichthyoplankton in the epibenthic sample

Z = the water depth at the station in meters (note that 34 cm of the water column is unaccounted for in the numerator above; this ~3-4% of the water column represents unsampled water just above and below the mouth of the epibenthic sampler. We made no adjustment for this discrepancy in the calculations).

The regional mean density for each survey was then calculated as:

$$C_{yst} = \frac{c_{ystSONGS} + c_{ystControl}}{2}$$

where C_{yst} = regional average density from time t, season s, year y

$c_{ystSONGS}$ = average density at SONGS on survey t, from season s, in year y

$c_{ystControl}$ = average density at Control on survey t, from season s, in year y

In a few instances Control data were not available (e.g., the intake loss surveys taken in late 1985 and early 1986: see Section 3.6 and Table 3-1); in these cases C_{yst} was taken as the Impact site density alone (i.e., $C_{yst} = c_{ystSONGS}$).

The average annual withdrawal volume was estimated in three ways. First, the maximum possible withdrawal volume was calculated as if all 8 circulating water pumps were operating all day every day (V = 9156672 m^3 per day * 365 days). A second estimate assumed the volume withdrawn was equal to three-quarters of the maximum volume. The third volume estimate used the actual average annual withdrawal volume, which equalled half the maximum volume.

Finally, the estimated average densities of organisms in the water available for withdrawal were multiplied by the estimated annual withdrawal volume to yield the average annual loss estimates.

Our method for calculating average annual intake withdrawal losses averaged over short term variations in abundance and intake withdrawal volume, and over regional variations in abundance, and thus gave less accurate, but also less variable loss estimates than would have been possible from summing estimated losses calculated on an observation-by-observation basis. The latter method of estimation would have required daily volume withdrawal and organism density data, which were not available for this study.

The loss estimates based on actual average annual withdrawal volumes include 2 years when only Unit 2 was operating and periods of circulation pump testing without heat for both Units 2 and 3. Thus these loss estimates are probably not representative of more fully operational years. The loss estimates based on withdrawal at 75% and 100% of capacity were made to take into account a higher level of plant operation. Withdrawal at 75% of capacity approximates the average level of operation over the 1983-1986 operational period and probably provides the best estimate of the annual average loss rate.

Loss estimates are given with 95% confidence bounds (lower confidence bound = L.C.B. and upper confidence bound = U.C.B. on Tables 5-4 through 5-12).

Only losses attributable to Units 2 and 3 operations are given. The Unit 1 withdrawal volume is about 20% of the combined Units 2 and 3 volume and its additional effects can be approximated by multiplying the losses for the 100% capacity case described herein by a factor of 1.2.

5.2.2 Ichthyoplantkon Results and Discussion

Results of the loss calculations for ichthyoplankton are presented in Tables 5-4 through 5-6. These estimates are for all larval stages (except yolksac) combined for each taxon and category, and thus tend to emphasize losses of the younger stages, which usually are more numerous than the older larvae in Blocks A and B, but which are also less important than the older larvae in terms of adult equivalents. As noted in Section 5.2.1, the lowest estimates of losses (Table 5-4) are those based on actual average water volumes withdrawn. Estimates based on 75% operation (Table 5-5) are representative of the 1983-1986 operational period and probably are the best, while the estimates based on continuous operation at 100% of capacity approximate a worst-case scenario. Estimates based on midwater withdrawal tend to be smaller than those based on proportional withdrawal from throughout the water column; it is unclear which of these yields the most realistic estimates. We made no adjustments in the loss estimates for the assumed improvement in the ability of the older, larger, larvae to resist transport and thus withdrawal. An early study at Unit 1 (Brown and Caldwell et al., 1979) suggested that size selective withdrawal may occur, but that the nature of the selectivity varies from species to species. For example, fewer larger larval white croaker were withdrawn than would have been predicted from their nearfield abundance, while more large larvae of queenfish were withdrawn than would have been expected (Brown and Caldwell et al., 1979).

Qualitative comparisons between the original MRC projections (MRC, 1979b, 1980) and the present analysis indicate that estimated numbers lost tended to be lower in the former. Exact comparisons are not possible because the two estimates were based on different parts of the water column; however, the estimates were based on similar assumptions. Since the original projections were based on withdrawal from midwater (95%) and epibenthos (5%) (e.g., DeMartini and Larson, 1980: in MRC Doc. 80-04 (I) Fish Appendix 1, Table 5-6) and assumed a daily water withdrawal rate of 9.0×10^6 m^3, or 98% of the actual capacity of Units 2 and 3, the final estimates based on operation at 100% of capacity and withdrawal from throughout the water column should be most comparable to the original projections (although, as we have noted, not the most realistic).

The original loss projections included two specific ichthyoplankton taxa, Paralichthys californicus (California halibut) and Paralabrax spp. (kelp and sand basses) (DeMartini and Larson, 1980: in MRC Doc. 80-04(I) Fish Appendix 1, Table 5-6). The final estimates of losses, assuming operation at full capacity for Units 2 and 3, were 27-35% (assuming withdrawal from throughout the water column and from midwater alone, respectively) higher than the original projections for P. californicus, and 353-392% higher than the original projections for Paralabrax spp. The more realistic estimated annual losses based on Units 2 and 3 operation at 75% of capacity were 3% lower (assuming withdrawal throughout the water column) to 1% higher (assuming withdrawal from midwater alone) than the original projection for Paralichthys, and 240-269% higher for Paralabrax.

Two composite groups, larvae of sport and commercial fish taxa and larvae of fodder fish taxa, were treated in both loss estimates. The fodder fish group included the same taxa in both analyses, but the sport/commercial group used in the original analysis contained fewer taxa than were used in the later estimates (Table 5-13). The additional taxa included in the sport/commercial composite group were, with the exception of rockfishes (Sebastes spp.) and English sole (Parophrys vetulus), either very rare or offshore species that contributed insignificantly to the loss estimates. When both of these taxa were subtracted from the sport/commercial group to facilitate comparison with the original projection, the final most realistic (withdrawal at 75% of capacity) estimated losses of sport/commercial taxa were 154-175% higher than the original projection, assuming withdrawal from throughout the water column and from midwater alone, respectively. In contrast, the final estimated losses of the larvae of nearshore planktonic-spawning fodder fishes were much lower than the original projections. For example, the most realistic estimates were 65-76% lower than the original projections for withdrawal from midwater alone and from the entire water column, respectively. These changes in loss estimates largely reflect the relatively low abundances of sport and commercial taxa and high abundances of the fodder taxa in the small data base used for the original projections. Higher abundances occurred in later years for several of the sport and commercial taxa, for example Paralichthys in 1980 (Figure D-253) and Paralabrax from about 1980-1985 (Figure D-216), while the dominant fodder taxa, Genyonemus lineatus and

Seriphus politus, both declined in abundance during later years (e.g., Table 4-5, Figures D-173, D-152).

The original loss projections by MRC (1979b, 1980) indicated that 1.8% of the larvae of nearshore planktonic spawners (approximately equal to the fodder plus sport and commercial groups, less Sebastes spp. and Parophrys vetulus) lost to Units 2 and 3 intake withdrawal would be those of sport and commercial species, with the remaining 98.2% comprising fodder species. This final analysis showed that the sport and commercial taxa (exclusive of Sebastes spp. and Parophrys vetulus) contributed approximately 11-16% of the total: 10.6% for withdrawal from the entire water column and 15.8% for midwater withdrawal alone. This again reflects the relatively higher abundances of several of the sport and commercial taxa in one or more years after 1979, and the relative decreases of the dominant fodder taxa. The higher estimate of losses based on the midwater withdrawal reflects the higher concentration of sport and commercial fish larvae in the midwater stratum.

The MRC (1979b) estimated that among the larvae of the sport and commercial species withdrawn, 51.4% would be California halibut, and 0.3% would be kelp and sand basses. This final analysis indicated that a smaller proportion of the withdrawn sport and commercial larvae would be California halibut (22%), but a much larger proportion would be kelp and sand basses (42%). In proportion to the total larvae of planktonic spawners withdrawn, the present study (assuming withdrawal at 75% of capacity) suggested that about twice as many California halibut larvae and about 600 times as many kelp and sand bass larvae would be withdrawn annually than were indicated by the original analysis (using comparable withdrawal volumes).

As noted above, the reason for these large increases in the estimated losses of California halibut larvae and of kelp and sand bass larvae over the original projections is that catches in 1978, the basis for the original estimates, were small for both taxa. In terms of cross-shelf abundance, in 1978 the average annual abundance for California halibut larvae was the third lowest during the MRC ichthyoplankton study, while for the basses it was the second lowest. Only 1986 was a worse year for the sand and kelp basses: mean annual cross-shelf abundance in 1986 was only one-quarter of the 1978 annual average and an order of magnitude lower than most other years. This appeared as a significant reduction in relative abundance in the BACI analysis (see Section 4.2.2.2.5), although we did not interpret it as a SONGS effect.

The annual fluctuations in estimated larval abundance of California halibut and of the kelp and sand basses are likely to have arisen principally from one or more of four main sources:

(1) year-to-year variation in reproduction;
(2) year-to-year variation in larval survival;
(3) shifts in larval distribution, either vertically or horizontally (i.e., cross-shelf); and
(4) random variations in catch.

Source (1) has several components, for example the size/age composition of the spawning female population, number of spawners, or duration of the spawning season. None of these can be adequately assessed. There is some evidence that California halibut in the San Onofre region may have been more abundant in late summer and fall 1981 (Innis, 1982) but declined somewhat after mid-1982 (DeMartini et al., 1985: Figure 17). However, California halibut collected by trawl in the San Onofre vicinity are predominantly juveniles and subadults (Innis, 1982), so that inferences cannot be made about the size of the spawning population. Diver surveys have shown that barred sandbass became more numerous at San Onofre Kelp (SOK) during El Nino in 1983, but subsequently (1984) were reduced in abundance (Patton, 1985). Subadult and young of the year kelp bass and barred sandbass decreased significantly in relative abundance at SOK-up during the operational period, but significant changes in the relative abundances of adults were not detected (E. DeMartini, pers. comm.) so reduced reproductive effort cannot be demonstrated.

The length of the spawning season can be approximated from larval abundance data. For California halibut the only complete "season" sampled was 1978-1979. For the basses, on the other hand, the beginning of the season could be approximated for six of the nine years, although the end could be resolved for only one of these. In all three years of lowest average cross-shelf larval abundance (1978, 1980, 1986) larvae were not taken before July, while in the other three years larvae occurred in June. Thus the lower abundance in 1978, 1980 and 1986 might have reflected delayed spawning in those years.

Source (2), year-to-year variation in larval survival, has been considered an important component in the recruitment to commercial fisheries stocks (e.g., Lasker, 1981). As a first order approximation to assess the importance of changes in larval survival for California halibut and kelp and sand basses, we calculated year-by-year ratios of cross-shelf abundance of old (=postflexion) to young (= preflexion) larvae. These calculations showed that the ratio varied between about 10^{-1} and 10^{-3} with no obvious year-to-year trend or relationship to

SONGS operation or larval abundance for the basses. Ratios for California halibut tended to be higher, varying between about 10^{-1} and 10^{-2}, but again with no clear year-to-year trend or relationship to larval abundance or SONGS operation. This implies one or more of three things: (a) variations in larval survival did not contribute to our results; (b) the abundance data were too variable to calculate reliable old:young larval abundance ratios; and (c) the approximation we used was too crude to detect real changes in survivorship.

Source (3), a persistent shift in larval distribution, was not evident. In the cross-shelf plane abundance did change in each block from year to year for each taxon, but no persistent shoreward or seaward shift was apparent. Similarly, abundances within strata varied from year to year but showed no persistent patterns of change, thus indicating that larval vertical distributions did not change. Source (4), random variation in catch with fortuitously large catches after 1978, might have been important during 1982 and 1983 when few samples were taken.

Potential losses of northern anchovy larvae (<u>Engraulis</u> <u>mordax</u>) and of the larvae of demersal spawners and ovoviviparous species were not estimated in the original MRC (1979b, 1980) projections, although the Units 1 - 3 intakes were qualitatively projected to kill as many as 10^{10} anchovy larvae. It was assumed that even if this many northern anchovy larvae were killed, no local depression in abundance would be detected (MRC, 1980). The final estimated annual northern anchovy losses were much lower, approximately 2.8×10^{9} larvae (assuming withdrawal at 75% of capacity), and a local depression in larval cross-shelf abundance, which we interpreted as a SONGS effect, was detected in the BACI analysis (Section 4.2.3.2.1). However, our estimate of withdrawal losses during the operational period (Table 4-6) was too small to have fully accounted for the local depression.

The MRC did not project losses for larvae of demersal spawners (e.g., clinids, gobies) but stated that these losses should be small because demersal spawners accounted for only 2.5% of the total cross-shelf larval fish abundance (MRC, 1980). The final analysis showed that approximately 5-8% of the total larvae lost were those of demersal spawners, predominantly gobies and atherinids (grunion, jacksmelt, topsmelt). (Estimated larval losses were not made for all demersally-spawning species, therefore actual percentages are likely to be somewhat higher, but probably not more than about 10% of the total larval losses).

5.2.3 Zooplankton Results and Discussion

As for ichthyoplankton, the original MRC projections of zooplankton losses (MRC, 1979b) were based on an assumption of 100% mortality for all withdrawn organisms. The loss and recovery survey (Section 5.1) showed that this was a reasonable assumption.

Our estimates of annual average macrozooplankton losses are presented in Tables 5-7 through 5-12. Comparison of these estimated losses, assuming Units 2 and 3 operation at 75% of capacity and 100% mortality of the plankters withdrawn, showed that our estimates for total macrozooplankton were 143% higher than the original projection if we assumed midwater withdrawal alone, or 188% higher for withdrawal from the entire water column.

Losses also were compared between the original MRC (1979a) projections and our final loss estimates for the cypris larvae of barnacles and for three copepods: _Acartia clausi_, _A. tonsa_ and _Oithona_ oculata. Except for A. tonsa, our final loss estimates based on midwater withdrawal alone were half or less of the initial loss estimates (51% lower than the original value for A. clausi, 252% higher for A. tonsa, 68% lower for O. oculata and 55% lower for the cypris larvae), if we assumed withdrawal at 75% of capacity. Assuming depth proportional withdrawal from the entire water column (at 75% of capacity), in contrast, led to higher estimated losses than the MRC projections for all but the barnacle cypris larvae: 54% higher for A. clausi, 350% higher for A. tonsa, 21% higher for O. oculata and 28% lower for cypris larvae.

Estimated numbers of total macrozooplankton lost to Units 2 and 3 intakes were compared with estimated numbers lost to natural mortality. Natural daily mortality values in the literature range from 0.5-1% for mixed zooplankton (Steele, 1970; Parsons and Takahashi, 1973) up to 10-40% for particular copepod species in laboratory conditions (e.g., Heinle, 1970; Mullin and Brooks, 1970; Barnett and Sertic, 1979a). We used 10% as a middle value for this analysis due to the preponderance of copepods in our samples, but the nearly two-orders-of-magnitude range here has obvious implications on the evaluation of the significance of these losses.

The nearshore area of ocean under which estimated natural mortality just equals estimated intake losses was calculated. To do this, the mean abundance of total macrozooplankton under a 1 m-wide strip extending from the 8 m to the 30 m isobaths (about 4 km) was calculated, based on abundance measurements from the Control area. This abundance was 289.2 x 10^6 organisms. One tenth (estimated natural mortality) of this value (28.9 x 10^6 organisms) was then divided into the estimated daily intake loss (e.g., 35.8 x 10^9 organisms per day withdrawn from the entire water column if both Units 2 and 3 operated at 75% of capacity; this is equivalent to the estimated daily natural mortality in a population of 358 x 10^9 macrozooplankters). The result of this calculation gave the longshore dimension of the area under which estimated natural mortality was equivalent to the estimated intake loss. For withdrawal from the entire water column with both Units 2 and 3 operating at 75% of capacity, this dimension was approximately 1.2 km. Thus, if Units 2 and 3 withdrew water at 75% of capacity proportionately from throughout the water column, daily losses would have been equivalent to daily natural mortality under an area of about 4.8 km^2 (1.2 km longshore x 4 km offshore) of nearshore ocean. This value was about 60% of the area estimated initially (MRC, 1979b), based on the same 10% natural daily mortality estimator.

Estimated macrozooplankton biomass losses could be compared between the MRC (1979b) projections and the final analysis only for total macrozooplankton. Assuming operation at 75% of Units 2 and 3 capacity, final biomass loss estimates were 93-119% higher than the original projections, for midwater withdrawal and full water column withdrawal, respectively. As we showed earlier (Section 5.1), much of this biomass loss apparently is consumed by the biofouling community in the intake conduits and screenwells.

Table 5-1. Results of loss and recovery survey. Macrozooplankton and hypoplankton abundances (number per cubic meter) in intake and diffuser waters of Units 2 and 3 are shown. Gains or losses are relative to intake values. Stages: A = adult, J = juvenile, C = copepodid

		Unit 3							Unit 2						
		Intake			Diffuser			% gain(+)	Intake			Diffuser			% gain(+)
Taxon	Stage	mean	2 S.E.	n	mean	2 S.E.	n	or loss(-)	mean	2 S.E.	n	mean	2 S.E.	n	or loss(-)
Holoplankton															
Evadne nordmanni	A/J	1.79	0.84	10	0.00	0.00	10	-100.00	0.22	0.32	10	0.12	0.24	10	-45.53
Podon polyphemoides	A/J	0.15	0.20	10	0.00	0.00	10	-100.00	0.00	0.00	10	0.00	0.00	10	.
Acartia tonsa	A	18.81	4.71	10	0.78	0.58	10	-95.86	4.53	1.72	10	0.85	0.82	10	-81.17
Acartia tonsa	C	6.12	2.31	10	0.11	0.22	10	-98.18	14.36	4.81	10	1.34	0.85	10	-90.66
Corycaeus anglicus	A/J	395.15	110.84	10	3.56	0.80	10	-99.10	38.50	6.86	10	3.90	2.35	10	-89.86
Labidocera trispinosa	A	0.07	0.15	10	0.00	0.00	10	-100.00	0.00	0.00	10	0.00	0.00	10	.
Labidocera trispinosa	C	0.30	0.24	10	0.00	0.00	10	-100.00	0.90	0.43	10	0.00	0.00	10	-100.00
Paracalanus parvus	A	24.63	6.76	10	0.67	0.49	10	-97.29	20.88	6.13	10	1.95	0.91	10	-90.65
Paracalanus parvus	C	8.13	1.80	10	0.33	0.67	10	-95.90	4.89	1.89	10	0.12	0.24	10	-97.51
Oithona plumifera	A/J	164.10	49.11	10	0.44	0.36	10	-99.73	47.33	8.27	10	2.80	1.26	10	-94.07
Calanus pacificus	A/J	0.82	0.61	10	0.00	0.00	10	-100.00	0.22	0.23	10	0.00	0.00	10	-100.00
Eucalanus californicus	A/J	0.07	0.15	10	0.00	0.00	10	-100.00	0.00	0.00	10	0.00	0.00	10	.
Rhincalanus nasutus	A/J	0.07	0.15	10	0.00	0.00	10	-100.00	0.00	0.00	10	0.00	0.00	10	.
Sagitta euneritica	A/J	20.22	3.24	10	0.22	0.30	10	-98.90	0.77	0.45	10	0.61	0.41	10	-20.49
Unidentified fish eggs		0.82	0.65	10	0.11	0.22	10	-86.46	1.11	0.55	10	0.73	0.83	10	-34.26
Unid. holoplankton	A/J	1159.3	254.88	10	14.44	2.73	10	-98.75	600.64	93.41	10	25.49	4.50	10	-95.76
Meroplankton															
Cyphonautes larvae		150.05	56.53	10	2.67	0.76	10	-98.22	222.22	35.43	10	35.00	7.10	10	-84.25
Cirriped nauplius		2.61	1.16	10	0.11	0.22	10	-95.75	0.27	0.32	10	0.00	0.00	10	-100.00
Cypris larvae		2.46	1.00	10	0.33	0.47	10	-86.46	0.59	0.37	10	3.54	1.60	10	498.75
Unid. meroplankton		52.09	10.68	10	7.33	1.79	10	-85.92	16.43	2.99	10	14.27	3.81	10	-13.14
Others															
Biofouling organisms*		2.09	0.73	10	14.22	3.52	10	580.63	1.36	0.71	10	4.51	1.86	10	232.37

* The group "Biofouling organisms" is comprised of amphipods, cumaceans, polyclads, flatworms, isopods, and mysids.

Table 5-2. Results of loss and recovery survey. Macrozooplankton and hypoplankton abundances (Number per cubic meter) in the Unit 2 intake and diffuser waters and in the plume station waters are shown. Unit 2 results are taken directly from Table 5-1.

		Unit 2										
		Intake			Diffuser			% gain(+) or loss(-)	Plume			% gain(+) or loss(-)**
Taxon	Stage	mean	2 S.E.	n	mean	2 S.E.	n		mean	2 S.E.	n	
Holoplankton												
Evadne nordmanni	A/J	0.22	0.32	10	0.12	0.24	10	-45.53	1.34	1.04	10	500.00
Podon polyphemoides	A/J	0.00	0.00	10	0.00	0.00	10	.	0.00	0.00	10	.
Acartia tonsa	adult	4.53	1.72	10	0.85	0.82	10	-81.17	12.99	10.33	10	186.44
Acartia tonsa	copepodid	14.36	4.81	10	1.34	0.85	10	-90.66	5.07	1.01	10	-64.67
Corycaeus anglicus	A/J	38.50	6.86	10	3.90	2.35	10	-89.86	102.09	20.90	10	165.18
Labidocera trispinosa	adult	0.00	0.00	10	0.00	0.00	10	.	0.00	0.00	10	.
Labidocera trispinosa	copepodid	0.90	0.43	10	0.00	0.00	10	-100.00	0.07	0.15	10	-91.67
Paracalanus parvus	adult	20.88	6.13	10	1.95	0.91	10	-90.65	28.21	4.39	10	35.11
Paracalanus parvus	copepodid	4.89	1.89	10	0.12	0.24	10	-97.51	6.34	1.51	10	29.67
Oithona plumifera	A/J	47.33	8.27	10	2.80	1.26	10	-94.07	46.64	6.75	10	-1.45
Calanus pacificus	A/J	0.22	0.23	10	0.00	0.00	10	-100.00	0.07	0.15	10	-66.67
Eucalanus californicus	A/J	0.00	0.00	10	0.00	0.00	10	.	0.00	0.00	10	.
Rhincalanus nasutus	A/J	0.00	0.00	10	0.00	0.00	10	.	0.00	0.00	10	.
Sagitta euneritica	A/J	0.77	0.45	10	0.61	0.41	10	-20.49	12.84	3.01	10	1573.7
Unidentified fish eggs		1.11	0.55	10	0.73	0.83	10	-34.26	1.27	0.59	10	13.98
Unid. holoplankton	A/J	600.64	93.41	10	25.49	4.50	10	-95.76	553.36	81.66	10	-7.87
Meroplankton												
Cyphonautes larvae		222.22	35.43	10	35.00	7.10	10	-84.25	43.58	7.05	10	-80.39
Cirriped nauplius		0.27	0.32	10	0.00	0.00	10	-100.00	3.36	1.16	10	1136.8] ?
Cypris larvae		0.59	0.37	10	3.54	1.60	10	498.75 ←	0.22	0.45	10	-62.10
Unid. meroplankton		16.43	2.99	10	14.27	3.81	10	-13.14	22.61	4.19	10	37.65
Others												
Biofouling organisms*		1.36	0.71	10	4.51	1.86	10	232.37	2.69	1.07	10	97.89

* The group "Biofouling organisms" is comprised of amphipods, cumaceans, polyclads, flatworms, isopods, and mysids.

** Relative to average intake values of Unit 2.

Table 5-3. Values for chemistry samples taken on the Loss and Recovery Survey. All values are the average of the 10 samples taken at each station. They are presented in units of mg/liter.

STATION	TOC	POC	DOC	SESTON DRY WEIGHT
Intake (Unit 3)	0.78	0.17	0.85	5.65
Diffuser (Unit 3)	0.92	0.20	0.80	14.54
Plume	0.63	0.21	0.57	15.80
Ambient	0.84	0.16	0.62	7.94

Table 5-4. Annual intake loss estimates (in millions) for ichthyoplankton. Loss based on actual pump volumes 1981-1986. Results of "Mid Mean" assume that the ichthyoplankton only in the midwater were withdrawn. Results of "Water Mean" assume that ichthyoplankton were withdrawn from all depths in proportion to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP	L.C.B.	MID MEAN	U.C.B.	L.C.B.	WATER MEAN	U.C.B.
(1) Epibenthic inshore	422.1	564.3	706.5	598.4	847.2	1095.9
(3) Midwater/epibenthic offshore	-0.1	0.5	1.2	-0.1	0.5	1.1
(4) Predominantly neuston > 13m	-3.2	15.8	34.8	-2.3	14.5	31.4
(5) Neuston > 13m	-0.1	1.0	2.0	-0.0	0.9	1.9
(6) Predominantly midwater cross-shelf	1286.0	1961.3	2636.6	1287.3	1912.2	2537.0
(7) Neuston/midwater cross-shelf	28.1	36.4	44.7	27.7	34.9	42.2
(8) Predominantly midwater > 13 m	21.6	114.5	207.4	18.6	107.4	196.3
(9) Midwater/epibenthic > 13 m	1.7	3.0	4.4	1.6	2.8	4.0
(10) Midwater > 13 m	-1.1	4.0	9.0	-1.0	3.6	8.1
Total larvae	2026.3	2841.0	3655.7	2234.4	3097.0	3959.6
Non-engraulid larvae	707.0	915.1	1123.2	930.0	1217.7	1505.4
Sport and commercial larvae	46.1	88.4	130.7	43.0	81.7	120.4
Forage larvae	1952.2	2752.6	3553.0	2164.6	3015.3	3866.0
Fodder larvae	337.4	470.0	602.7	464.3	684.3	904.2
Engraulis mordax	1259.1	1925.9	2592.7	1262.2	1879.3	2496.5
Stenobrachius leucopsarus	1.0	5.9	10.7	0.8	5.9	11.0
Citharichthys spp	0.5	2.0	3.4	0.5	1.8	3.1
Paralichthys californicus	9.8	19.5	29.2	9.1	18.3	27.5
Hypsopsetta guttulata	3.0	4.8	6.6	2.8	4.4	6.0
Parophrys vetulus	-0.0	0.0	0.1	-0.0	0.0	0.1
Pleuronichthys ritteri	0.1	0.7	1.3	0.2	0.7	1.2
Pleuronichthys verticalis	1.0	2.2	3.4	0.9	2.0	3.1
Paralabrax spp	5.0	37.0	68.9	5.1	34.0	62.9
Atherinopsis californiensis	11.0	27.8	44.6	22.1	37.9	53.6
Leuresthes tenuis	0.1	2.6	5.1	4.7	9.3	13.9
Atherinidae	19.1	36.7	54.4	38.8	56.1	73.4
Sphyraena argentea	-0.6	1.3	3.3	-0.5	1.2	3.0
Peprilus simillimus	-0.1	0.6	1.3	-0.1	0.5	1.2
Anisotremus davidsoni	-0.1	0.8	1.7	-0.1	0.9	1.9
Atractoscion nobilis	0.0	0.2	0.3	0.0	0.1	0.3
Genyonemus lineatus	156.3	262.4	368.5	222.9	428.0	633.0
Menticirrhus undulatus	-0.6	7.8	16.1	-0.3	7.1	14.6
Roncador stearnsii	-0.8	2.2	5.3	-0.8	2.0	4.7
Seriphus politus	131.1	192.1	253.0	178.1	241.0	303.9
Chromis punctipinnis	0.0	0.0	0.0	-0.0	0.0	0.0
Semicossyphus pulcher	-0.3	0.7	1.7	-0.2	0.7	1.6
Girella nigricans	-0.0	0.2	0.5	-0.0	0.2	0.5
Medialuna californiensis	-0.2	0.9	2.0	-0.2	0.8	1.8
Sebastes spp	-0.0	0.3	0.5	0.0	0.2	0.5
Clevelandia ios	6.5	12.0	17.6	19.4	28.1	36.7
Ilypnus gilberti	29.0	49.9	70.9	52.5	86.7	121.0
Quietula y-cauda	7.1	12.3	17.5	15.8	23.2	30.5
Gobiidae type a	50.0	79.5	109.0	101.1	143.1	185.1
Gobiesox rhessodon	2.1	6.0	9.8	3.4	7.0	10.6
Gibbonsia type a	5.3	11.3	17.2	5.4	10.9	16.4
Hypsoblennius spp	24.4	31.9	39.4	24.3	31.0	37.7
Engraulis mordax eggs	420.9	1216.4	2011.9	381.7	1212.9	2044.0
Non-engraulid eggs	6742.4	8287.1	9831.8	6555.9	7962.9	9369.9

Table 5-5. Annual intake loss estimates (in millions) for ichthyoplankton. Loss based on 75% volume (6 pumps operating). Results of "Mid Mean" assume that the ichthyoplankton only in the midwater were withdrawn. Results of "Water Mean" assume that ichthyoplankton were withdrawn from all depths in proportion to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP	L.C.B.	MID MEAN	U.C.B.	L.C.B.	WATER MEAN	U.C.B.
(1) Epibenthic inshore	633.1	846.4	1059.7	897.6	1270.7	1643.9
(3) Midwater/epibenthic offshore	-0.2	0.8	1.7	-0.2	0.8	1.7
(4) Predominantly neuston > 13m	-4.8	23.7	52.2	-3.5	21.8	47.2
(5) Neuston > 13m	-0.1	1.5	3.0	-0.0	1.4	2.8
(6) Predominantly midwater cross-shelf	1929.0	2942.0	3955.0	1931.0	2868.3	3805.6
(7) Neuston/midwater cross-shelf	42.2	54.6	67.1	41.5	52.4	63.3
(8) Predominantly midwater > 13 m	32.4	171.7	311.1	27.9	161.2	294.4
(9) Midwater/epibenthic > 13 m	2.5	4.5	6.6	2.4	4.2	6.1
(10) Midwater > 13 m	-1.6	5.9	13.5	-1.4	5.4	12.2
Total larvae	3039.4	4261.5	5483.6	3351.7	4645.6	5939.5
Non-engraulid larvae	1060.5	1372.7	1684.8	1395.0	1826.6	2258.2
Sport and commercial larvae	69.1	132.6	196.1	64.5	122.6	180.6
Forage larvae	2928.3	4128.9	5329.5	3246.9	4523.0	5799.1
Fodder larvae	506.1	705.0	904.0	696.5	1026.4	1356.3
Engraulis mordax	1888.7	2888.8	3889.0	1893.3	2819.0	3744.7
Stenobrachius leucopsarus	1.5	8.8	16.1	1.1	8.9	16.6
Citharichthys spp	0.8	2.9	5.1	0.8	2.7	4.7
Paralichthys californicus	14.7	29.2	43.8	13.6	27.4	41.2
Hypsopsetta guttulata	4.6	7.2	9.9	4.2	6.6	9.0
Parophrys vetulus	-0.0	0.0	0.1	-0.0	0.0	0.1
Pleuronichthys ritteri	0.2	1.0	1.9	0.3	1.0	1.8
Pleuronichthys verticalis	1.5	3.3	5.1	1.3	3.0	4.6
Paralabrax spp	7.6	55.4	103.3	7.7	51.0	94.4
Atherinopsis californiensis	16.5	41.7	66.9	33.2	56.8	80.5
Leuresthes tenuis	0.2	3.9	7.6	7.0	14.0	20.9
Atherinidae	28.7	55.1	81.5	58.2	84.2	110.1
Sphyraena argentea	-1.0	2.0	5.0	-0.8	1.9	4.6
Peprilus simillimus	-0.2	0.9	2.0	-0.1	0.8	1.8
Anisotremus davidsoni	-0.2	1.2	2.6	-0.1	1.4	2.8
Atractoscion nobilis	0.0	0.2	0.5	0.0	0.2	0.4
Genyonemus lineatus	234.5	393.6	552.8	334.4	641.9	949.5
Menticirrhus undulatus	-0.8	11.7	24.2	-0.5	10.7	21.9
Roncador stearnsii	-1.3	3.4	8.0	-1.1	3.0	7.1
Seriphus politus	196.6	288.1	379.6	267.2	361.5	455.8
Chromis punctipinnis	0.0	0.0	0.0	-0.0	0.0	0.1
Semicossyphus pulcher	-0.4	1.1	2.6	-0.3	1.0	2.4
Girella nigricans	-0.0	0.4	0.8	-0.0	0.3	0.7
Medialuna californiensis	-0.4	1.3	3.0	-0.3	1.2	2.7
Sebastes spp	-0.0	0.4	0.8	0.0	0.4	0.7
Clevelandia ios	9.7	18.1	26.4	29.1	42.1	55.1
Ilypnus gilberti	43.5	74.9	106.4	78.7	130.1	181.5
Quietula y-cauda	10.7	18.5	26.3	23.8	34.7	45.7
Gobiidae type a	75.0	119.2	163.5	151.7	214.7	277.6
Gobiesox rhessodon	3.1	8.9	14.7	5.1	10.5	15.9
Gibbonsia type a	8.0	16.9	25.8	8.1	16.4	24.6
Hypsoblennius spp	36.6	47.9	59.2	36.5	46.5	56.6
Engraulis mordax eggs	631.3	1824.6	3017.9	572.5	1819.3	3066.1
Non-engraulid eggs	10113.5	12430.6	14747.7	9833.9	11944.4	14054.8

Table 5-6. Annual intake loss estimates (in millions) for ichthyoplankton. Loss based on 100% volume (8 pumps operating). Results of "Mid Mean" assume that the ichthyoplankton only in the midwater were withdrawn. Results of "Water Mean" assume that ichthyoplankton were withdrawn from all depths in proportion to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP	L.C.B.	MID MEAN	U.C.B.	L.C.B.	WATER MEAN	U.C.B.
(1) Epibenthic inshore	844.1	1128.5	1412.9	1196.8	1694.3	2191.9
(3) Midwater/epibenthic offshore	-0.2	1.0	2.3	-0.2	1.0	2.3
(4) Predominantly neuston > 13m	-6.4	31.6	69.6	-4.7	29.1	62.9
(5) Neuston > 13m	-0.1	2.0	4.0	-0.1	1.8	3.7
(6) Predominantly midwater cross-shelf	2572.0	3922.6	5273.3	2574.7	3824.4	5074.1
(7) Neuston/midwater cross-shelf	56.3	72.9	89.4	55.3	69.9	84.4
(8) Predominantly midwater > 13 m	43.2	229.0	414.8	37.2	214.9	392.6
(9) Midwater/epibenthic > 13 m	3.3	6.0	8.8	3.2	5.6	8.1
(10) Midwater > 13 m	-2.2	7.9	18.0	-1.9	7.1	16.2
Total larvae	4052.5	5682.0	7311.5	4468.9	6194.1	7919.3
Non-engraulid larvae	1414.0	1830.2	2246.4	1860.0	2435.4	3010.9
Sport and commercial larvae	92.2	176.8	261.4	86.1	163.4	240.8
Forage larvae	3904.4	5505.2	7106.0	4329.2	6030.6	7732.1
Fodder larvae	674.8	940.0	1205.3	928.6	1368.5	1808.4
Engraulis mordax	2518.2	3851.8	5185.3	2524.4	3758.7	4992.9
Stenobrachius leucopsarus	2.1	11.8	21.5	1.5	11.8	22.1
Citharichthys spp	1.0	3.9	6.8	1.1	3.6	6.2
Paralichthys californicus	19.5	39.0	58.4	18.2	36.6	55.0
Hypsopsetta guttulata	6.1	9.6	13.2	5.6	8.8	12.0
Parophrys vetulus	-0.1	0.1	0.2	-0.1	0.1	0.2
Pleuronichthys ritteri	0.2	1.4	2.5	0.3	1.4	2.4
Pleuronichthys verticalis	2.0	4.4	6.8	1.8	4.0	6.2
Paralabrax spp	10.1	73.9	137.8	10.3	68.1	125.8
Atherinopsis californiensis	22.0	55.6	89.2	44.3	75.8	107.3
Leuresthes tenuis	0.2	5.2	10.1	9.3	18.6	27.9
Atherinidae	38.3	73.5	108.7	77.6	112.2	146.8
Sphyraena argentea	-1.3	2.7	6.6	-1.1	2.5	6.1
Peprilus simillimus	-0.2	1.2	2.6	-0.2	1.1	2.4
Anisotremus davidsoni	-0.2	1.6	3.5	-0.1	1.8	3.7
Atractoscion nobilis	0.0	0.3	0.6	0.0	0.3	0.5
Genyonemus lineatus	312.6	524.8	737.0	445.9	855.9	1266.0
Menticirrhus undulatus	-1.1	15.6	32.2	-0.7	14.3	29.2
Roncador stearnsii	-1.7	4.5	10.7	-1.5	4.0	9.5
Seriphus politus	262.2	384.1	506.1	356.2	482.0	607.8
Chromis punctipinnis	0.0	0.0	0.0	-0.0	0.0	0.1
Semicossyphus pulcher	-0.5	1.5	3.5	-0.4	1.4	3.2
Girella nigricans	-0.0	0.5	1.0	-0.0	0.4	0.9
Medialuna californiensis	-0.5	1.8	4.0	-0.4	1.6	3.6
Sebastes spp	-0.0	0.5	1.0	0.0	0.5	0.9
Clevelandia ios	13.0	24.1	35.2	38.8	56.2	73.5
Ilypnus gilberti	57.9	99.9	141.8	104.9	173.5	242.0
Quietula y-cauda	14.2	24.6	35.1	31.7	46.3	61.0
Gobiidae type a	100.0	159.0	218.0	202.3	286.2	370.2
Gobiesox rhessodon	4.2	11.9	19.6	6.8	14.0	21.3
Gibbonsia type a	10.7	22.5	34.4	10.9	21.8	32.8
Hypsoblennius spp	48.8	63.8	78.9	48.7	62.1	75.4
Engraulis mordax eggs	841.7	2432.8	4023.9	763.3	2425.7	4088.1
Non-engraulid eggs	13484.7	16574.1	19663.5	13111.9	15925.8	18739.7

Table 5-7. Annual intake loss estimates (in billions) for zooplankton. Loss based on actual operating volumes 1981-1986. Results of "Mid Mean" assume that the zooplankton only in the midwater were withdrawn; Results of "Water Mean" assume that zooplankton were withdrawn from all depths in proportion to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP	L.C.B.	MID MEAN	U.C.B.	L.C.B.	WATER MEAN	U.C.B.
Total holoplankton	3763.0	7405.6	11048.2	7138.1	8966.9	10795.6
Total meroplankton	496.3	799.3	1102.3	563.4	759.1	954.8
Total zooplankton	4491.5	8204.9	11918.4	7893.8	9726.0	11558.2
Evadne nordmanni	51.6	111.8	172.0	63.5	106.6	149.7
Evadne spinifera	7.2	33.5	59.9	10.9	25.0	39.0
Penilia avirostris	5.2	44.5	83.9	23.4	50.2	76.9
Podon polyphemoides	2.1	1070.6	2139.1	-14.6	818.6	1651.7
Acartia clausi	4.8	72.4	140.0	115.0	226.3	337.6
Acartia tonsa	1951.0	3410.0	4869.0	3257.0	4363.7	5470.5
Corycaeus anglicus	122.2	155.3	188.4	125.9	172.7	219.5
Labidocera trispinosa	46.0	59.5	73.1	51.9	94.9	137.9
Paracalanus parvus	514.6	650.4	786.1	645.2	812.5	979.7
Oithona oculata	4.2	22.8	41.5	39.0	87.0	135.0
Oithona plumifera	46.7	68.9	91.2	47.1	64.3	81.5
Calanus pacificus	1.6	3.3	4.9	2.4	3.9	5.5
Eucalanus californicus	-0.0	0.0	0.1	-0.2	0.4	0.9
Rhincalanus nasutus	-0.2	0.6	1.4	0.0	0.6	1.3
Cypris larvae	15.5	22.6	29.7	23.0	36.2	49.5
Sagitta euneritica	58.4	95.0	131.5	70.8	101.3	131.9
Cyphonautes larvae	139.1	211.1	283.1	130.6	188.4	246.3
Unid. meroplankton	80.8	135.9	191.1	126.3	174.2	222.2
Unid. holoplankton	153.1	472.3	791.4	331.3	562.4	793.5

Table 5-8. Annual intake loss estimates (in billions) for zooplankton. Loss based on 75% volume (6 pumps operating). Results of "Mid Mean" assume that the zooplankton only in the midwater were withdrawn. Results of "Water Mean" assume that zooplankton were withdrawn from all depths in proportion to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP		MID			WATER	
	L.C.B.	MEAN	U.C.B.	L.C.B.	MEAN	U.C.B.
Total holoplankton	5054.8	9947.8	14840.9	9588.5	12045.1	14501.6
Total meroplankton	666.7	1073.7	1480.8	756.8	1019.7	1282.5
Total zooplankton	6033.4	11021.6	16009.7	10603.6	13064.7	15525.9
Evadne nordmanni	69.3	150.2	231.1	85.3	143.2	201.1
Evadne spinifera	9.6	45.0	80.4	14.7	33.5	52.4
Penilia avirostris	7.0	59.8	112.7	31.5	67.4	103.3
Podon polyphemoides	2.8	1438.1	2873.4	-19.6	1099.6	2218.8
Acartia clausi	6.4	97.2	188.0	154.4	303.9	453.5
Acartia tonsa	2620.8	4580.6	6540.4	4375.1	5861.7	7348.4
Corycaeus anglicus	164.1	208.6	253.0	169.1	232.0	294.9
Labidocera trispinosa	61.8	80.0	98.1	69.8	127.5	185.3
Paracalanus parvus	691.3	873.6	1056.0	866.6	1091.4	1316.1
Oithona oculata	5.6	30.7	55.8	52.4	116.9	181.4
Oithona plumifera	62.7	92.6	122.5	63.2	86.4	109.5
Calanus pacificus	2.1	4.4	6.6	3.2	5.3	7.4
Eucalanus californicus	-0.0	0.0	0.1	-0.2	0.5	1.2
Rhincalanus nasutus	-0.3	0.8	1.9	0.0	0.9	1.7
Cypris larvae	20.8	30.4	39.9	30.9	48.7	66.4
Sagitta euneritica	78.5	127.6	176.7	95.2	136.1	177.1
Cyphonautes larvae	186.8	283.5	380.3	175.4	253.1	330.8
Unid. meroplankton	108.5	182.6	256.7	169.6	234.0	298.5
Unid. holoplankton	205.7	634.4	1063.1	445.1	755.5	1065.9

Table 5-9. Annual intake loss estimates (in billions) for zooplankton. Loss based on 100% volume (8 pumps operating). Results of "Mid Mean" assume that the zooplankton only in the midwater were withdrawn. Results of "Water Mean" assume that zooplankton were withdrawn from all depths in proportion to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP	L.C.B.	MID MEAN	U.C.B.	L.C.B.	WATER MEAN	U.C.B.
Total holoplankton	6739.8	13263.8	19787.8	12784.7	16060.1	19335.5
Total meroplankton	888.9	1431.6	1974.3	1009.0	1359.5	1710.1
Total zooplankton	8044.5	14695.4	21346.3	14138.1	17419.6	20701.2
Evadne nordmanni	92.5	200.3	308.1	113.8	191.0	268.2
Evadne spinifera	12.8	60.0	107.2	19.5	44.7	69.9
Penilia avirostris	9.3	79.8	150.3	42.0	89.8	137.7
Podon polyphemoides	3.7	1917.4	3831.1	-26.1	1466.1	2958.3
Acartia clausi	8.6	129.6	250.7	205.9	405.3	604.6
Acartia tonsa	3494.4	6107.5	8720.6	5833.4	7815.6	9797.8
Corycaeus anglicus	218.8	278.1	337.4	225.5	309.3	393.2
Labidocera trispinosa	82.4	106.6	130.8	93.0	170.0	247.1
Paracalanus parvus	921.7	1164.9	1408.0	1155.5	1455.1	1754.8
Oithona oculata	7.5	40.9	74.3	69.9	155.8	241.8
Oithona plumifera	83.6	123.5	163.4	84.3	115.1	146.0
Calanus pacificus	2.8	5.8	8.8	4.3	7.0	9.8
Eucalanus californicus	-0.1	0.1	0.2	-0.3	0.7	1.7
Rhincalanus nasutus	-0.4	1.1	2.6	0.0	1.1	2.3
Cypris larvae	27.8	40.5	53.2	41.2	64.9	88.6
Sagitta euneritica	104.7	170.1	235.5	126.9	181.5	236.2
Cyphonautes larvae	249.0	378.0	507.0	233.9	337.5	441.1
Unid. meroplankton	144.6	243.5	342.3	226.1	312.1	398.0
Unid. holoplankton	274.3	845.8	1417.4	593.4	1007.3	1421.2

Table 5-10. Annual intake loss estimates (in metric tons) for zooplankton biomass. Loss based on actual operating volumes 1981-1986. Results of "Mid Mean" assume that the zooplankton only in the midwater were withdrawn. Results of "Water Mean" assume that zooplankton were withdrawn from all depths in proportion to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP		MID			WATER	
	L.C.B.	MEAN	U.C.B.	L.C.B.	MEAN	U.C.B.
Total holoplankton	344.1	619.3	894.5	514.2	707.4	900.6
Total meroplankton	20.8	33.1	45.5	24.7	32.8	40.8
Total zooplankton	373.8	652.5	931.1	546.6	740.1	933.7
Evadne nordmanni	3.4	7.3	11.2	4.1	6.9	9.7
Evadne spinifera	0.3	1.3	2.3	0.4	1.0	1.5
Penilia avirostris	0.5	4.6	8.7	2.4	5.2	8.0
Podon polyphemoides	0.1	25.7	51.3	-0.3	19.6	39.6
Acartia clausi	0.1	2.0	3.9	3.2	6.3	9.5
Acartia tonsa	59.5	104.0	148.5	99.3	133.1	166.8
Corycaeus anglicus	2.6	3.3	4.0	2.6	3.6	4.6
Labidocera trispinosa	9.1	11.8	14.5	10.3	18.8	27.4
Paracalanus parvus	13.1	16.6	20.0	16.5	20.7	25.0
Oithona oculata	0.0	0.2	0.4	0.4	0.8	1.2
Oithona plumifera	0.4	0.6	0.7	0.4	0.5	0.7
Calanus pacificus	0.6	1.3	1.9	0.9	1.5	2.1
Eucalanus californicus	-0.0	0.0	0.1	-0.2	0.5	1.1
Rhincalanus nasutus	-0.1	0.2	0.4	0.0	0.2	0.3
Cypris larvae	0.5	0.7	0.9	0.7	1.1	1.5
Sagitta euneritica	118.5	192.6	266.7	143.7	205.5	267.4
Cyphonautes larvae	4.4	6.8	9.1	4.2	6.0	7.9
Unid. meroplankton	4.9	8.3	11.7	7.7	10.6	13.6
Unid. holoplankton	12.1	37.3	62.5	26.2	44.4	62.7

Table 5-11. Annual *intake* loss estimates (in metric tons) for zooplankton biomass. Loss based on 75% volume (6 pumps operating). Results of "Mid Mean" assume that the zooplankton only in the midwater were withdrawn. Results of "Water Mean" assume that zooplankton were withdrawn from all depths in *proportion* to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP	L.C.B.	MID MEAN	U.C.B.	L.C.B.	WATER MEAN	U.C.B.
Total holoplankton	462.3	831.9	1201.6	690.7	950.2	1209.8
Total meroplankton	27.9	44.5	61.1	33.2	44.0	54.8
Total zooplankton	502.2	876.4	1250.7	734.2	994.2	1254.3
Evadne nordmanni	4.5	9.8	15.0	5.5	9.3	13.1
Evadne spinifera	0.4	1.8	3.1	0.6	1.3	2.0
Penilia avirostris	0.7	6.2	11.7	3.3	7.0	10.7
Podon polyphemoides	0.1	34.5	69.0	-0.5	26.4	53.3
Acartia clausi	0.2	2.7	5.3	4.3	8.5	12.7
Acartia tonsa	79.9	139.7	199.5	133.4	178.8	224.1
Corycaeus anglicus	3.4	4.4	5.3	3.6	4.9	6.2
Labidocera trispinosa	12.3	15.9	19.5	13.8	25.3	36.8
Paracalanus parvus	17.6	22.3	26.9	22.1	27.8	33.6
Oithona oculata	0.1	0.3	0.5	0.5	1.1	1.6
Oithona plumifera	0.5	0.7	1.0	0.5	0.7	0.9
Calanus pacificus	0.8	1.7	2.6	1.2	2.1	2.9
Eucalanus californicus	-0.1	0.1	0.2	-0.2	0.6	1.5
Rhincalanus nasutus	-0.1	0.2	0.5	0.0	0.2	0.5
Cypris larvae	0.6	0.9	1.2	0.9	1.5	2.0
Sagitta euneritica	159.2	258.7	358.3	193.0	276.1	359.2
Cyphonautes larvae	6.0	9.1	12.2	5.6	8.1	10.6
Unid. meroplankton	6.6	11.1	15.7	10.3	14.3	18.2
Unid. holoplankton	16.3	50.1	84.0	35.2	59.7	84.2

Table 5-12. Annual intake loss estimates (in metric tons) for zooplankton biomass. Loss based on 100% volume (8 pumps operating). Results of "Mid Mean" assume that the zooplankton only in the midwater were withdrawn. Results of "Water Mean" assume that zooplankton were withdrawn from all depths in proportion to that depth's fraction of the water column; see Section 5.2.1. L.C.B. is the lower confidence bound, U.C.B. is the upper confidence bound.

TAXON OR GROUP	L.C.B.	MID MEAN	U.C.B.	L.C.B.	WATER MEAN	U.C.B.
Total holoplankton	616.4	1109.2	1602.1	920.9	1267.0	1613.0
Total meroplankton	37.2	59.3	81.4	44.2	58.7	73.1
Total zooplankton	669.5	1168.6	1667.6	978.9	1325.6	1672.3
Evadne nordmanni	6.0	13.0	20.0	7.4	12.4	17.4
Evadne spinifera	0.5	2.3	4.2	0.8	1.7	2.7
Penilia avirostris	1.0	8.3	15.6	4.4	9.3	14.3
Podon polyphemoides	0.1	46.0	91.9	-0.6	35.2	71.0
Acartia clausi	0.2	3.6	7.0	5.8	11.3	16.9
Acartia tonsa	106.6	186.3	266.0	177.9	238.4	298.8
Corycaeus anglicus	4.6	5.8	7.1	4.7	6.5	8.3
Labidocera trispinosa	16.4	21.2	26.0	18.5	33.8	49.0
Paracalanus parvus	23.5	29.7	35.9	29.5	37.1	44.7
Oithona oculata	0.1	0.4	0.7	0.6	1.4	2.2
Oithona plumifera	0.7	1.0	1.3	0.7	0.9	1.2
Calanus pacificus	1.1	2.3	3.4	1.7	2.7	3.8
Eucalanus californicus	-0.1	0.1	0.2	-0.3	0.8	2.0
Rhincalanus nasutus	-0.1	0.3	0.7	0.0	0.3	0.6
Cypris larvae	0.8	1.2	1.6	1.2	1.9	2.7
Sagitta euneritica	212.3	345.0	477.7	257.3	368.1	478.9
Cyphonautes larvae	8.0	12.1	16.2	7.5	10.8	14.1
Unid. meroplankton	8.8	14.9	20.9	13.8	19.0	24.3
Unid. holoplankton	21.7	66.8	112.0	46.9	79.6	112.3

Table 5-13. Sport and commercial (S/C) species included in the "sport and commercial larvae" composite group. Starred taxa are those comprising the S/C group in the MRC (1980) projected intake losses.

TAXON	COMMON NAME
* Paralichthys californicus	California halibut
* Seriola dorsalis	Yellowtail
Trachurus symmetricus	Jack mackerel
* Anisotremus davidsoni	Sargo
Ophiodon elongatus	Lingcod
Semicossyphus pulcher	California sheephead
Merluccius productus	Pacific hake
Eopsetta jordani	Petrale sole
Glyplocephalus zachirus	Rex sole
* Hypsopsetta guttulata	Diamond turbot
Isopsetta isolepis	Butter sole
Parophrys vetulus	English sole
Platichthys stellatus	Starry flounder
* Pleuronichthys ritteri	Spotted turbot
* Pleuronichthys verticalis	Hornyhead turbot
* Atractoscion nobilis	White seabass
* Menticirrhus undulatus	California corbina
* Roncador stearnsii	Spotfin croaker
Scomber japonicus	Pacific mackerel
Scomberomorus sp. A	Sierra, or Spanish mackerel
* Scorpaena guttata	Sculpin
Sebastes paucispinis	Bocaccio
Sebastes spp. (17 types)	Rockfishes
* Girella nigricans	Opaleye
* Medialuna californiensis	Halfmoon
* Paralabrax spp.	Kelp and sand basses
* Sphyraena argentea	California barracuda

Table 5-14. Fish species included in the "forage larvae" composite group. Starred taxa are those included in the "fodder larvae" (all are larvae of nearshore pelagic spawners) composite group of both the MRC (1980) projection and the present analysis.

	TAXON	COMMON NAME
	Agonidae	Poachers
	Argentina sialis	Pacific argentine
	Atherinidae	Silversides
	Bathylagus ochotensis	Popeye blacksmelt
	Bathylagus pacificus	Pacific blacksmelt
	Bathylagus wesethi	Snubnose blacksmelt
	Leuroglossus stilbius	California smoothtongue
	Strongylura exilis	California needlefish
	Beloniformes	
	Hypsoblennius spp.	Blennies
	Bothidae Type A	Flatfish
*	*Citharichthys* spp.	Sanddabs
	Hippoglossina stomata	Bigmouth sole
	Xystreurys liolepis	Fantail sole
	Icichthys lockingtoni	Medusafish
	Chauliodus macouni	Pacific viperfish
	Gibbonsia sp. A	Kelpfish
	Heterostichus rostratus	Giant kelpfish
	Neoclinus sp. A	Fringehead
	Paraclinus integripinnis	Reef finspot
	Sardinops sagax	Pacific sardine
	Etrumeus teres	Round herring
	Artedius creaseri	Roughcheek sculpin
	Artedius lateralis	Smoothhead sculpin
	Cottidae (unid. types)	Sculpins
	Icelinus quadriseriatus	Yellowchin sculpin
	Leptocottus armatus	Staghorn sculpin
	Scorpaenichthys marmoratus	Cabezon
*	*Symphurus atricauda*	California tonguefish
	Engraulis mordax	Northern anchovy
	Cypselurus californicus	California flyingfish
	Cypselurus heterurus	Blotchwing flyingfish
	Cypselurus spp.	Flyingfish
	Exocoetidae	Flyingfish
	Fodiator acutus	Sharpchin flyingfish
	Gobiesocidae Type A	Clingfish
	Gobiesox maeandricus	Northern clingfish
	Gobiesox rhessodon	California clingfish
	Rimicola muscarum	Kelp clingfish
	Rimicola spp.	Clingfish
	Clevelandia ios	Arrow goby
	Coryphopterus nicholsi	Blackeye goby
	Gillichthys mirabilis	Longjaw mudsucker
	Ilypnus gilberti	Cheekspot goby
	Lepidogobius lepidus	Bay goby
	Lythrypnus dalli	Bluebanded goby
	Lythrypnus zebra	Zebra goby
	Quietula y-cauda	Shadow goby
	Typhlogobius californiensis	Blind goby

Table 5-14. (Cont.)

	TAXON	COMMON NAME
	Cyclothone spp.	Bristlemouth
	Vinciguerria nimbaria	Lightfish
	Xenistius californiensis	Salema
	Hexagrammos decagrammus	Kelp greenling
	Oxylebius pictus	Painted greenling
*	*Halichoeres semicinctus*	Rock wrasse
*	*Oxyjulis californica*	Senorita
	Liparis mucosus	Slimy snailfish
*	*Mugil cephalus*	Striped mullet
	Diaphus theta	California headlightfish
	Diogenichthys atlanticus	Lanternfish
	Lampanyctus ritteri	Broadfin lampfish
	Lampanyctus spp.	Lampfish
	Protomyctophum crockeri	California flashlightfish
	Stenobrachius leucopsarus	Northern lampfish
	Symbolophorus californiensis	California lanternfish
	Tarletonbeania crenularis	Blue lanternfish
	Triphoturus mexicanus	Mexican lampfish
	Brotulid Type A	Brotula
*	*Chilara taylori*	Spotted cusk-eel
*	*Ophidion scrippsae*	Basketweave cusk-eel
	Lestidiops ringens	Slender barracudina
	Lyopsetta exilis	Slender sole
A	*Pleuronichthys coenosus*	C-O turbot
	Chromis punctipinnis	Blacksmith
	Hypsypops rubicunda	Garibaldi
*	*Cheilotrema saturnum*	Black croaker
*	*Genyonemus lineatus*	White croaker
*	*Seriphus politus*	Queenfish
	Cololabis saira	Pacific saury
	Hermosilla azurea	Zebraperch
	Argyropelecus spp.	Hatchetfish
	Sternoptyx spp.	Dollar hatchetfishes
	Stomias atriventer	Dragonfish
*	*Peprilus simillimus*	Pacific butterfish
*	*Synodus lucioceps*	California lizardfish
	Zaniolepis spp.	Combfish
	Unidentified (several types)	

[A] *Pleuronichthys coenosus* larvae were included in the sport and commercial group in the MRC (1980) projections; these larvae occur only infrequently and in small numbers so that misclassification in either analysis should have little effect.

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