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ENVIRONMENTAL TECHNICAL SPECIFICATIONS
Unit 1

CONSTRUCTION MONITORING PROGRAM
Units 2 and 3

PREOPERATIONAL MONITORING PROGRAM
Units 2 and 3

Prepared for

Southern California Edison Company
P.O. Box 800
Rosemead, CA 91770

By

BROWN and CALDWELL
Environmental Sciences Division
150 South Arroyo Parkway
Pasadena, CA 91109

LOCKHEED CENTER for MARINE RESEARCH
6350 Yarrow Drive
Carlsbad, CA 92008

MARINE BIOLOGICAL CONSULTANTS, INC.
947 Newhall Street
Costa Mesa, CA 92627

PROJECT STAFF

SOUTHERN CALIFORNIA EDISON COMPANY

R. S. Grove
B. J. Mechalas
G. L. Richardson
D.A. Rundstrom
T.C. Sciarrotta
A.R. Strachan

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938019

TABLE OF CONTENTS

935020

Page

Page

Page

CHAPTER 6

PLANKTON (Lockheed Center for Marine Research)

CHAPTER 7

A. SANDY INTERTIDAL (Marine Biological Consultants, Inc.)

938023

Page

Page

CHAPTER 11

KELP (Marine Biological Consultants, Inc.)

938027

LIST OF FIGURES

938028

938029

938030

938032

LIST OF TABLES

LIST OF TABLES

938035

LIST OF TABLES

938036

LIST OF APPENDICES

Appendix No.

938037

SUMMARY

INTRODUCTION

This report presents analyses and discussions of oceanographic and marine ecological studies conducted during 1978 for the Southern California Edison Company in the vicinity of San Onofre Nuclear Generating Station (SONGS). Physical, chemical, and biological data were analyzed to characterize the marine environment offshore of SONGS and to evaluate the effects of SONGS on the marine ecosystem.

SONGS is located on the coast of southern California between the cities of San Clemente and Oceanside. San Onofre Unit 1 is a pressurized water nuclear reactor producing 456 MW and utilizing a once-through seawater cooling system with a flow rate of 1,325 m^3/min (350,000 GPM). San Onofre Units 2 and 3 (1,180 MW each) are now under construction and will have once-through cooling systems with flow rates of 3,137 m^3/min (830,000 GPM).

The objectives of these studies are: 1) to assess the effects of the operation of SONGS Unit 1; 2) to determine the effects of the construction of Units 2 and 3; and 3) to provide a baseline for future measurement of the effects of Units 2 and 3 when they become operational.

These studies meet the requirements of the Nuclear Regulatory Commission - Environmental Technical Specifications for Unit 1 and Preoperational Monitoring Program for Units 2 and 3, as well as the California Regional Water Quality Control Board, San Diego Region - NPDES Permit Monitoring for Units 1, 2, and 3 and Construction Monitoring Program for Units 2 and 3. The Environmental Technical Specifications and NPDES Monitoring began in 1975 and 1976, respectively. The Construction Monitoring Program began in 1977 and the Preoperational Monitoring Program began during 1978.

Unit 1 was operational for most of 1978 but was offline for maintenance and refueling for a total of 73 days. Construction of the Unit 2 offshore intake and discharge structures continued during the year reaching approximately 2,130 m (7,000 ft) offshore by the end of the year.

The following general statements can be made from the findings of the 1978 studies examining impacts of Unit 1 operation and construction of Units 2 and 3. These statements and auxiliary findings are detailed in the summary below. In all cases, effects of operation and construction on the marine communities and resources of the San Onofre region were minimal and localized. No adverse effects on the beneficial uses of the receiving waters were detected by these sampling programs. Community and resource fluctuations following natural events such as storms were greater in magnitude than any effects attributed to the generating station. The communities in the study area are adapted to an ever-changing habitat, and their tolerance limits apparently fall well within the magnitude of any plant-induced effects.

TEMPERATURE

Temperature of receiving waters in 1978 was determined bimonthly from vertical temperature profiles, aerial infrared thermal mapping, shoreline temperature measurements, and continuous temperature measurements taken hourly. Results of these studies show:

1. Ambient surface water temperature in 1978 was generally warmer than the 13-year mean from 1965 through 1977 at San Clemente Pier. During 1978, ambient monthly mean temperature as measured at the downcoast control station was 1.5 to 2.4°C warmer than the 13-year mean at San Clemente Pier for months of January through May and September, and was beyond the maximum of monthly mean temperatures at San Clemente Pier for those months during 1965 to 1977.

2. Water temperature and vertical stratification in the study area exhibited natural seasonal trends of summer warming and winter cooling, with minimum stratification during winter months and maximum stratification during summer months.

3. Short-term variations in the natural temperature cycle were observed throughout the year. Natural bottom water temperature fluctuations of as much as 5°C over several hours and natural surface areal differences of 1.4°C over a few thousand feet were measured. Over a period of a day, the surface temperature often varied 1.5°C and occasionally as much as 3°C. Short period cooling and warming trends were especially apparent from May through September.

4. Currents at San Onofre flow primarily alongshore and are composed of tidal and regional circulation components. Currents affected both the shape and size of the thermal field. Greater extent of the 1°F thermal field was observed during periods of maximum current velocities, and when current direction reversed.

5. Winds also effect the extent of the thermal field. A diurnal wind pattern is normally observed at San Onofre, with winds blowing towards shore during the afternoon and away from shore in the early morning. These winds modified the onshore/offshore extent of the thermal field. Surface currents are induced in the general direction of the wind, at San Onofre. Shoreline contact of the 1°F thermal field was observed during periods of onshore winds, and was not observed during periods of offshore winds (Santa Ana wind conditions).

6. Areal extent of the thermal field was typically less during periods of strong natural temperature stratification than during periods when the temperature was uniform with depth.

7. Surface temperatures measured continuously near the discharge (610 m south of the SONGS Unit 1 discharge) were warmer than those measured at the downcoast control station (6,710 m south of the discharge) during cooler months and slightly cooler during warmer months. Surface temperature fluctuations measured near the discharge were slightly greater than those measured at the downcoast control station during late fall and winter months, and are probably related to the cooling water discharge from

SONGS Unit 1. The variation of receiving water temperature due to the generating station was relatively small in summer and similar in winter when compared to the natural variation. Nevertheless, the plant induced variation is additive to the natural variation. All temperture differences noted between measurements taken near the discharge and those taken at the downcoast control station were within the natural variability of temperature reported for the Southern California Bight and vicinity of San Onofre.

8. Seasonal and diurnal variations in intake and discharge temperatures were similar in magnitude and phase to variations in ambient temperatures.

9. During periods of normal plant operation, the discharge temperatures exceeded surface ambient temperatures by 9.3° to 12.9°C. Inplant intake temperatures were warmer than mid-depth ambient temperatures by more than 1.0°C from 16 to 85% of the time during any month with an annual mean of 61%. Offshore intake temperature from profile measurements did not exceed ambient profile temperatures at similar depths by more than 1.0°C during any of the 1978 bimonthly surveys.

10. Bimonthly offshore intake profile data were consistently cooler (0.2 to 1.6°C) than temperatures recorded at the inplant intake thermistor. The amount of recirculation may be less than that which has been assumed in past data analyses.

11. Although the difference between discharge and surface ambient temperatures was greater than input $^*T_0$ by as much as 1.4°C during fall and winter months, there was no evidence of a cumulative increase in di ̣harge temperatures as a result of recirculation.

12. In the offshore study area, stations of minimum surface and mid-depth temperatures were variable with distance offshore. Variability among stations was much smaller for each survey than was found in the inshore area.

13. There was no effect of the SONGS Unit 1 cooling water discharge on the distribution of temperatures in the offshore study area.

TURBIDITY

In compliance with ETS Section 3.1.1.a.(4) and the NRC Preoperational Monitoring Program, turbidity of the receiving waters was monitored by: 1) profiles of light transmittance along a 1 m patch length; 2) concentration of suspended and settleable solids; 3) Secchi disc depth of visibility; and 4) aerial photographs to determine any effects of the discharge upon local water clarity. Results of these studies showed the following:

1. Turbidity decreased with distance offshore. An offshore mean transmittance gradient of 16%/300 m was obtained for the 1978 surveys. Decreasing turbidity with distance offshore is consistent with results of the Unit 1 preoperational surveys (1964 to 1968) of the inshore survey area.

2. A longshore gradient of decreased turbidity with distance downcoast was seen in the inshore survey area, but not in the offshore survey area.

Downcoast rip tide induced turbidity and upcoast current transport of turbidity plumes attributed to this gradient.

3. Turbidity increased with distance below the surface. Transmittance was frequently less than 1% near bottom. Bottom sediments are suspended naturally by tidal currents, waves, and coastal currents. The extent of this turbid bottom layer is dependent on bottom water velocity and on the size and specific gravity of the suspended particles.

4. Increasing turbidity with depth was less pronounced in the offshore survey area (farther than 1850 m offshore).

5. Seasonal trends in turbidity were consistent with previous bimonthly surveys. Turbidity was highest during winter and spring and lowest during the fall. Seasonal variation of turbidity at San Onofre is affected primarily by rainfall, waves, currents, and thermoclines.

6. Highest turbidity of the 1978 surveys occurred during January and March. During each survey all light transmittance measurements were less than 10% and all Secchi disc depths were less than 3 m. Low water clarity was attributed to heavy rainfall and large swells.

7. Natural variability of nearshore turbidity was seen by comparing aerial photographs taken during the May survey and two days later. Turbidity plumes generated by rip tides, surf, and dredging were seen during the survey while none were seen two days after the survey.

8 Conditions such as restriction of vertical stratification by a strong thermocline above the depth of the intake, mild onshore winds, and weak surface currents (less than 15 cm/sec) flowing onshore and upcoast as seen during the July survey, account for low turbidity at San Onofre.

9. High turbidity during the September survey was attributed to the natural vertical stratification of turbidity induced by bottom currents, reversed flow of the Unit 1 cooling system (heat treatment) and the lack of a thermocline.

10 Lowest turbidity of the 1978 surveys occurred during November. In the inshore survey area mean transmittance was 53% at the surface and 36% at the bottom while in the offshore survey area transmittance 70% at the surface and 60% at the bottom. Mean suspended solids concentrations were less than or equal to 1.5 mg/* in the inshore survey area and less than or equal to 0.9 mg/* in the offshore survey area. Mean Secchi disc depths were 7.3 m in the inshore survey area and 13.8 m in the offshore survey area. The lack of heavy rainfall, swells, and dredging attributed to the water clarity. The lack of vertical stratification and dredging indicated that the slight surface turbidity plume noted was the result of entrainment of bottom sediments near the outfall.

WATER QUALITY

Receiving water profile measurements for dissolved oxygen and hydrogen ion concentrations (pH) were recorded bimonthly during 1978. Heavy metals concen-

trations in receiving waters and sediments were collected in March, and bimonthly during the remainder of 1978. Results of the studies show:

1. Dissolved oxygen concentrations during each survey at the intake and discharge stations were within 10% of those taken at the downcoast control station (C22S) and were comparable to values normally found along the southern California coast. Survey means ranged from 7.3 to 8.3 mg/* for all Unit 1 operational (inshore) and offshore monitoring stations during 1978.

2. Surface concentrations of dissolved oxygen at all stations varied among surveys. Surface percent saturation at required inshore and offshore monitoring stations ranged from 89.7 to 114%. Lowest dissolved oxygen concentrations, lowest percent saturation, and least spatial variations were observed during fall and winter months. Highest concentrations, highest percent saturation, and greatest spatial variations were observed during spring and summer months.

3. The cooling water discharge from SONGS Unit 1 or construction on Units 2 and 3 did not significantly affect dissolved oxygen concentrations or surface percent saturation in receiving waters.

4. The pH values obtained during 1978 were all within the specified limits (7.1 to 8.7) and were comparable to values normally found along the southern California coast.

5. Surface pH observed at inshore and offshore monitoring stations ranged from 7.98 to 8.54 during 1978. Surface pH varied at all monitoring stations among surveys. Lowest pH values were observed during fall and winter months, and highest values were observed during spring and summer months.

6. The cooling water discharge from SONGS Unit 1 or construction on Units 2 and 3 did not significantly affect pH of receiving waters.

7. Four years of monitoring concentrations of copper, chromium, nickel, and iron has revealed no apparent patterns of spatial or temporal distribution in the water column or sediment samples.

8. Copper, chromium, and nickel sediment concentrations exhibited no increase in the vicinity of the SONGS Unit 1 discharge (Station X0) throughout the four year study.

9. From May 1977 through November 1978, sediment iron concentrations at the SONGS Unit 1 discharge were consistently higher than at other monitoring stations. The greatest difference of iron concentration between the SONGS Unit 1 discharge and the downcoast control (6600 m south of the discharge) was 2,500 mg/kg during March 1978. However, all observed sediment iron concentrations during the four years of monitoring were less than that reported for coastal waters in southern California (Galloway, 1972).

10. Receiving water and sediment heavy metals concentrations did not significantly increase throughout the four year study.

SEDIMENT MONITORING

The sedimentology in the vicinity of SONGS was investigated as part of the monitoring program related to construction of Units 2 and 3. The parameters examined were sediment physical and chemical characteristics, distributional patterns, and relationships to various environmental processes. The analysis revealed:

Intertidal

1. In general, the beach at San Onofre was steep and veneered with coarse sand except for occasional patches of exposed cobble and rock.

2. Large fluctuations in beach profile configuration between surveys were noted in the construction area and were related to the presence of the laydown pad and trestles.

3. Placement of dredge spoils on the beach downcoast of SONGS laydown pad and trestle altered the textural character of the beach, but did contribute to the high temporal variability in profiles.

Subtidal

1. Sediment analysis identified four texturally unique regions (facies) in the study area. These included a fine sandy facies (A) at 6 m stations that graded seaward into mixed sand-silt facies (B) at the 9 m stations terminating in a silt dominated facies (C) at the 15 m isobath stations. The fourth facies (D) included texturally coarse relict sediments which were confined to 15 m stations downcoast of the Units 2 and 3 centerline.

2. The distribution of these facies appear to be a reflection of the decrease in wave and associated current activity that occurs with increasing depth.

3. The spatial distribution of textural facies appear to reflect natural sedimentary conditions. No influence due to the operation of Unit 1 or construction activities associated with Units 2 and 3 was apparent.

4. No apparent long-term effects on the sedimentary environment have been observed during the study period (1977 to 1978) as a result of dredging or construction activities.

PLANKTON

Five bimonthly plankton surveys were conducted in 1978. The January survey could not be completed because of persistently inclement weather. The second and third ETS surveys were carried out at seven stations along the 10 m depth contour. The combined ETS-PMP plankton studies began with the July survey and continued with the September and November surveys. The combined ETS-PMP sampling program encompassed a more extensive study area including sampling along the 15 and 30 m isobaths. Plankton was sampled from two depth strata during daylight hours using a Lockheed designed pump system. Plankton samples were integrated throughout each depth stratum. Select taxa of zooplankton were identified and

enumerated. Chlorophyll a and phaeopigment concentration were measured from whole-water samples. An analysis of the data and a comparison with 1975 to 1977 results indicated the following:

1. Chlorophyll a concentrations were highest in November and March. The November peak differs from previous years but may represent an autumn phytoplankton bloom. Significant differences in onshore-offshore distribution of chlorophyll a were observed with higher values consistently present at the 10 m stations and decreasing seaward. No consistent pattern of upcoast-downcoast distribution of chlorophyll a was observed.

2. Phaeopigment concentrations showed a similar pattern of spatial and temporal distribution to chlorophyll a. Phaeopigment concentrations were generally lower at the offshore 30 m stations than at the 10 or 15-m stations. No consistent pattern of upcoast-downcoast distribution of phaeopigment was observed.

3. Total zooplankton abundance was lowest in July and highest in September. Zooplankton abundance was significantly greater at the 15 and 30-m stations in July, but well defined onshore-offshore patterns were not present in September or November. No consistent pattern of upcoast-downcoast distribution was observed for total zooplankton abundance.

4. Zooplankton dry weight biomass was lowest in July and highest in September, paralleling the total abundance data. No consistent pattern in either onshore-offshore or upcoast-downcoast distribution was observed for zooplankton biomass.

5. Zooplankton species composition and rank order of abundance for select taxa was similar to that observed in previous studies of 1975-1977. Deviations in 1978 may be attributed to the inclusion of additional stations farther offshore in the combined ETS-PMP studies.

6. Significantly higher values of chlorophyll a, phaeopigments and total zooplankton abundance were observed for the lower depth stratum. No obvious pattern of depth distribution was observed for zooplankton biomass.

7. Significant day to day variation was observed within a survey for each parameter measured except biomass.

8. No patterns of distribution or abundance (or concentration) were observed that could be related to the operation of SONGS Unit 1.

9. The inherent variability within the planktonic community offshore SONGS far exceeds any differences attributable to Unit 1 operations.

INTERTIDAL

Sandy

The results of intertidal sand monitoring in 1978 may be summarized as follows:

1. All analyses showed that each site differed physically and biologically from each other site, despite basic similarities.

2. Changes in the beach profile at sites adjacent to the construction laydown pad and trestles were evident. These changes were probably a direct result of construction activities and the temporary structures associated with them.

3. It is not clear that physical changes resulted in corresponding modifications of the intertidal biota.

4. Species enrichment of the biota within 500 m downcoast of the trestle was evident, but did not appear related to construction activities or Unit 1 operation.

5. Emerita recruitment was highest adjacent to the construction trestle, however reduction in substrate stability at those sites appeared to reduce Emerita post-recruitment survival.

6. Classification analysis showed the underlying similarity of the biota along all five occupied transects, and also pointed out a basic division of the study area into sites upcoast and downcoast of the construction trestles during February.

7. No evidence was found in the annual classification for the existence of a discretely different faunal assemblage at any one transect, in any part of the study area, or during individual quarters.

8. Heavy winter quarter storms had no apparent effect on the intertidal biota.

9. Comparisons with other exposed sandy beaches in the Southern California Bight indicated that the biota at SONGS, while basically similar, differed from that of other areas by the present of Pisione remota and Excirolana kincaidi.

10. The observed physical modifications associated with SONGS construction had no apparent effect on the intertidal biota.

11. Operation of SONGS Unit 1 had no apparent impact on the sandy intertidal biota.

Cobble

Intertidal surveys to sample macroorganisms on cobble substratum were conducted quarterly, weather conditions and tide levels permitting, during 1977 and 1978. Surveys were conducted in February, June, and November 1978 at five stations. No acceptable low tides (lower than -0.6 MLLW) occurred during the third quarter of 1978; therefore, sampling was not conducted. The intertidal data analyzed include the results of the 1977 surveys which had not previously been reported. The 1977 intertidal surveys occurred in February, June, October, and December. The intertidal sampling design was developed to monitor the intertidal area for major changes in biota and substrata attributable and estimation of the abundance of the two most abundant organisms and the amount of sand cover within three 0.25-m^2 permanently located quadrats at each of five stations. Four of

the stations were within the predicted extent of the 1°F thermal plume. A qualitative analysis of the 1977 and 1978 data, and a comparison with previous intertidal studies in the area indicated the following:

1. Comparison of data collected at all cobble stations in 1977 and 1978 surveys with historical data indicated that the most abundant taxa in areal coverage were those that have previously been reported as common in the geographical area and noted in past studies of the stations areas.

2. The observed variability in biotra may be attributable to a variety of factors including natural seasonal differences in abundances of populations due to recruitment, mortality, and/or long term fluctuations in populations.

3. Sand inundation and human intervention, resulting from recreational activities such as intertidal walking, clamming, and surfing, at all stations remained the only directly observable community altering factors in the intertidal cobble quadrats.

4. A review of photographs and station data indicated that new areas of cobble surface were exposed to settlement of organisms, especially during winter months at Station 1 and during summer months at the remianing stations. Wave induced cobble movement, beach slope, fresh water runoff, sedimentation, erosion, size heterogeneity of cobble habitat components, and/or other factors probably contributed to this change in substratum exposure.

5. The Station 1 intertidal cobble area was probably within the +1°F influence of SONGS Unit 1 discharge during 2 May, 4 May, 6 July, and 3 November 1977. No noticeable biotic changes were noted. During 1978, Station 1 was not reported within the +1°F isotherm. The most pronounced biotic change that occurred at this station was apparently related to substratum instability and not to SONGS Unit 1 operation.

6. Stations 2 and 3 were within the +1°F isotherm more frequently than the other stations. Variation in biological factors due to generating station operation was not discernible. The most visible biotic changes that occurred were caused by sand inundation apparently due to natural winter-summer beach processes and possibly to winter storms.

7. Based on data collected, there was no evidence that the operation of SONGS Unit 1 or construction of SONGS Units 2 and 3 caused major changes in the intertidal cobble biota. This is in agreement with previous findings.

BENTHOS

The benthic infaunal community in the vicinity of SONGS was investigated as part of the monitoring program related to construction of Units 2 and 3. The parameters examined were species diversity, abundance, biomass, trophic structure, distribution characteristics, and relationships to various habitat variables. The analysis revealed:

1. Elevated species diversity, numbers of individuals, and biomass at stations upcoast and immediately adjacent to the Unit 1 discharge and the construction areas for Units 2 and 3 discharge and intake structures. These patterns were probably related to SONGS operation and construction.

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1. Elevated species diversity, numbers of individuals, and biomass at stations upcoast and immediately adjacent to the Unit 1 discharge and the construction areas for Units 2 and 3 discharge and intake structures. These patterns were probably related to SONGS operation and construction.

2. Lower species diversity, numbers of individuals, and biomass at stations downcoast and immediately adjacent to the construction areas for Units 2 and 3 discharge and intake structures. These patterns were probably related to SONGS construction activities.

3. Increased species diversity proceeding offshore from the 6 m to the 15 m isobath stations. This patterns was consistent with natural distributions observed by other authors.

4. Numerical dominance of the benthic infaunal community by deposit feeding species.

5. Patterns of enhanced and depressed species numbers in deposit feeders, filter feeders, carnivores, and omnivores which generally parallelled those patterns described for species diversity (1 and 2 above).

6. A general increase in the number of species at all trophic levels throughout the survey year (March through November), which may be part of a multi year cycle.

7. Community modifications at the 15 m isobath stations possibly corresponding to sediment modification by storm activity precceding the March and June surveys.

8. Community distribution patterns characterized by:

   a. Groups of stations whose communities displayed distinct onshore-offshore patterns corresponding to a depth gradient.

   b. Groups of species whose distribution and highest abundances characterized specific isobaths.

   c. Species which were ubiquitous to all areas sampled.

9. An association between depth, sediment composition, water clarity, sedimentation, organic carbon content of sediment, and species distribution patterns. The important factors associated with community distribution patterns were influenced by both natural and construction related activities. It was not possible to separate their relative input.

EPIBENTHIC BIOTA

Diving surveys to sample macroorganisms on cobble substratum were conducted quarterly, weather permitting, at eight inshore cobble stations; five offshore

and ten paired stations located at offshore cobble areas. The objectives of these studies include collection of preoperational baseline data for Units 2 and 3, determination of the operational effects of Unit 1, and assessment of the environmental effects of Units 2 and 3 construction activities. During 1978 unusually heavy rainfall and persistent nearshore storm activity prevented ten stations from being sampled during the second quarterly survey. Nondestructive sampling techniques were employed at each station. The inshore cobble stations and the offshore cobble stations associated with kelp beds were sampled by diver-biologists who identified and enumerated all dominant macroscopic organisms observed within each 1-m^2 area along a 10-m long band transect at each station. The offshore cobble stations were sampled using a point contact method to estimate mean abundances of organisms identified within one 6-m^2 and four 0.125-m^2 areas at each station. A detailed analysis of the 1978 data and a comparison with 1975, 1976, and 1977 results indicated the following:

Inshore 10-m Cobble Habitat

1. Significant terrestrial runoff associated with persistent nearshore storms and abnormally heavy rainfall resulted in rapid and extensive sand inundation of numerous cobble habitats along the inshore (10-m) isobath. Extensive areas of cobble surrounding inshore ETS stations in the area near the discharge and at stations located in the downcoast reference area were completely covered by at least 30 cm of sand.

2. The rapid and extensive burial of inshore cobble resulted in substantial decreases in the total number of taxa sampled compared to previous surveys (1975, 1976, 1977). Additionally, considerable decreases in mean abundance estimates of historically dominant primary producing taxa including *Rhodymenia* spp. and the turf-like growth form of Parvosilvosa were observed on the inshore isobath.

3. Catastrophic burial of numerous cobble habitats resulted in mass mortalities of many saxicolous organisms. For example, mass mortality of the mobile chestnut cowry, *Cyprea spadicea*, was attributed to the extensive and rapid burial of many cobble habitats.

4. No significant ecological effects associated with SONGS Unit 1 operation or construction activities of Units 2 and 3 were detected or suggested at the nearshore cobble stations.

Offshore 14-m Cobble Habitat

1. The sand accretion phenomenon observed at the inshore (10-m) cobble stations was also noted in moderation on the offshore (14-m) isobath.

2. No significant ecological effects associated with construction activities of Units 2 and 3 were detected or suggested at the offshore cobble stations.

Kelp Bed Cobble Habitat

1. Relative stability of the substrata at five offshore areas near San Mateo, San Onofre, and Barn Kelp was evaluated. Results strongly suggest that the San Onofre kelp area is subject to frequent periods of cobble movement and

sand scour, which ultimately affect the composition and constancy of the biological communities in vicinity of the San Onofre kelp bed.

2. Encrusting corraline algae were observed in disproportionately high abundances at San Onofre kelp compared to San Mateo and Barn Kelp stations. The higher abundance estimates at San Onofre Kelp may be attributed to the functional adaptations of crustose coralline algae, which appear to exhibit persistent slow growth and recruitment during periods of exposure, alternated with the ability to withstand sand scour and burial. These adaptations to a relatively unstable and harsh environment may result in a competitive advantage over organisms sensitive to similar environmental perturbations.

3. Age estimates of the colonial anthozoan, Muricea californica, suggested that substrata movement has historically been significantly more dynamic at San Onofre Kelp station compared to San Mateo or Barn Kelp stations.

4. No significant ecological effects associated with the operation of SONGS Unit 1 or construction activities of Unit 2 and 3 were detected or suggested at the offshore kelp stations.

FISH

Integrated gill net and otter trawl sampling was conducted bimonthly during 1978 in March, June, August, October, and December at stations located on the 9 m (30 ft) and 14 m (45 ft) isobaths. Fish collected were identified, enumerated, measured, sexed, and visually inspected for parasites and anomalies.

A detailed analysis of the 1978 data compared with 1975, 1976, and 1977 results indicated the following:

1. Queenfish Seriphus politus, white croaker Genyonemus lineatus, walleye surfperch Hyperprosopon argenteum, and northern anchovy Engraulis mordax were the numerically dominant species sampled by gill nets and otter trawls in 1978.

2. The distribution of the number of individuals among the species (Pielou's evenness coefficient, J') indicated numerical dominance by a few species from March through October followed by an even distribution (individuals apportioned equally among species) in December. Numerical dominance from March through October is attributed to recruitment of juvenile queenfish and white croaker while movement offshore in December results in an even distribution of individuals among the species.

3. Analysis of abundances throughout the overall study area for Seriphus politus, Genyonemus lineatus, and Hyperprosopon argenteum caught in gill nets revealed seasonal increases in abundance from March through August followed by declining abundance from October through December. Phanerodon furcatus abundances are low March through August and high October through December. Increasing embiotocid abundances in December may be attributed to reproductive behavior, while declining sciaenid abundance may result from offshore movement in response to colder water temperatures.

4. Length frequency structure of Seriphus politus and Genyonemus lineatus is bimodal for most of the year. The high incidence of juvenile queenfish

and white croakers from March through October in shallow depths (20 to 40 ft) suggests a period of high recruitment during 1978 and that nearshore depths represent areas for early growth and development for both sciaenids and embiotocids.

5. The recruitment of queenfish and white croaker observed at SONGS was also observed offshore of several other southern California coastal localities based upon other otter trawl studies conducted in 1978.

6. Analysis of sex composition revealed no seasonal trends for Genyonemus, Hyperprosopon or Phanerodon. Female Seriphus were predominant in gill net catches at 9 m throughout the San Onofre region. Otter trawl samples were dominated by juveniles of both sciaenid species throughout most of the year.

7. The estimated 1978 annual impingement for SONGS Unit 1 is 601,193 ± 84,820 individuals weighing an estimated 43,820.77±4,668.37 pounds.

8. The estimated number of fish in 1978 was 2.0, 3.0, and 2.5 times greater than the 1975, 1976, and 1977 impingement catch, respectively. This increased impingement probably resulted from severe storm conditions coupled with recruitment of a large number of juvenile queenfish and white croaker into neretic waters of southern California. The total estimated weight of fish impinged in 1978 was 1.4 to 2.1 times greater than previous years (1975-1977).

9. The average weight per fish has declined from 0.124 lb/fish in 1976 to 0.073 lb/fish in 1978, primarily due to higher percentages of juvenile fish impinged.

10. Sex composition of impinged Seriphus shows a seasonal pattern paralleling the dominance by females in gill net samples collected on the 9 m isobath.

11. Although a large percentage of juvenile queenfish were impinged in SONGS Unit 1 in 1978, it is anticipated that this impingement will not adversely affect queenfish standing stock due to the high fecundity of this species.

12. The fish community offshore does not appear to be adversely affected by the discharge of Unit 1 cooling water; the discharge and intake riser structures may attract certain species of fish.

13. It appears that much of the variability in species composition, abundance, and diversity may be attributable to natural onshore-offshore movements.

14. Although seasonal variability in catch appears less at the SONGS site, fish there generally do not show any marked and unexpected irregularities in these movement patterns.

KELP

Studies of the kelp beds in the San Onofre region were conducted from January 1978 through December 1978. The investigations included: 1) mapping the areal extent of the kelp canopy and associated substrate of the San Mateo, San Onofre, and Barn kelp beds; 2) determination of the general health of the kelp

plants within the three kelp beds; 3) nutrient analysis of the waters adjacent to the three kelp beds; and 4) determination of nitrogen concentrations of kelp leaves from the three kelp beds.

1. Since dredging operations were initiated June 1977 off SONGS, available data suggest that dredge related turbidity or sedimentation has had no detectable effect on maintenance or growth of the San Onofre kelp bed. Data collected in the general area suggest that changes in the area and configuration of the San Onofre kelp bed, as well as the San Mateo and Barn kelp beds, was a response to natural environmental conditions (e.g. storm damage, terrestrial runoff, available nutrients).

2. The major storms that passed through the study area during February and March 1978, and possibly toxicants in associated terrestrial runoff, appear to have had a detrimental affect on the San Mateo and Barn kelp beds. In comparison, no short term effect was observed at the San Onofre kelp bed.

3. Since the initiation of the present monitoring program in December 1976, the area of the San Onofre kelp bed has generally increased, while areas of the San Mateo and Barn kelp bed canopies experienced major declines. The data suggest that environmental factors effecting the growth of kelp plants, (e.g. nutrient regimes, storm related damage, terrestrial runoff and sediment movement) were not equal at the three kelp beds during the course of the investigation.

CHAPTER 1

INTRODUCTION

This report presents analyses and interpretations of the data collected during oceanographic and marine ecological studies studies conducted in 1978 for the Southern California Edison Company in the vicinity of the San Onofre Nuclear Generating Station (SONGS). The data are contained in Volumes I, II, and III of the SONGS 1978 Annual Operating Report. The studies meet the requirements of state and federal regulatory agencies.

The analyses and discussions in this report combined the physical, chemical, and biological information to provide a coherent basis for characterizing the marine envirnnment offshore of SONGS, and for evaluating the effects of SONGS on the marine ecosystem.

PURPOSE OF STUDIES

The purpose of these studies is: 1) to assess the effects of the operation of SONGS Unit 1; 2) to assess the effects of the construction of Units 2 and 3; and 3) to provide a baseline for future assessment of the effects of Units 2 and 3 when they become operational.

REGULATORY REQUIREMENTS

The following regulatory agency requirements are being satisfied by these studies:

- Nuclear Regulatory Commission - San Onofre Nuclear Generating Station, Unit 1, Environmental Technical Specifications, Docket No. 50-206, Section 3.1 Nonradiological Survelliance. Section 4 Special Surveillance and Study Activities
- Nuclear Regulatory Commission - San Onofre Nuclear Generating Station, Units 2 and 3, Precperational Monitoring Program, dated 31 May 1978
- California Regional Water Quality Control Board, San Diego Region - NPDES Permit No. CA0001228 for San Onofre Nuclear Generating Station Unit 1. Monitoring and Reporting Program No. 76-11, Section A, Fish Entrainment Monitoring and Section D, Receiving Water and Sediment Monitoring
- California Regional Water Quality Control Board, San Diego Region - NPDES Permit No. CA0003395 for San Onofre Nuclear Generating Station, Units 2 and 3, Monitoring and Reporting Program No. 76-21, Section D, Receiving Water and Sediment Monitoring
- California Regional Water Quality Control Board, San Diego Region - Monitoring Reporting Program No. 71-6 for Construction of San Onofre Nuclear Generating Station, Units 2 and 3, including Technical Change Orders 1, 2, and 3

Table 1-1 shows the data collection schedule for 1978 and indicates the regulatory agency requirements were fulfilled by each sampling task.

DESCRIPTION OF THE STUDY AREA

The San Onofre Nuclear Generating Station is located on the California coast at 33° 22.5'N and 117° 32.5'W between the cites of San Clemente and

Table 1-1. Data collection schedule for 1978.

	Unit 1 Environmental Technical Specifications	Units 1, 2, and 3 NPDES Permits	Units 2 and 3 Construction Monitoring Program	Units 2 and 3 Preoperational Monitoring Program	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oceanographic Surveys																
Temperature Vertical Profiles	X	X		X	18		7		4[a]		10		13		16	
Aerial Infrared Radiometry	X	X					7		4,11[b]		10		13			
Surface Temperature Mapping	X	X			18		7		4,11[b]		10		13		[illegible]	
Shoreline Temperature	X	X			18		7		4,11[b]		10		13		16	
Continuous Temperature Maintenance	X			X	9	7,28		4,13	2	1	6	10[a]	12	10,20	15	14
Turbidity Vertical Profiles	X	X		X	18		7		4[a]		10		13		16	
Secchi Disc Visibility	X	X		X	18		7		4[a]		10		13		16	
Suspended and Settleable Solids											10		13		16	
Aerial Photographs of Turbidity	X						7		4,6		10		13		16	
Currents											9-10		12-13		15-16	
Heavy Metals	X	X		X			23		2[a]		12		12		15	
Dissolved Oxygen	X	X		X	18		7		4[a]		10		1[illegible]		16	
Hydrogen Ion Concentration	X	X		X	18		7		4[a]		10		13		16	
Biological Surveys																
Plankton	X	X		X	*		7		11		14-20[a]		8-10		16-18	
Intertidal																
Sand			X			22-23			25-26			16-17			15-16	
Cobble						6				23					29	
Subtidal																
Sand			X				20-24			5-7			18-20		20-22	
Cobble	X	X				1*			10-25		14 →	25		16-26		
				X								2-9a		31 →	8	
Kelp Bed Macrobiota			X				*	11		8			22		27	
Fish																
Receiving Waters	X	X		X	*		30,31			14,15[a]		15,16		11,12		12,13
Impingement																
Normal Operation	X	X			W	W	W	W	W	W	W	W	W	W	W	W
Heat Treatments	X	X				12		2	17	24		20	13			3
Kelp Bed Mapping			X				14,16,18			3,7,9			10,13,14			6,10,12
Nutrient Analysis			X		4	15	6	4	9	13	11	15	12	10	16	5

* Task not completed because of inclement weather or insufficient underwater visibility.
[a] Units 2 and 3 Preoperational Monitoring Program sampling initiated.
[b] Survey attempted on 4 May, not completed due to weather conditions.
W = Weekly.

Oceanside (Figure 1-1). The study area extends approximately 6.4 km (4 mi) upcoast (NW), 11.5 km (7 mi) downcoast (SE), and 3.3 km (2 mi) offshore from the generating station site. This is an exposed coastal area of the Pacific Ocean identified on hydrographic charts as the Gulf of Santa Catalina.

DESCRIPTION OF THE GENERATING STATION

San Onofre Unit 1 is an electrical generating facility utilizing a pressurized water nuclear reactor which began commercial operation in 1968. San Onofre Unit 1 is a base load plant and is normally operated at full capacity. Gross electrical output of Unit 1 is 456 MW.

A once-through cooling system is used to cool the steam condensers. As shown in Figure 1-2, seawater is drawn from a point 975 m (3,200 ft) offshore, located

Location of intake and discharge structures for SONGS Units 1, 2, and 3.

in approximately 8.2 m (27 ft) of water. The offshore intake structure is fitted with a velocity cap which draws water horizontally from a depth of 4-5 m and is designed to reduce the entrapment of marine organisms. After passage through the condensers, the cooling water travels through a discharge conduit which

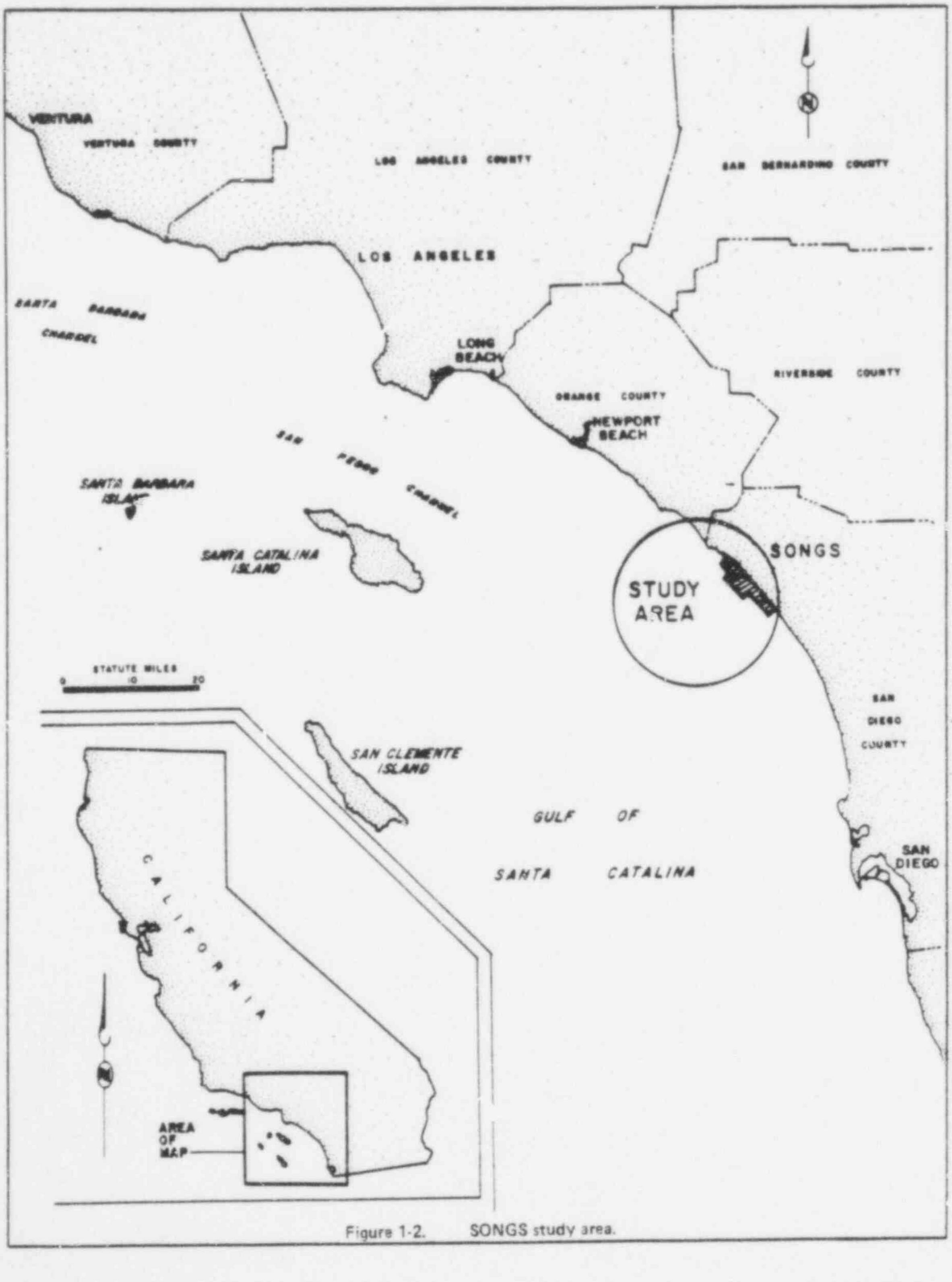

Figure 1-2. SONGS study area.

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terminates in a vertical discharge structure, 792 m (2,600 ft) offshore in approximately 7.3 m (24 ft) of water. The discharge results in a surface-oriented thermal plume. Under normal operating conditions, the temperature of the cooling water is raised approximately 10°C (18°F) across the condensers at a flow rate of 1,325 m^3/min (350,000 gpm).

Inside Unit 1 is a screenwell which contains two sets of traveling screens and bar racks to remove debris and entrapped marine organisms from the cooling water before it reaches the pumps and steam condensers. Marine fouling growth in the cooling water system is controlled through periodic heat treatments which are typically conducted at intervals of from six to ten weeks. During heat treatments the temperature of the cooling water in the screenwell is raised to approximately 100°F for 1.75 hr. At this time, all of the fish within the screenwell which have avoided impingement on the traveling screens during normal operation are killed by the higher temperature and removed from the system.

San Onofre Units 2 and 3 are under construction and are scheduled to begin operation in 1981 and 1983 respectively. Each of the new Units will have an electrical output of 1,180 MW. The once through cooling system for each unit will have a flow rate of 3,137 m^3/min (830,000 gpm) and a normal operational temperature increase of 10.6°C (19 . .). As seen in Figure 1-2, the intakes will be located 1,040 m (3,400 ft) offshore in 9 m (30 ft) of water. Both units will have diffuser type discharges consisting of 63 ports spread over a distance of 762 m (2,500 ft). The Unit 2 discharge diffuser will extend from 1,828 m (6,000 ft) to 2,590 m (8,500 ft) offshore, ranging in depth from 12 m (39 ft) to 15 m (49 ft). The Unit 3 discharge diffuser will extend from 1,127 m (3,700 ft) to 1,840 m (6,200 ft) offshore and range in depth fro 10 m (32 ft) to 11.5 m (38 ft).

BACKGROUND INFORMATION

A general discussion of studies conducted at SONGS for the Southern California Edison Company is included here to provide historical perspective to the ongoing programs.

Oceanographic and marine biological studies, referred to as the Marine Environmental Monitoring (MEM), began in 1963 in the San Onofre area and were reported on a semiannual basis to the California Regional Water Quality Control Board. San Diego Region (CRWQCB) until 1975. In 1975, the Unit 1 Environmental Technical Specification (ETS) program was implemented in compliance with Nuclear Regulatory Commission requirements. The ETS program has continued to the present. In 1976, the CRWQCB issued permits for SONGS Units 1, 2, and 3 under the National Pollutant Discharge Elimination System (NPDES) which included marine monitoring programs to replace previous MEM requirements. The NPDES marine monitoring programs, which are similar to the ETS program, have continued to the present.

Studies of the effects of SONGS Units 2 and 3 construction were initiated in 1974 as required by the CRWQCB. These studies focused on the impacts of sand disposal onto the beach from onshore construction site excavations. These studies, called the Sand Disposal Monitoring Program, continued through 1976. The emphasis shifted in 1977 when dredging for the emplacement of the offshore portions of Units 2 and 3 cooling systems began. Studies focused on the offshore construction activities started in December 1976, as set forth in the CRWQCB order No. 71-6, Technical Change No. 2. These studies are referred to as the Construction Monitoring Program and have continued to the present.

In 1978, a Preoperational Monitoring Program (PMP) was initiated in compliance with requirements of the Nuclear Regulatory Commission. This Program along with the others metioned above, will provide a baseline of oceanographic and marine biological data prior to the operation of Units 2 and 3. The Pre-

operational Monitoring Program is complementary to the Unit 1 ETS Program and essentially expands the study area further offshore into the area of Units 2 and 3 diffusers. The PMP did not start at the beginning of the 1978 calendar year; consequently, the data included in this report are from less than a full year of studies. For this reason, these data were insufficient to assess seasonal cycles, nor could certain statistical methods be properly applied. However, the data are presented and discussed, within the appropriate limitations of the data set, to aid in meeting the various study objectives.

The Preoperational Monitoring Program has a requirement for a special study of ichthyoplankton in the San Onofre area. This study has been initiated and sampling will be completed during 1979. Both the data and results of this study will be reported in next year's Annual Operating Report, along with the rest of the 1979 data.

SCOPE AND ORGANIZATION OF THE REPORT

Volumes I, II, and III of the San Onofre, 1978 Annual Operating report were data reports containing the detailed results of the 1978 sampling. Volume I presented the physical-chemical oceanographic data from the Unit 1 ETS program, Units 2 and 3 Preoperational Monitoring Program, and NPDES monitoring. Volume II presented the biological data of those same programs. Volume III presented the biological and sedimentological data from the Construction Monitoring Program.

This report, Volume IV, includes the results of analyses of these data and a discussion of how the results relate to the objectives of the studies. In the sequence, the chapters address oceanographic, geological, and finally the biological elements of the ecosystem. Each chapter contains an introduction which outlines the scope of the work, discusses pertinent background information, briefly describes the methods, presents the results and analyses, and discusses the significance of the findings relative to the study objectives.

GENERATING STATION ACTIVITIES IN 1978

San Onofre Nuclear Generating Station, Unit 1 operational characteristics for 1978 are presented in Figure 1-3. The station was off-line for maintenance

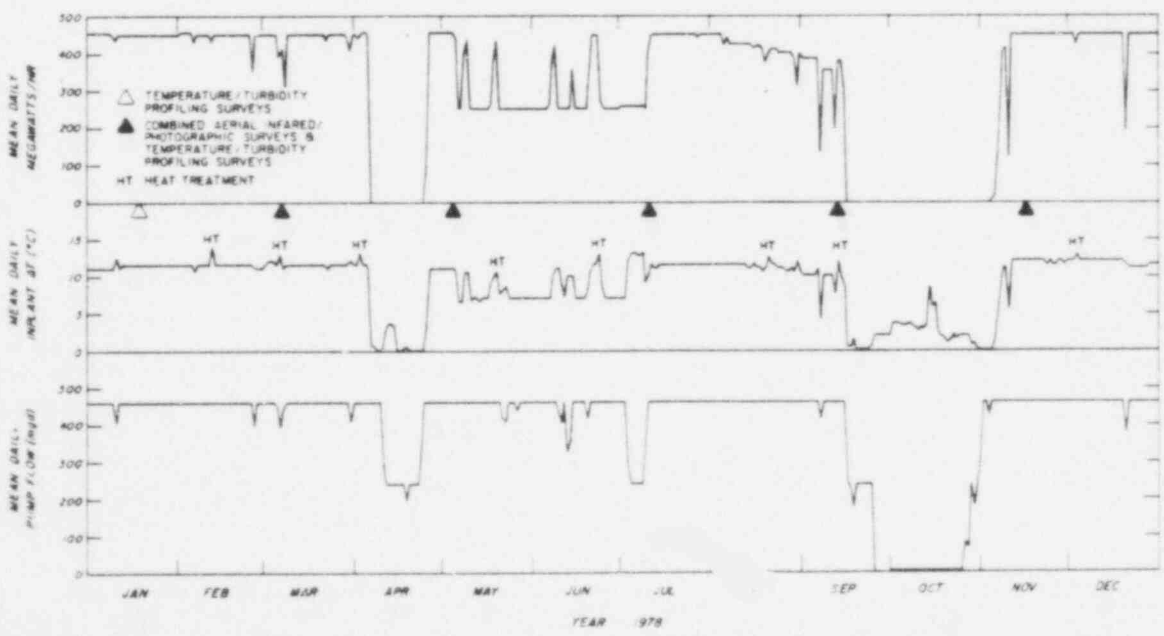

Figure 1-3. SONGS Unit 1 operating characteristics during 1978.

during April 5-25, and for overhaul and refueling between September 15 and November 5. A detailed monthly log of station operation is found in Volume II of the 1978 Annual Operating Report.

Construction of the Unit 2 offshore intake and discharge structures continued during 1978, reaching about 2,130 m (7,000 ft) offshore by the end of the year. A description of the amount and location of dredge spoil placement is included in Chapter 5 of this report.

CHAPTER 2

TEMPERATURE

INTRODUCTION

This chapter contains a discussion of temperature data which were presented in Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data Report - 1978 (BC, 1979).

The objectives of the Environmental Technical Specifications (ETS) Temperature Monitoring program for SONGS Unit 1 were to: 1) document large scale temperature variations within the survey area; 2) determine the horizontal and vertical extent of the thermal plume; 3) determine the area of influence of the surface thermal plume; 4) document daily variations in surface, mid-depth, and near bottom temperatures in the vicinity of the discharge and at a location outside the influence of the discharge; and 5) estimate the extent of recirculation of discharged waters back into the cooling water flow. The objective of the temperature monitoring phase of the Preoperational Environmental Monitoring Program (PEM) for Units 2 and 3 was to provide a receiving water temperature baseline for determination of the extent and significance of the thermal discharge from Units 2 and 3 once operations begin.

BACKGROUND

Unit 1 preoperational water temperature studies began in 1963. From 1964 to 1968, 32 hydrographic stations were surveyed bimonthly. From 1968 to the present, temperature studies of various Unit 1 operating conditions were conducted and have been routinely recorded in semiannual and annual oceanographic reports, copies of which are on file.

Unit 1 operational bimonthly oceanographic surveys were continued at 51 monitoring stations from January through April 1978 in compliance with NRC's ETS Monitoring Program. In May 1978, 23 additional stations were added to the study area to fulfill requirements of the Preoperational Monitoring Program for Units 2 and 3. The location of oceanographic monitoring stations at San Onofre are shown in Figure 2-1.

Beginning in May 1978, infrared flights were conducted during each bimonthly survey in order to measure the horizontal extent of the elevated temperature field. Surface temperature distribution was also determined by direct contact temperature measurements from survey vessels, scheduled to coincide with the aerial infrared flights. Shoreline temperatures were measured bimonthly at 11 shoreline stations to aid in determining whether or not the elevated temperature field came in contact with the shoreline.

Continuous temperature measurements provide documentation of daily temperature variations. Endeco Type 109 recording thermographs are operating at three depths at two stations (Station C2S, located 610 m south of the SONGS Unit 1 discharge, and downcoast control Station C22S, located 6710 m south of the Unit 1 discharge), to continuously measure water temperature at surface, mid-depth, and bottom. Beginning in August 1978, continuous temperature sensors were installed at four depths at Station F2S.

Intake and discharge temperatured were recorded using thermocouples within the intake and discharge conduits at the tsunami wall at San Onofre Unit 1.

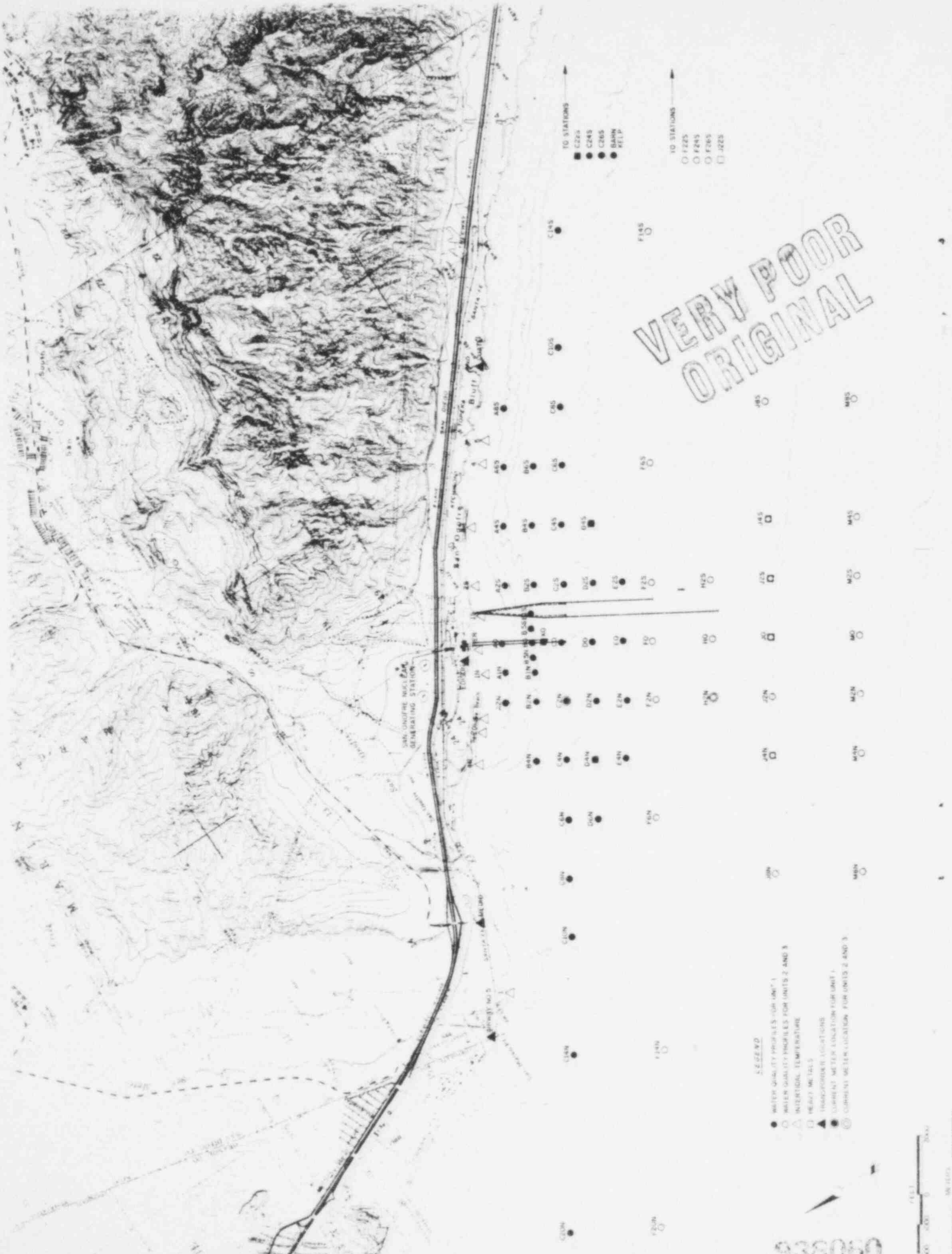

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Figure 2-1. Location and identification of sampling stations.

These data were used to compare inplant intake and discharge temperature data with ambient temperatures measured by the continuous temperature sensors at downcoast control Station C22S.

METHODS

Methods for the vertical temperature profiles, aerial infrared radiometer thermal mapping, survey vessel thermal dispersion runs, intertidal temperature measurements, continuous temperature measurements, and intake and discharge temperature measurements are presented in Chapter 2 of Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979). Measurements of water currents and wind were also made beginning in July 1978 to aid in the interpretation of the horizontal extent of the thermal field. Methods of these measurements are presented in this section. Vector plots of current and wind speed and direction, with predicted tide height, are shown in Appendices A-3 through A-5.

CURRENTS

Current measurements were taken at 1 m and 7.5 m of depth at Station H0 on 9 and 10 July 1978, at 1 m at Stations C2N and H2N on 12 and 13 September 1978, and at 1 m at Stations C2N and H0 on 15 and 16 November 1978 using EG&G Model CT/3 electromagnetic current meters. The EG&G meters are self-contained, in situ recording instruments which orient themselves in the direction of the current flow by means of a large vane. Speed is detected using electromagnetic sensors. Direction is referenced to magnetic north by means of a flux gate compass. An internal program controlled by a crystal clock governs the rate of data recorded on a magnetic cassette tape recorder.

The meters have an accuracy of ±0.015 m/sec in the speed range of 0.03 to 3.0 m/sec and a directional accuracy of ±5 degrees. The three meters were programmed to record every 6 sec over a 2-min period at 15 min intervals.

Current meter data recorded on magnetic cassette tapes were processed using a minicomputer. Oscillatory wave motion was filtered out and vectors were averaged to produce values of current speed and direction.

WIND

Wind speed and direction data were recorded by Dames and Moore, the meteorological consultants for Southern California Edison at San Onofre (DM, 1978). Data were recorded at a meteorological tower located on the bluff just north of SONGS Unit 1. The wind sensor was located approximately 34 m above the sea surface.

RESULTS

Results of bimonthly survey temperature monitoring, aerial infrared thermal mapping, shoreline temperature measurements, continuous temperature measurements, and comparisons of intake, discharge, and ambient temperature measurements were reported in Chapters 3, 4, and 5 of Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979).

Water temperature followed a natural temperature cycle with warmer summer temperatures and cooler winter temperatures. Water temperature was relatively

isothermal with depth during winter. Warming of surface waters in the spring produced natural temperature stratification. The resultant thermocline increased in depth and intensity as solar radiation and atmospheric warming increased during the summer months. The water column returned to isothermal conditions in fall to complete the annual cycle.

Short-term variations in the natural temperature cycle were observed throughout the year. Natural bottom water temperature fluctuations of as much as 5°C over several hours and natural surface areal differences of 1.4°C over a few thousand feet were measured during 1978. Over a period of a day, the surface temperatures often varied 1.5°C and occasionally as much as 3°C (BC, 1979).

DISCUSSION

WATER TEMPERATURE DISTRIBUTION

Changes in water temperature over the study area at the surface, 4 m, and bottom are summarized in Appendix A-1 for each bimonthly survey in 1978. Appendix A-1 presents the minimum and maximum temperatures, the station at which each extreme occurred, and the mean temperature and standard deviation of all stations including the discharge and the control stations. Four meters (4 m) was chosen as representative of mid-depth for the entire study area to avoid introducing a bias due to differences in depth at each station. When interpreting bottom temperatures for the entire study area, station depth must be considered because of the natural decrease in temperature with depth, especially during summer months.

Mean surface, 4 m depth, and bottom temperatures for the SONGS Unit 1 operational (inshore) study area followed a seasonal pattern, with coolest mean temperatures occurring in January and warmest mean temperatures in September. Stations with minimum surface temperatures varied between surveys. Minimum surface temperatures were observed at stations within 610 m of the shore (A-line and B-line) during winter months, and 1,210 m offshore (D-line) during the remaining months. Upcoast/ downcoast distribution of surface temperature distribution was also variable. Maximum surface temperatures during all surveys except November were observed at the Unit 1 cooling discharge (Station X0). During November, maximum surface temperature was observed immediately inshore of the discharge (Station B0). Mid-depth maximum and minimum temperatures followed patterns similar to those exhibited by surface temperatures. Minimum bottom temperatures were observed at stations farther offshore (E-line), and maximum bottom temperatures were observed at stations closest to shore (A-line). Bottom temperature extremes were most influenced by depth of bottom at each station: warmer bottom temperatures were observed at shallower inshore stations due to solar warming, conduction of heat from land, and vigorous mixing with warmer surface waters due to wave action, while cooler bottom temperatures were observed at deeper stations.

The smallest variability in surface temperature among stations, as indicated by the standard deviations in Appendix A-1, occurred during November. The highest variability among stations was observed during March.

In the SONGS Units 2 and 3 pre-operational (offshore) study area, stations of minimum surface and mid-depth (4 m) temperatures were variable with distance offshore. All minimum temperatures were reported for stations upcoast of the discharge. Minimum bottom temperatures were reported for the stations 4000 m offshore (M-line), due mainly to greater depth of bottom (30 to 40 m) along this line. Maximum temperatures at surface, mid-depth, and bottom nearly always

occurred at stations 2000 m offshore (F-line) downcoast of the discharge. A natural offshore temperature gradient, with temperature increasing with distance offshore, is present in nearshore waters. This natural gradient occurs due to solar warming, conduction of heat from land, and turbulent mixing at shallower depths. Maximum temperatures were found most frequently at stations furthest inshore due to this natural phenomenon. Maximum bottom temperatures were observed at stations 2000 m offshore (F-line) at 12 m depth. The small absolute temperature difference between maximum and minimum surface and mid-depth (usually less than 1°C over the survey area during each survey) indicates less spatial variation of temperatures with distance offshore. Variability among offshore stations, as indicated by the standard deviation, was much smaller for each survey than that among inshore stations.

Natural water temperature at San Onofre exhibited seasonal fluctuations. Figure 2-2 shows the variations in daily mean natural surface temperature recorded at continuous temperature monitoring Station C22S. Also shown are monthly means calculated from daily (0800 hrs) readings taken from continuous temperature records at Station C22S, referred to as natural surface temperature. These results are compared to monthly mean surface temperture calculated from daily readings (0800 hrs) taken at San Clemente Pier from 1965 through 1977, as well as the ranges of these readings during this period (Robinson, 1977). Data from San Clemente Pier are used for comparison because they represent one of the longest continuous records of natural temperature close to San Onofre. Monthly mean natural surface temperature from data collected at Station C22S were never more than 0.8°C higher than those reported for San Clemente Pier during 1977, and were generally within 0.5°C, indicating that temperatures recorded for both stations do not differ significantly (Robinson, 1977; BC, 1978).

The natural surface temperature during early spring of 1978 was warmer than the 1965 to 1977 mean and exceeded the range of temperatures reported for the same 13-year period. During 1978, natural surface temperature increased from a mean of 15.9°C in January to 17.5°C in May, which was from 1.5 to 2.4°C warmer than the 13-year mean temperature. During June through August, natural temperature increased to 20.2°C, and was near normal for that time of the year, differing from the 13-year mean by -0.1 to 0.4°C. The maximum monthly mean temperature (20.9°C) occurred during September and was 1.9°C warmer than the mean and outside the range of values reported for the previous 13 years. Mean temperatures decreased during the remaining months of 1978 to 16.0°C in December, and were lower than the 13 year mean by 0.5°C in December.

A t-test comparing the monthly mean calculated for 1978 with the mean of monthly means for 1965 through 1977, showed that temperatures during 1978 were significantly different from the 13-year mean ($P<0.05$) in January, March, and September. During the remaining nine months of 1978, temperature differences were not statistically significant.

The mean and standard deviation of surface temperatures from temperature profiles sampled during bimonthly surveys are also shown in Figure 2-2. Data collected during bimonthly surveys were representative of natural conditions present during each survey period.

Variations in 4 m depth temperatures for the inshore study area were smaller than those observed at the surface due to the limited influence of the discharge on temperature at that depth. Variations in bottom temperatures for the study area were much greater during summer surveys than during winter surveys. This was due to the presence of a natural thermocline during the summer as compared to isothermal conditions during winter. As the tide height changed, bottom temperature sensors were alternately exposed to warm water from above the thermocline and cold water from below the thermocline.

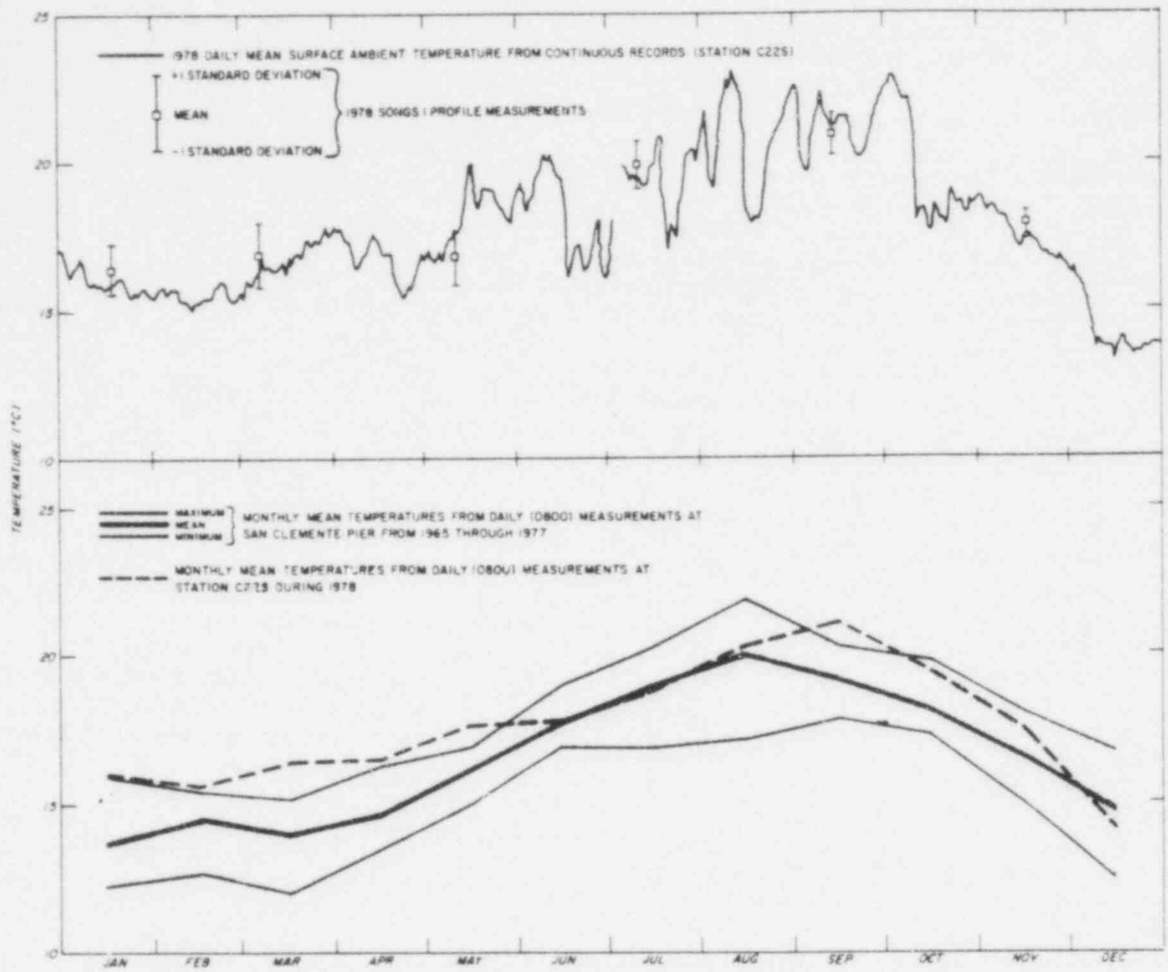

Figure 2-2. Variations in daily mean natural surface temperature from continuous temperature measurements and 1978 composite profile data.

The spatial distribution of temperature observed during 1978 at the surface, 4 m, and bottom is further characterized in Appendix A-2. In the inshore study area, coolest temperatures at the surface and 4 m were observed most frequently during January and March. Coolest bottom temperatures were most frequently observed at stations within 610 m of the shore line (A-line and B-line) during January and March, and from 900 m to 1,800 m offshore (C-line through F-line) during July, when a well developed thermocline was present. Warmest temperatures were observed during September at all stations and at all dpeths. Warmest absolute temperatures were recorded at inshore stations (A-line and B-line) and at stations closest to the discharge. Mean temperatures at all depths along the B-line and C-line north of the discharge were slightly higher than those south of the discharge. This is due to currents observed during bimonthly surveys. Near-shore currents in the vicinity of SONGS are related primarily to diurnal tidal fluctuations, and net current direction is variable throughout the year. During bimonthly surveys, currents were observed most frequently flowing upcoast, and consequently elevated temperatures were observed at stations north of the discharge more frequently than at stations south of the discharge.

The spatial distribution of temperature in the offshore study area was more homogeneous than in the inshore study area. Coolest surface and 4 m temperatures were observed during May at all stations. Coolest bottom temperatures were observed during July at all stations. The cooler bottom temperatures observed

during July were related to the natural stratification present during July. During winter months, waters are nearly isothermal, and free mixing occurs throughout the entire water column. Solar and atmospheric heating of surface waters is therefore mixed to deeper bottom layers. During summer months a thermocline is usually present which restricts mixing of surface and bottom waters. Solar and atmospheric heating of surface waters is therefore restricted to the surface layer above the thermocline, and bottom waters remain cool. Warmest surface, 4m, and bottom water temperatures were observed during September at nearly all stations. The deepening of the thermocline which had occurred by September allowed mixing of warm surface waters to greater depths, and warmer temperatures were observed throughout the water column.

HORIZONTAL EXTENT OF THE THERMAL FIELD

The horizontal extent of the thermal field from SONGS Unit 1 is presented in Table 2-1 along with a summary of generating station operating conditions, wind speed and direction, and air temperature. Areal extent of the thermal field was determined from 1°F and 4°F isotherms. The extents of the 1°F and 4°F elevated fields were determined so that they may be compared with previous studies which defined extents of 1 and 4°F elevated temperature fields. Figures 2-3 and 2-4 present composites of the 1°F and 4°F thermal fields as measured during the bimonthly surveys. The circled fraction in each environmental surveillance zone indicates the number of times any portion of the thermal field was present in that zone. Care must be used when interpreting these data because the thermal field was not measured the same number of times during each survey, and the 1°F elevated temperature field may have been observed only in a small portion of some of the zones. Receiving water parameters which influence the horizontal extent of the thermal field include generating station plant load and inplant ΔT (the temperature rise across the cooling water condenser), temperature stratification, currents, and surface heat transfer (air temperature and wind) (IAEA, 1974).

Generating station plant load varied among survey periods between 450 MW (100% capacity) during November and 250 MW (56% capacity) during May (Table 2-1). Inplant ΔT is a parameter which can greatly affect the size and distribution of the elevated temperature field. Inplant ΔT was proportional to plant lo~d

Table 2-1. Characteristics of the 1°F and 4°F elevated temperature fields.

Date	Time[a]	Tidal Height (ft)	Wind Speed (knots)	Wind Dir. (°T)	Air Temp (°F)	Plant Load MW	Plant Load ΔT(°F)	Natural Surface Temp (°F)	Thermal Field Area[b] (acres) 4°F	Thermal Field Area[b] (acres) 1°F	Thermal Field Horizontal Extent (meters)[c] 4°F UC	4°F DC	4°F IS	4°F OS	1°F UC	1°F DC	1°F IS	1°F OS
Mar 7	1300-1550	-1.0	9.5	300	62.8	410	20.5	62.2±0.4	<1	430	30	90	20	20	140	3500	120	120
May 11	1031-1218	+1.9	6.1	225	62.6	250	12.2	64.2±0.4	<1	200	20	20	20	20	1580	90	750[d]	150
	1323-1510	+3.2	7.0	270	63.5	250	12.2	64.9±0.2	2	380	50	30	60	50	1770[e]	100	750[d]	300
Jul 10	1000-1100	+2.6	6.3	250	63.0	400	20.2	67.3±0.4	2	220	70	70	50	30	1620[e]	220	750[d]	170
Sep 13	1017-1112	+3.3	3.6	188	66.9	380	22.7	68.9±0.4	46	400	270	120	400	250	1310	270	750[d]	610
	1305-1405	+1.6	4.0	241	67.2	380	25.3	68.9±0.4	3	300	40	20	120	20	950	160	750[d]	470
Nov 16	0841-0926	+6.0	3.9	279	59.2	450	21.4	63.1±0.4	30	800	580	60	180	30	1080	2300	580	720
	1157-1241	+2.8	7.3	263	60.3	450	21.2	63.7±0.2	4	890	70	60	100	120	1330	810	750[d]	1200
	1519-1554	-0.2	5.1	278	60.6	450	21.3	63.7±0.4	90	1300	150	630	220	300	1460[e]	2440[e]	750[d]	820

KEY: UC = upcoast DC = downcoast IS = inshore OS = offshore

a March and November 1978 in PST; May, July, and September 1978 in PDT.
b Surface area enclosed by the 4°F and 1°F elevated temperature field.
c Extent along the sea surface of the 4°F and 1°F temperature contours as measured from the point of discharge (XO).
d Thermal field came in contact with the shoreline.
e A portion of the 1°F field extends beyond the limits of the study area.

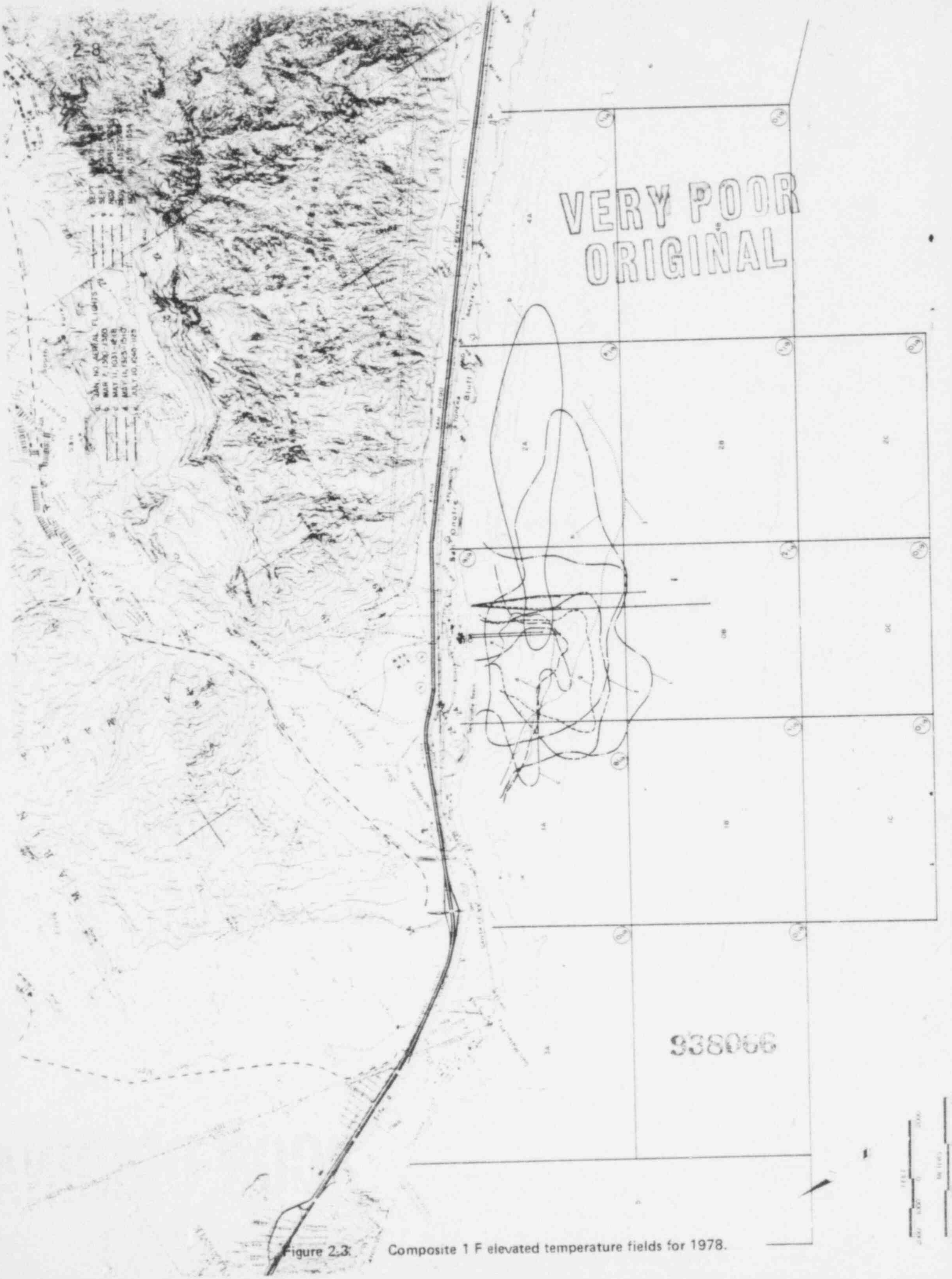

Figure 2.3. Composite 1 F elevated temperature fields for 1978.

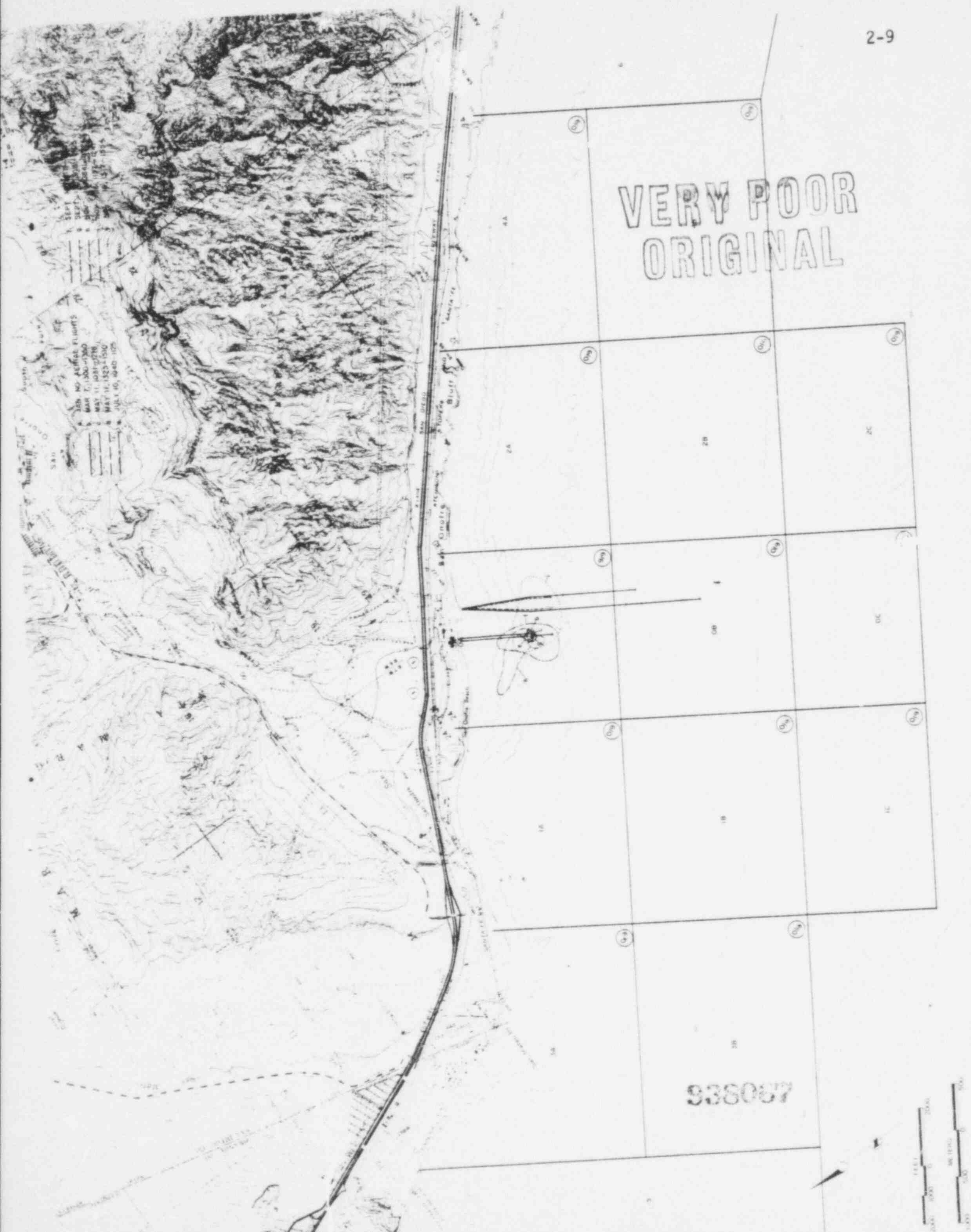

Figure 2.4. Composite 4F elevated temperature fields for 1978.

during each survey except 13 September. During September the generating station was undergoing heat treatment of the intake conduit to remove fouling organisms, and inplant ΔT was 1 to 4°C higher than had been observed during other bimonthly surveys.

Areal extent of the 1°F and 4°F elevated temperature fields was greatest during the 16 November survey when plant load was 100% and inplant ΔT was 21.2°F. The 1°F field covered from 800 to 1300 acres, and the 4°F field covered from 4 to 90 acres. Areal extent of the 1°F elevated temperature field during the remaining surveys was smaller in proportion to lesser plant load except for the 10 July survey. During the 10 July survey, areal extent of the 1°F elevated temperature field was 220 acres, less than would be expected in comparison to the other surveys for a plant load of 89% (400 MW) and inplant ΔT of 20.2°F. However, the areal extent of the thermal field is typically less during periods of strong natural temperature stratification than when the temperature is uniform with depth. When stratification occurs, bottom waters entrained into the intake structure are cooler than surface waters. Similarily, cooler bottom waters entrained by the discharge during periods of stratification decreases the discharge temperature significantly by the time the discharge reaches the surface. Discharged cooling water is therefore cooler relative to surface receiving water when a thermocline is present than that which occurs when water column temperatures are isothermal. A strong thermocline was present during the 10 July survey at or slightly at or above the depth of the discharge. The smaller areal extent of the thermal plume during July was due to this thermal stratification. No thermocline was present during the remaining surveys. The log of the areal extent of the 1°F and 4°F elevated temperature fields was plotted with the difference between surface and bottom water temperature, and with the temperature gradient (°C/m) between surface and bottom, surface and mid-depth, and mid-depth and bottom. Data were used from all surveys that were conducted from 1969 to 1978 when plant operating load was 420 to 450 MW. The data was subjected to a least squares analysis. The results of these analyses indicated that an inverse correlation existed between areal extent of the thermal field and thermal stratification, but the results were not statistically significant. Indices of correlation (r) ranged from about -0.1 to -0.3, where -1.0 indicates a perfect inverse correlation.

Environmental surveillance zones in which the thermal field was observed are also shown in Figures 2-3 and 2-4. The 1°F elevated temperature field was observed at least once in environmental surveillance Zones 0A, 1A, 2A, 3A, 0B, 1B, and 2B. The 4°F elevated temperature field was never observed outside of the environmental surveillance Zone 0A.

The 1°F elevated temperature field was observed in contact with the shoreline during all of the 1978 surveys except during the 7 March survey and the first aerial infrared radiometer flight on 16 November. The 1°F elevated temperature field did not extend into the offshore study area. The 4°F elevated temperature field did not contact the shoreline during any of the 1978 surveys.

Currents. Currents affect both the shape and size of the thermal field. Current direction in the nearshore region at San Onofre is mainly a function of tide, with the main current components alternating in the upcoast/downcoast direction. Currents also show a downcoast regional transport from the California current during most times of the year (Koh and List, 1974). Data collected by the Marine Review Committee (MRC) at San Onofre show that mean upcoast and downcoast currents appear to rapidly reverse directions at times with a periodicity of several days to two weeks. Current speed is also a function of season, with maximum southward transport and velocities occurring during summer months and minimum during winter months (January and February) coinciding with the Davidson Current (Koh & List, 1974; Parkhurst, et al, 1964; Jones, 1971). Beginning in

July, currents were measured at SONGS during a 36-hour period prior to, and during each bimonthly survey. Results of current measurements are presented as current vectors in Appendix A. Wind vectors and predicted tide are also plotted in Appendix A. Results of current measurements agree with current data collected at San Onofre by MRC during the survey dates.

Upcoast and downcoast extents of the 1°F temperature field correlated well with currents. The maximum upcoast extent of the 1°F elevated temperature field occurred during periods of strongest upcoast currents, and maximum downcoast extent occurred during periods of strongest downcoast currents. The maximum area of the 1°F field was observed on 16 November after a period of moderately strong upcoast currents immediately followed by moderately strong downcoast currents.

Wind. Wind is another important factor which influences the distribution of the elevated temperature field. Wind blowing across the sea surface induces surface currents to the right of the wind stress, at angles which may range from 15 degrees in shallow waters (Kirwan, et al., 1979) to 45 degrees in very deep waters (McClellan, 1965), at speeds averaging 2% of the total wind speed. This motion is transferred to successively deeper layers with decreasing speeds. The depth of influence of wind-induced currents depends upon the duration of the wind and the stability of the water column. When no thermocline is present and waters are isothermal with depth, wind induced currents are coupled with the entire water column, and must therefore move a larger volume of water. When a thermocline is present, surface waters are decoupled from those below, and wind induced currents affect only the surface layer above the thermocline. Wind-induced currents, which are superimposed on tidal currents, usually have a strong diurnal component in response to local wind patterns (Jones, 1971). At San Onofre, winds usually blow onshore during the afternoon and offshore during early morning. During Santa Ana wind conditions, winds blow offshore during the morning, afternoon, and evening hours. Parkhurst, et al. (1964) observed that wind is the factor which predominantly influenced current direction above the thermocline, although it did not significantly affect current speeds.

Wind modified the onshore/offshore extent of the elevated temperature fields. Onshore winds which occurred during most surveys pushed surface waters onshore, and may have induced shoreline contact of the 1°F elevated temperature field. Offshore winds (Santa Ana conditions) were observed during the November survey. During the November survey, offshore winds greater than 5 m/sec moved surface waters offshore prior to the first aerial infrared measurement of the elevated temperature field, and shoreline contact of the elevated temperature field was not observed. Wind data also indicates that Santa Ana conditions may have been present during the March survey. This was the only other instance where shoreline contact of the 1°F elevated temperature field was not observed.

VERTICAL EXTENT OF THE THERMAL FIELD

The vertical extent of the thermal field is best illustrated by the vertical temperature profiles (Figure A-1 to A-6) and vertical isometric cross-sections (Figures A-7 to A-12) in Appendix A of Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979).

The vertical cross-sections perpendicular to shore along the 0-line of stations provide the best representation of the influence of the thermal discharge on water temperature in the immediate vicinity of the discharge, because the cross-section includes actual temperature measurements made at the discharge. The cross-sections parallel to shore along the B-line and C-line of stations illustrate the depth of influence of the thermal field just inshore and just offshore of the thermal discharge.

The vertical cross-sections parallel and perpendicular to shore show the elevated temperature field as a warm water lens immersed in the surface of a cooler body of water. Average depth of the 1°F thermal field during the 1978 bimonthly surveys was about 4 m at stations within 150 m of the outfall and about 3 m at stations within 300 m of the outfall. The results of the 1978 surveys are similar to historical results of surveys offshore of the generating station.

Frequency of occurrence of surface area enclosed by the 1°F and 4°F elevated temperature contours is shown in Figure 2-5. Data includes measurements of areas reported from 1969 to 1977 (EQA/MBC, 1973; LAS, 1976a; LAS, 1976b; BC, 1977; BC, 1978), as well as data collected during 1978. To prepare this figure, values of surface area for each field were ranked in descending order of magnitude. Data for this analysis only includes areas measured while the generating station was operating at full megawatt capacity (420-450 MW) to prevent biasing of data due to plant load. An occurrence frequency was then assigned to each value, where:

$$\text{Frequency (percent)} = \frac{\text{Rank Number}}{\text{Total Number} + 1} \times 100$$

Data were plotted with surface area on a logarithmic scale versus a linear scale for percent frequency of occurrence.

It is important to note that this figure is not meant to be used as a predictive tool, but rather indicates what the thermal field conditions were during the surveys. For example, it may be said that the 1°F elevated temperature field was enclosed within an area of less than 1000 acres 80 percent of the time for which measurements were made. Additionally, this type of analysis should be viewed with caution since the choice of a natural background reference temperature can significantly alter the magnitude of the computed elevated temperature field area. For instance, EQA/MBC (1973) reported that a +0.3°C correction in the chosen natural surface temperature changed the computed 4°F elevated temperature from 159 acres to 40 acres.

CONTINUOUS TEMPERATURES

Continuous temperature data from Stations C2S and C22S were subjected to a filter analysis to separate the actual temperature records into period components of fluctuations. Hourly data were analyzed by power specturm calculated by a fast fourier transform based on Cooley and Tukey's algorithm (Blackman and Tukey, 1958). Since temperature records were discontinuous at the beginning and end of the records, data for spectral analysis were subjected to a Kaiser-Bessel window to force continuity at end points and prevent masking of low frequency spectral densities (Harris, 1976). Further discussion of this type of analysis is provided by Jenkins and Watts (1968). Using the results of spectral analysis, continuous temperature records were filtered into frequency bands of periods less than eight days (to represent short term, i.e., diurnal fluctuations), periods between eight and sixty days (to represent regional variations common to the SONGS study area), and periods greater than sixty days (to represent seasonal fluctuations). Therefore T, the actual temperature, can be written as: $T = T_l + T_m + T_h$, where T_l is the low frequency component (periods greater than 60 days), T_m is the mid-frequency component (periods between 8 and 60 days), and T_h is the high frequency component (periods less than 8 days). Each of the four temperature components (T, T_l, T_m, and T_h) were plotted versus time in days for SONGS 1 continuous temperature Stations C2S and C22S at the surface, mid-depth (4 m), and bottom (Appendix A).

For clarity, curves representing T_l, T_m, and T_h have been displaced +10°C, -10°C, and -20°C, respectively. Data from Station F2S, the continuous temperature station for the offshore study area were not submitted to filter analysis because the temperature record was complete for only the latter portion of 1978.

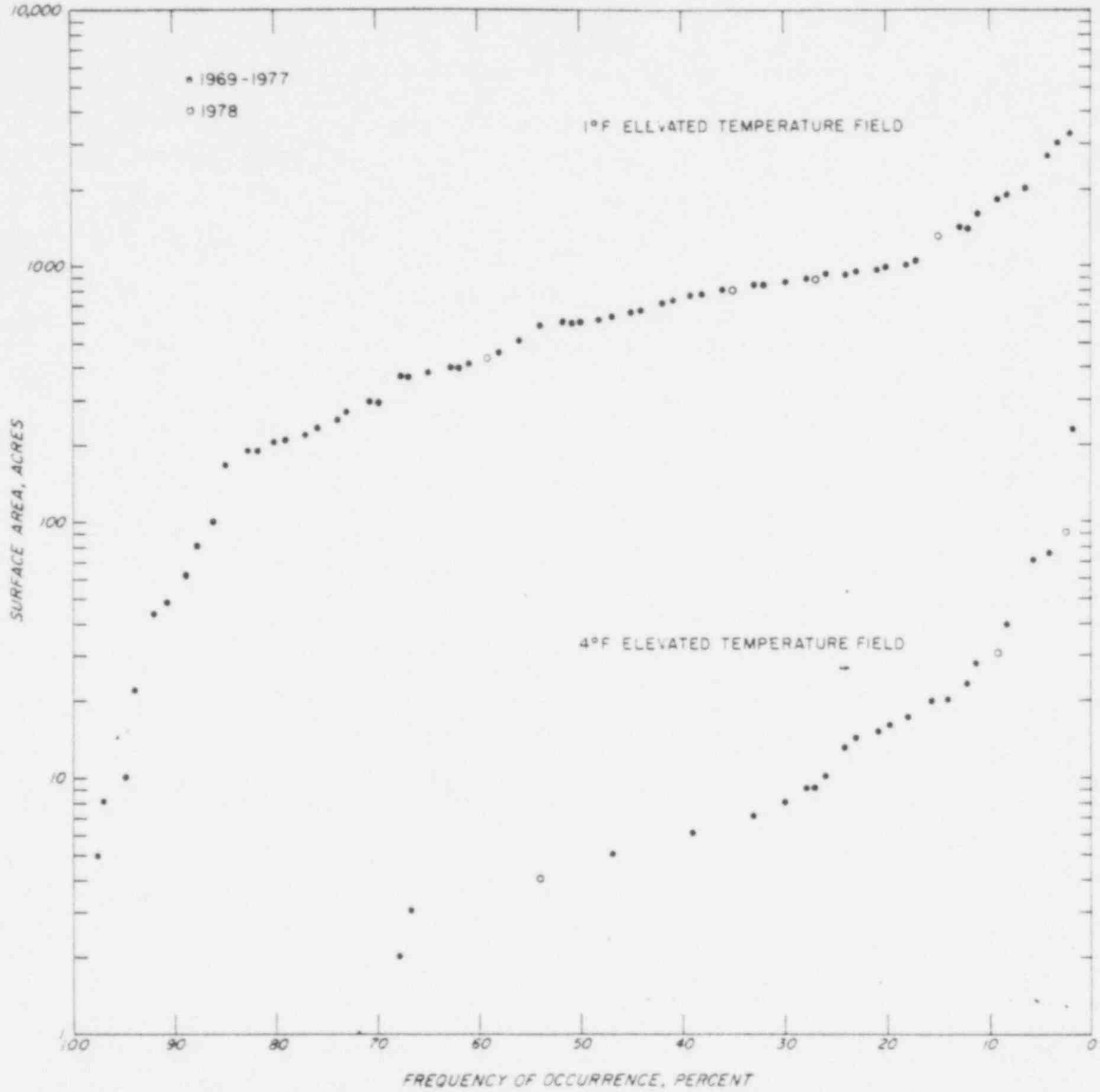

Figure 2-5. Frequency with which observed areas of the 1° and 4° F elevated temperature fields were equaled or exceeded, 1969 through 1978.

Low frequency components of continuous temperature show seasonal trends of summer warming and winter cooling. The low frequency component shows that surface temperature at Station C2S was slightly warmer than at Station C22S during cooler months (January through May, and November through December), and slightly cooler during warmer months. The difference, however, was less than 1°C during the entire year. The warmer surface temperatures observed at Station C2S during cooler months may be due to effects of the thermal discharge from SONGS 1. During January through March, and November through December, slightly negative or no thermal stratification was observed.

SONGS 1 entrains subsurface waters by turbulent mixing, and due to the lack of thermal stratification during winter, the heat input from the discharge could elevate surface temperatures 1°F or greater above surface ambient at Station C2S. The largest areas of the 1°F thermal field were observed during winter months, as discussed earlier in this chapter, and extended as far as Station C2S during both

the March and November aerial infrared surveys. In contrast, during warmer months, a thermocline is generally well developed. A temperature difference of up to 5°C between surface and bottom was present at both Stations C2S and C22S during warmer months, and was most pronounced from June through September. The thermocline was at or near the depth of the discharge. Entrainment of subsurface waters during these months produced surface temperatures equal to or slightly cooler than ambient at Station C2S, thereby lowering that station's seasonal average temperature.

Mid frequency components were well correlated between Stations C2S and C22S, and highest correlation occurred with no time lag between stations. These results indicate that the temperature response at both stations was a function of the same factors (storms, Santa Ana winds, solar irradiance, etc.), rather than transport mechanisms. The mid frequency curves showed periodic temperature fluctuations (oscillations) of less than 1°C at all depths during winter months, and of 2 to 3°C during summer months. Temperature fluctuations during cooler months were slightly greater at the surface than at mid-depth and bottom. Temperature fluctuations during the warmer months were greater at mid-depth and bottom than at the surface.

The high frequency component of temperature shows variations on the order of 1 to 2°C during winter and late fall months, and 1 to 5°C during summer months. Surface temperature fluctuations were greater at Station C2S than at Station C22S during winter and late fall months. At downcoast control Station C22S, larger daily fluctuations in ambient surface temperature ranged from 1°C during winter to 4°C during summer. At Station C2S, near the SONGS Unit 1 cooling water discharge, larger daily fluctuations in surface temperature ranged from 2°C during winter to 5°C during summer. Temperatures in the thermal plume from Unit 1 were approximately 1°C above ambient. Therefore, the variation of receiving water surface temperature due to the generating station was relatively small in summer and greater in winter when compared to natural variations. Nevertheless, plant induced variations are additive to natural variations.

Daily standard deviations of surface temperature at Station C2S during winter and late fall months ranged from 0.1 to 0.7°C, and averaged 0.3°C. Daily standard deviations of surface temperature at Station C22S during the same period ranged from 0.1 to 0.5°C, and averaged 0.2°C. The greater fluctuations at Station C2S were related to the cooling water discharge from SONGS 1. Reversing current direction, primarily a function of tides, and mainly in the upcoast/downcoast component, may have alternately exposed the temperature sensor at Station C2S to the thermal plume from the SONGS 1 discharge and cooler ambient surface waters, accounting for the higher variability. Mid-depth and bottom temperatures at Station C2S remained virtually unaffected by the thermal plume, as reflected in the similarity of high frequency records for both stations at these depths.

All temperature differences noted between Stations C2S and C22S were within the natural limits of variability of temperatures in the Southern California Bight and the vicinity of San Onofre (Koh & List, 1975; Winant, 1974).

INTAKE, DISCHARGE, AND AMBIENT TEMPERATURE COMPARISON

Data for intake, discharge, and ambient temperature comparison were measured hourly during 1978 to determine the increase in discharge temperature as compared to reference ocean ambient temperature and to estimate the extent to which heated water is recirculated back into the intake of the circulating water system. Data used as the basis for these comparisons was taken from Southern California Edison's inplant intake and discharge thermistor data and from Station C22S

surface and mid-depth continuous temperature data as presented in Chapter 5, Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979).

Intake, discharge, and ambient temperature comparison trends for 1978 were similar to those observed during previous years. Normal seasonal warming and cooling trends were observed for intake and ocean ambient surface and mid-depth temperatures. Discharge temperatures varied in relation to intake temperature and plant operation. Ambient, intake, and discharge temperatures exhibited seasonal warming and cooling periods. These relatively shorter period natural cooling and warming trends ranged in duration from less than a day to approximately two weeks. Ambient temperatures varied as much as 4°C in two days during some of these periods. Short period cooling and warming trends were especially apparent from May through September.

Diurnal variations in intake and discharge temperatures were similar in magnitude and phase to diurnal variations in ambient temperature. These diurnal variations were relatively small during winter months and larger during summer months. Intake and discharge temperatures were more variable than ambient temperatures.

A visual comparison of vertical temperature profiles taken at the discharge (XO) and at the downcoast control station (C22S) is presented in Figure 2-6 for each bimonthly survey. Figure 2-6 presents inplant intake (A), inplant discharge (B), and the difference between intake and discharge (ΔT_O) temperatures as measured during the profile period. This figure also depicts the temperature difference between profiles which is attributed to the cooling water discharge (C_D).

Due to the surface turbulence created by the discharge plume, it is nearly impossible for the profiling sensor to measure bottom temperature at the point of discharge. The profiles do, however, illustrate the capacity of the receiving waters to dilute the heated effluent. The increase in surface temperature, as a result of the thermal discharge, represents only a fraction of the total amount of heat entering the receiving waters at the point of discharge.

During periods of normal plant operation, the discharge temperatures exceeded surface ambient temperatures by 9.3 to 12.9°C, while inplant ΔT_O temperatures were approximately 11.5°C. The difference between discharge and surface ambient temperatures was greater than the inplant ΔT_O by as much as 1.4°C during fall and winter months. These data suggest possible recirculation of heated discharge water back into the intake. However, there was no evidence of a cumulative increase discharge temperature (relative to ocean ambient temperatures) as a result of recirculation during 1978.

Due to the combined uncertainty introduced by temperature measurements and the natural variations in ocean ambient temperature with time and space, it is difficult to accurately determine the extent of recirculation based on this type of temperature comparison. The determination is particularly difficult when the temperature differences observed are less than the accuracy of the temperature sensors and the natural variations in ambient temperature. Nevertheless, a qualified estimate of possible occurrences of recirculation may be determined by analyzing differences between intake and natural temperatures.

Inplant intake temperatures were cooler than surface ambient temperatures during the warmer months, May through September, when natural water column stratification was present and warmer during cooler months when stratification was reduced or absent. Inplant intake temperatures were warmer than mid-depth ambient temperatures, taken at a similar depth to the intake structure, during each month for 1978.

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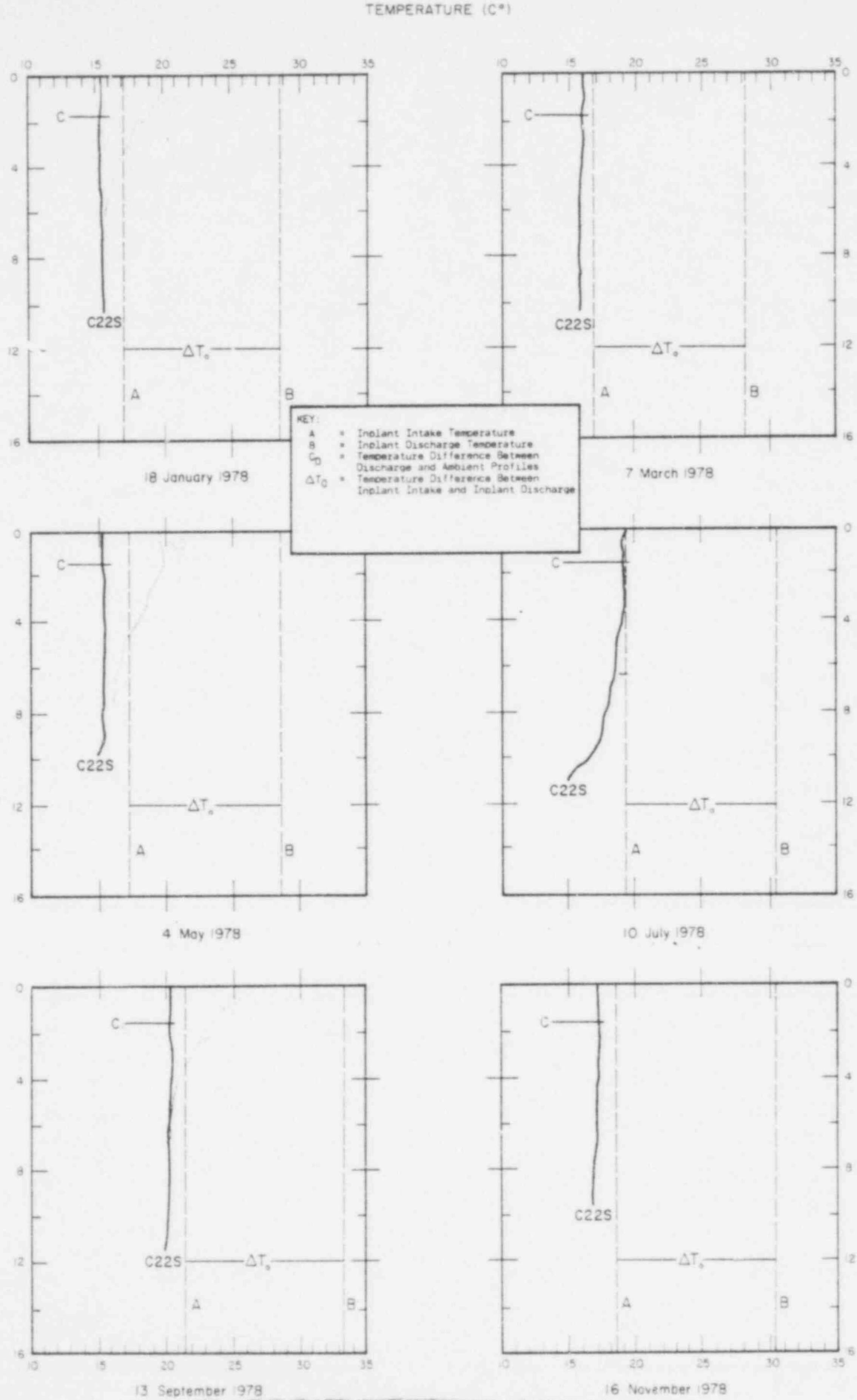

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Figure 2-6. Offshore discharge versus ambient profile comparison.

Table 2-2 presents receiving water temperature at the depth of the intake at Stations CO (intake) and C22S (6,710 m south of the intake), and inplant intake and discharge temperatures measured during each of the bimonthly surveys. A graphical representation of these data is presented in Figure 2-7 where:

A = Inplant intake temperature
B = Inplant discharge temperature
C_I = Temperature difference between offshore intake and ambient profiles
D = Depth of the intake structure
ΔT_0 = Temperature difference between inplant intake and inplant discharge
ΔT_1 = Temperature difference between offshore intake and ambient
ΔT_2 = Temperature difference between offshore intake and inplant intake

Recirculation is assumed to occur when inplant intake temperatures exceed ambient temperatures by greater than 1.0°C.

Inplant intake temperatures were warmer than mid-depth ambient temperatures by more than 1.0°C from 16% to 85% of the time during the month in 1978, with an annual mean of 61%. During five of the six bimonthly surveys, inplant intake exceeded ambient by 1.0°C or greater.

The temperatures recorded at the intake thermistor at the tsunami wall were consistently warmer than those measured offshore at the intake structure during the same period. Although there are insufficient data to adequately determine the cause of these differences, the consistency of occurrence raises doubt as to the validity of using inplant intake data for the purpose of accurately determining recirculation.

During the September survey, inplant intake temperature exceeded ambient by 1.3°C, indicating the presence of some recirculation. The offshore intake temperature during September however, was the same as ambient temperature at that depth. During November the inplant intake temperature was warmer than the temperature measured offshore at the intake structure (Station CO) from surface to bottom.

The bimonthly offshore intake profile data were consistenty cooler than the temperature recorded at the inplant intake thermistor, and the amount of recirculation may actually be less than that which has been assumed in past data analyses.

Temperatures from the offshore intake profiles exceeded ambient measurements during only three of the six survey periods, and never by more than 0.8°C.

Table 2-2. Comparison of inplant intake and discharge temperatures with offshore intake and ambient temperature profiles.

Survey Date	Offshore Intake Temp [a] (°C)	Ambient Temp [b] (°C)	Inplant Temp (°C) Intake	Inplant Temp (°C) Discharge	Offshore Intake Minus Ambient	Inplant Intake Minus Ambient	Inplant Intake Minus Offshore Intake	Inplant Discharge Minus Inplant Intake
Jan 18	16.1	16.0	17.2	28.8	+0.1	+1.2	+1.1	+11.6
Mar 7	16.7	15.9	16.9	28.3	+0.8	+1.0	+0.2	+11.4
May 4	16.7	16.2	17.7	28.9	+0.5	+1.5	+1.0	+11.2
Jul 10	17.7	18.6	19.3	30.5	-0.9	+0.7	+1.6	+11.2
Sep 13	20.3	20.3	21.6	33.3	0.0	+1.3	+1.3	+11.7
Nov 16	17.3	17.4	18.6	30.4	-0.1	+1.2	+1.3	+11.8

[a] Receiving water temperature at intake depth at Station CO.
[b] Receiving water temperature at intake depth at Station C22S.

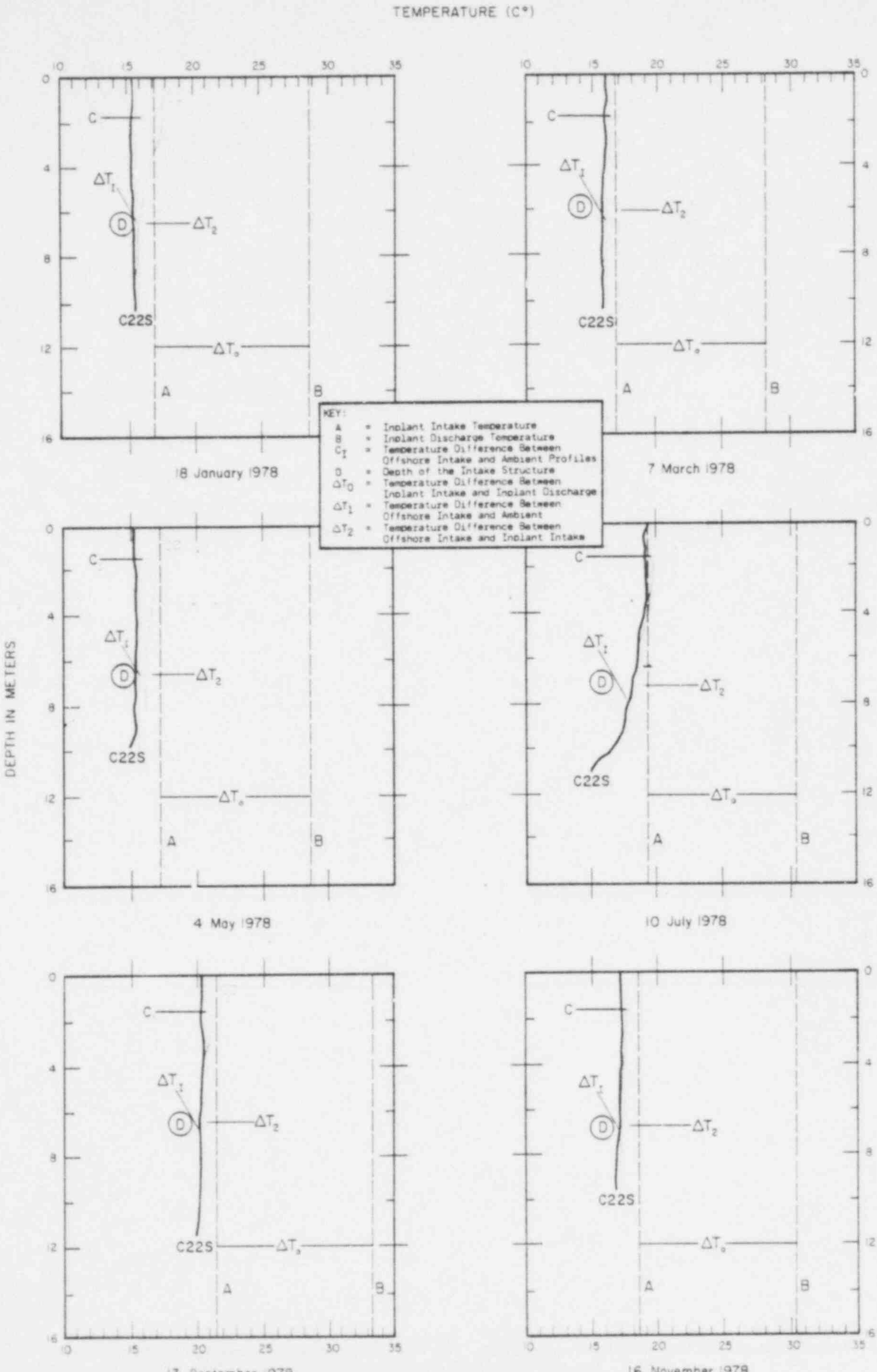

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Figure 2-7. Offshore intake versus ambient profile comparison.

Offshore intake temperature profile measurements did not exceed ambient profile temperatures by more than 1.0°C during any of the 1978 bimonthly surveys.

SUMMARY

Temperature of receiving waters in 1978 was determined bimonthly from vertical temperature profiles, aerial infrared thermal mapping, shoreline temperature measurements, and continuous temperature measurements taken hourly. Results of these studies show:

1. Ambient surface water temperature in 1978 was generally warmer than the 13-year mean from 1965 through 1977 at San Clemente Pier. During 1978, ambient monthly mean temperature as measured at the downcoast control station was 1.5 to 2.4°C warmer than the 13-year mean at San Clemente Pier for months of January through May and September, and was beyond the maximum of monthly mean temperatures at San Clemente Pier for those months during 1965 to 1977.

2. Water temperature and vertical stratification in the study area exhibited natural seasonal trends of summer warming and winter cooling, with minimum stratification during winter months and maximum stratification during summer months.

3. Short-term variations in the natural temperature cycle were observed throughout the year. Natural bottom water temperature fluctuations of as much as 5°C over several hours and natural surface areal differences of 1.4°C over a few thousand feet were measured. Over a period of a day, the surface temperature often varied 1.5°C and occasionally as much as 3°C. Short period cooling and warming trends were especially apparent from May through September.

4. Currents at San Onofre flow primarily alongshore and are composed of tidal and regional circulation components. Currents affected both the shape and size of the thermal field. Greater extent of the 1°F thermal field was observed during periods of maximum current velocities, and when current direction reversed.

5. Winds also effect the extent of the thermal field. A diurnal wind pattern is normally observed at San Onofre, with winds blowing towards shore during the afternoon and away from shore in the early morning. These winds modified the onshore/offshore extent of the thermal field. Surface currents are induced in the general direction of the wind, at San Onofre. Shoreline contact of the 1°F thermal field was observed during periods of onshore winds, and was not observed during periods of offshore winds (Santa Ana wind conditions).

6. Areal extent of the thermal field was typically less during periods of strong natural temperature stratification than during periods when the temperature was uniform with depth.

7. Surface temperatures measured continuously near the discharge (610 m south of the SONGS Unit 1 discharge) were warmer than those measured at the downcoast control station (6,710 m south of the discharge) during cooler months and slightly cooler during warmer months. Surface temperture fluctuations measured near the discharge were slightly greater than those measured at the downcoast control station during late fall and winter months, and are probably related to the cooling water discharge from SONGS Unit 1. The variation of receiving water temperature due to the

generating station was relatively small in summer and similar in winter when compared to the natural variation. Nevertheless, the plant induced variation is additive to the natural variation. All temperature differences noted between measurements taken near the discharge and those taken at the down-coast control station were with.. the natural variability of temperature reported for the Southern California Bight and vicinity of San Onofre.

8. Seasonal and diurnal variations in intake and discharge temperatures were similar in magnitude and phase to variations in ambient temperatures.

9. During periods of normal plant operation, the discharge temperatures exceeded surface ambient temperatures by 9.3° to 12.9°C. Inplant intake temperatures were warmer than mid-depth ambient temperatures by more than 1.0°C from 16 to 85% of the time during any month with an annual mean of 61%. Offshore intake temperature from profile measurements did not exceed ambient profile temperatures at similar depths by more than 1.0°C during any of the 1978 bimonthly surveys.

10. Bimonthly offshore intake profile data were consistently cooler (0.2 to 1.6°C) than temperatures recorded at the inplant intake thermistor. The amount of recirculation may be less than that which has been assumed in past data analyses.

11. Although the difference between discharge and surface ambient temperatures was greater than input ΔT_0 by as much as 1.4°C during fall and winter months, there was no evidence of a cumulative increase in discharge temperatures as a result of recirculation.

12. In the offshore study area, stations of minmum surface and mid-depth tempertures were variable with distance offshore. Variability among stations was much smaller for each survey than was found in the inshore area.

13. There was no effect of the SONGS Unit 1 cooling water discharge on the distribution of temperatures in the offshore study area.

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CHAPTER 3
TURBIDITY

INTRODUCTION

This chapter contains a synopsis and discussion of turbidity monitoring data which were presented in Chapter 6 of Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data Report - 1978 (BC, 1979).

Turbidity was measured in the SONGS Unit 1 receiving waters in compliance with ETS Section 3.1.1.a.(4) and NPDES Permit No. CA0001228 (CRWQCB, SDR Order No. 76-11). Turbidity study objectives are to monitor suspended solids in terms of turbidity in the receiving waters near SONGS Unit 1 in order to determine any effect of the discharge upon water clarity. The objective of preoperational turbidity monitoring is to provide a receiving water baseline for water clarity and turbidity for the determination of the extent and significance of the potential turbid discharge effects of Units 2 and 3.

BACKGROUND

The Unit 1 intake structure is oriented vertically and extends approximately 3 m above the ocean bottom, and is fitted with a velocity cap to produce a horizontal flow of water entering the intake. Therefore, the generating station intakes water from the area approximately 1000 m offshore (8 m of water, MLLW) 3 to 4 m above the ocean floor (and to a lesser extent from waters above and below this depth), which is often more turbid than surface waters. After passing through steam condensers this water is discharged vertically through a discharge structure located approximately 800 m offshore in 7 m of water (MLLW). Under normal operating conditions, this vertically discharged seawater is initially about 11 to 12°C warmer than the intake water.

For the purpose of this study, the period between May 1964 and December 1968 constitutes the SONGS Unit 1 preoperational phase of oceanographic monitoring. Unit 1 operational bimonthly oceanographic surveys were conducted at 32 monitoring stations from 1968 through 1974. The ETS monitoring program began in 1975 and included bimonthly measurements of light transmittance and Secchi disc depths of visibility at 34 stations and quarterly aerial photographs. The program was expanded in 1976 to include 51 sampling stations and remained as such through 1977. The frequency of monitoring by aerial photographs was increased to bimonthly in March 1978. During May 1978, turbidity studies were expanded to include 23 additional sampling stations in order to compile a data base as part of the Preoperational Monitoring Program for SONGS Units 2 and 3. This data base will be used to assess the effects of SONGS Units 2 and 3 during their operation. In July 1978 the monitoring program was expanded to include sampling of suspended and settleable solids.

METHODS

A detailed description of methods used in monitoring the nearshore turbidity at the San Onofre Generating Station is presented in Chapter 2 of Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979). A summary of these methods is presented in this section.

TRANSMITTANCE

Vertical profiles of light transmittance were made with a Martek XMS Transmissometer. Transmissivity profiles were obtained by plotting percent transmittance versus depth for each sampling station. Horizontal isopleth contour maps of surface and mid-depth (4 m) percent transmittance were constructed to show distributions of turbidity throughout the study area. Vertical isometric cross-sectional profiles were constructed to assist in developing a three-dimensional picture of transmittance at each station. These plots are presented in Volume I, Appendix E.

SUSPENDED SOLIDS

Suspended and settleable solids concentrations were compiled to supplement other turbidity data. Samples were collected from the surface and 4 m depth. Analysis of sediment samples was by standard methods (APHA, 1975). During November the procedure for determining the amount of settleable solids was modified to measure by weight rather than volume. This modification increased the detection limit of the analysis. Results of suspended solids measurements were compiled into horizontal isopleth contour maps of the surface and 4 m depth to show the variation in turbidity throughout the survey area and as a comparison with other parameters measured. These plots are presented in Volume I, Appendix E.

SECCHI DISC

Secchi disc depth of visibility measurements from each station were used as an aid in determining the distribution of suspended solids in the receiving waters, however, Secchi disc readings cannot be directly related to light transmittance values or to suspended sediment concentrations. Horizontal isopleth contour maps of Secchi disc depths of visibility are presented in Volume I, Appendix E.

AERIAL PHOTOGRAPHS

Aerial color photographs of the survey area were taken during the surveys. Photographs were used to assess the visible extent of turbidity in the survey area and to assist in the analysis of other data. Reproductions of these photographs are presented in Volume I, Appendix E.

RESULTS

Results of 1978 bimonthly turbidity monitoring at San Onofre are presented in detail in Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979). The following is a brief synopsis of those results.

General trends in water clarity within the nearshore environment at San Onofre during 1978 were as follows: 1) turbidity decreased with distance offshore; 2) turbidity decreased with distance downcoast; 3) turbidity increased with distance below the surface; 4) turbidity was greatest during winter and spring and least during summer and fall, appearing to follow seasonal trends in weather and sea state.

Factors contributing to turbidity at San Onofre were as follows: 1) rainfall and consequent runoff 2) waves; 3) oscillatory tidal currents; 4) coastal currents; 5) rip tides; 6) wind drift; 7) thermoclines; 8) generating station operation; and 9) dredging along the Units 2 and 3 construction trestle. The

most significant factors contributing to turbidity at San Onofre were: 1) rainfall; 2) waves; 3) tidal currents; and 4) thermoclines.

Vertical stratification of turbidity at San Onofre is a natural and frequent occurrence. Near bottom water is generally turbid and the extent of turbidity depends on water motion along the bottom. The vertical extent of turbid bottom waters is amplified by periods of accelerated water motion when not restricted by a thermocline. Under these conditions: 1) turbid bottom waters are circulated directly through the Unit 1 cooling system and discharged vertically; 2) turbid bottom waters are entrained in the rising discharge plume; or 3) there is a combination of these phenomena, creating a surface turbidity plume. The areal extent of this plume is dependent upon the nature of the particles within the plume, the buoyancy of the water, and surface currents.

DISCUSSION

DISTRIBUTION OF TURBIDITY

This section discusses the spatial characteristics of water clarity throughout the SONGS Unit 1 survey area (inshore) and Units 2 and 3 pre-operational survey area (offshore) at the surface, 4 m, and bottom. Figures 3-1, 3-2, and 3-3 illustrate general trends in offshore and longshore turbidity gradients, based on means of all 1978 turbidity parameters along station lines. Appendices B-1, B-2, and B-3 present the survey means and standard deviations, the extreme values, and the stations at which the extremes occurred for each bimonthly turbidity parameter.

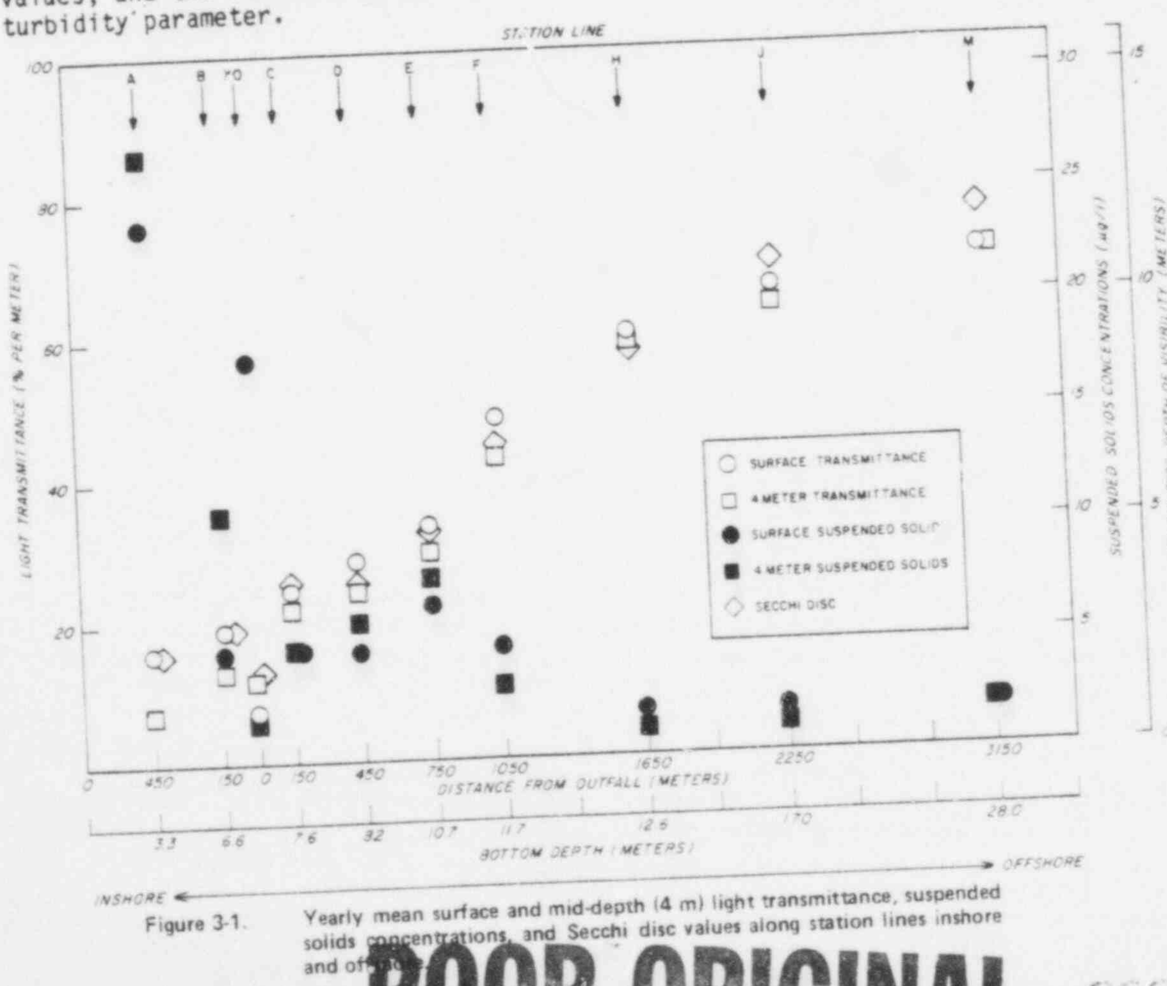

Figure 3-1. Yearly mean surface and mid-depth (4 m) light transmittance, suspended solids concentrations, and Secchi disc values along station lines inshore and offshore.

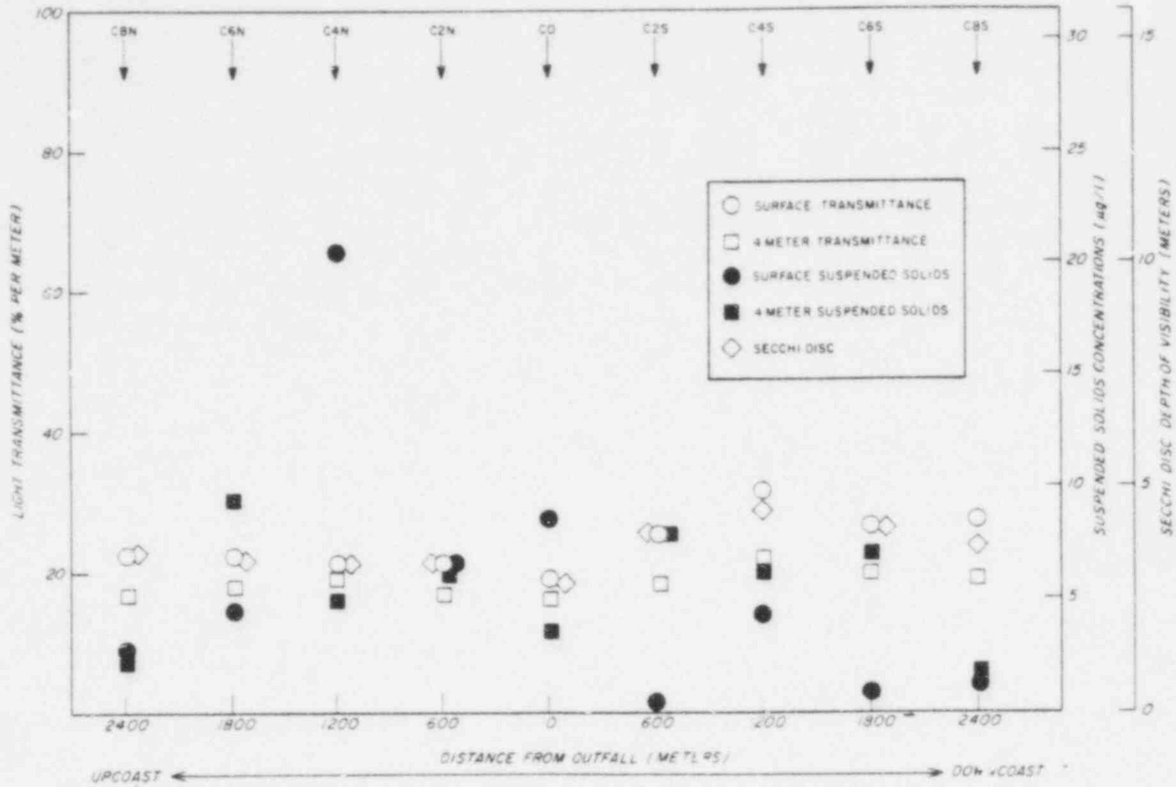

Figure 3-2. Yearly mean surface and mid-depth (4m) light transmittance, suspended solids concentrations, and Secchi disc values up and downcoast in 8 m of water.

Onshore/Offshore Distribution

The turbidity monitoring results presented in Volume I are summarized as yearly means of each parameter measured along station lines parallel to shore (Figure 3-1). The yearly means showed increasing light transmittance and Secchi disc depths, and decreasing suspended solids concentrations with distance offshore, except at the outfall (Station XO). This trend is consistent with the results of preoperational surveys and is considered typical of sandy coastal sites subjected to land runoff, waves, and oceanic circulation (BC, 1978; IRC, 197 and MA, 1969). Similarly, longshore yearly means and survey means showed greater water clarity in the offshore survey area than in the inshore survey area during each survey.

Longshore Distribution

Though no longshore gradient in turbidity has been noted in the past, results of this analysis indicate a slight increase in nearshore water clarity with distance downcoast of the Unit 1 discharge in 1978. This longshore gradient was based on yearly means of transmittance, suspended solids, and Secchi disc depths along the C-line of stations (approximately 1000 m offshore) (Figure 3-2). The C-line of stations was most representative of the inshore survey area and was usually beyond the influence of the surf zone (IRC, 1972). It has been noted that rip tides frequently occurred in the surf zone downcoast of Unit 1 and sometimes created turbid plumes which extended 1000 m offshore (BC, 1978, 1979). Considerable variability existed between yearly means (Figure 3-2). Mean transmittance, suspended solids, and Secchi disc depths exhibited greater water clarity at downcoast stations than at upcoast stations of the same distance from the Unit 1 discharge, except at 4 m below the surface at Stations C2S and C4S. This

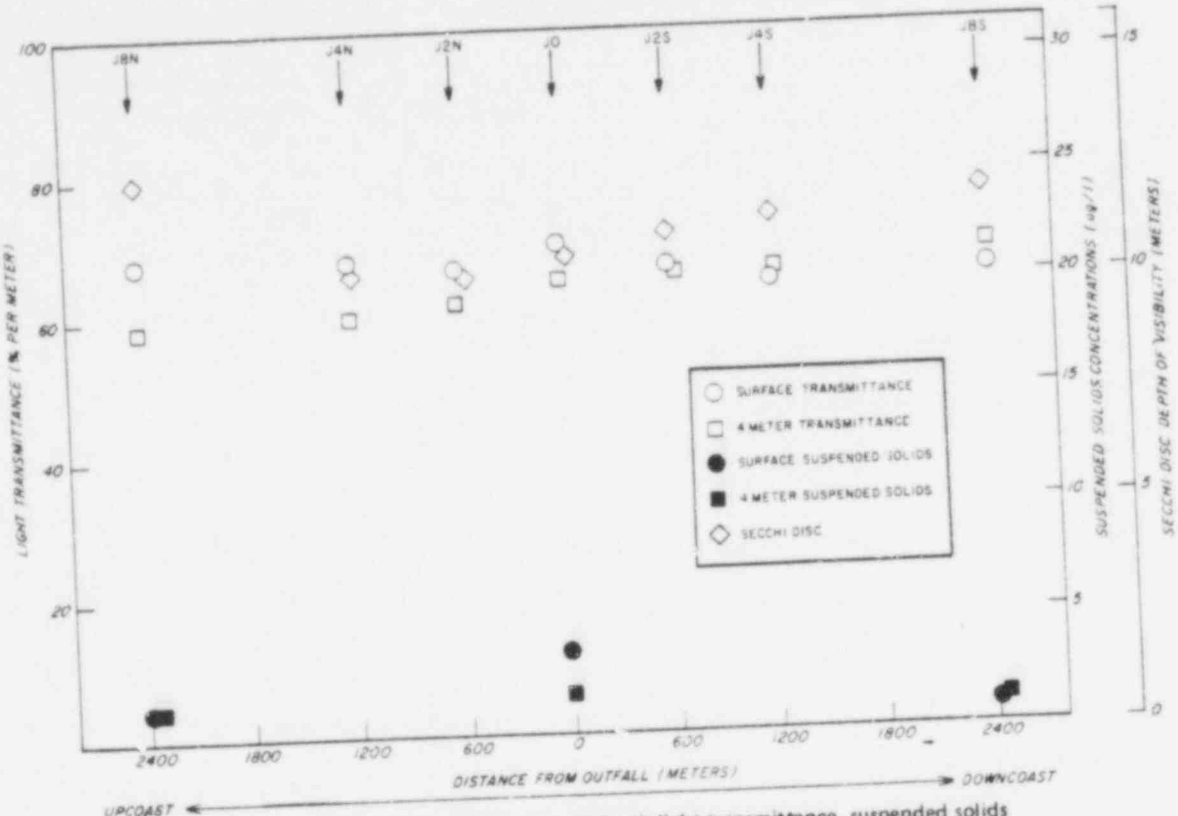

Figure 3-3. Yearly mean surface and mid-depth light transmittance, suspended solids concentrations, and Secchi disc values up and downcoast in 17 m of water.

longshore gradient appeared to be the result of turbidity plume transport by upcoast currents. It should be noted that one very high suspended solids concentration measured at Station C4N raised the 4 m mean beyond normal values. No longshore gradient was observed in the offshore survey area (Figure 3-3).

Vertical Distribution

Vertical stratification of turbidity at San Onofre is important in determining the specific effects of the Unit 1 discharge. Nearshore bottom sediments at San Onofre are suspended naturally by tides, waves, and currents. The extent of this turbid bottom layer is dependent on the velocity of bottom water and on the size and specific gravity of the resuspended particles. When the turbid layer extends above the bottom to the depth of the discharge or intake, entrainment by the discharge or withdrawal through the intake and eventual discharge after transit through the Unit 1 cooling system will result in a turbid surface plume. The subsequent areal extent of the surface plume is then dependent upon surface currents, the nature of the particles, and buoyancy of the plume. In the absence of natural vertical stratification turbidity of discharge waters is nearly indistinguishable from surrounding surface waters, as seen during the November survey.

Profiles of light transmittance and suspended solids measurements (Volume I, Appendix E) established increasing turbidity with distance below the surface, with localized exceptions. Similar trends have been noted in the past (IRC, 1972; BC, 1978). Assessment of changing water clarity with depth is aided by consideration of yearly trends and survey trends. As illustrated in Figure 3-1, surface light transmittance and suspended solids concentrations indicated that turbidity was greater at mid-depth than at the surface except at the discharge.

Examination of longshore variations in water clarity with depth (Figure 3-2) indicated slight differences between transmittance and suspended solids at mid-depth (4 m) while surface values varied considerably. A longshore comparison of these variations indicated that depressed surface water clarity extended as far as 1200 m upcoast of the outfall. Longshore differences between surface and mid-depth water clarity were less pronounced in the offshore survey area (depth of 12 m or more). The annual mean for the offshore area (Figure 3-3) indicated no depression of water clarity. During the surveys of May through November, mean surface transmittance exceeded mid-depth and bottom transmittance in both the operational and preoperational survey areas (Appendix B-1). As a result of storms, large waves, and runoff, natural water clarity during January and March was too low (less than 10% transmittance) to distinguish trends in the turbidity distribution.

SEASONAL CHARACTERISTICS

Seasonal characteristics of water clarity throughout the Unit 1 operational survey area and Units 2 and 3 preoperational survey area at the surface, 4 m, and bottom are indicated by summaries of bimonthly data in Appendices B-1, B-2, and B-3. Appendix B-1 presents mean values of light transmittance, corresponding standard deviations and extreme values at three depths, by survey. Appendix B-2 is a similar presentation of suspended solids, and Appendix B-3 presents Secchi disc depths of visibility.

The seasonality of nearshore water clarity at San Onofre is affected naturally by rainfall, wind, waves, currents, plankton blooms, and depth and intensity of the thermoclines. Amounts of rainfall seven days prior to each survey and the characteristics of the thermoclines during each survey were reported in Volume I. Wind and current data are reported in Appendix A of this report. Total wave energy per unit surface area (E) was collected from Oceanside by the Institute of Marine Resources (IMR) at Scripps Institution of Oceanography. Wave energies at Oceanside are assumed to be representative of those at San Onofre and therefore, have been used in this report (IMR, 1978). Wave energy is presented in terms of the total variance of sea surface elevation, $\langle\sigma^2\rangle$ by the equation

$$E = \rho g\langle\sigma^2\rangle$$

Where ρ is the fluid density, g is gravitation acceleration, and $\langle\sigma^2\rangle$ is reported in cm^2. It is customary to report E as a function of $\langle\sigma^2\rangle$ only. Wave energies relevant to San Onofre were available only for the January survey because the Oceanside installation failed in a large storm in March 1978. Swells during surveys were noted in Volume I.

As has been observed in the past, turbidity in the nearshore area at San Onofre was highest during winter and spring and lowest during the fall (BC, 1977, 1978; SCE, 1971). Lowest water clarity of 1978 occurred during the January and March surveys. High natural turbidity and the lack of vertical stratification masked any influence on turbidity from plant operation. Low water clarity was attributed to relatively heavy rainfall, high wind, large swells, dredging along the Units 2 and 3 construction trestle, and the lack of a thermocline within the survey area. The primary contributors to this turbid condition were swells (wave energy) and rainfall (and corresponding runoff). Swells were in excess of 1.2 m during the January survey and, therefore, capable of generating a significant turbid bottom layer (1.5 to 3.0 m thick) in the Unit 1 survey area (MA, 1969). Wave energies measured near San Onofre 24 hrs prior to and during the January survey were in excess of 1300 cm^2 and 2300 cm^2 (IMR, 1978). This is more than three times the energy required to generate bottom water velocities sufficient to suspend bottom sediments (20 cm/sec) as far as 450 m offshore of the Unit 1

outfall (IRC, 1972; Hill, 1966). Though no Oceanside wave energy data were available for any survey following January, a correlation of wave energies taken from stations north and south of San Onofre indicates that wave energies at San Onofre prior to and during the surveys were higher in March than January.

Water clarity during the May survey was somewhat greater than during January and March. Swells were high during May and dredging operations were being conducted along the Units 2 and 3 construction trestle. A nearshore turbidity plume was noted from 600 to 1800 m downcoast of the discharge (BC, 1979). This type of turbidity distribution has been noted previously (BC, 1978) and was attributed to rip tides. Suspension of bottom sediments by wave-induced bottom currents created a turbid bottom layer which extended above the depth of the Unit 1 intake structure throughout the survey area. Circulation of the turbid bottom layer through the Unit 1 cooling system and dredging activities created a turbid surface plume which was spread by upcoast currents and wind. Natural variability at San Onofre was seen by comparing aerial photographs taken during the survey and two days later (Volume I, Figures E-39 and E-40). The aerial photograph taken of the Unit 1 survey area during the survey (Figure E-39) showed surface turbidity plumes generated by surf, rip tides, and dredging. The photograph taken two days after the survey (Figure E-40) showed no discernable turbidity within the survey area.

Water clarity was greater during July than during the previous surveys of 1978. The low turbidity was attributed to a lack of rainfall, low swell, low wind, slow currents, a strong thermocline, and no construction related dredging. Swells were barely sufficient to suspend bottom sediments in the survey area. A strong thermocline was present at the depth of the outfall (7 m), contributing to vertical stratification of turbidity and the magnitude and direction of surface currents (Defant, 1961). As presented in Volume I, turbidity was highly startified above 5 m throughout the survey area. The presence of a strong thermocline restricted the naturally turbid bottom layer to depths below 5 m except above the outfall. Turbid bottom waters were circulated through the Unit 1 cooling system and discharged to the surface, subsequently creating a turbid surface plume. Mild winds blowing inshore and weak surface currents flowing upcoast and onshore (Appendix A-3) restricted the surface plume to within about 1000 m of the outfall. Rip tides generated a turbidity plume 1800 m downcoast of the discharge.

Water clarity in the survey areas during the September survey was less than during the July survey. Contributing to the natural turbidity were rainfall, weak surface currents, mild winds, and the lack of a thermocline. Natural vertical stratification of turbidity existed throughout the survey areas except where a turbid bottom layer extended to the surface inshore, upcoast, and offshore of Station C0 (intake). Heat treatment during the survey and subsequent reversal of flow through the cooling system circulated turbid bottom waters from the outfall to the intake. This brought turbid nearshore bottom waters farther offshore and because of the velocity cap of the intake structure, discharged them horizontally, forcing the plume to spread horizontally while rising to the surface. The lack of a thermocline above the depth of the intake enabled the plume to rise with the buoyant warmer discharged water. At the surface, wind and onshore currents spread the plume upcoast and onshore. Later in the day, offshore currents spread the plume offshore and downcoast (Appendix A-4).

Highest water clarity of the 1978 surveys occurred during November when clarity was greater than during any November Unit 1 preoperational survey (MA, 1969). The lack of heavy rainfall, swells, and dredging attributed to the general water clarity. By correlating histories of wave energies at San Onofre and stations north and south of San Onofre (IMR, 1978), it was concluded that wave energies at San Onofre were between 185 and 213 cm^2. At these wave

energies, wave induced currents may have been sufficient to induce slight sediment suspension within the inshore survey area. Current measurements taken from 1 m below the surface at Station C2N indicated that velocities were less than 20 cm/sec (Appendix A-4), and therefore insufficient to induce significant sediment suspension within the survey area (IRC, 1972). Aerial photographs showed no visible effects of construction or dredging along the Units 2 and 3 construction trestle during the survey. Consequently, the slight surface turbidity plume near the outfall, indicated by transmittance profiles, was the result of entrainment of bottom sediments near the outfall. The horizontal distribution of the plume was affected by onshore winds and upcoast currents in the morning and downcoast currents in the afternoon.

SUMMARY

In compliance with ETS Section 3.1.1.a.(4) and the NRC Preoperational Monitoring Program, turbidity of the receiving waters was monitored by: 1) profiles of light transmittance along a 1 m path length; 2) concentration of suspended and settleable solids; 3) Secchi disc depth of visibility; and 4) aerial photographs to determine any effects of the discharge upon local water clarity. Results of these studies showed the following:

1. Turbidity decreased with distance offshore. An offshore mean transmittance gradient of 18%/300 m was obtained for the 1978 surveys. Decreasing turbidity with distance offshore is consistent with results of the Unit 1 preoperational surveys (1964 to 1968) of the inshore survey area.

2. Alongshore gradient of decreased turbidity with distance downcoast was seen in the inshore survey area, but not in the offshore survey area. Downcoast rip tide induced turbidity and upcoast current transport of turbidity plumes attributed to this gradient.

3. Turbidity increased with distance below the surface. Transmittance was frequently less than 1% near bottom. Bottom sediments are suspended naturally by tidal currents, waves, and coastal currents. The extent of this turbid bottom layer is dependent on bottom water velocity and on the size and specific gravity of the suspended particles.

4. Increasing turbidity with depth was less pronounced in the offshore survey area (farther than 1850 m offshore).

5. Seasonal trends in turbidity were consistent with previous bimonthly surveys. Turbidity was highest during winter and spring and lowest during the fall. Seasonal variation of turbidity at San Onofre is affected primarily by rainfall, waves, currents, and thermoclines.

6. Highest turbidity of the 1978 surveys occurred during January and March. During each survey all light transmittance measurements were less than 10% and all Secchi disc depths were less than 3 m. Low water clarity was attributed to heavy rainfall and large swells.

7. Natural variability of nearshore turbidity was seen by comparing aerial photographs taken during the May survey and two days later. Turbidity plumes generated by rip tides, surf, and dredging were seen during the survey while none were seen two days after the survey.

8 Conditions such as restriction of vertical stratification by a strong thermocline above the depth of the intake, mild onshore winds, and weak

surface currents (less than 15 cm/sec) flowing onshore and upcoast as seen during the July survey, account for low turbidity at San Onofre.

9. High turbidity during the September survey was attributed to the natural flow of the Unit 1 cooling system (heat treatment) and the lack of a vertical stratification of turbidity induced by bottom currents, reversed thermocline.

10 Lowest turbidity of the 1978 surveys occurred during November. In the inshore survey area mean transmittance was 53% at the surface and 36% at the bottom while in the offshore survey area transmittance was 70% at the surface and 60% at the bottom. Mean suspended solids concentrations were less than or equal to 1.5 mg/ℓ in the inshore survey area and less than or equal to 0.9 mg/ℓ in the offshore survey area. Mean Secchi disc depths were 7.3 m in the inshore survey area and 13.8 m in the offshore survey area. The lack of heavy rainfall, swells, and dredging attributed to the water clarity. The lack of vertical stratification and dredging indicated that the slight surface turbidity plume noted was the result of entrainment of bottom sediments near the outfall.

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CHAPTER 4

WATER QUALITY

INTRODUCTION

This chapter discusses the results of the dissolved oxygen, hydrogen ion concentration (pH), and heavy metals data which were presented in Volume I, San Onofre Nucler Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979).

The objectives of the dissolved oxygen and pH monitoring phases of the Environmental Technical Specifications (ETS) monitoring program for SONGS Unit 1 were to assure that natural dissolved oxygen and pH levels were maintained, to continue the data base that has been established, and to indicate the extent to which operations of SONGS Unit 1 affected levels of dissolved oxygen and pH. The objectives of the dissolved oxygen and pH phases of the Preoperational Monitoring Program for Units 2 and 3 were to provide a receiving water baseline to be used as a reference for the determination of the extent and significance of discharge effects of Units 2 and 3.

The objectives of ETS heavy metals monitoring phase for SONGS Unit 1 were to: 1) indicate the extent of any persistent increase in heavy metals concentration in receiving waters in the vicinity of the Unit 1 discharge, and 2) to detect any buildup of heavy metals concentrations in the sediments as a result of Unit 1 operation. The objectives of the heavy metals phase of the Preoperational Monitoring Program were to provide a receiving water and ocean bottom sediment baseline to be used as a reference to determine the extent and significance of discharge effects of Units 2 and 3.

BACKGROUND

The requirements for dissolved oxygen and pH, as specified in the ETS, are those which are permitted by the Water Quality Control Plan for Ocean Waters of California. The Water Quality Control Plan states that dissolved oxygen concentrations shall not at any time be depressed more than 10% from that which occurs naturally, as measured at a suitable control station. Historically, surface dissolved oxygen concentrations ranged from 4.3 to 12.6 mg/ℓ in the coastal waters near San Onofre, with lowest concentrations in winter and highest concentrations during spring (Allan Hancock Foundation, 1965; SCCWRP, 1973). The Water Quality Control Plan also states that pH shall not be changed at any time more than 0.2 units from that which occurs naturally. The natural range of pH for the SONGS study area, based on data measured from 1967 to 1973, has been defined as 7.3 to 8.5. Allan Hancock (1965) reported a range of surface pH in coastal waters near San Onofre from 7.5 to 8.6, with an average of 8.1. Similar results were reported by SCWPCB (1959).

Monitoring of heavy metals concentrations in the SONGS Unit 1 receiving waters and ocean bottom sediments were intiated in 1975 as part of the ETS Monitoring Program. Samples were collected quarterly at four stations in the SONGS Unit 1 study area and analyzed for copper, chromium, nickel, and iron concentrations. Beginning in May 1978, the number of stations was increased to include five additional stations in the SONGS Units 2 and 3 study area, sampling frequency was increased to bimonthly, and samples were analyzed for copper, chromium, nickel, iron, and titanium.

METHODS

Methods for measurements of dissolved oxygen, pH, and heavy metals are presented in Chapter 2 of Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979).

RESULTS

Results of dissolved oxygen and pH measurements, and heavy metals analysis are presented in Chapter 7 of Volume I, San Onofre Nuclear Generating Station Annual Operating Report, Oceanographic Data - 1978 (BC, 1979).

DISCUSSION

DISSOLVED OXYGEN AND pH

The surface waters in the SONGS area are almost always near saturation in oxygen regardless of the consumption and evolution through photosynthesis because of the constant contact with the atmosphere. The oxygen saturation values are inversely related to temperature and salinity. Hence, the cold, less saline water that is characteristic of the surface flow is relatively rich in dissolved oxygen (4.5 to 7.0 mℓ/ℓ). Beneath the mixed layer, oxygen values are decreased by consumption, and replenishment from the surface is inhibited by the stable stratification of the water column (Reid, 1958).

Surface concentrations of dissolved oxygen at all stations varied among surveys. Lowest dissolved oxygen concentrations, lowest percent saturation, and least spatial variations were observed during fall and winter months. Highest concentrations, highest percent saturations, and greatest spatial variations were observed during spring and summer months. The total seasonal difference in dissolved oxygen concentration among stations was generally less than 1.0 mg/ℓ.

Dissolved oxygen concentrations during each survey at the intake and discharge stations were within 10% of those taken at the downcoast control station (Station C22S). Surface dissolved oxygen concentration at the discharge was greater than or equal to the concentration at the downcoast control station during two of the six bimonthly surveys, while at the intake, surface concentrations were greater or equal to the concentration at the downcoast control station during three of the six surveys. San Onofre Unit 1 did not cause dissolved oxygen concentrations to be reduced by more than 10% during the 1978 surveys.

Surface pH varied at all monitoring stations among surveys. Lowest pH values were observed during fall and winter months, and highest were observed during spring and summer months. For each survey, surface pH was within the normal range of values in southern California coastal waters. San Onofre Unit 1 did not cause pH to be changed by more than 0.2 units during the 1978 surveys.

HEAVY METALS

After four years of monitoring concentrations of copper, chromium, nickel, and iron in water column and sediment samples from the four operational Unit 1 stations (inshore), no apparent spatial or temporal trends were evident.

A schematic diagram representing the theoretical heavy metals transport system in the SONGS study area is presented in Figure 4-1. This figure is not a result of the study and should be used only as a theoretical flow diagram.

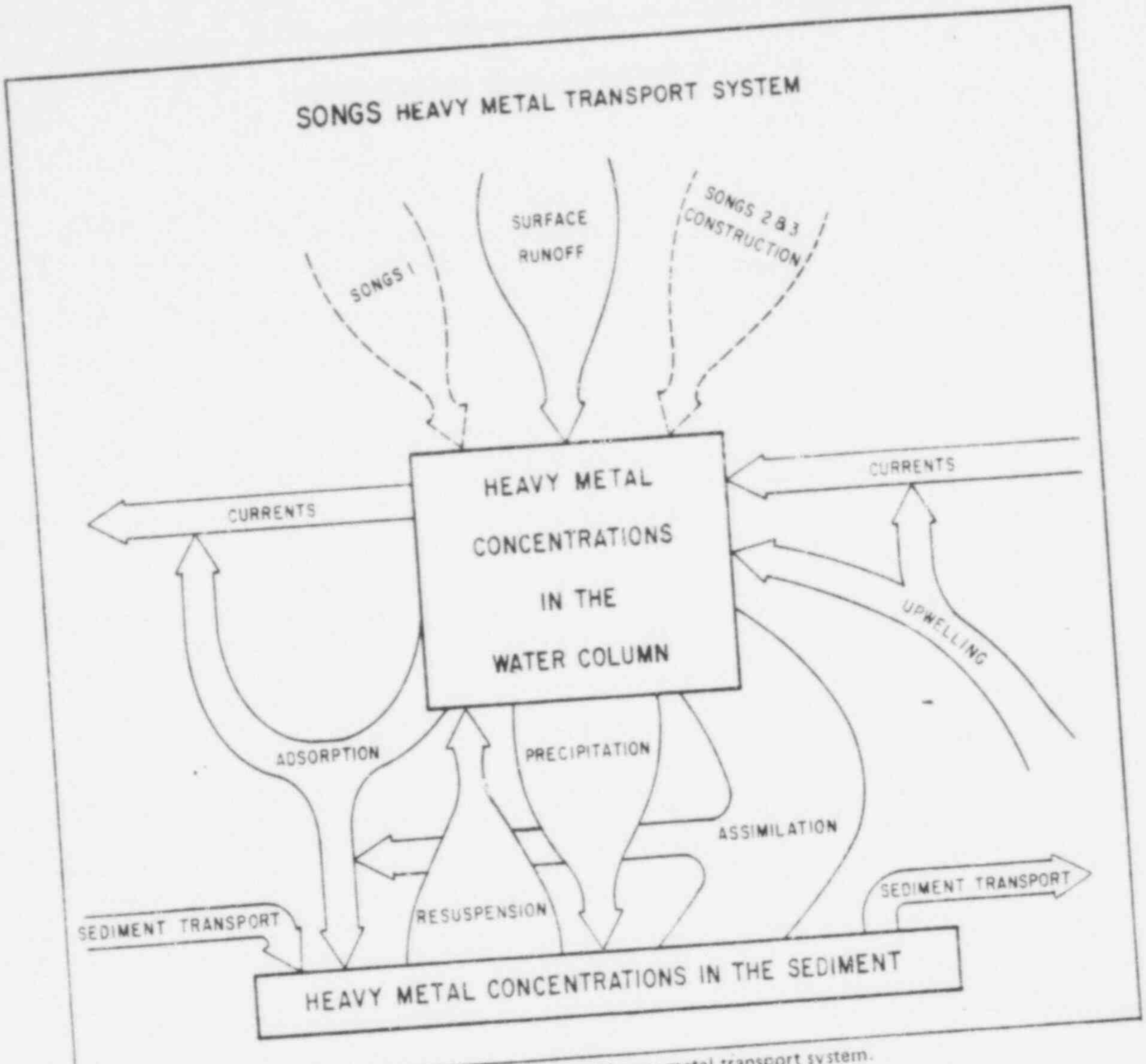

Figure 4-1. Theoretical heavy metal transport system.

The transport system is divided into two sections. The first section illustrates the interaction of heavy metal concentrations within the water column. The second section presents factors which influence heavy metals concentrations in the sediment. Natural factors which increase concentrations of heavy metals in the water column include: 1) surface runoff from rainfall and river runoff; 2) currents, which transport heavy metals from other areas; 3) upwelling, which bring heavy metals to the study area from deeper offshore waters; and 4) resuspension of sediment heavy metals during periods of high physical mixing between the sediments and water column. The natural factors decreasing heavy metals concentrations in the water column include: 1) heavy metals falling out of suspension in the water column (precipitation); 2) heavy metals adhering to inorganic and organic particles (adsorption); 3) assimilation by marine biota; and 4) current transport away from the study area. Natural factors increasing concentrations of heavy metals in the sediments include: 1) sediment transport from other areas to the study area; 2) precipitation from the water column; and 3) adsorption by sediment particles. Natural factors decreasing concentrations of heavy metals in the sediment include: 1) sediment transport away from the study area; 2) resuspension of heavy metals into the water column; and 3) assimilation by marine biota. The possible input to the system from the operation of SONGS

Unit 1 and the construction of SONGS Units 2 and 3 may provide other factors influencing the concentrations of heavy metals in the study area.

The sediment heavy metal concentrations from 1975 through 1978 are presented graphically by station in Figure 4-2.

Copper

Water column copper concentrations at inshore stations ranged from 0.24 to 3.5 μg/ℓ with a mean of 1.8 μg/ℓ during 1978. Water column copper concentrations at offshore stations ranged from 0.7 to 13.0 μg/ℓ during 1978. Ranges of copper reported for southern California coastal waters are 1.6 to 9.0 μg/ℓ (Brooks, et al., 1967), and 0.44 to 4.7 μg/ℓ (Williams, 1969). All water column copper concentrations observed at inshore stations during 1978 were within the ranges reported for southern California coastal waters by Brooks et al. (1967) and Williams (1969). The high concentration (13.0 μg/ℓ) reported for the offshore study area was observed at one station, and is not representative of concentrations throughout the study area. All other water column copper concentrations observed at offshore stations during 1978 were less than 3.9 μg/ℓ, and within the ranges reported by Brooks et al (1967) and Williams (1969).

Sediment copper concentrations at inshore stations ranged from 3.1 to 6.1 mg/kg with a mean of 4.2 mg/kg. Sediment copper concentrations at offshore stations ranged from 2.3 to 8.9 mg/kg during 1978. The mean concentration of copper in bottom sediments in southern California waters was 16 mg/kg (Galloway, 1972; SCCWRP, 1973). Concentrations in the SONGS study area during 1978 were lower than concentrations found by either SCCWRP (1973) or Galloway (1972).

Concentrations of copper in sediment samples at the four inshore stations showed relatively little variation between survey and station after August 1976 (Figure 4-2). All copper concentrations were below 10 mg/kg after August 1976. During the first year of monitoring, from April 1975 through May 1976, concentrations varied considerably between surveys. Concentrations of over 45.0 mg/kg were measured at the downcoast control station during the May 1976 survey, while at the station nearest the Unit 1 discharge, the lowest copper concentration (35.0 mg/kg) was measured during the May 1976 survey.

Chromium

Water column chromium concentrations at inshore stations ranged from 0.11 to 5.2 μg/ℓ, with a mean of 1.6 μg/ℓ during 1978. Water column chromium concentrations at offshore stations ranged from 0.33 to 2.5 μg/ℓ during 1978. All concentrations of chromium in the water column observed during 1978 were comparable to concentrations observed during previous years.

Sediment chromium concentrations during 1978 at inshore stations ranged from 8.0 to 13 mg/kg, with a mean of 11 mg/kg. Sediment chromium concentrations at offshore stations ranged from 7.6 to 23 mg/kg during 1978. Mean sediment chromium concentrations reported by SCCWRP (1973) for southern California waters were 46 mg/kg. Observed concentrations in the SONGS study area during 1978 never reached concentrations of that magnitude. Concentrations of chromium in the sediment varied significantly between station and survey from the initiation of heavy metals monitoring through March 1977 (Figure 4-2). The highest concentration observed was 139 mg/kg during August 1976 at Station D4N, 1200 m north and 500 m offshore of the discharge for SONGS Unit 1. After March 1977, concentrations remained relatively constant.

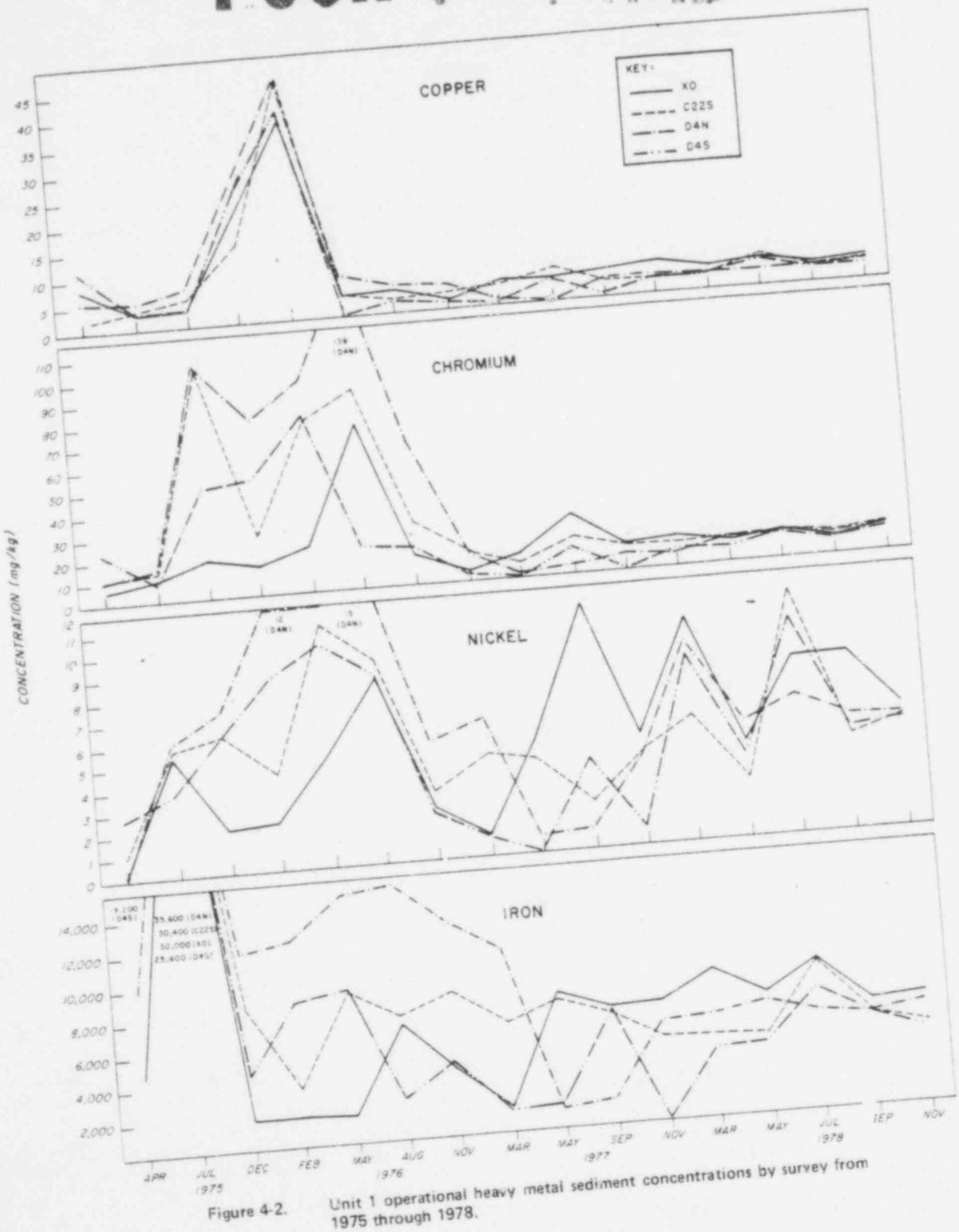

Figure 4-2. Unit 1 operational heavy metal sediment concentrations by survey from 1975 through 1978.

Nickel

Water column nickel concentrations at inshore stations ranged from 0.28 to 70.0 μg/ℓ with a mean of 11.0 μg/ℓ during 1978. Water column nickel concentrations at offshore stations ranged from 0.39 to 77 μg/ℓ during 1978. Nickel

concentrations ranged from 0.4 to 2.5 μg/ℓ. Nickel concentrations observed during 1978 at SONGS were higher than those reported for southern California waters by SCCWRP (1973). However, these concentrations were not significantly different from those observed at San Onofre during previous years.

Sediment nickel concentrations at inshore stations ranged from 2.9 to 11 mg/kg with a mean of 6.4 mg/kg during 1978. Sediment nickel concentrations at offshore stations ranged from 2.9 to 12 mg/kg during 1978. Average nickel concentrations in southern California nearshore sediments were reported by SCCWRP (1973) to be 14 mg/kg. Concentrations observed in the SONGS study area during 1978 were lower than those reported by SCCWRP (1973).

Throughout the entire four years of heavy metal monitoring, nickel varied less than the other metals (Figure 4-2). The highest nickel concentrations during the four years were observed during February through August 1976 (approximately 12.0 mg/kg at a station 1200 m upcoast of the Unit 1 discharge).

Iron

Water column iron concentrations at inshore stations during 1978 ranged from 4.7 to 610 μg/ℓ. Water column concentrations at offshore stations ranged from 3.9 to 130 μg/ℓ during 1978. The range of iron concentrations reported for southern California waters is 1.9 to 44.3 μg/ℓ (SCCWRP, 1973). Water column iron concentrations in the SONGS study area during 1978 were higher than values reported by SCCWRP (1973), but were comparable to concentrations observed at San Onofre during previous years.

Sediment iron concentrations during 1978 at inshore stations ranged from 4100 to 9100 mg/kg with a mean of 6200 mg/kg. Sediment iron concentrations at offshore stations ranged from 2600 to 13,000 mg/kg during 1978. The average iron concentration occurring naturally in southern California sediments is 32,000 mg/kg (Galloway, 1972). Concentration of iron in sediment samples during 1978 were much lower than the mean reported by Galloway (1972). Only once during the four years of monitoring (July, 1975) did concentrations exceed 32,000 mg/kg.

During the four years of heavy metals monitoring in the SONGS study area, iron concentrations varied more than the other metals between surveys and stations (Figure 4-2). Concentrations ranged from 33,600 mg/kg approximately 1200 m north of the discharge during July 1975 to <500 mg/kg approximately 1200 m south of the discharge during November 1977. Higher concentrations of iron were observed at the discharge than the other stations from May 1977 through November 1978, while during previous surveys, lower concentrations were observed at the discharge.

Titanium

Titanium analysis was added as part of the SONGS 2 and 3 heavy metal monitoring program due to its planned use in the condensers in Units 2 and 3. Water column titanium concentrations at all stations were <0.1 mg/ℓ during 1978. Sediment titanium concentrations at all stations ranged from 180 mg/kg to 850 mg/kg. No spatial or temporal trends were observed during 1978.

Impact of SONGS Unit 1

Four years of monitoring concentrations of copper, chromium, nickel, and iron has revealed no apparent patterns of spatial or temporal distribution in the water column or sediment samples. Due to the great variation in water column heavy metal concentrations with time and space, only sediment heavy metals concentrations were graphically represented (Figure 4-2). Copper, chromium, and

nickel sediment concentrations exhibited no increase in the vicinity of SONGS Unit 1 discharge throughout the four year study. From May 1977 through November 1978 sediment iron concentrations at the SONGS Unit 1 discharge (Station XO) were consistently higher than at other stations. The average sediment iron concentration observed at Station XO from May 1977 through November 1978 was 7,600 mg/kg, while concentrations at the downcoast control station (C22S) averaged 6,100 mg/kg during the same period. The greatest difference observed between the discharge and the downcoast control station was 2,500 mg/kg. These mean concentrations are lower than those reported for southern California waters by Galloway (1972). Overall concentrations of heavy metals monitored did not significantly increase throughout the four year study.

SUMMARY

Receiving water profile measurements for dissolved oxygen and hydrogen ion concentrations (pH) were recorded bimonthly during 1978. Heavy metals concentrations in receiving waters and sediments were collected in March, and bimonthly during the remainder of 1978. Results of the studies show:

1. Dissolved oxygen concentrations during each survey at the intake and discharge stations were within 10% of those taken at the downcoast control station (C22S) and were comparable to values normally found along the southern California coast. Survey means ranged from 7.3 to 8.3 mg/ℓ for all Unit 1 operational (inshore) and offshore monitoring stations during 1978.

2. Surface concentrations of dissolved oxygen at all stations varied among surveys. Surface percent saturation at required inshore and offshore monitoring stations ranged from 89.7 to 114%. Lowest dissolved oxygen concentrations, lowest percent saturation, and least spatial variations were observed during fall and winter months. Highest concentrations, highest percent saturation, and greatest spatial variations were observed during spring and summer months.

3. The cooling water discharge from SONGS Unit 1 or construction on Units 2 and 3 did not significantly affect dissolved oxygen concentrations or surface percent saturation in receiving waters.

4. The pH values obtained during 1978 were all within the specified limits (7.1 to 8.7) and were comparable to values normally found along the southern California coast.

5. Surface pH observed at inshore and offshore monitoring stations ranged from 7.98 to 8.54 during 1978. Surface pH varied at all monitoring stations among surveys. Lowest pH values were observed during fall and winter months, and highest values were observed during spring and summer months.

6. The cooling water discharge from SONGS Unit 1 or construction on Units 2 and 3 did not significantly affect pH of receiving waters.

7. Four years of monitoring concentrations of copper, chromium, nickel, and iron has revealed no apparent patterns of spatial or temporal distribution in the water column or sediment samples.

8. Copper, chromium, and nickel sediment concentrations exhibited no increase in the vicinity of the SONGS Unit 1 discharge (Station XO) throughout the four year study.

9. From May 1977 through November 1978, sediment iron concentrations at the SONGS Unit 1 discharge were consistently higher than at other monitoring stations. The greatest difference of iron concentration between the SONGS Unit 1 discharge and the downcoast control (6600 m south of the discharge) was 2,500 mg/kg during March 1978. However, all observed sediment iron concentrations during the four years of monitoring were less than that reported for coastal waters in southern California (Galloway, 1972).

10. Receiving water and sediment heavy metals concentrations did not significantly increase throughout the four year study.

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CHAPTER 5

SEDIMENT MONITORING

This chapter summarizes the results of the second year of monitoring marine sediments to determine effects resulting from construction and dredging operations associated with placement of offshore cooling water conduits and related structures for San Onofre Nuclear Generating Station (SONGS) Units 2 and 3. The findings presented in this chapter are the results of quarterly sediment investigations conducted from February 1978 through November 1978.

HISTORY

Environmental studies of San Onofre intertidal and subtidal areas began in the fall of 1963 and have continued through all phases of construction and operation of Unit 1. Similar studies are continuing through the construction phase of Units 2 and 3.

The oceanographic and biological consulting firms that have been conducting field investigation and data analysis during construction of the San Onofre facility include: Bendix Marine Advisers of Solana Beach, California 1963 through 1971; Intersea Research Corporation of La Jolla, California 1971 to 1977; Lockheed Center for Marine Research, Carlsbad, California 1974 to 1978; and Marine Biological Consultants, Inc., Costa Mesa, California 1976 to 1978.

SCOPE AND OBJECTIVES OF THE STUDY

The purpose of the sediment monitoring is to assist in the quantitatively assess environmental effects of sand dispersal during construction and dredging operations associated with the addition of SONGS Units 2 and 3 to the existing generating facility.

Previous studies (LCMR, 1974) emphasized the effects of cliff excavation and related construction activities on the beach environment. The present investigation is concerned with the effects of dredging operations on the offshore as well as beach environment. The data presented herein can also provide baseline information for comparison with conduits that will be monitored during operation of Units 2 and 3.

Areas under sedimentological investigation included intertidal and subtidal nearshore environments adjacent to SONGS.

Station Locations

Twenty intertidal sampling stations along 5 transects and 18 subtidal stations along 6 transects were established (Figure 5-1). Sampling was initiated in December 1976, four months prior to commencement of dredging, and continued quarterly through November 1978. The results, analysis, and interpretations presented herein are based on data collected during quarterly surveys conducted in 1978. The results of prior sediment studies were presented in a 1977 annual report (Marine Biological Consultants, Inc., 1978).

HISTORY OF CONSTRUCTION

Preparation of the construction site for SONGS Units 2 and 3 was initiated on 1 March 1974. The construction site is located adjacent to and southeast of

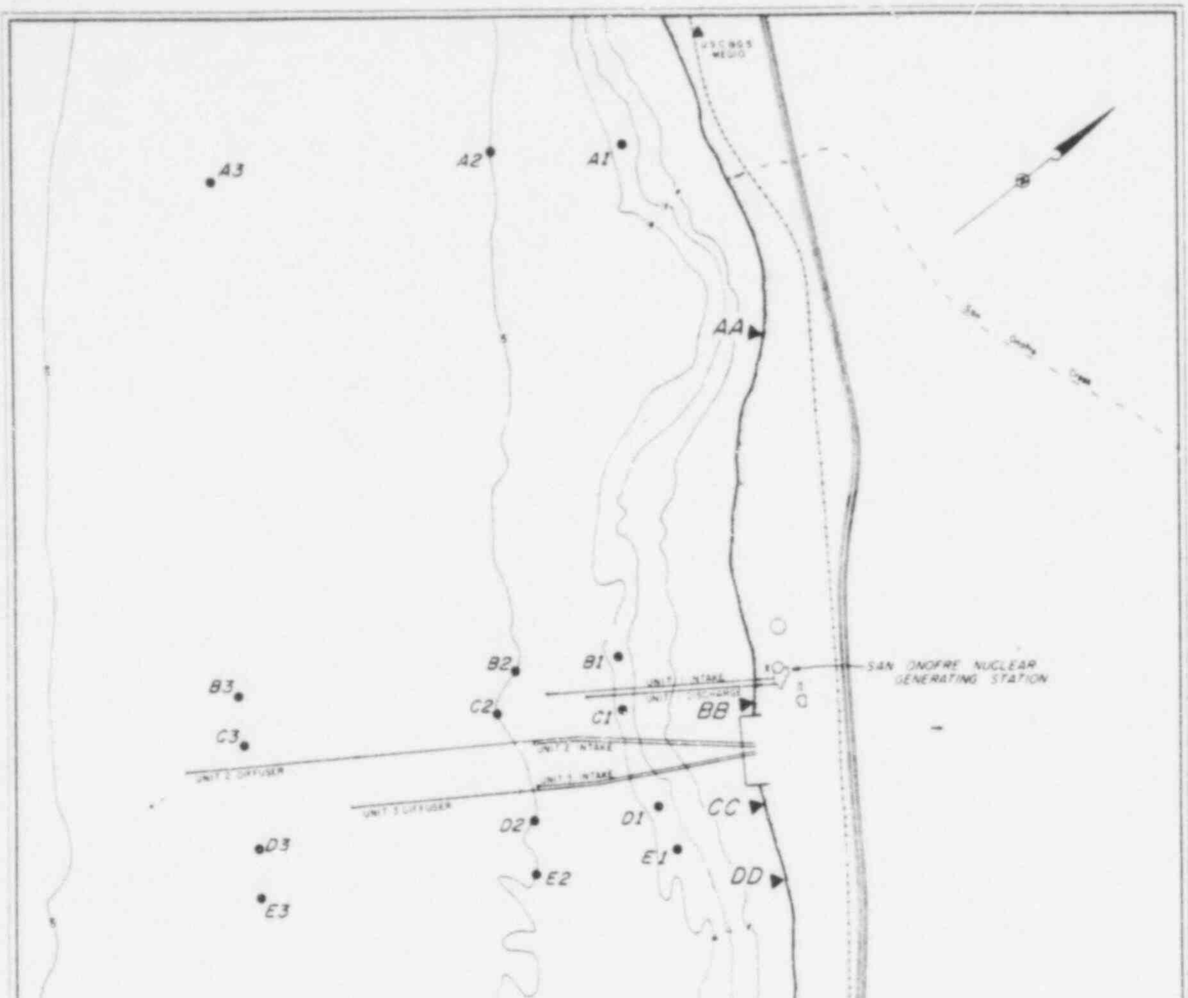

Figure 5-1. Intertidal and subtidal sampling locations.

POOR ORIGINAL

SONGS Unit 1. In the process of preparing the construction site, approximately 1,739,923 m^3 of spoil material was excavated from the bluff adjacent to SONGS Unit 1 (SCE, 1978). Approximately 1,571,725 m^3 of the excavated material was deposited on the beach south of the construction site, while the remaining 168,198 m^3 was deposited as a pad behind sheetpilings. The pad area has been utilized during the construction of the offshore conduits as a material and equipment staging area. Upon completion of the conduit construction, the sheet-pilings will be removed and the fill material allowed to be distributed by wave action.

Beginning in March 1977 and continuing through December 1977, approximately 215,222 m^3 of dredge material from conduit installation was placed on the beach in front of the offshore wall of the construction laydown pad (SCE, 1978). Monthly volumes of sand deposited on the beach ranged from 7,692 m^3 in March to 63,763 m^3 during August (Table 5-1). In addition to the dredge material deposited on the beach, approximately 69,314 m^3 of dredge material was used as conduit backfill between July 1977 and November 1977 (Table 5-1).

Table 5-1. Volume and disposition of disposed sand (m3) March 1977 through December 1978.

Month	Offshore Placement	Beach Placement	Backfill
1977			
Mar		7,692	-
Apr		11,842	-
May		9,467	-
Jun		12,852	-
Jul		19,603	7,248
Aug		63,763	-
Sep		37,734	27,597
Oct		43,142	12,125
Nov		9,410	22,434
Dec		25,800	-
1978			
Jan	8,334	16,171	
Feb	13,257		
Mar	22,089		
Apr	42,039		
May	29,942		
Jun	14,660		
Jul	13,763		
Aug	11,010		
Sep	2,753	6,346	
Oct	7,187	5,368	
Nov	-	8,182	
Dec	6,117	8,831	

A summary of the dredge material displacement at SONGS during 1978 is presented in Table 5-1. with the quantity, location, and time of placement shown in Figure 5-2.

Dredge placement activity during 1978 was high in the winter and spring (January to May) with the displacement averaging over 25,996 m^3/month (SCE, 1979). It was low during the summer, fall, and early winter months (June to November) with a monthly average displacement of just over 11,469 m^3. Moreover, Figure 5-2 shows dredge placement activity was considerably greater just inside the 6 m and 9 m isobaths.

Material was deposited inshore on the south side of the trestles for Unit 3 cooling conduit (Figure 5-2) in order to compensate for interruption of the natural sand transport path by the construction laydown pad on the beach. Natural sand transport rates with a predominantly downcoast movement for the San Onofre area are estimated at 76,460 m^3/year (U.S. Army Coastal Research Center, 1973).

Two contiguous trestles were constructed during July through December 1976 for installation of intake and discharge conduits for SONGS Unit 2. From the onshore staging area, the trestles extend approximately 1006 m offshore. After Unit 2 cooling water conduit installation along the length of the trestles was completed, the trestles were removed and installed slightly downcoast for emplacement of cooling water conduits for SONGS Unit 3.

MATERIALS AND METHODS

Sediment characteristics of the intertidal and subtidal areas adjacent to SONGS were sampled during four quarterly surveys from February through December 1978.

Complete survey data are recorded on microfiche. Data for selected variables are presented in Appendices C-1 and C-2 (MBC, 1979).

Because intertidal and subtidal environments at San Onofre have distinctly different and easily distinguishable abiotic and biotic characteristics, the sedimentology of the two environments was analyzed separately.

INTERTIDAL SEDIMENTOLOGY

Measurement of the beach profile, collection of samples for sediment grain size analysis, and sampling of the intertidal biota were conducted along five permanently established transects located along the beach and perpendicular to the shoreline (Figure 5-1). Transects were located with respect to a reference transect running midway between the cooling water conduits of SONGS Units 2 and 3.

Beach Profiles

Prior to the initiation of intertidal surveys, the +8 ft tidal elevation (from MLLW) at each transect was located by surveying from permanent reference marks of known elevation.

During each quarterly survey, beach profiles were measured at each of the transects. The profiles were made using a surveyor's self-leveling level. Profiles were determined using pre-established reference marks located at each transect. The profiles were surveyed in from the reference mark to MLLW. Sampling sites were established at 1 ft elevation intervals from +6 ft to MLLW.

Grain Size Analysis

Along each transect, core samples for sediment grain size analysis were collected at 0, +2, +4, and +6 ft tidal elevations (MLLW). Sediment cores were collected to a depth of 30 cm except when cobble prevented core penetration to this depth.

Grain size distributions at each level were determined by mechanical sieving through various sized meshes. The retained portions were weighed and proportionally related to the total sample weight. The mesh sizes used were -2.25, -1.5, -0.5, 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 phi units (phi = $\log_2$ x diameter in millimeters).

Statistical analyses of the cumulative size frequency curves were performed using descriptive measures according to Folk and Ward (1957).

The interpretation of grain size characteristics was based on the general hypothesis that all detrital sediments can be classified into one or more populations which are defined by a select group of grain size fractions (Spencer, 1963; Tanner, 1964; Visher, 1969). This hypothesis is supported by much theoretical work and field investigation that indicate that grain size populations composed of groupings of different grain size fractions occur as a result of selection through different modes of transport for different grain sizes (Moss, 1962, 1963; Inman, 1949; Visher, 1969; Middleton, 1978; Swift and Ludwick, 1976; Clark and Clark, 1976).

The transport mechanisms are surface creep (traction), intermittent-suspension, and suspension transport. It follows that differential transport of one or several of the grain size populations will result in grain size variations in sediment sample.

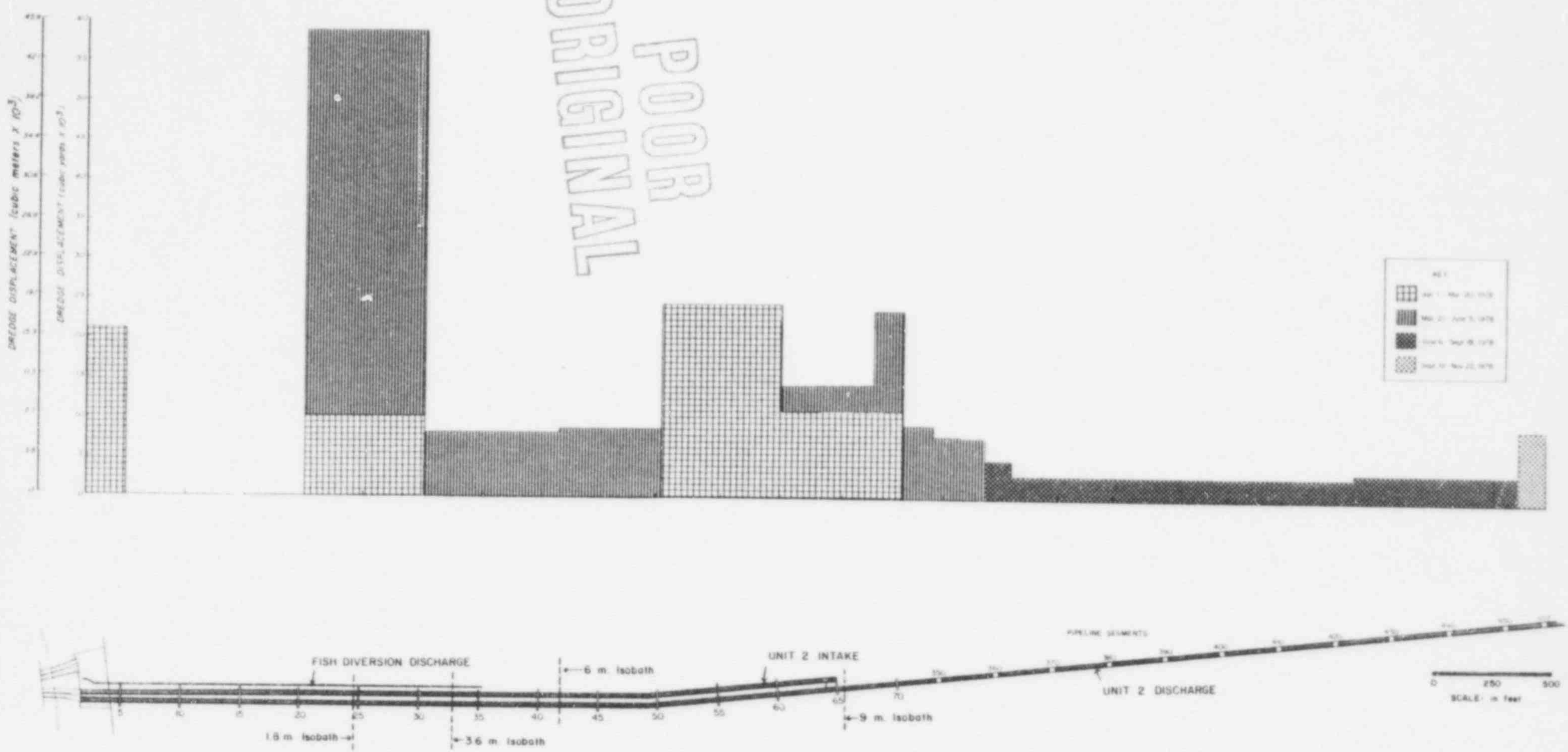

Figure 5-2. Dredge spoil displacement quantities along SONGS Unit 2 cooling water conduits.

However, assigning specific processes to grain size populations is complicated by the inherent textural character of the source material, its availability, and the variability of the type and intensity of prevailing hydraulic conditions (Middleton, 1978). Since mechanisms influencing sediment dispersal were not concurrently monitored during this study, only general inferences are made about their relationship based on what is generally known about hydraulic conditions in the study area.

Grain size populations are identified objectively by evaluating the entire size distribution of each sample (as defined by the weight percent in each whole phi size fraction). Distinct grain size associations and patterns were examined by methods of correlation analysis, correspondence factor analysis, and agglomerative hierarcical classification.

Other Physical Measurements

Estimates of wave period, height, and direction as well as water temperatures were recorded at each transect.

SUBTIDAL SEDIMENTOLOGY

Samples for sediment characterization and determination of sedimentation rates were collected by divers using SCUBA equipment. During each survey, permanent stations at the 6, 9, and 15 m isobaths along each of six transects were occupied (Figure 5-1). Three transects were located upcoast and three downcoast at prescribed distances from a reference transect running midway between the cooling water conduits of SONGS Units 2 and 3.

Grain Size Analysis

A single core sample (minimum penetration depth 10 cm) was collected at each station for grain size analysis. Cores were collected adjacent to the area of biological sampling.

The sand and gravel grain size distributions were determined as described for the intertidal sediment samples. The silt-clay distribution was determined by a hydrometer method based on the settling rates of different sized particles and fluid density (ASTM, D422, 1963).

Statistical analyses of the cumulative size frequency curves and characterization of the fundmental populations were performed as previously described.

Sedimentation Analysis

At each station, a sediment trap for determining deposition rates of suspended sediments was attached to a monument shown in Figure 5-3.

The sediment traps used in the study were 52 cm long with a 10.6 in diameter and made from thin-wall ABS plastic pipe. A funnel recessed 4.5 cm below the top of the trap with a 3.0 cm opening at its bottom was installed to inhibit resuspension and subsequent loss of sediments during the collection period. In addition, a clear plastic liner was fitted inside the trap housing in which the sediments were collected. Quarterly, the height of the trap above the bottom was measured. The height of the traps above the bottom was used to estimate the change in elevation of the sea bed. The plastic liner and container contents were removed, and returned to the laboratory for analysis. The amount of sediment collected in each chamber was measured and reported as gm (dry wt)/m^2/time interval.

Organic Carbon Analysis

At each station, the organic carbon content of the sediments was measured to determine the amount of organic nutrients available to infaunal species. A single sample was collected from the sediments adjacent to each biological sampling station and frozen in the field. Samples were subsequently analyzed with a LECO semi-automatic gasometric carbon analyzer according to the procedures described in Kolpack and Bell (1968). The organic fraction of the total carbon content was determined by subtracting the inorganic C-CO_3 value. Results are expressed as percent dry weight.

Physical Measurements

Water column clarity was measured at the time of collection of sediment samples at each station using a Secchi disc. The disc was lowered into the water from the surface. The maximum depth of water clarity occurred at the depth the disc disappeared from view.

A general description of the bottom was recorded at each station including ripple mark parameters and bottom water and sediment temperatures.

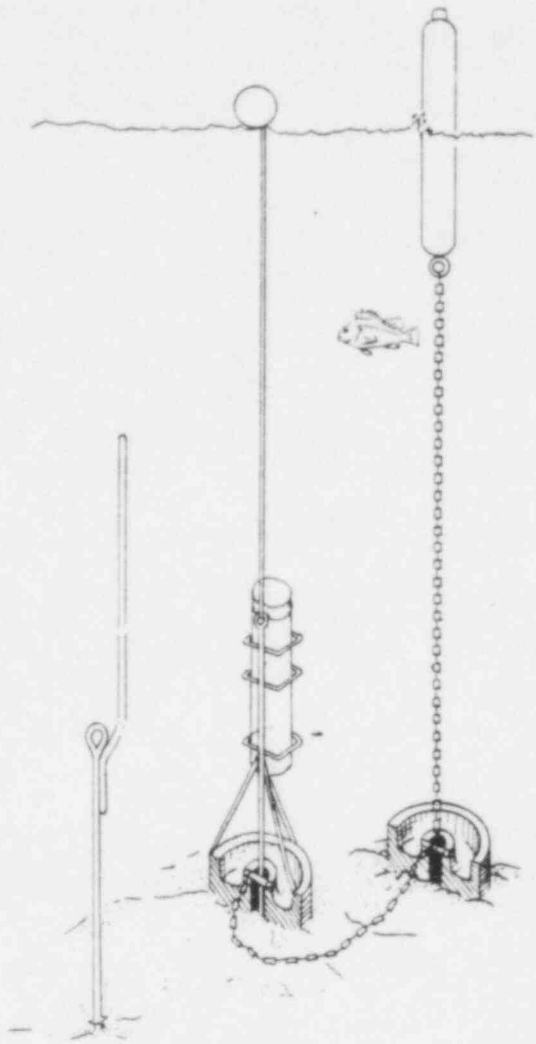

Figure 5-3. Subtidal sediment trap and monument construction.

STATISTICAL ANALYSIS

Sediment data were analyzed utilizing the Ecological Analysis Package as documented in Smith (1976). The routines that were utilized include Correspondence Factor Analysis, Correlation Analysis, and Agglomerative Hierarchial Classification Analysis.

Correspondence Factor Analysis

Factor analysis (David, et al.,1974; Hill, 1974; Melguen, 1974) was employed to: 1) delineate the grain size associations (as defined by the percent weight in whole phi size fractions) that subsequently define the important grain size populations, and 2) show spatial patterns in the samples (stations) with respect to the grain size populations.

The analysis defines a theoretical variable and station space which efficiently summarizes associations among the stations and variables. Each station and variable is represented by a point in this combined space; the position of each point in each dimension (and consequently its position in the entire space) is dependent on the variable and station values.

The relative association between the variables and stations, respectively, is proportional to the distance between them in the space. The space can be viewed from many different directions. The "view" of the space is expressed as an "axis" or "factor", which is a line set perpendicular to the "view", and onto which each variable and station point is perpendicularly projected. Examination of graphical plots of these point projections (called scores) the variable and station associations revealed may suggest the causal environmental mechanism.

The number of environmental mechanisms detected may correspond to the number of views or factors extracted from the analysis. The first factor accounts for the largest share of measured variation in the sediment variables with subsequent factors accounting for progessively lesser amounts of the remaining variation. Some importance can be estimated for each factor, hence the importance of the environmental mechanism. The first factor identifies the most important mechanism while the remaining factors identify those of progressively lesser importance. However, depending on the complexity of the environment, more than one mechanism may be indicated by a single factor.

Correlation Analysis

In the intertidal and subtidal analyses, Pearson's product-moment correlation (r) was used to provide an alternate method to examine the associations between selected sediment parameters (Sokal and Rohlf, 1969). This method of analysis also is an effective tool for helping to recognize environmental patterns particularly when the patterns are not to complex.

The association between two variables may be positive, as when an increase in variable A is associated with an increase in variable B, or negative as when a decrease in variable B is associated with an increase in variable A. If changes in one variable are random with respect to specific changes in the other variable, then there is no association between the two variables.

Classification Analysis

Agglomerative, hierarchical classification analysis as was applied to the sediment textural data collected at subtidal stations in order to determine natural station groupings. The analysis classified the stations (entities) by the first two sets of factor scores (attributes) derived from correspondence analysis (Smith, personal communication). The Euclidean distance similarity measure was employed as described by Clifford and Stephenson (1975). Dendrograms were constructed utilizing the "flexible" sorting strategy of Lance and Williams (1966).

RESULTS

INTERTIDAL SEDIMENTOLOGY

Beach profile and sediment textural characteristics were measured to 1) assess changes in beach configuration and grain size due to natural processes and to placement of excavated sand, and 2) to provide a basis for interpreting changes in the distribution and composition of the intertidal biota.

Two intertidal transects (AA and BB) were located upcoast from the SONGS construction site and three transects (CC, DD, and EE) downcoast (Figure 5-1). Core samples of the beach foreshore were collected quarterly.

Beach Profiles

Profile areas calculated from data collected during December 1977 through November 1978 indicated that the greatest changes occurred at Transects BB and CC nearest the construction site, and that the amount of areal change decreased with increasing distance from the site (Figures 5-4 and 5-5).

Relative changes in profile area and associated beach geometry at each transect were as follows:

1) Transect AA, located farthest upcoast, experienced an increase in area between consecutive survey periods through August, followed by a slight decline between August and November. The beach profiles (Figures 5-4 and 5-5) and beach slope cotangents (Table 5-2) show that adjustments in beach profile area resulted in the development of relatively steep linear beach slopes in February and May and curvilinear slopes in August and November. The curvilinear beach slopes are characterized by a relatively steep upper slope that progressively flattens in a seaward direction (Figure 5-4).

2) At Transect BB, located upcoast and adjacent to the construction site, the profile area increased substantially between December 1977 and February 1978 and again between August 1978 and November 1978. Decreases in area were recorded between February and August 1978. Changes in the beach slope during accretion periods were characterized by upward bulging of the profile which caused the lower beach face to be steeper than the upper. However, during all surveys, the shore was relatively linear between 0 and +6 ft with the slope during eroding periods being steeper than during accretion periods. Sharp berm scarps noted in the May and November surveys (Figure 5-4) were caused by profiles crossing well developed beach cusps.

3) The profile area at Transect CC decreased greatly between December 1977 and February 1978 but the trend reversed in May when a small increase in profile area was recorded. The foreshore profile area during the August and November surveys showed large increases which probably reflected, in part, artificial increases in the volume of sand being introduced on the beach during that period. The foreshore slope during August was extremely flat and relatively linear compared to the curvilinear slopes measured in February and November. Geological and biological samples collected in the 0 through +2 tidal levels in February and November were taken from a relatively flat foreshore, whereas samples collected from the +3 through +6 level were taken on a relatively steep foreshore. In contrast, all samples collected during August were taken from a relatively flat foreshore.

4) At Transect DD located downcoast and adjacent to Transect CC, the profile area decreased between December 1977 and May 1978, followed by increases between May and November. The foreshore slope within the sampling zone was relatively linear and steep during the first three surveys (February through August), but became curvilinear in November (Table 5-2, Figure 5-4).

5) Profile area changes at Transect EE, located farthest downcoast from the construction site were characterized by a small progressive increases over the year. The foreshore slopes in the sampling zone were generally linear except for slightly increased flattening of the lower foreshore slope compared to the upper foreshore slope in May and August.

Beach Grain Size Characteristics

Textural characteristics including the beach foreshore slope data are presented in Table 5-2.

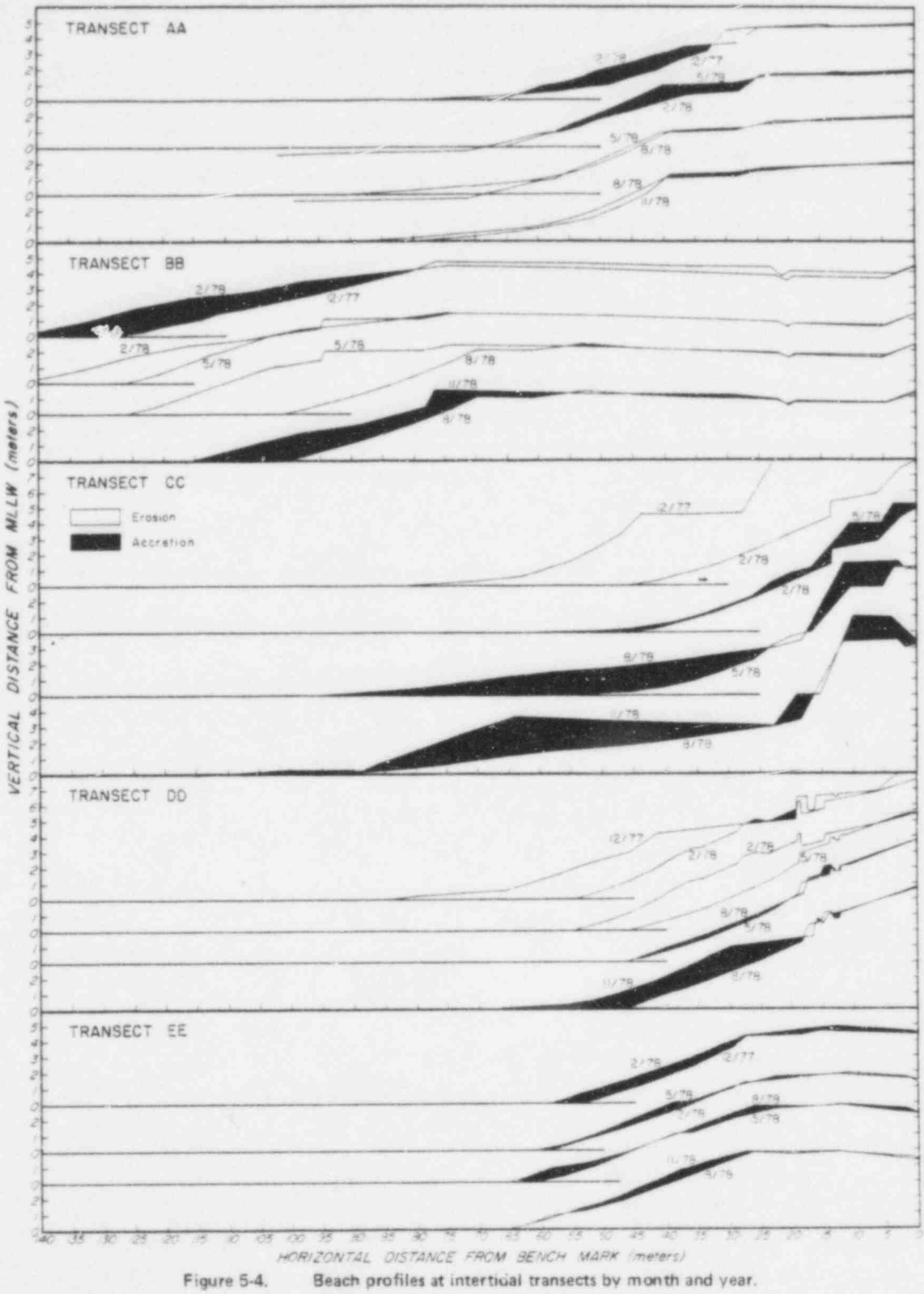

Figure 5-4. Beach profiles at intertidal transects by month and year.

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The beach sediments at San Onofre are composed of a polymodal mixture of medium to very coarse sand and gravel. Fine sand usually becomes a dominant component only on lower beach faces when the slopes are relatively flat.

The degree of polymodality was related, in part, to effects of sampling. A sediment core sample 30 cm long was used. The cores contained sediments with a gravel layer and/or coarse and fine grain layers. However, individual layers may contain more than one mode (population) based on the grain size multipopulation hypothesis previously discussed. Homogenizing stratified cores prior to mechanical analysis resulted in reinforcing the dominant grain size modes. Therefore, the grain size characteristics of a sediment core represented the average effect of the hydraulic processes that are operative on the beach.

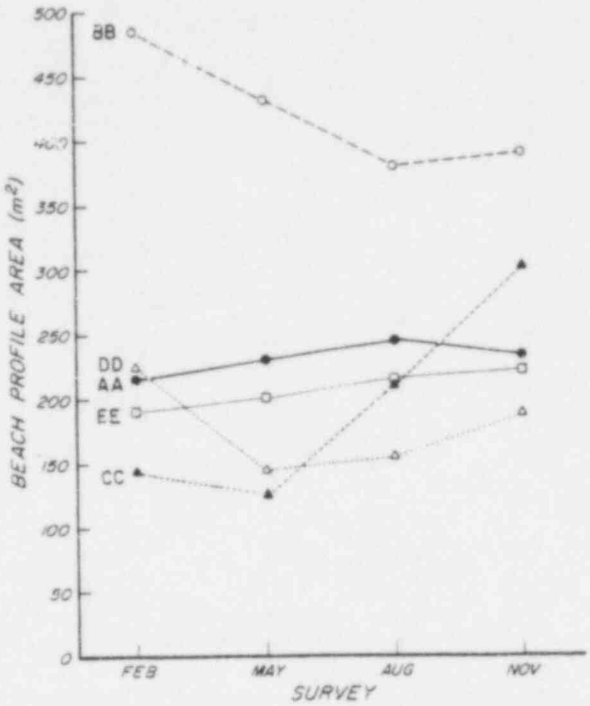

Figure 5-5. Changes in beach profile area by transect between quarterly surveys for 1978.

Although grain sizes were not determined for individual layers, correlation analysis of the grain size fractions whole phi integrals (Table 5-3) suggested a number of modes that might relate to the observed textural contrasts within the cores. They include a predominantly gravel mode (0 to 5 phi), a fine gravel to very coarse sand mode (-2 to 0 phi), a coarse sand to medium sand mode (+1 to +2 phi), and a mode consisting of fine and very fine sand (+3 to +4 phi). These modes were determined on the basis of significant ($P>0.05$) intercorrelation among the grains size fractions, except for the +1 to +2 phi mode which was based on a positive but not significant association. The modes, thus determined, seem to reflect the grain size range of the different laminae detected by visual inspection.

No meaningful spatial patterns were revealed by factor analysis of beach grain size data. Because textural variablity within most cores was equal to or greater than that between transects, any existing spatial patterns were obscured. Factor analysis defined the same grain size modes previously identified by simple correlation analysis.

Gravel and Sand Distribution

The relative mixing of gravel and sand modes was reflected in the mean grain size and sorting of the beach sediments (Table 5-2). Sediments with very low or negative mean grain sizes and high sorting values had relatively large percentages of the gravel mode. The parameters presented in Table 5-2 reflect the averaged values from samples collected at 0, +2, +4, and +6 ft tidal levels (MLLW). In general, sediments with prominent gravel modes were more often found in the longshore trough that occurred at the intersection of the lower foreshore and the low tide terrace. These troughs usually occurred between MLLW and +2 ft. The low tide terraces seaward of the troughs were composed mostly of the fine sand mode to a depth of 30 cm or more. In contrast, upper foreshore sediments were dominated by the fine gravel and coarse to medium sand modes.

Table 5-2. Beach physical characteristics.

	Mean Grain Size (phi)	Sorting Coefficient (phi)	Cotangent of the Beach Slope	Beach Slope (°)
Transect AA				
February	0.49	1.74	8.70	6.56
May	0.95	1.34	7.85	7.28
August	1.84	0.72	15.85	3.62
November	1.80	0.70	13.65	4.20
$\bar{x}$	1.27	1.12	11.51	5.42
Transect BB				
February	1.29	0.95	14.85	3.85
May	0.42	1.15	7.80	7.31
August	1.05	0.60	7.50	7.59
November	0.58	0.85	12.30	4.60
$\bar{x}$	0.86	0.89	10.61	5.85
Transect CC				
February	0.70	1.20	8.05	7.10
May	0.99	1.02	28.30	2.03
August	0.94	1.15	23.75	2.43
November	0.80	1.05	27.60	2.10
$\bar{x}$	0.86	1.11	21.92	3.42
Transect DD				
February	-0.37	1.33	5.90	9.62
May	0.22	1.88	6.95	8.20
August	0.02	1.06	6.35	8.95
November	1.08	1.02	14.05	4.08
$\bar{x}$	0.24	1.32	8.31	7.71
Transect EE				
February	0.21	1.17	7.40	7.71
May	-0.35	1.71	9.25	6.18
August	0.79	1.29	8.50	6.72
November	0.32	1.82	7.90	7.23
$\bar{x}$	0.24	1.50	8.26	6.96

Relationship Between Mean Grain Size and Beach Slope

The primary factors that control the mean grain size of beach sediments are: 1) sediment source, 2) wave energy level, and 3) the general offshore slope on which the beach is constructed (Komar, 1976). Because of the interdependence usually found between mean grain size and the beach slope, the textural characterstics of the beach sediments may be examined by determining their mutual interaction.

The scatter diagram of mean grain size vs. beach slope (Figure 5-6) shows that the beachs with steeper slopes were generally composed of sediments with a larger mean grain size. An exception to this trend occurred at Transect CC (May, August, and November surveys) where the beach slopes were much flatter than would be predicted based on the mean grain size. The latter trend is important because it may be related to the disposal of dredge spoils on the beach subsequently discussed.

The relationship between these two variables was statistically tested by correlation and regression analyses. The statistical analysis was applied, first without the Transect CC May through November data, then re-analyzed with all data included. The analysis showed a significant positive correlation between beach slope and beach sediment mean grain size when Transect CC data were excluded ($r = 0.77$; $P \geq 0.01$), confirming the pattern implied by the scatter diagram. Inclusion of the anomalous Transect CC values rendered the correlation insignificant ($r=0.41$, $P<0.05$).

Other relationships partially obscured by relatively high data variability but which were evident when values were averaged in Figure 5-6 and Table 5-2

Table 5-3. Correlation matrix of grain size fractions for intertidal sediments.

phi		VCG	CG	MG	FG	G	VCS	CS	MS	FS	VFS
-5	VCG				Gravel Mode			Coarse		Fine	
-4	CG	0.56						Sand		Sand	
-3	MG	0.62	0.93					Mode		Mode	
-2	FG	0.50	0.75	0.80			Fine Gravel				
-1	G	+	0.63	0.55	0.86		Mode				
0	VCS	+	0.38	+	0.43	0.70					
+1	CS	-	-	-	-	-	+				
+2	MS	+	-	-	-	-0.57	-0.74	+			
+3	FS	-	-	-	-	-	-0.40	-0.76	-		
+4	VFS	-	-	-	-	-	-	-0.71	-	0.95	

V = very C = coarse F = fine S = sand G = gravel M = medium
+/- Direction of associations that were not significant at the 0.05 level or greater.

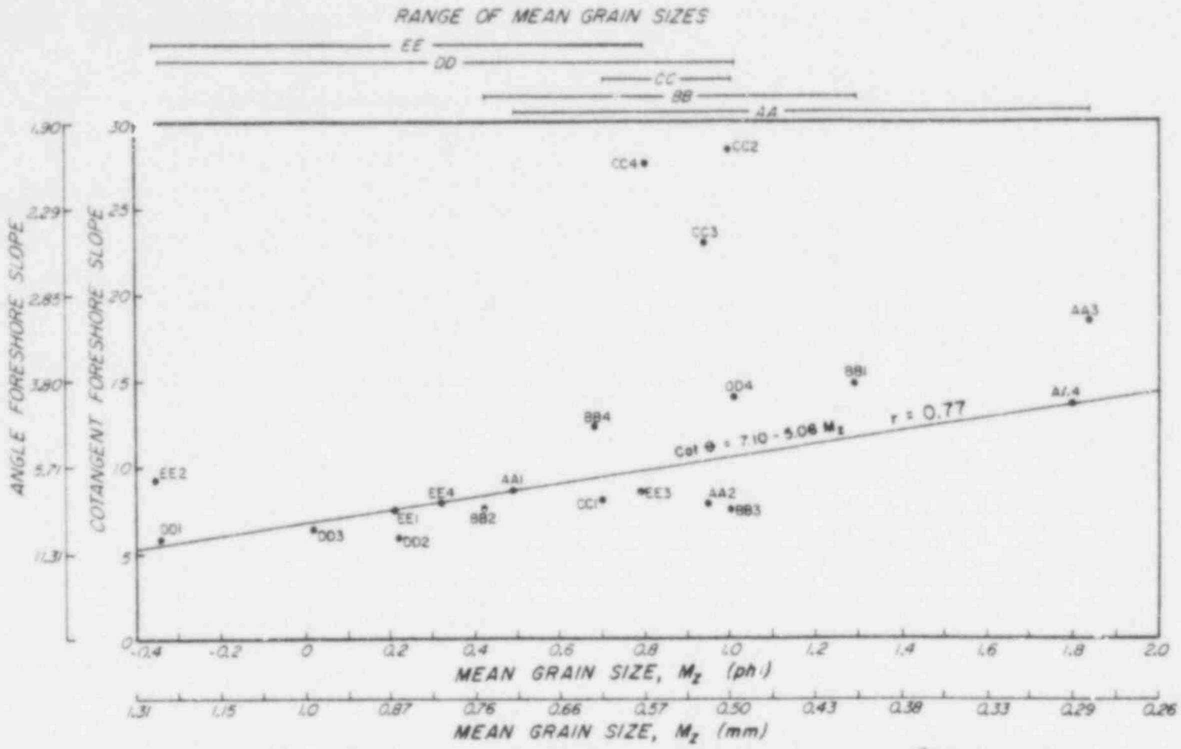

Figure 5-6. Mean grain size vs. cotangent of the foreshore slope at intertidal transects.

include: 1) the steepest beach slopes were more often represented at the downcoast Transects D and E; 2) the mean grain size of the beach sediments was usually larger at the downcoast Transects D and E; and, 3) the temporal variability in mean grain size at Transects B and C (located nearest the construction centerline) was considerably less than at the other transects. The lower textural variability resulted, in part, from the relatively small amounts of gravel encountered at Transects B and C during 1978.

SUBTIDAL SEDIMENTOLOGY

Offshore sediments were analyzed to aid in determining normal sedimentation from sedimentation induced by dredging activities and also to relate sedimentatin patterns to the composition and distribution of the benthic biota.

Multivariate Statistical Analysis of Sediment Grain Size Data

Correspondence factor analysis was used to determine the major grain size populations and depict the gradational trends among the sediment samples with respect to these populations. Agglomerative, hierarchical classification was employed to detect any naturally occurring sample groups.

Correspondence analysis of the sediment variables for each of the four surveys indicates 85% of the variability in the data on the average can be explained by the first two factors. For this reason and because the remaining unexplained variability may contain a large proportion of random components related to analytical and sampling errors, the remaining factors were not interpreted.

A summarization of the influence of the first two factors on certain grain size fractions for each survey is shown in factor loading profiles (Figure 5-7).

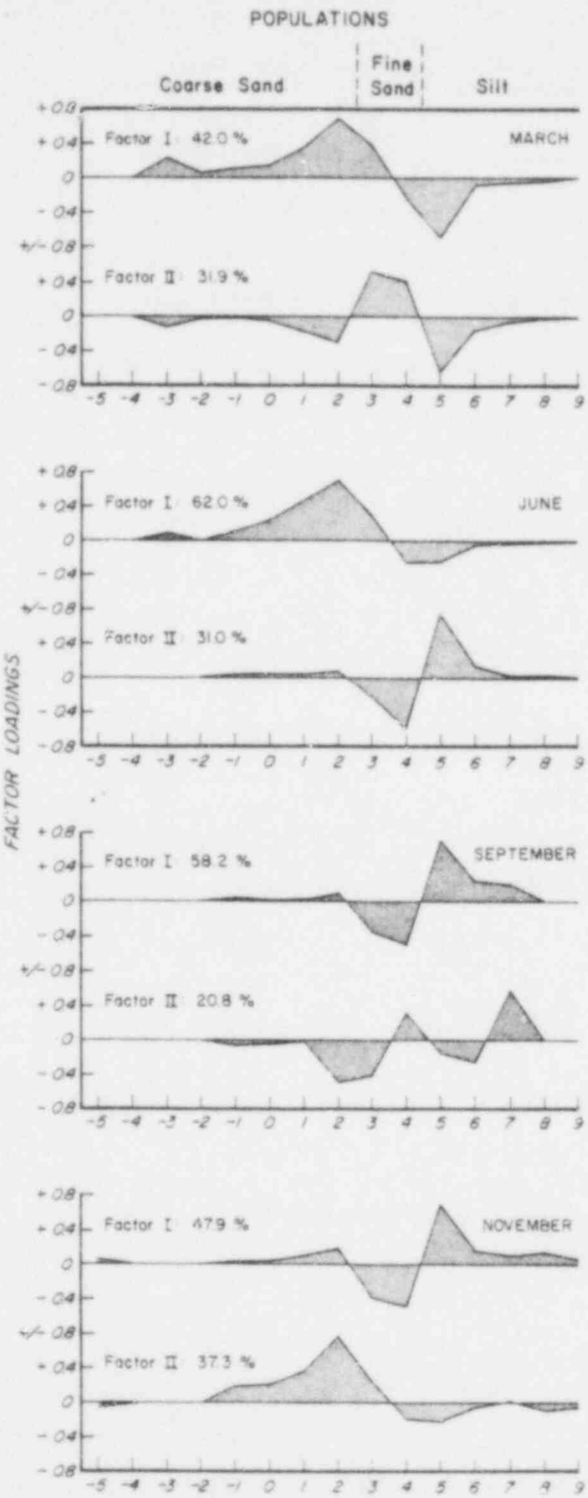

Figure 5-7. Correspondence factor analysis grain size scores on the first two factors.

From the factor loading values shown in Figure 5-7, several grain size populations can be recognized. The maximum loading values located the modes of the populations. The population boundaries were delineated by change of sign of the loading values and/or loading value minimums. It may be helpful to note that the shape of the loading profiles depicted in Figure 5-7 approximate the shape of the grain size poulations which are shown in Figure 5-8b. Overlapping size population distributions which are not distinguishable in the percent frequency distributions are easily recognized in the factor loading profiles.

The grain size characteristics of the principal populations interpreted from the factor profiles included: 1) a coarse sand population composed of grain sizes ranging from 3.5 phi to 0.5 phi with a modal size of 2 phi; 2) a fine sand popuTation consisting of grain sizes between 2.5 and 4.5 phi with a modal grain size between 3.5 phi and 4.0 phi; 3) a silt population consisting of grain sizes finer than 3.5 phi with modal sizes between 4.5 phi and 7.5 phi; and 4) a secondary mixed sandy silt population defined by grain sizes between 3.5 phi and 6 phi with a modal grain size of approximately 4.5 phi. The latter population was detected in the analysis of June and November sediment data.

The sedimentary environmental significance of these major grain size populations became more apparent when their proximity to the stations was viewed in the correspondence factor diagrams (Figure 5-8a). Factor diagrams (Figure 5-8a) for each survey showed four prominent station clusters with different grain size population modes associated with each of these clusters. Stations within each cluster had similar textural properties, thus reflecting a similar environmental influence. The four station clusters can be described as textural facies based on their textural uniqueness illustrated in Figure 5-8a.

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Although each of the four facies clusters were fairly distinct on the correspondence analysis diagrams (Figure 5-8a), the station-facies memberships were assessed by methods of hierarchical classification.

The results of the classification analysis are portrayed in the dendrograms shown in Figure 5-8b. Inter-facies relative similarity for each facies over the four surveys were above 75%, suggesting definite discontinuities existed among the four facies. The uniqueness of the resultant facies was also revealed in their respective grain size distributions (Figure 5-8b).

The strong depth zonation of facies A through C (Figure 5-8a) indicated they were located in the area where sediment distribution was principally controlled by the present hydrodynamic regime. Thus, the above facies were designated contemporary textural facies. The seaward transition from facies A through C was primarily reflected in systematic changes in relative proportions of the fine sand and silt populations (Figure 5-8a,b and Appendix C-2).

The factor analysis diagram shows that textural facies D was widely segregated from the contemporary facies and primarily associated with the coarse sand population. The coarse sand population was apparently derived from an underlying relict cobble, gravel and sand terrace that was intermittently exposed, particularily at sites on Transects D and E. Coarse sands, gravels, and cobble were usually found intermixed with varying amounts of fine sands and silts. This combination of relict and contemporary sediments defined facies D as a reworked-relict facies.

Facies Associations

Facies A sediments were collected on the 6 and 9 m isobaths. Fine sand was the dominant population averaging over 80%. Silt ranged between 4 and 25%, while the coarse sand population was least abundant ranging from less than 1 to 14%. Although this nearshore facies was texturally distinct, noticeable textural variations occurred within it. The average contribution of the silt population was higher in March and June and its distribution was characterized by a trend of increasing abundance with increasing distance from the Units 2 and 3 conduit centerline. This pattern did not appear in September and November when the silt population declined and its distribution became more even. A pattern of increasing abundance of the coarse sand population approaching the construction centerline was observed during all four surveys.

The various mixtures of these three populations was also reflected in the composite grain size statistics (Appendix C-2). Facies A sediments consisting of unmixed predominantly fine sand populations were best sorted (lowest sorting values). Conversely, as population mixing increased, sorting values also increased. The relationship between skewness and mixing of the grain size population was not as clear. However, as one population became more singly dominant, skewness values tended to approach zero. With increased mixing of the coarse and fine sand populations, skewness values generally became negative. Conversely, as the silt population increased with respect to fine sand, skewness values increased positively. Mean grain size, as expected, was also influenced by the relative mixing of the grain size populations. Greater abundances of coarse sand and silt were respectively associated with larger and smaller composite mean grain sizes.

Facies B, a very texturally mixed facies, consisted of subequal proportions of silt and fine sand populations. Coarse sand was generally a minor component, except in June at Station E2 when it represented 13.7% of the total sample. The distribution of facies B sediment during the March and June surveys was

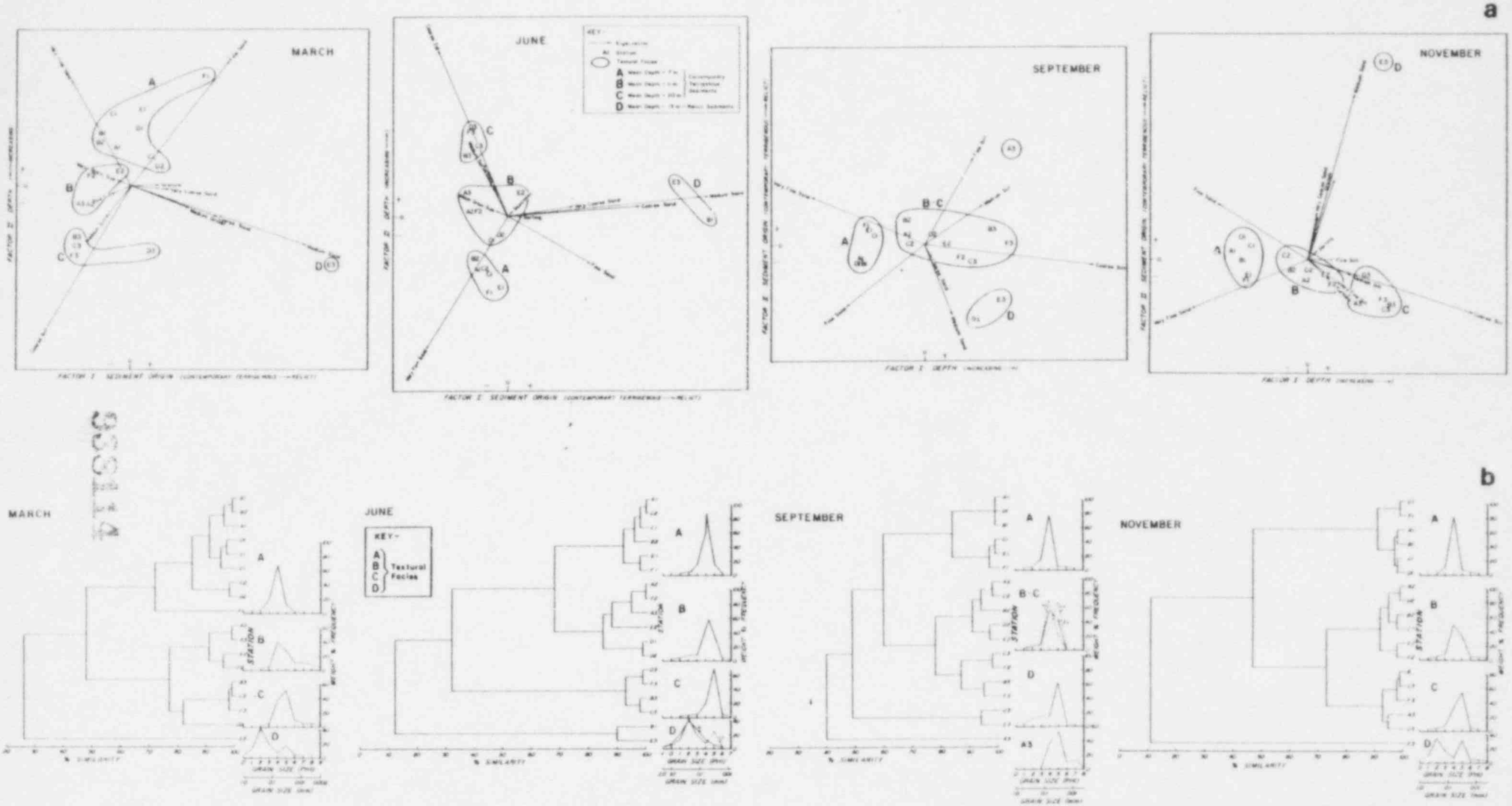

Figure 5-8. a) Subtidal station and varible coordinates on correspondence factors I and II and b) dendrogram portraying classification produced by similarity analysis of grain size data with percent frequency polygons of grain size distributions characterizing each cluster.

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characterized by the occurrence of somewhat isolated patches at alsampling depths. During the September and November surveys, the faciements were confined to the 9 m isobath.

Facies B sediments along the 6 and 9 m isobaths were dominatee sand, whereas at 15 m the mixture of fine sand and silt was more equal (C-2).

Composite mean grain size increased with increased abundance sand. The coarse sand population had little effect on the compositrain size. Composite sorting values generally increased as the proportiilt and fine sand became more even. The extremely poor sorting (high-sorti) of the sediments at Station A2 in March was attributed to relatively xing of fine sand and coarse silt and addition of a secondary fine silt po. Skewness values were also primarily influenced by the relative mixine sand and silt except when the coarse sand population became promingeneral, the sample distribution became more negatively skewed as finecame more dominant. Conversely, when the silt population was dominant, values became positive.

Facies C sediments were restricted to depths of 15 m except nber when they also occurred at Station F2. Silt was dominant, averagin0%, with fine sand ranging between 20 and 47%. Coarse sand was least dranging from less than 1% to almost 9%. The generally reduced population maracteristic of facies C sediments was reflected in lower sorting and values compared to facies B. Mean grain size also decreased as a silt dominance.

Facies C sediments exhibited no striking trends except in Sephen differences between facies B and C were much less distinct. The me th two facies (Figure 5-8a) show the differences between them was gra rather than discrete.

Facies D, the reworked relict textural facies, was distinguisarily on the basis of the high abundance of the coarse sand population, ty, and its lack of correlation with depth. The bimodal character of the rrelict sediments produced high sorting and skewness values.

Station E3 was the only site where relict sediments were founnt during all surveys. Other stations where relict sediments predominluded Station B1 in June and Station D3 in September.

The apparently restricted distribution of the relict facies s is more a reflection of sampling selectivity than a natural consequem relict sediments were often associated with cobble beds were avoided whessible during infaunal sampling. Side scan sonar records depicting substes, presented in Chapter 11, and field observation show that relict se were more widely distributed than was indicated by discrete sampling. ad relict sediment distribution was also apparent in the mixture of and with finer contemporary sediments at many stations.

The shallow water relict sediments at B1 (June) were characte fine sand as a subdominant. In contrast, the deep water relict sedimeninants were a more even mixture of fine sand and silt. Thus, the depth athe relict facies sediments were located was reflected in the relativtion of their subordinate populations.

Water Clarity

Variations in water clarity results from a number of causes ude surface runoff, resuspension by wave activity, plankton productiv

dredging activity. Because light is often a limiting factor in biological productivity, variations in water clarity can have profound effects on aquatic biota. Vertical transparency of the water column was estimated by noting the depth at which a standard Secchi disc disappeared from view. Observations were taken quarterly at 18 subtidal stations from March to November 1978 (Figure 5-9).

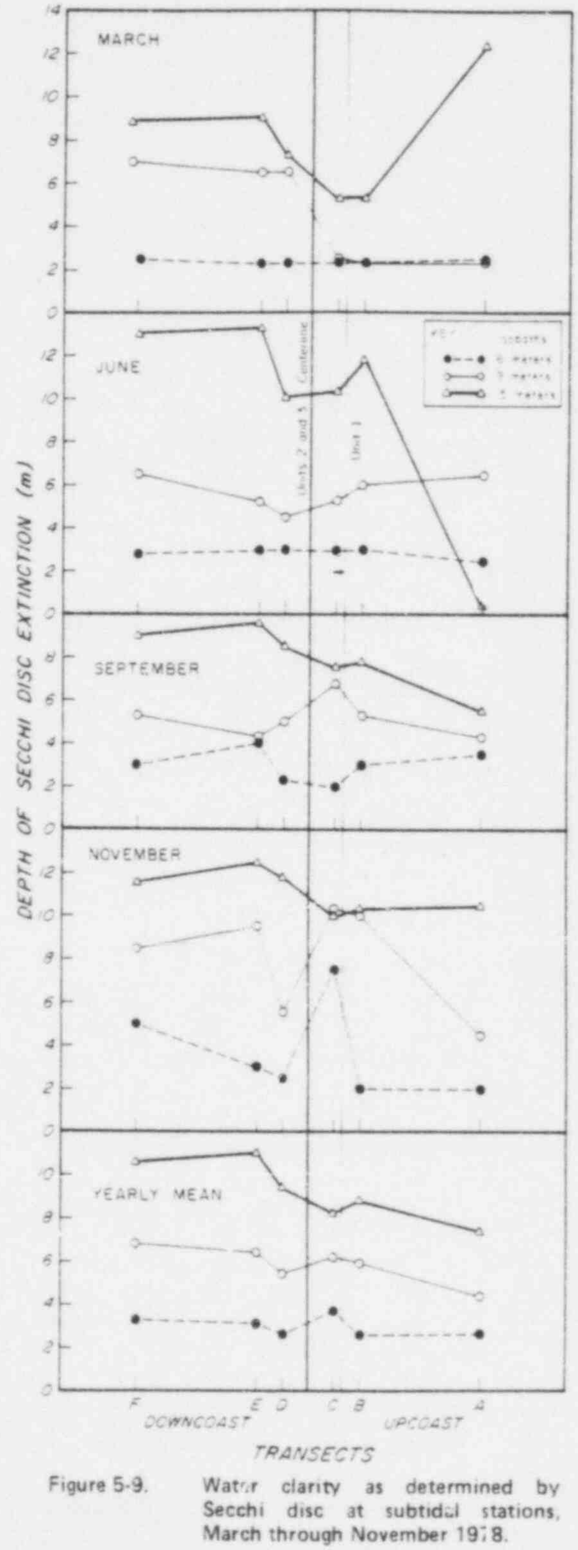

Figure 5-9. Water clarity as determined by Secchi disc at subtidal stations, March through November 1978.

March Survey. Principal trends in water clarity were characterized by increased clarity with increasing depth or distance offshore and, with the exception of the 6 m isobath, a pronounced decrease in water clarity approaching the Units 2 and 3 centerlines.

Mean water transparency along each isobath ranged from 2.3 m at 6 m isobath stations to 8.0 m at stations along the 9 m isobath. Mean water clarity for the survey was 4.9 m with the minimum value of 2.3 m at Stations B1, B2, C1, D1, and E1 and the maximum value of 12.3 m at Station A3.

June Survey. The principal trend was increasing water clarity with increasing distance offshore, except along Transect A where water clarity was lowest at the 15 m isobath and highest at the 9 m isobath. Except for this reduction in water clarity along the 15 m isobath upcoast of the dredge line, water clarity tended to decrease towards the centerlines of Units 2 and 3.

Mean water transparency by isobath ranged from 2.9 m (6 m isobath) to 8.0 m (15 m isobath). Mean water clarity for the survey was 5.5 m with the minimum value of 1.4 m at Station A1 and the maximum value of 13.3 at Station E3.

September Survey. Water clarity was characterized by increase offshore and reduction near the centerline. Slightly greater water clarity at 9 m isobath Station C2, near the Unit 1 discharge was the only exception.

Mean water transparency by isobath ranged from 3.0 m (6 m isobath) to 8.0 m (15 m isobath). Mean water clarity for the survey was 5.3 m with the minimum of 2.0 m at Stations A2 and B2 and the maximum of 12.5 m at Station E3.

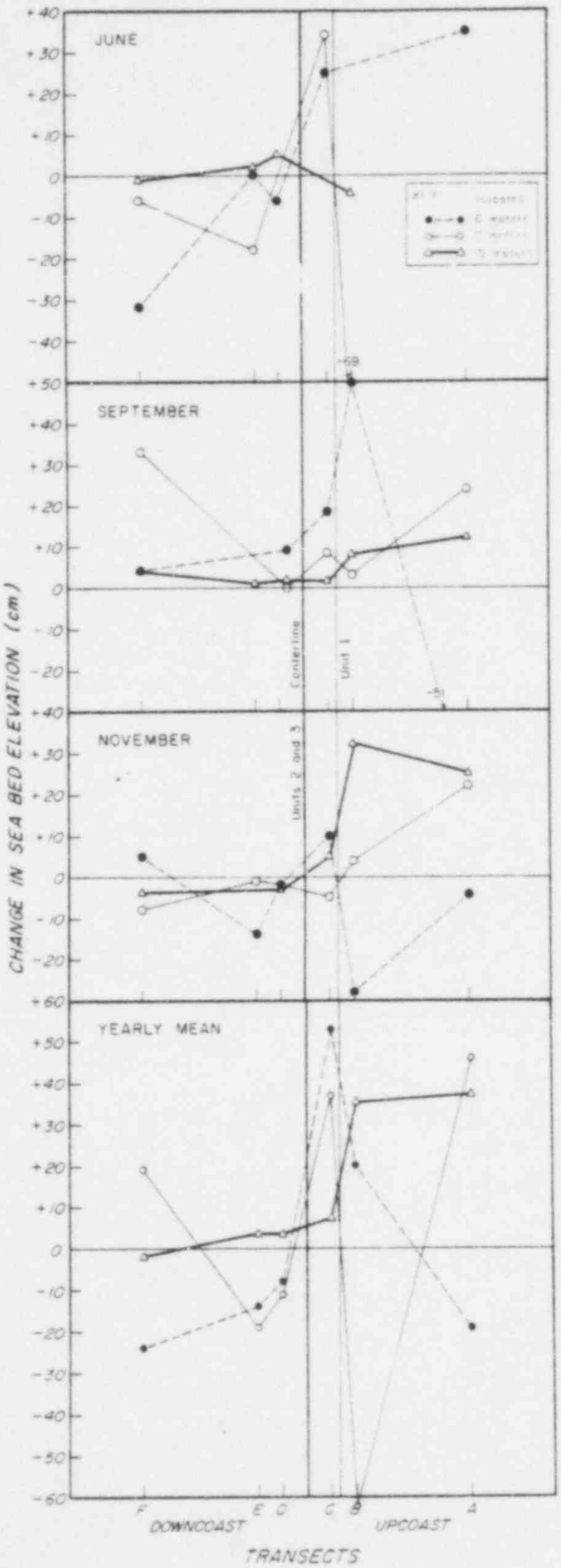

Figure 5-10. Change in sea bed elevation between survey periods at subtidal stations, June through November 1978.

November Survey. Principal trends in water clarity were decrease with distance offshore and greater clarity upcoast of the Unit 1 centerline downcoast along the 9 and 15 m isobaths.

Mean water transparency by isobath ranged from 3.7 m (6 m isobath) to 11.0 m (15 m isobath). Mean transparency for the survey was 7.6 m with minimum values at Stations A1 and B1 and the maximum of 12.5 m at Station E3.

SEA BED ELEVATIONS AND SEDIMENTATION RATES

Dredging operations offshore of SONGS may result in increased sedimentation, thus sea bed elevations sediment rates were analyzed.

No sedimentation data are available for the first four months (December 1977 through March 1978) because severe winter storm activity destroyed or dislodged most of the sediment traps and stakes.

Changes in sea bed elevation between consecutive surveys are presented in Figure 5-10. Sedimentation rates are presented in Table 5-4.

Changes Between March-June Surveys

Patterns in sea bed elevation changes were incompletely documented because a number of sediment stakes had disappeared between March and June. Sediment deposition was confined to Transects C, D, and E, and inshore Station A1. Increases in sea bed elevation ranged from less than 5 cm at Station E3 to 35 cm at Station A1.

Decreases in sea bed elevations (erosion) were particularly evident inshore along Transects B and F, and at the 9 m isobath on Transect E.

The remaining stations exhibited small decreases or no change in sea bed elevation. Decreases in sea bed elevation ranged from less than 2 cm at Station E3 to 69 cm at Station B1.

Table 5-4. Sedimentation rates at subtidal stations (g/m2/day).

Station	Mar	Jun	Sep	Nov
A1	-	585.27	-	115.54
A2	-	120.23	639.49	72.03
A3	-	97.98	-	57.62
B1	-	532.43	797.24	314.14
B2	-	318.59	607.32	35.50
B3	-	-	178.46	41.37
C1	-	1250.63	988.70	30.57
C2	-	-	455.10	5.91
C3	-	266.05	398.25	68.66
D1	-	2738.99	2593.66	34.18
D2	-	168.37	186.33	22.19
D3	-	236.79	261.94	77.93
E1	-	-	-	47.05
E2	-	70.44	965.34	3.22
E3	-	445.86	-	-
F1	-	1930.53	-	7.54
F2	-	104.32	-	86.22
F3	-	87.06	165.92	49.00

Changes Between June-September Surveys

All stations except A1 and D1 recorded net increases in sea bed elevation. Increases ranged from less than 5 cm at Stations B3, D3, and E3 to 50 cm at Station B1. Deposition increased shoreward except along Transect F. Sea bed elevations increased seaward along Transect F from 5 cm (Station F1) to 34 cm (Station F2) then fell to 5 cm at Station F3.

A sea bed elevation decrease of 51 cm at Station A1 was the only negative change recorded.

Changes Between September-November Surveys.

Depositional areas were generally located upcoast of the dredge line and offshore. The only downcoast station with an increase in sea bed elevation was F1. Decreases in sea bed elevation were primarily at downcoast and/or inshore stations. Greatest sea bed erosion, reflected in the difference in sediment stake heights, was the nearly 60 cm at Station B1.

The results of the sediment trap analysis are shown in Table 5-4. Although the sediment traps were initially the same distance above the bottom, changes in sea bed elevation resulted in corresponding changes in height of some traps. Moreover, at least three and possibly six traps were known to be intermittently occupied by octopus during periods between collection. Stations where traps are known or suspected to have been occupied include C2, B2, C1, E1, E2, and F1, all collected in November. Therefore, only general and tentative conclusions can be drawn from the sediment trap data.

Some general trends in sedim tation rates were noted, particularly between June and September. They were 1) a seaward decrease in sedimentation rates at offshore stations, and 2) higher sedimentation rates at stations near the dredgeline. Sedimentation rates ranged between 41 and 2739 $g/m^2/day$ (Table 5-4).

SEDIMENT ORGANIC AND CARBONATE CARBON

Samples collected from the upper 2 cm of bottom sediments were analyzed for total carbon and carbonate carbon ($C-CO_3$) (Figures 5-11 and 5-12). Total carbon is a general indicator of faunal or secondary productivity. The difference between total carbon and $C-CO_3$ represents organic carbon, which is a measure of the amount of available organic nutrients. The carbonate fraction represents mostly $CaCO_3$ in the form of shell debris and foraminiferal tests, and is frequently referred to as inorganic carbon. Sediment organic carbon values of $C-CO_3$ values may range substantially higher.

Organic Carbon

March Survey. Sediment organic carbon content ranged from 0.02% at Station F1 to 0.44% at Station C1. Trends in the distribution of organic carbon included

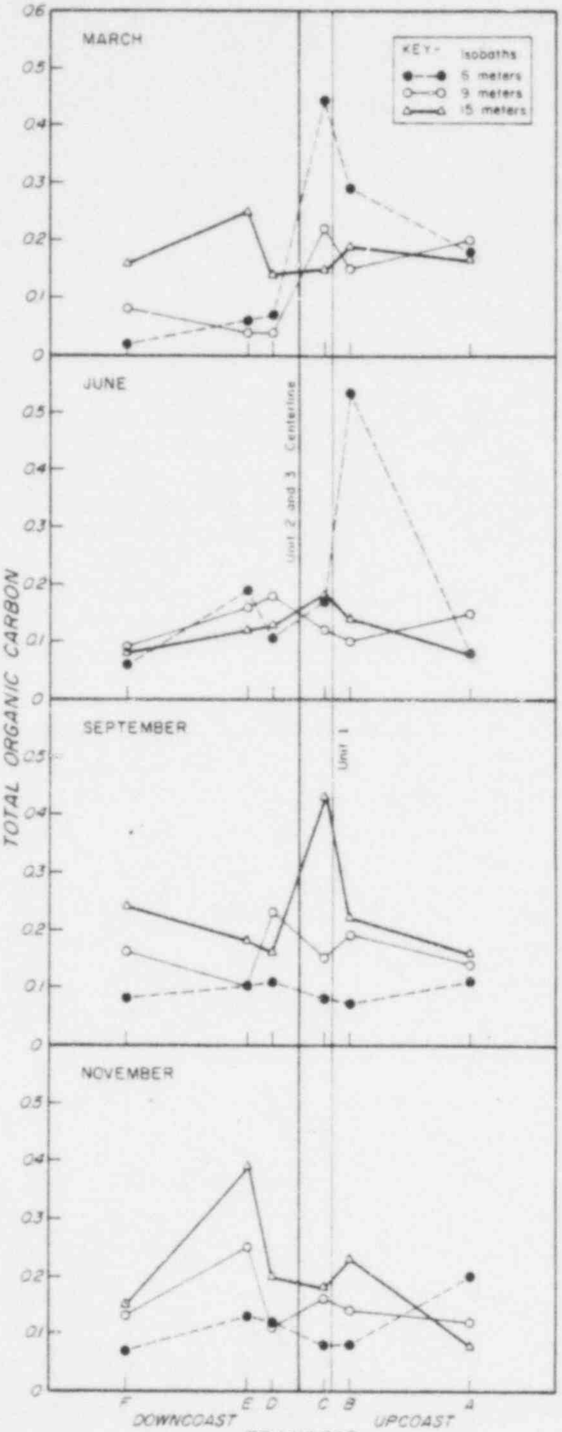

Figure 5-11. Sediment organic carbon content at subtidal stations, March through November 1978.

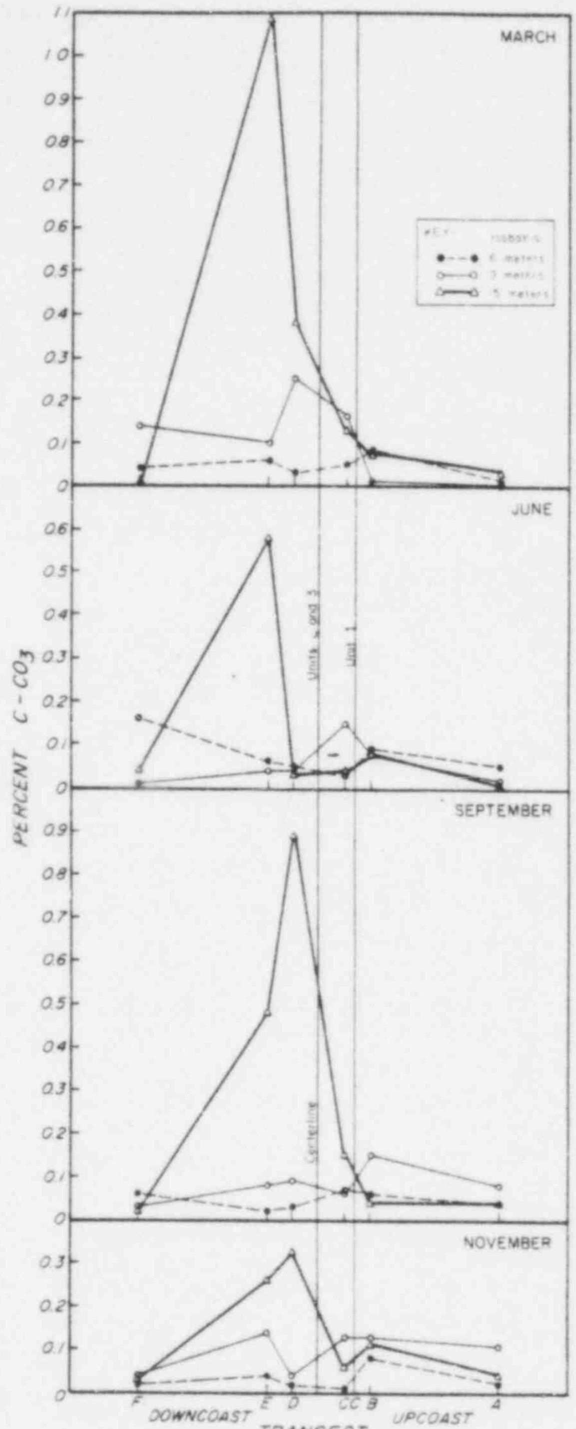

Figure 5-12. Sediment carbonate carbon ($C\text{-}CO_3$) content at subtidal stations, March through November 1878.

a seaward increase in organic carbon along Transe... F, a shoreward increase along Transect C, and a trend of increasing organic carbon approaching the dredgeline along the 6 m isobath.

June Survey. Sediment organic carbon content ranged from 0.06% at Station F1 to 0.52% at Station B1. Other than a relative high organic carbon content at

Station B1, and a shoreward increase in organic carbon along Transect E, no distinctive distributional pattern in organic carbon was noted.

September Survey. A pattern of seaward increase in organic carbon was fairly well developed along most transects during the September survey. Sediment organic carbon content ranged from 0.07% at Station B1 to 0.43% at Station C3.

November Survey. The distribution of organic carbon in the sediments during November was characterized by seaward increase along Transects B, C, and E and a seaward decreased along Transect A. The lowest organic carbon levels occurred at Station C1 and A3 (0.08%) and the highest levels at Station F1 (0.72%).

Carbonate Carbon

March Survey. Carbonate carbon content of the sediments increased sharply seaward, particularly along Transects C and D. Variation in sediment carbonate carbon content along the isobaths was most pronounced along the 15 m isobath and decreased shoreward. Maximum levels of carbonate carbon by isobath were 0.08% (6 m - Transect B), 0.26% (9 m -Transect D), and 1.10% (15 m - Transect E).

June Survey. Sediment carbonate carbon content in June ranged from a low of 0.01% at the 15 m isobath at Transect A to a relatively high value of 0.58% at a depth of 15 m at Transect E. Sediment carbonate carbon was otherwise relatively low, and no distinct distributional trends were noted.

September Survey. Sediment carbonate carbon content, was similar to that reported in June. Highest levels and seaward increases were noted along Transects D and E. Variations in $C-CO_3$ along the remaining transects exhibited no distinct directional trends. Values ranged from 0.027% at Stations F2 and F3 to 0.88% at Station D3.

November Survey. Sediment carbonate carbon was relatively low, averaging 0.09% for the survey. The notable exceptions occurred at Stations D3 and E3 where sediment carbonate carbon was 0.32% and 0.26%, respectively. Inspection of Figure 5-11 shows higher levels of carbonate carbon were recorded at the offshore stations, although differences along transects other than D and E were small.

DISCUSSION

INTERTIDAL SEDIMENTOLOGY

Changes in the beach morphology at San Onofre were related to seasonal and natural variations in wave climate along the beach, interference of longshore transport path by temporary installation structures (laydown pad and trestle), and placement of dredge spoils on the beach. Changes in the beach configuration as a result of construction activities can best be demonstrated by isolating the principal factors causing natural variations.

Natural morphological and grain size changes in a beach are caused by the dispersal of unconsolidated sediments resulting from the activity of wind, waves, and tidal currents (Komar, 1976). The frequency of these morphological changes range from seconds (swash and back wash) to thousands of years resulting from isostacy (uplift or subsidence of the earth's surface) and eustacy (rise or fall of sea level). The greatest changes in beach configuration occur as a result of the action of large gravity waves that develop during storms. The duration of these storm events is usually measured in days.

In California, storm waves occur mainly during the winter months and generally approach the coastline from the west (Shepard, 1950a). They are responsible for the transport of beach sediments offshore and the progressive retreat of the beach foreshore. During summer months, long period waves (swells) approaching from the south are generally associated with building of the beach or seaward advancement of the beach foreshore.

Previous studies of beach profile changes at San Onofre (Shepard, 1950a; MBC, 1978) have not substantiated a constant seasonal trend. However, field observations indicate some areas of the beach are experiencing the normal retreat of the foreshore during the winter months. Some of the changes in the beach configuration can be explained by factors including the installation of structures across the beach and the artificial addition or removal of dredge material.

Based on the orientation of the study area in relation to the primary direction of wave approach, it would seem that longshore currents, which are caused by oblique wave aproach, would be predominently downcoast in winter and upcoast in summer. However, longshore current measurements by Shepard (1950b) taken at various times of the year at three stations near upcoast Transects AA and BB demonstrated no seasonal shift in the longshore current patterns, but instead a predominently downcoast longshore water movement year-round. Shepard's findings demonstrate that factors other than deep water wave characteristics are needed to explain nearshore water movements and related beach responses at SONGS.

The most important influences that Shepard's (1950b) investigation implicated included effects of 1) nearshore bathymetry on wave energy divergence and convergence; 2) rip currents; 3) offshore circulation; 4) wind stress; 5) offshore kelp beds; and 6) bottom irregularities not detectible on bathymetric charts. Subsequent theoretical and field studies now indicate inshore circulation in general can be influenced by edgewaves that interact with the incoming waves in such a way as to produce longshore variations in wave setup and associated rip currents (Bowen, 1969, Bowen and Inman, 1969). Other studies (Sonu, 1972) on irregular beaches indicate that bathymetry as it applies to development of spilling vs. plunging waves can control inshore circulation patterns. Since evaluation of most of the above factors was beyond the scope of this study, the discussion will be restricted to the effects at nearshore bathymetry which appears to be important at San Onofre.

The interaction of an irregular nearshore bathymetry and the approaching offshore waves at San Onofre resulted in discernable convergence and divergence of wave energy at two locations within the study area.

Where the nearshore bathymetric contours form a shoreward indentation such as occurrs to seaward of Transect AA (Figure 5-1) waves tend to diverge, resulting in development of smaller waves. Wave heights measured at and adjacent to transect AA were usually smaller than those measured at the other transects (MBC, 1977; Shepard, 1950b). The proximity of Transect AA indicates it is also partially sheltered from waves approaching from the west and northwest, thus accentuating smaller waves. The seaward bulge of bathymetric contours to seaward of Transects BB, CC, and to some extent Transect DD identifies wave energy convergence zone. Larger waves reported at these transects attest the influence of the bathymetry on the local wave climate. Some differences in the sheltering effect of the coastal outline at these three transects is evident. The laydown pad and trestle that extend across the beach and offshore constitute an immediate impact on beach processes at Transects BB, CC, and DD. The effects of these structures and dredge disposal on the beach will be discussed separately.

Transect EE is situated where nearshore subtidal contours are nearly parallel to the shoreline. Thus, wave energy distribution along this segment of the beach should be more even. Wave heights at Transect EE were generally lower than at the upcoast Transects DD, CC, and BB. The location of Transect EE lends itself to exposure to waves approaching from both the south and west.

FORESHORE SLOPE, GRAIN SIZE, AND BEACH PROFILE

The significant correlation between beach mean grain size and slope demonstrated a dynamic equilibrium that generally existed between the beach slope grain size and prevailing wave conditions. This equilibrium was mediated by the swash and backwash flow characteristics which in turn was dependent on particle size and wave climate (Shepard, 1963).

In general, coarse sand beaches attain steeper slopes because their higher permeability causes much of the swash water (runup) to percolate into the beach; thus less water is available for return flow. Sand piles up, thereby enhancing beach steepness because the reduced return flow (backwash) cannot erode away the amount of sediment carried upslope by the swash. However, large waves can overide the percolation effect by introducing water in excess of the ability of the beach to absorb, thus causing greater backwash flows and subsequent erosion and slope flattening.

Periodic small scale fluctuations in the beach slope profile are associated with the tidal cycle, wave conditions, and their interaction with the beach water table level. According to Duncan (1964), the beach profile in the swash-backwash zone is dependent on alternations of sand deposition and erosion. Basically, at low tide when beach water table levels are low, swash deposition and backwash erosion predominate, forming a thick sediment lens on the shoreward side and a scoured area on the surf side of the swash-backwash zone, thereby steepening the beach profile. In contrast, relatively high beach water table levels result in maximum upper beach backwash deposition and erosion near the surf boundary which tend to flatten the beach profile.

On fine sand beaches with low permeability such as at San Onofre, the backwash flow is always sufficient to prevent swash slope building and beach profiles remain relatively flat.

The apparent lack of relationship between foreshore slope and mean grain size at Transect CC during March and November was a result of an abrupt transition from a steep upper to a f at lower foreshore. Comparison of mean grain size (Figure 5-3) and slope altitudes (MBC, 1979) shows that the upper foreshore slopes were relatively steep and veneered with medium to coarse sand, whereas the lower foreshore was nearly horizontal and predominantly composed of fine sand. Therefore, a relationship between mean grain size and foreshore slopes was evident when the upper and lower foreshore segments of the beach profile were examined separately.

However, in August, the entire foreshore slope at Transect CC was relatively flat yet the mean grain size was greater than would be predicted by the slope attitude. This condition was probably caused by the introduction of dredge spoils on the beach at a rate above that at which the beach profile could adjust to the prevailing wave climate. An alternate explanation would be that the gentler slope attitude in August reflected an equilibrium profile that had adjusted to large waves at some time prior to the survey.

EFFECT OF CONSTRUCTION ACTIVITIES ON THE BEACH

Superimposed on the naturally operating inshore environmental processes were influences introduced by the construction laydown pad and trestle that extend offshore between transects BB and CC.

Previous studies (MBC, 1978) and present data demonstrated that longshore sand transport was partially interrupted by these structures. Field observations and profile measurements indicate that either a maximum sand storage on the upcoast side of the laydown pad (Transect BB) occurred between December 1977 and March 1978, or that a natural upcoast redistribution of sand had occurred. The increase in sand storage on the downcoast side of the laydown pad indicated considerable sediment flux between February and November 1978. This large increase in sand volume was probably related to the disposal of dredge material.

SUBTIDAL SEDIMENTOLOGY

Multivariate statistical analysis of the sediment data differentiated the offshore region into areas that located three contemporary textural facies and one reworked relict textural facies. It should be noted that the above facies correspond closely to station groupings based on infaunal species classification discussed in Chapter 8.

Grain size distributions of nearshore sediments predominantly sand (facies A), were well sorted, and nearly symmetrical. The textural characteristics of this region appear to agree with the prevailing nearshore hydrodynamic climate which was characterized by a nearly constant and vigorous oscillary bottom wave surge. As pointed out by Inman (1949), sand is usually transported as bed load by virtue of its high settling velocity, which is defined as material transported in traction and/or intermittent suspension. Thus, the fine sand populations identifying facies A sediment may be called a bed load sediment size population.

Facies B sediments were generally no as well sorted as those of facies A and appeared to mark a transition zone separating inshore sandy bottom environments from silty bottom environments further offshore. This transition zone was also reported along the southern California coast by other investigators. Inman and Chamberlain (1956), Kolpack (1972) interpreted the zone as a region where the reduced wave surge associated with increased depth allowed deposition of silt as well as sand. Particles in the silt size range, although relatively difficult to erode initially because of cohesion, when suspended tend to remain there (Inman, 1949). Thus, the silt population can be identified with suspension transport. The mingling of bed load as well as suspension sediment populations can be interpreted as reflecting a region where hydrodynamic conditions are variable relative to inshore (facies A region) and offshore (facies C region). Under conditions of reduced wave surge suspension fall out of silt predominates. However, facies B sediment contained nearly equal proportions of sand, thus suggesting "quiet water" conditions were never long lasting.

The predominance of a well sorted singly dominant silt population offshore at depths greater than 9 m suggest hydrodynamic variability decreased. Apparently beyond this depth, changes in bottom surge conditions usually are not very significant.

In general, the contemporary textural facies distribution reflected a seaward gradation in intensity of hydrodynamic conditions. Variability in those conditions, however, was maximum at a depth of 9 m and decreased seaward and shoreward from this isobath. Moreover, the re-occurrence of these facies indicate a temporal stability throughout the study area. This stability was further substantiated by a similar recurrent textural pattern recorded during the 1976-1977 survey period (MBC, 1978).

Sediments that were not deposited under the present hydraulic conditions included those defining the relict facies. The relict sediments were generally coarse but texturally diverse, with grain sizes ranging from medium sand to boulder. The configuration of these deposits was fairly dynamic in that their

exposure was dependent on the movement of a thin veneer of contemporary sand and silt. Exposure of these relict sediments more often occurred in the area of Transects C, D, and E.

The relict exposures supported giant kelp stands. The presence of large kelp beds have influenced local chemical and biological processes and the physical processes of wave energy convergence inshore and wave current damping offshore (Shepard, 1950b).

SEDIMENTATION

General patterns of sedimentation that were observed in the study area in 1978 included: 1) generally higher variability in sea bed elevation inshore, 2) increased sea bed elevation reflecting deposition more often recorded upcoast of the construction centerline, 3) sedimentation rates, estimated from sediment trap locations between 0.5 m and 1.8 m off the bottom, generally decreased with increasing distance offshore.

A regional description of sediment movement was not obtained with sediment traps or stake field data; however, the sedimentation trends noted above were in agreement with the prevailing hydrodynamic regime and primary sediment sources including San Mateo Creek and sediment disposal from construction activities. The decreasing variability in sea bed elevations and sedimentation rates offshore was related to the seaward decrease in available energy required to mobilize and transport sediments.

The influence of the San Mateo Creek runoff may have been reflected in the higher levels of sedimentation that occurred upcoast of the construction centerline, particularly in March. This period coincided with time of maximum precipitation recorded for the San Onofre area (B & C, 1979).

RELATION OF ORGANIC AND CARBONATE CARBON TO GRAIN SIZE

The superficial sediments of the offshore region at San Onofre contained a level of organic carbon expected in shallow, well mixed open coastal waters. However, the strong associations usually observed between organic carbon and fine grained sediments was not consistently demonstrated. Correlation analysis of organic carbon with the grain size fractions showed organic carbon to be highly correlated ($P<0.05$) with the coarse sand and gravel fraction in June.

September was the only month during which organic carbon correlated significantly with the fine grain fractions. Inspection of the carbon data indicated some of the correlations were influenced by one or two anomalously high values which masked associations otherwise evident. The correlation analysis was also complicated by samples containing bimodal mixtures of fine and coarse grain size populations.

Station E3 exemplified sediments composed of a bimodal mixture of coarse sand and silt and exhibiting relatively high organic carbon. In such cases percent organic carbon was positively correlated to both the coase sand and silt population, but in reality the organic carbon was bound to the silt population.

The distribution of carbonate carbon was associated with the general pattern of the sediments. A significant positive correlation of percent $C-CO_3$ with the coarse sand and gravel fraction ($P<0.05$) and a negative correlation with the fine sand and silt fractions ($P\leq\overline{0.05}$) indicated sediment carbonate carbon was primarily associated with relict textural facies. However, changes in the level of percent $C-CO_3$ in the contemporary sediments also followed the variation of their coarse sand components.

The variation in sediment carbonate carbon content in the study area was probably controlled more by an imbalance between sediment influx and current and wave velocity than by carbonate production. At the offshore Stations D2, D3, E2, and E3, $C\text{-}CO_3$ was relatively high for reasons that remain unknown at present. An undetermined amount of $C\text{-}CO_3$ is derived from the fouling community associated with Unit 1 intake and discharge structures.

Sediment studies conducted in the vicinity of Unit 1 discharge and intake structures following heat treatment and operation (Diener and Parr, 1977) suggest that appreciable amounts of shell debris ($C\text{-}CO_3$) from the remains of fouling organisms were introduced into the sediments. These remains were probably distributed by the natural wave and current regimes as well as turbulence induced by the discharge plume. The present study did not reveal a discernible gradient of increasing $C\text{-}CO_3$ associated with Unit 1. The lack of a recognizable gradient was probably related to the location of sampling sites, and to the high degree of variability in sediment conditions reported in that area (Diener and Parr, 1977; MBC, 1978).

VARIATIONS IN WATER CLARITY

Decreased water clarity with decreasing depth was the dominant pattern at SONGS. The seaward pattern was related to hydrodynamic and biological processes that determined offshore variations in the water clarity.

Natural processes that led to variations in water clarity were wave action, airborn debris, and shoreward transport of surface water by afternoon onshore winds. All these processes were both spatially and temporally variable at SONGS. In addition, the disposal of dredge material was observed to cause decreased water clarity offshore.

In general, the overall distribution of water clarity is caused by 1) variation in suspendent distributive processes, 2) variation in the suspendents characteristics, and 3) supply of the suspendents. At San Onofre, the important materials include suspendents derived from both shoreline and offshore sources.

In addition to variation in sources and distribution processes were factors related to dredging operations, offshore structures, and thermal effluent discharge from SONGS Unit 1.

The effects of dredging and Unit 1 discharge were seen as localized gradients of decreased water clarity with proximity to these structures. Possible impacts of decreased water clarity on the benthic community are discussed in Chapter 8.

Sedimentary Trends, Dredge Activity, and Sand Disposal

Evaluation of the effects of dredge operations on the sedimentary regime was complicated by high natural variability in environmental conditions coupled with the paucity of historical data.

Possible impacts included resuspension of sediments by dredging and blockage of the longshore sand transport path by the laydown construction pad.

Augmentation of sedimentation by dredging activities was not confirmed by the sediment data. However, offshore and nearshore suspension plumes associated with the dredge spoil were visible during field sampling. The offshore plume, when observed, was oriented downcoast and offshore. A second plume associated with onshore disposal was also observed nearshore which transported suspendents downcoast, generally within the surf zone.

The grain size of the suspended material was qualitatively estimated from water samples taken from the inshore dredge plume. Because of the observed dredge plume dispersion characteristics and estimated grain size of the plume suspension, the resident time of the plume material was probably relatively short in the study area. In this respect, the sediment data suggests that dredging related sedimentation effects are temporary.

SUMMARY

The sedimentology in the vicinity of SONGS was investigated as part of the monitoring program related to construction of Units 2 and 3. The parameters examined were sediment physical and chemical characteristics, distributional patterns, and relationships to various environmental processes. The analysis revealed:

INTERTIDAL SEDIMENTS

1. In general, the beach at San Onofre was steep and veneered with coarse sand except for occasional patches of exposed cobble and rock.

2. Large fluctuations in beach profile configuration between surveys were noted in the construction area and were related to the presence of the laydown pad and trestles.

3. Placement of dredge spoils on the beach downcoast of SONGS laydown pad and trestle altered the textural character of the beach, but did contribute to the high temporal variability in profiles.

SUBTIDAL SEDIMENT

1. Sediment analysis identified four texturally unique regions (facies) in the study area. These included a fine sandy facies (A) at 6 m stations that graded seaward into mixed sand-silt facies (B) at the 9 m stations terminating in a silt dominated facies (C) at the 15 m isobath stations. The fourth facies (D) included texturally coarse relict sediments which were confined to 15 m stations downcoast of the Units 2 and 3 centerline.

2. The distribution of these facies appear to be a reflection of the decrease in wave and associated current activity that occurs with increasing depth.

3. The spatial distribution of textural facies appear to reflect natural sedimentary conditions. No influence due to the operation of Unit 1 or construction activities associated with Units 2 and 3 was apparent.

4. No apparent long-term effects on the sedimentary environment have been observed during the study period (1977 to 1978) as a result of dredging or construction activities.

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CHAPTER 6

PLANKTON

INTRODUCTION

The ongoing marine monitoring studies reported in this chapter are being conducted to meet objectives approved by the Nuclear Regulatory Commission (NRC) as stated in the Environmental Technical Specifications (ETS), Docket No. 50-206, Sections 3.1.2a(1) General Ecological Survey for the San Onofre Nuclear Generating Station (SONGS) Unit 1 and the Preoperational Monitoring Program (PMP) for SONGS Units 2 and 3. Broadly stated, the Preoperational Monitoring Program objective is designed to provide a baseline for the determination of the nature, extent, and significance of the effects of SONGS Units 2 and 3 on the species composition, distribution, and abundance of plankton inhabiting the receiving waters offshore of the generating station. The ETS objective is to determine the effects of SONGS Unit 1 on the plankton resources in the vicinity of the generating stations. These studies are also being conducted in compliance with the National Pollution Discharge Elimination System (NPDES) permit for SONGS Unit 1 which requires that results be reported to the California Regional Water Quality Control Board (CRWQCB), San Diego Region and the regional office of the Environmental Protection Agency.

The 1978 biological and physical data utilized in this analysis report was presented in the Annual Operating Report, an Onofre Nuclear Generating Station, Volume II; Biological Data-1978 (LCMR, 1979a).

This chapter presents the objectives of the ETS and PMP, the unified approach to meeting both these objectives with one combined program, and environmental and historical background information to put these studies into perspective. Methods of data collection as well as data analysis and the results of analysis by tabular and graphical techniques are also given. Finally a discussion and evaluation of the specific topics being addressed is presented with reference to the combined study objectives.

APPROACH

This chapter is organized into four sections: introductory material, methods, results, and discussion. The methods section includes the methods used for data collection, laboratory analysis and the techniques for analysis of the data. In the results section the results of various analyses are given for and organized by data type. Analysis has been conducted in terms of patterns of distribution for a given parameter. This includes spatial distributions in onshore-offshore orientation and distribution with regard to distance upcoast and downcoast from SONGS. The vertical distribution of biological parameters with regard to the two depth strata sampled is then described and discussed, followed by a discussion of temporal patterns observed during 1978 and how this pattern compares with similar observations made for previous years. Following the description of spatial and temporal patterns of the biological data, the physical data collected during the plankton surveys is presented and discussed as it relates to biological observations. The specific data types examined are the concentrations of phytoplankton biomass as expressed by chlorophyll *a* and phaeopigments, and the abundance, biomass, and community structure of zooplankton. Tem-

perature, transmissivity, and current data are considered in general terms as related to the biological data. In the discussion section the distribution patterns of these parameters are described. Each biological data set is considered in terms of whether any effect of SONGS Unit 1 has been detected on any component examined.

BACKGROUND

In order to place the study objectives and results into perspective, a brief description of the marine environment offshore SONGS is presented as well as a historical review summarizing previous and ongoing plankton studies conducted in the SONGS receiving waters.

Physical factors which may affect the distribution and abundance of plankton include water temperature, nutrients, turbidity, and currents. Water temperatures generally decrease with depth. During the winter, temperature is fairly uniform due to the well mixed nature of the water. In the summer a shallow thermocline is established due to solar heating. Mixed-layer winter temperatures are normally in the range of 13 to 17°C. Surface summer temperatures may be 17 to 22°C while temperatures 10 m deeper are two to three degrees cooler (IRC, 1973; LCMR, 1976d; BC, 1979). Chemical nutrients are distributed in a typical pattern, with low concentrations at the surface and increasing with depth. During winter, values may be relatively uniform from the surface to the bottom at 15-16 m (MBC, 1979). Turbidity is due to suspended particles of sediment and organic detritus as well as plankton. High turbidity in inshore coastal waters is largely due to the increased turbulence and wave action stirring up and suspending bottom materials (Raymont, 1963). Turbidity in the San Onofre area increases both near-shore and near-bottom (LCMR, 1976d; BC, 1979). Current speeds typically range from 5 to 40 cm/sec and average 10 cm/sec. Currents near the coast vary in direction and speed as a result of wind and tidal-induced motions (EQA/MBC, 1973).

The San Onofre Nuclear Generating Station is located on the open coast, an area which, on the whole, is relatively uniform in terms of plankton faunal composition and productivity. The plankton in the receiving waters of the generating station is typical of the near-shore plankton of southern California (LCMR, 1974b).

The present plankton sudies have evolved from a qualitative examination in 1964 followed by quantitative semiannual plankton studies, conducted in the San Onofre area between 1965 and 1975 for the California Regional Water Quality Control Board, San Diego Region. The scope of these early studies included collection of zooplankton samples at the surface (0-2 m) with a net and surface phytoplankton in whole-water samples. The 1965 to 1972 data were summarized and reviewed by Barnett (1973), Enright and McGowan (1973), and Dodson (1973). These data revealed that there was an increase in abundance of many zooplankton taxa during periods of SONGS operation at all stations, including "controls" (Barnett, 1973; Enright and McGowan, 1973). Variability in abundance between stations decreased during operational periods (Barnett, 1973). Phytoplankton species variety and cell numbers were similar between SONGS and control stations (Dodson, 1973) and variability in abundance at all stations decreased during operational periods (Enright and McGowan, 1973).

The ongoing ETS study began in May 1975 with the establishment of seven stations spaced at increasing distances upcoast and downcoast from the SONGS Unit 1 intake/discharge line (Figure 6-1). This study was designed to assess

area-wide effects rather than nearfield intake/discharge effects. All stations were located along the 10-m depth contour to permit possible correlations of plankton data with physical and biological data collected during other related studies which have stations at similar depths. Integrated zooplankton samples and point source whole-water samples were collected from the upper and lower half of the water column separately to enable assessment of changes in vertical distribution. Sampling began in May 1975 and surveys have been conducted bimonthly thereafter. Replicate plankton samples were collected semiannually. The ETS data have revealed that, while differences may occur between stations during a survey, there have been no consistent patterns in the distribution and abundance of zooplankton or phytoplankton by station. Chlorophyll a and phaeopigment concentrations have been generally greater near the bottom than close to the surface while no zooplankter has exhibited a consistent distribution with depth. An analysis of the first three years of ETS data collection concluded that any effects on distribution and abundance of plankton associated with SONGS Unit 1 operation are less than the natural variability of local plankton populations.

Very localized (up to 500 m from the discharge) changes in the vertical distribution of some species has been observed and attributed to the entrainment and upward transport of near bottom water by the Unit 1 discharge plume (MRC, 1979). The total abundance in the area, however, was unchanged.

In April 1978 a preliminary sampling program was conducted to determine optimal sample sizes and numbers of replicates for the combined ETS and PMP program. A new program based on the results of this preliminary and historical studies was initiated in July 1978. This combined program greatly expands both the area sampled and the number of samples collected at each station. A more detailed description of this ongoing program is presented in the following methods section.

The purpose of this report is to analyze and interpret the 1978 data collected by the combined ETS-PMP program. This includes the initiation of data presentation to establish baseline conditions which can be compared to conditions that occur after Units 2 and 3 become operational, and the identification of any significant alterations to the marine environment which may be attributed to the operation of SONGS Unit 1.

METHODS

A detailed description of station locations and field and laboratory methodology is given in combined ETS and PMP procedures (SCE R&D/LCMR, Procedures P-0-8/78). A general review is presented below.

FIELD

Seventeen stations make up the array of plankton sampling stations included in the combined Unit 1 ETS and Units 2 and 3 PMP programs (Figure 6-1). These are arranged in three transects, each transect being oriented parallel to the coastline. Each transect includes stations located directly offshore of SONGS and stations extending upcoast and downcoast from SONGS. Eight stations (1-8) lie along the 10-m isobath, five stations (9-13) lie along the 15-m isobath and the remaining four (14-17) lie along the 30-m isobath.

Biological samples collected at these stations include zooplankton samples and whole-water samples for analysis of chlorophyll a and phaeopigment concentra-

tion. These are collected concurrently at each station using a Lockheed designed plankton pump system. Samples are collected from two strata within the water column at each station. The upper stratum extends from the surface to 5-m depth for the stations located along the 10-m isobath and from the surface to 8-m depth at stations along the 15 and 30-m isobaths. The lower stratum encompasses the depth interval from 5 to 10-m at the stations located on the 10-m isobath and from 8-m to the bottom for the deeper stations. Within each of these strata, samples are integrated with 1/3 m^3 of water being sampled at each 1-m depth interval within a stratum. Zooplankton samples are concentrated by filtering through 0.202-mm mesh plankton net. A 450-ml whole-water sample is obtained for analysis of chlorophyll a and phaeopigments by collecting a small fraction of the water prior to being pumped through the plankton net. Two replicate water samples and two replicate zooplankton samples are collected from each stratum at each station. The first replicate is taken as the intake is lowered and the second as it is raised. This procedure is repeated on three days within a seven day period for each bimonthly survey except that inshore Stations 2, 3, and 5 are not sampled on the second and third days. All samples are collected during daylight hours. Prior to implementation of the combined ETS-PMP program in July, field sampling was conducted in the manner of previous ETS surveys (LCMR, 1975g). Only Stations 1-7 on the 10-m isobath were occupied, with replicates taken semiannually. At each 1-m depth interval within the two strata sampled, 1 m^3 was filtered with a plankton pump and 0.202-mm mesh net. Unfiltered whole-water samples were taken from two fixed depths, for phytoplankton pigment analysis.

Physical data are collected concurrently with biological sampling. Temperature-depth and transmissivity-depth profiles, with measurements taken at 1-m intervals, are obtained each time a plankton station is occupied using a Martek XMS temperature-transmissivity unit. Gross current speed and direction of flow is estimated by deployment of a sub-surface drogue for a measured length of time (15 min to 1 h) while each station is occupied. Meteorological information, including cloud cover, wind, and sea conditions is obtained at each station occupied.

Plankton surveys are conducted on a bimonthly basis, however, during 1978 the January ETS survey could not be completed due to persistently inclement weather. The remaining surveys were completed as follows: ETS surveys only on 7 March and 11 May; combined program surveys on 14, 17, 19, and 20 July; 8, 9, and 10 September; 16, 17, and 18 November.

LABORATORY

Phytoplankton populations are assessed by determining phytopigment concentrations from whole-water samples. These samples are glass-fiber filtered, ground in acetone, and examined with a Turner flourometer for the determination of chlorophyll a and phaeopigment concentrations (Yentsch and Menzel, 1963; Strickland and Parsons, 1972).

Assessment of zooplankton populations is conducted on the basis of identification and enumeration of select zooplankton taxa and determination of total dry weight biomass. Using properly selected zooplankton species, the time and expense of sample processing can be reduced without an accompanying loss of information (Gardner, 1977). Each of the select taxa examined is numerically abundant based on three years of ETS data and is a major component of the taxonomic and trophic structure of the zooplankton community offshore from San Onofre (LCMR, 1978c). These select taxa consist of Penilia avirostris, Acartia tonsa, Acartia

spp. copepodites, Corycaeus anglicus, Euterpina acutifrons, Labidocera trispinosa copepodites, Oithona oculata, Paracalanus parvus, Paracalanus parvus copepodites, all other copepods as an aggregate, cypris larvae, cyphonautes larvae, Sagitta spp., and all other plankton taxa as an aggregate. If an additional taxon is found to comprise more than 30% of the samples during a survey, it is enumerated as well. Generally, zooplankton samples are sufficiently dense that sample abundances are estimated from subsamples. Stempel pipettes are used to obtain measured subsamples, or, if abundances are very low, a Folsom plankton splitter is used.

Biomass has been measured for each zooplankton sample since the July 1978 survey. Biomass determinations are conducted using the method of Lovegrove (1966), with samples filtered and dried at 60°C for 24 h prior to weighing.

DATA ANALYSES

Prior to analysis, plots of the raw data indicated that the data tended to be skewed. In order to better meet the assumptions of normality and homogeneity of variance required by the parametric tests, logarithmic transformations were made. A log $(x + 0.01)$ transformation was used in data sets which contained zeros. Means and 90% confidence intervals were calculated for transformed total zooplankton abundance, zooplankton dry weight biomass, chlorophyll a, and phaeopigment concentrations. Antilogs of these values were taken and the confidence intervals and geometric means expressed in the original number scale. Up to six values (two observations per day, times three days) were used for these determinations. These calculations were performed for each station and survey.

Analysis of variance (ANOVA) was used to test for significant differences between stations and depths. Onshore-offshore and upcoast-downcoast distributions of zooplankton abundance, biomass, chlorophyll, and phaeopigment concentrations were examined. The analysis of variance model developed for the analyses was divided into two components. The main effects made up the factors and their interactions which were of primary interest, while nested effects were a result of the sampling scheme. The main effects consisted of depth (i.e., two strata), transect (i.e., onshore-offshore lines of stations), and isobath (i.e., lines of similar-depth stations). Two samples were taken each day for each combination of main effects. These duplicates were considered to be nested within the day in which they were taken. The resulting fixed block design, with DAY as the blocking factor, was used for all ANOVA's. This model allowed the variability between sampling days to be used to test for differences between the other main effects. A Student-Newman-Keuls multiple range test (Sokal and Rohlf, 1969) was used to locate significantly different stations. Analyses were carried out separately by survey since seasonal fluctuations could serve to confound otherwise meaningful results.

To aid in characterization of zooplankton community structure, Heip's evenness values were calculated for each sample (Heip and Engels, 1974). Evenness was selected as the most appropriate community index since the approach of using select taxa to describe the zooplankton community artificially defines the richness (number of species present) of a sample and thus drastically biases diversity indices. This is much less of a problem with evenness indices.

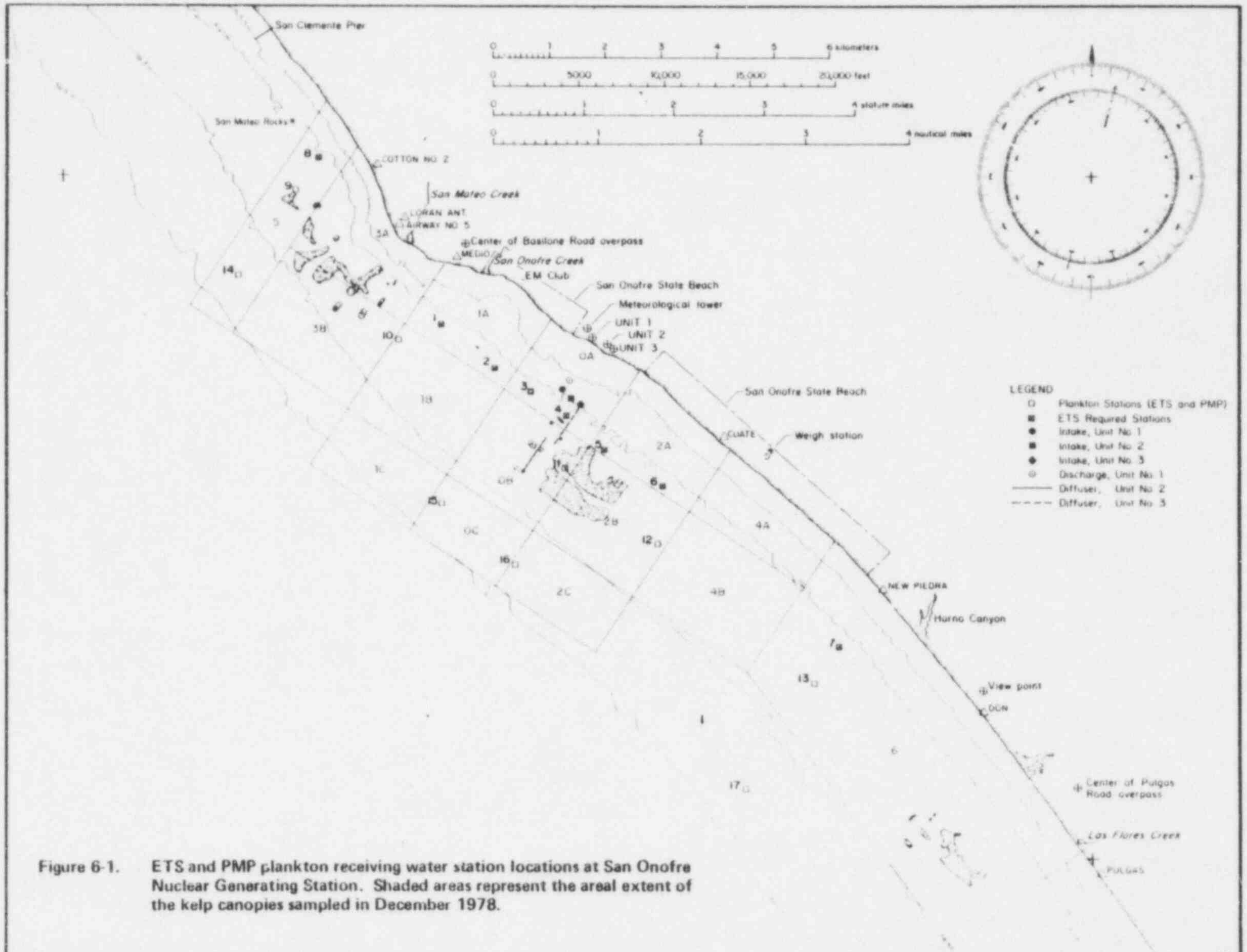

Figure 6-1. ETS and PMP plankton receiving water station locations at San Onofre Nuclear Generating Station. Shaded areas represent the areal extent of the kelp canopies sampled in December 1978.

RESULTS

In this section each of the biological parameters examined is considered in terms of gross spatial and temporal patterns observed during 1978. Plankton surveys conducted on 7 March and 11 May included sampling only at Stations 1-7 for the ETS program. Combined ETS and PMP surveys were conducted on 14-20 July, 8-10 September, and 16-18 November. Plankton Station 8 was established in September and was sampled on two surveys in 1978. The January ETS survey could not be completed due to persistent inclement weather.

In the following subsections, summary figures and tables show the distribution of abundance and concentration data at each station by survey. Geometric means are indicated. Confidence intervals placed about the geometric mean, are based on all samples collected at that station and depth range. Ninety percent confidence limits were chosen to demonstrate visually the general trends and patterns shown by the graphically presented data. Salient features are pointed out for each survey and temporal trends noted. Following the summary presentation of data, the results of statistical analyses are presented and important results noted. For rigorous statistical testing, the 95% significance level was retained.

PHYTOPLANKTON

Chlorophyll a and phaeopigment concentrations were measured as a method of assessing phytoplankton populations. Mean values by survey, isobath, and depth stratum are presented in Figure 6-2 for chlorophyll a and phaeopigment concentrations.

Chlorophyll a

The results of the chlorophyll a analyses conducted for the 1978 surveys are presented in Figures 6-3 through 6-7. In March, chlorophyll a concentrations ranged from 0.31 to 5.30 mg/m^3. No obvious pattern was present between stations (Figure 6-3). Most near-surface samples had higher concentrations than the near-bottom samples. Because only one sample was collected per station-stratum confidence levels were not placed about these values. In May values ranged from 0.75 to 4.88 mg/m^3. No readily discernible pattern was evident among stations (Figure 6-4). Higher concentrations were found in the near-bottom samples than in the near-surface samples. Using the revised sampling techniques of the combined ETS-PMP program, which obtain integrated phytoplankton samples rather than point samples, July chlorophyll a concentrations ranged from 0.14 to 3.50 mg/m^3. Values were generally lower at the 30-m stations than at either the 10- or 15-m stations, which were similar with respect to the magnitude of values observed (Figure 6-5). No marked vertical stratification was apparent in the data. In September, concentrations ranged from 0.29 to 6.35 mg/m^3. Concentrations tended to be higher in the lower stratum at the 15- and 30-m stations but not at the 10-m stations (Figure 6-6). November values ranged from 2.39 to 9.48 mg/m^3. No obvious patterns of distribution were evident among stations, nor was any obvious pattern of distribution between depths discernible (Figure 6-7). The chlorophyll a concentrations measured during the November survey were the highest recorded during 1978. Concentrations recorded in September were somewhat lower, and March through July were similar in magnitude.

Analysis of variance revealed that chlorophyll a concentrations were significantly different ($p < 0.01$) among the three days of the survey in both July and

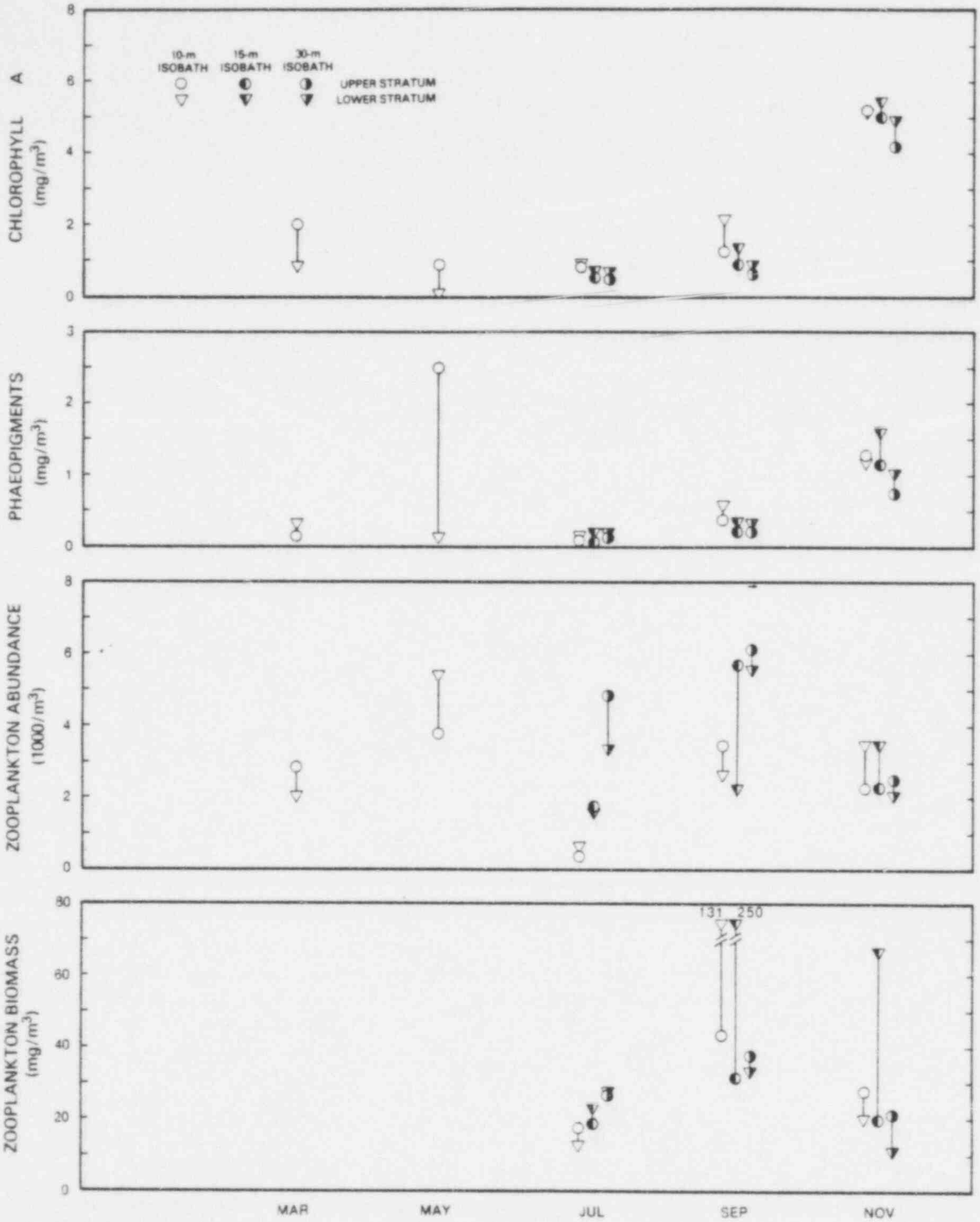

Figure 6-2. Summary of 1978 biological data. Arithmetic means of concentrations of chlorophyll a, phaeopigment, and zooplankton abundance and biomass.

Table 6-1. Results of analysis of variance for each of the biological data types for the combined ETS-PMP surveys. Tabled values are the probability (p) that the magnitude could be due to random chance alone. Asterisked values (*) denote those considered to be significantly ($p \leq 0.05$) different than chance.

Source	Chlorophyll a	Phaeopigment	Zooplankton Abundance	Zooplankton Biomass
JULY				
Main Effects				
Depth (D)	0.093	0.003*	0.263	0.171
Transect (T)	0.715	0.909	0.350	0.570
DT	0.709	0.169	0.603	0.750
Isobath (I)	<0.001*	0.001*	<0.001*	<0.001*
DI	0.733	0.287	0.133	0.541
TI	0.950	0.916	0.504	0.069
DTI	0.700	0.968	0.976	0.792
Day	<0.001*	0.043*	0.050*	0.328
Nested Effects				
Duplicate	0.676	0.186	0.423	0.243
Day X Duplicate	0.389	0.400	0.196	0.839
SEPTEMBER				
Main Effects				
Depth (D)	<0.001*	0.007*	0.002*	0.094
Transect (T)	0.036*	0.608	0.006*	0.074
DT	0.309	0.887	0.192	0.161
Isobath (I)	<0.001*	0.067	<0.010*	0.315
DI	0.767	0.496	0.104	0.071
TI	0.377	0.825	0.002*	0.012*
DTI	0.422	0.967	0.709	0.691
Day	0.063	0.006*	0.030*	0.052
Nested Effects				
Duplicate	0.271	0.736	0.853	0.155
Day X Duplicate	0.259	0.927	0.651	0.569
NOVEMBER				
Main Effects				
Depth (D)	<0.001*	<0.001*	0.002*	0.228
Transect (T)	0.037*	0.033*	0.405	0.019*
DT	0.261	0.457	0.875	0.292
Isobath (I)	<0.001*	<0.001*	0.040*	0.002*
DI	0.902	0.945	0.009*	<0.001*
TI	0.089	0.013*	0.230	0.714
DTI	0.805	0.220	0.788	0.273
Day	<0.001*	<0.001*	<0.001*	0.603
Nested Effects				
Duplicate	0.140	0.581	0.809	0.941
Day X Duplicate	0.631	0.096	0.742	0.040*

Phaeopigments

Graphical summarizations of results of phaeopigment concentrations appear in Figures 6-8 through 6-12. Phaeopigment concentrations follow closely the general pattern observed for chlorophyll a. Minimum concentrations of zero measurable phaeopigments were recorded during each survey. Maximum values for the ETS March and May surveys were 1.01 and 0.43 mg/m^3. Maximum phaeopigment concentrations

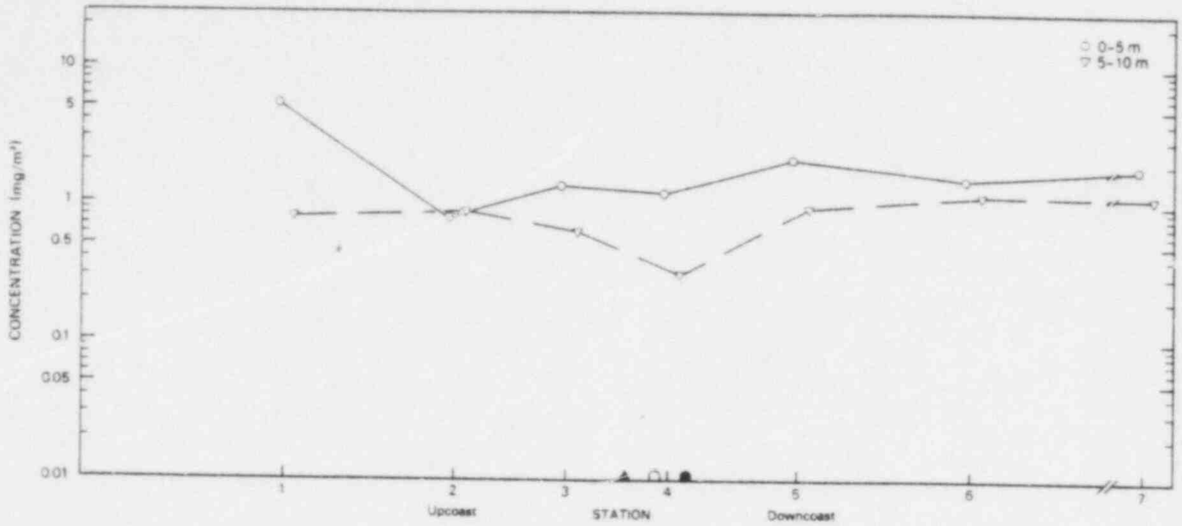

Figure 6-3. Chlorophyll a concentrations at ETS stations in March 1978, Triangle and hemispheres on station axis indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS.

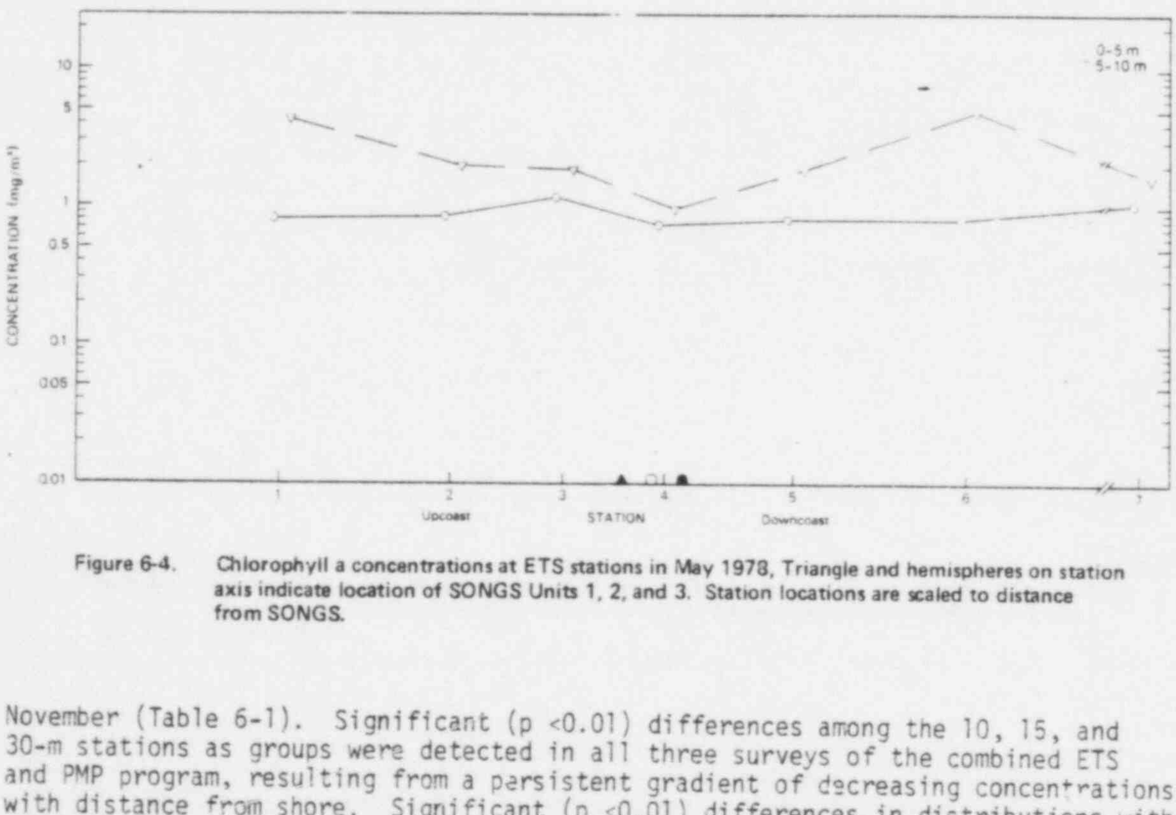

Figure 6-4. Chlorophyll a concentrations at ETS stations in May 1978, Triangle and hemispheres on station axis indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS.

November (Table 6-1). Significant ($p < 0.01$) differences among the 10, 15, and 30-m stations as groups were detected in all three surveys of the combined ETS and PMP program, resulting from a persistent gradient of decreasing concentrations with distance from shore. Significant ($p < 0.01$) differences in distributions with depth were detected in September and November surveys. In July a similar trend existed, although it was not statistically significant. In both surveys where differences were detected chlorophyll a concentrations were highest in the lower stratum. In September and November, significant ($p < 0.05$) differences between transects (i.e., upcoast-downcoast differences) were detected. No interaction terms were significant.

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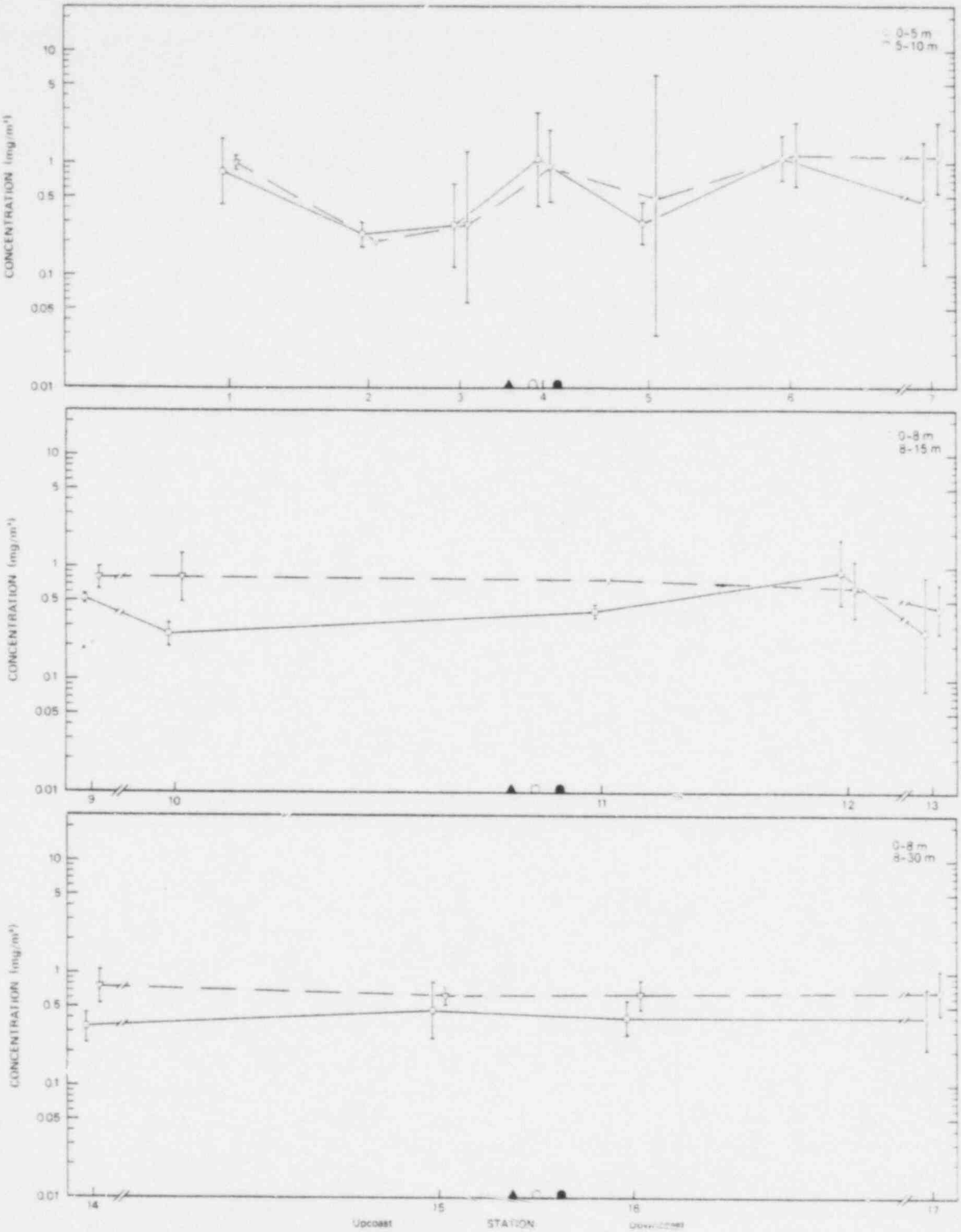

Figure 6-5. Chlorophyll a concentration (geometric mean and 90% confidence interval) for each station in July 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

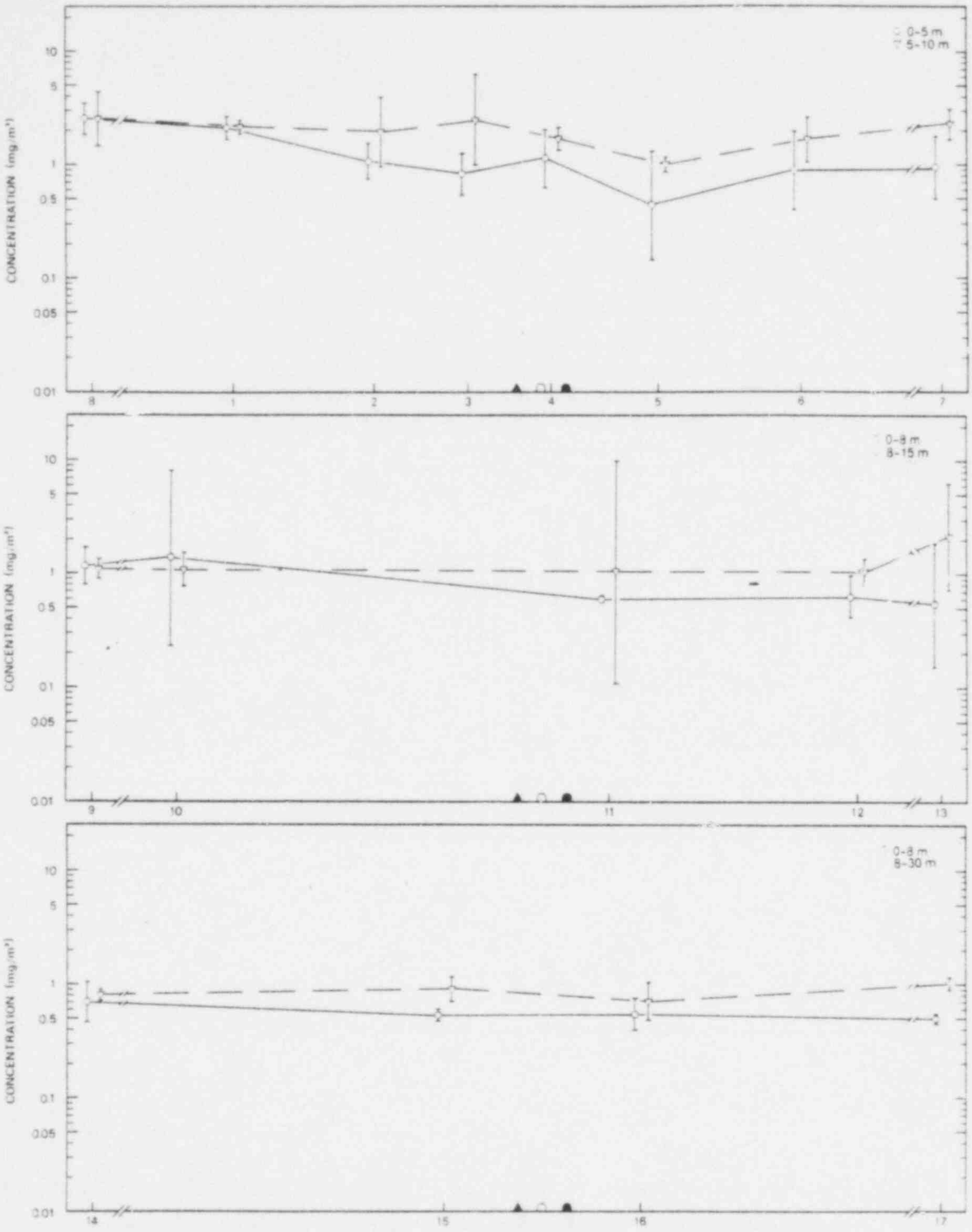

Figure 6-6. Chlorophyll a concentration (geometric mean and 90% confidence interval) for each station in September 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

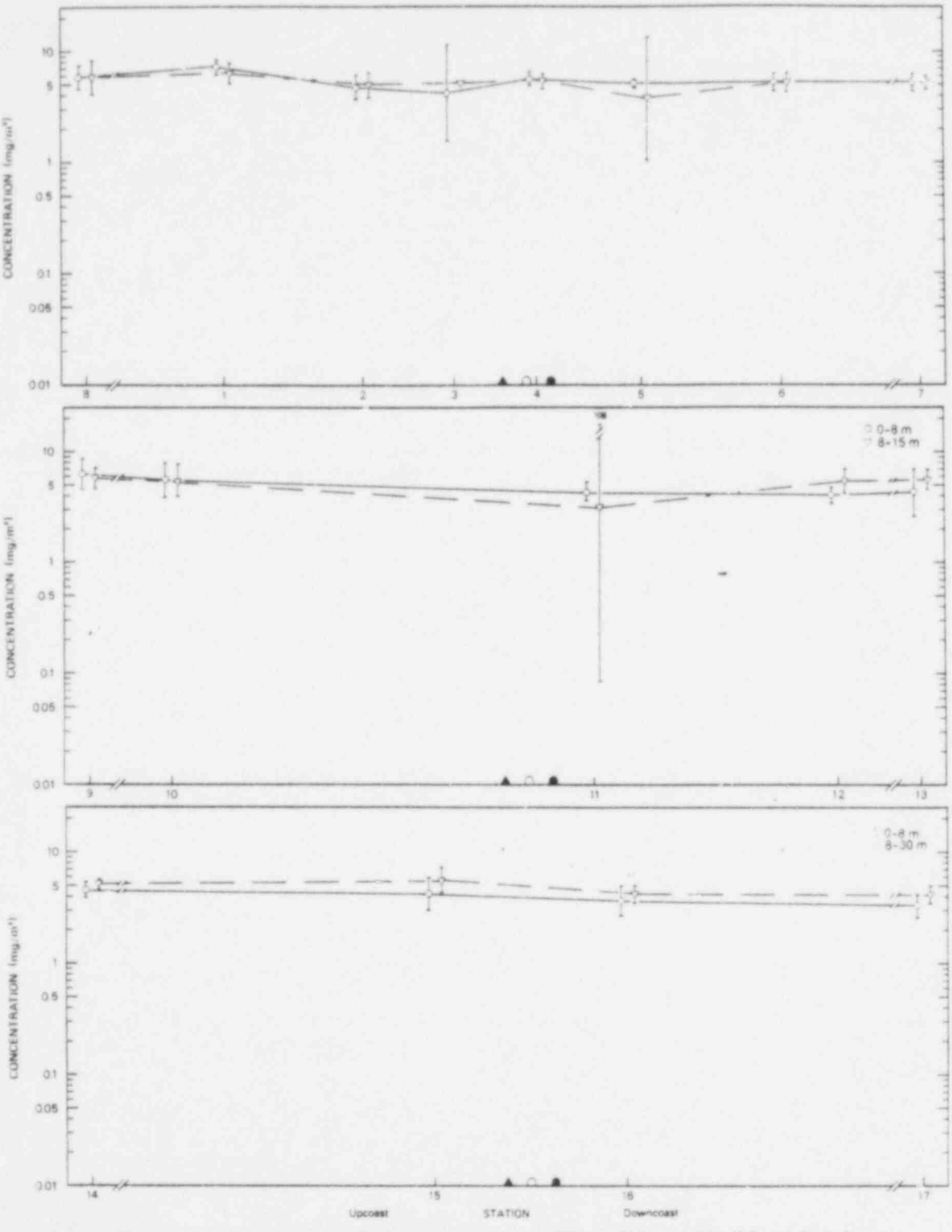

Figure 6-7. Chlorophyll a concentration (geometric mean and 90% confidence interval) for each station in November 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

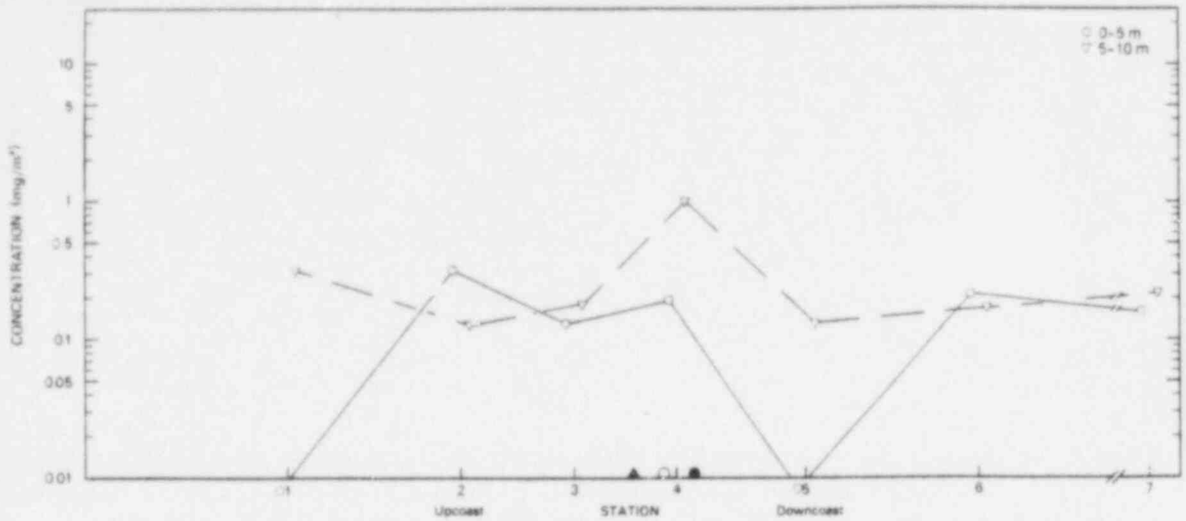

Figure 6-8. Phaeopigment concentrations at ETS stations in March 1978. Triangle and hemispheres on station axis indicate location of SONGS Units 1, 2, and 3. Symbols below axis represent zero values. Station locations are scaled to distance from SONGS.

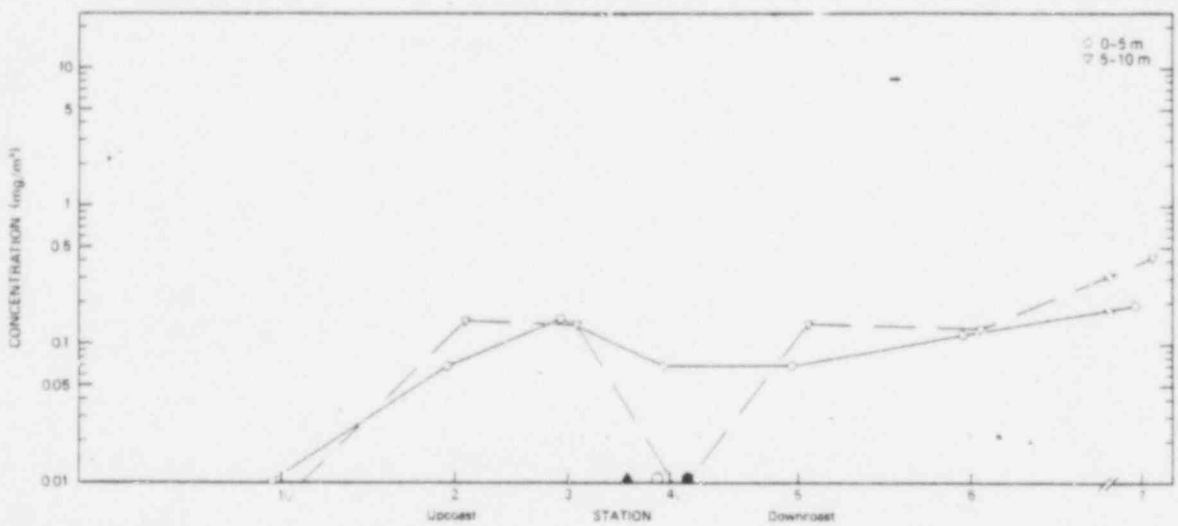

Figure 6-9. Phaeopigment concentrations at ETS stations in May 1978. Triangle and hemispheres on station axis indicate location of SONGS Units 1, 2, and 3. Symbols below axis represent zero values. Station locations are scaled to distance from SONGS.

for the ETS-PMP combined program surveys of July, September, and November were 1.07, 2.04, and 2.66 mg/m^3, respectively.

No obvious distribution patterns of phaeopigment concentration was apparent from inspection of the summary figures for March through July (Figures 6-8, 6-9, 6-10). While there was no apparent distributional trend of phaeopigment concentration in September, variability at the 30-m stations appeared to be less than at the shallower stations (Figure 6-11). In November, concentrations were lowest at the 30-m stations and very similar at the 10 and 15-m stations (Figure 6-12). Phaeopigment concentrations were greater in September and November, which had similar values, than March through July, which were similar to each other in mag-

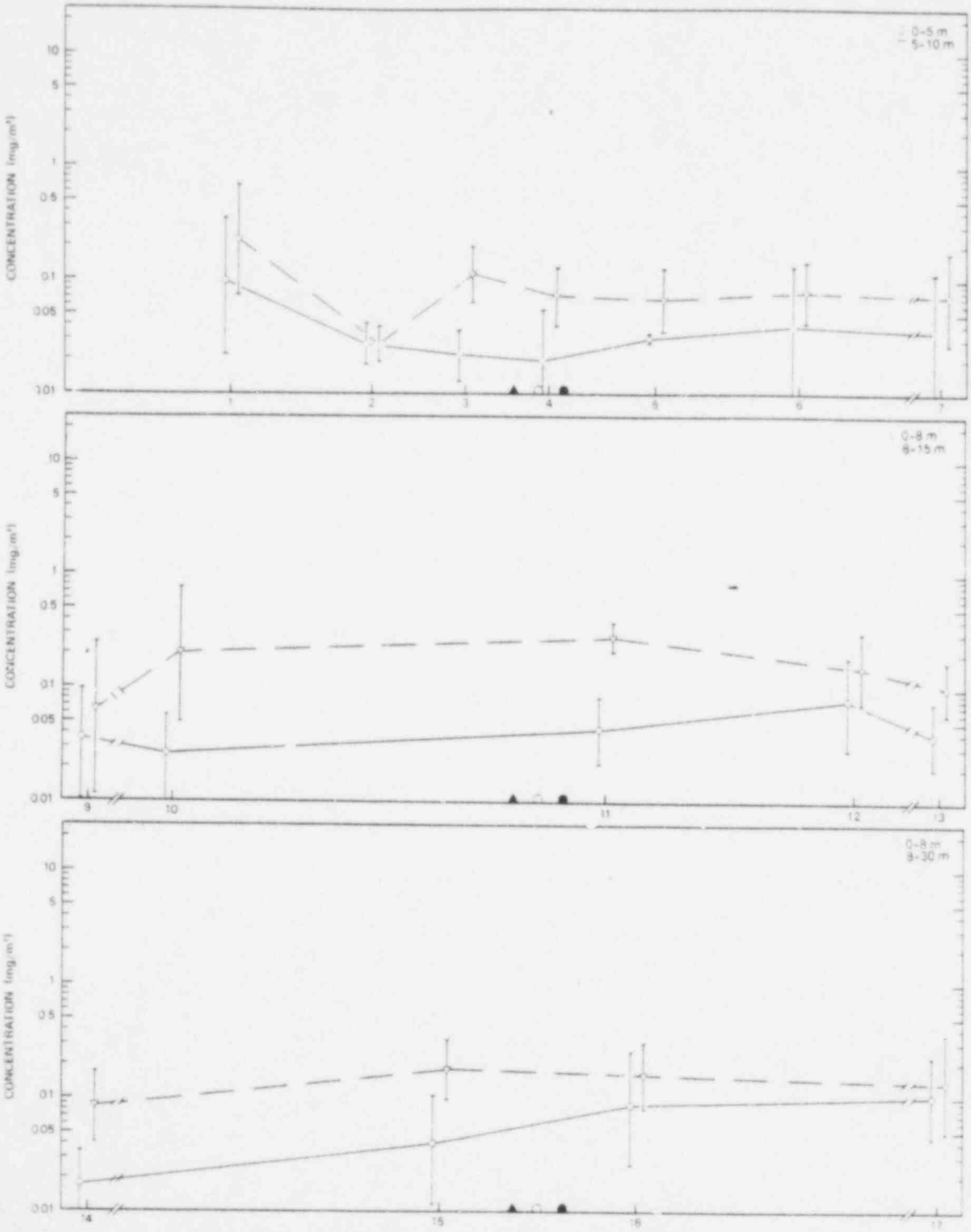

Figure 6-10. Phaeopigment concentration (geometric mean and 90% confidence interval) for each station in July 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

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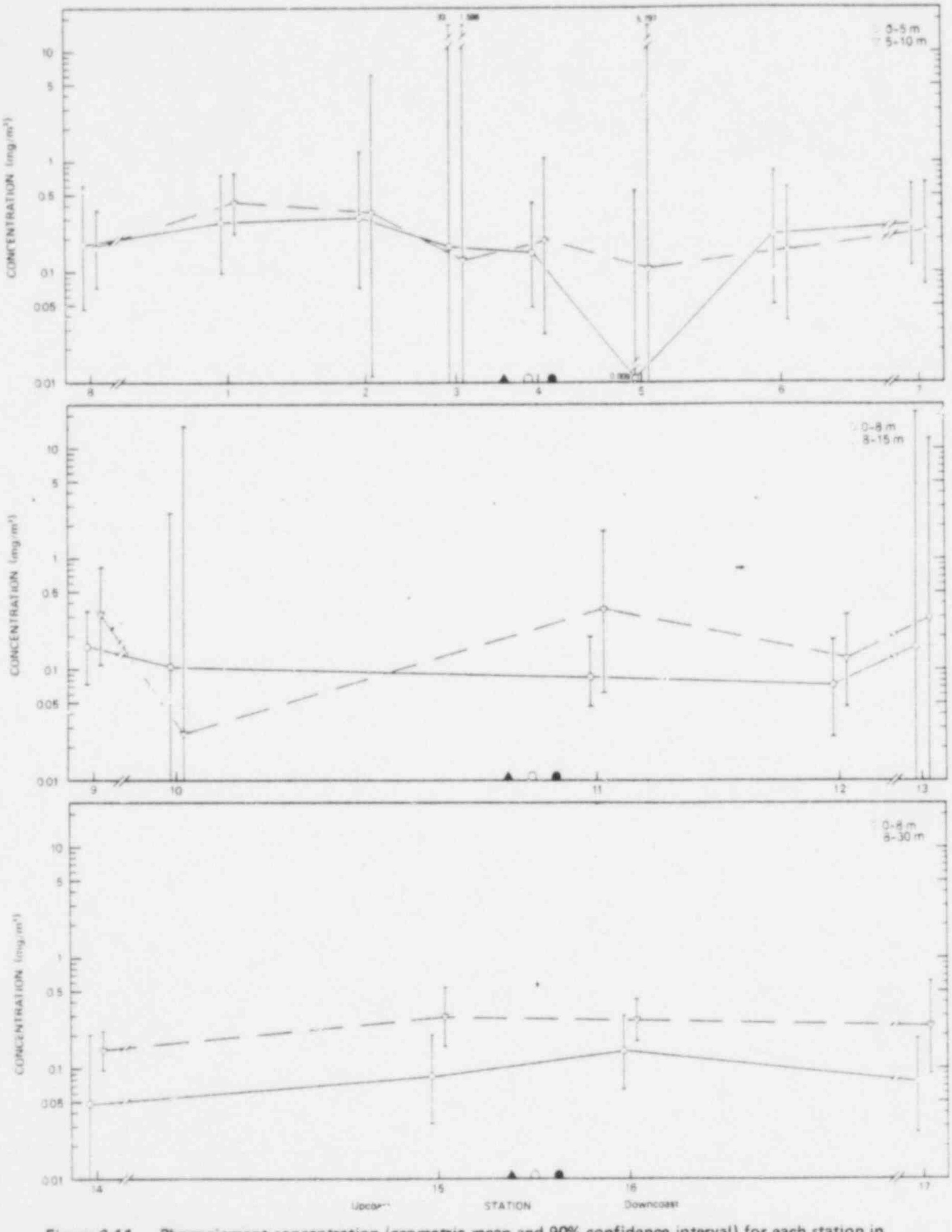

Figure 6-11. Phaeopigment concentration (geometric mean and 90% confidence interval) for each station in September 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

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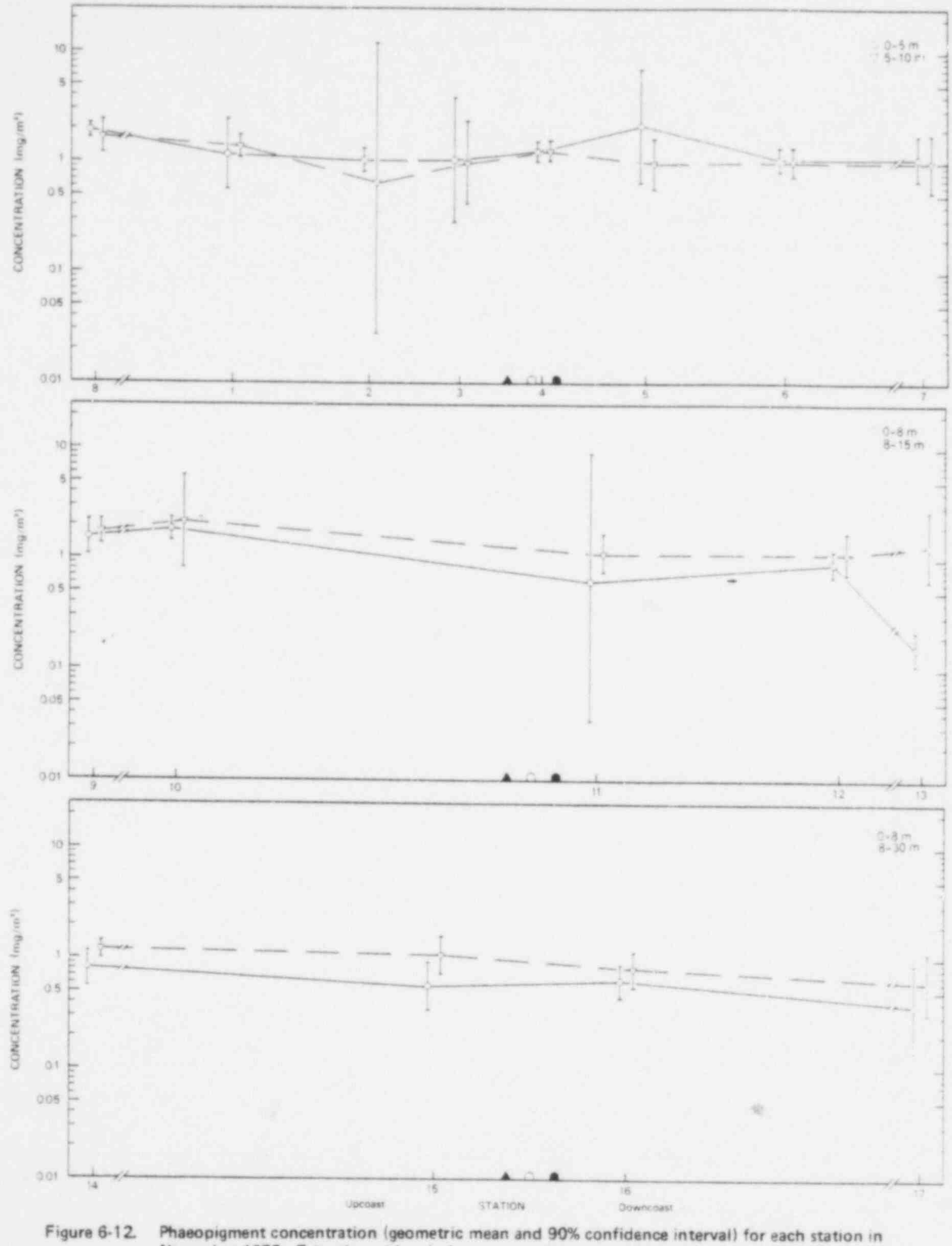

Figure 6-12. Phaeopigment concentration (geometric mean and 90% confidence interval) for each station in November 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

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nitude. A slight tendency towards greater phaeopigment concentrations in the lower stratum was observed, especially for the 15 and 30-m stations.

Analysis of variance showed that phaeopigment concentrations from combined ETS and PMP surveys were significantly different ($p < 0.05$) between days for all surveys (Table 6-1). Differences between depth strata were significant, with greater concentrations occurring in the lower depth stratum during all three surveys. In the November survey, significant ($p < 0.01$) differences were detected for both onshore-offshore and upcoast-downcoast station patterns, and the interaction between these factors.

ZOOPLANKTON

Total zooplankton abundance, dry weight biomass, species composition and community structure were examined for the zooplankton community offshore SONGS. Mean values by survey, isobath, and depth stratum are presented in Figure 6-2 for total zooplankton abundance and dry weight biomass.

Total Abundance

Figures 6-13 through 6-17 summarize the results of the 1978 plankton surveys for all zooplankton organisms combined. The range of zooplankton concentrations for the March and May ETS surveys was 1210 to $3615/m^3$ and 1803 to $8170/m^3$, respectively. No obvious patterns in the distribution of total zooplankton abundance were apparent in either March or May based on the graphical presentation of data for stations and depths (Figures 6-13, 6-14). With the increased number of stations in the combined ETS-PMP program, July abundances ranged from 11 to $29{,}773/m^3$. Total zooplankton abundance was obviously greater at the 15 and 30-m stations than at the 10-m stations, but no patterns within those groups were apparent (Figure 6-15). The vertical distribution of total zooplankton abundance

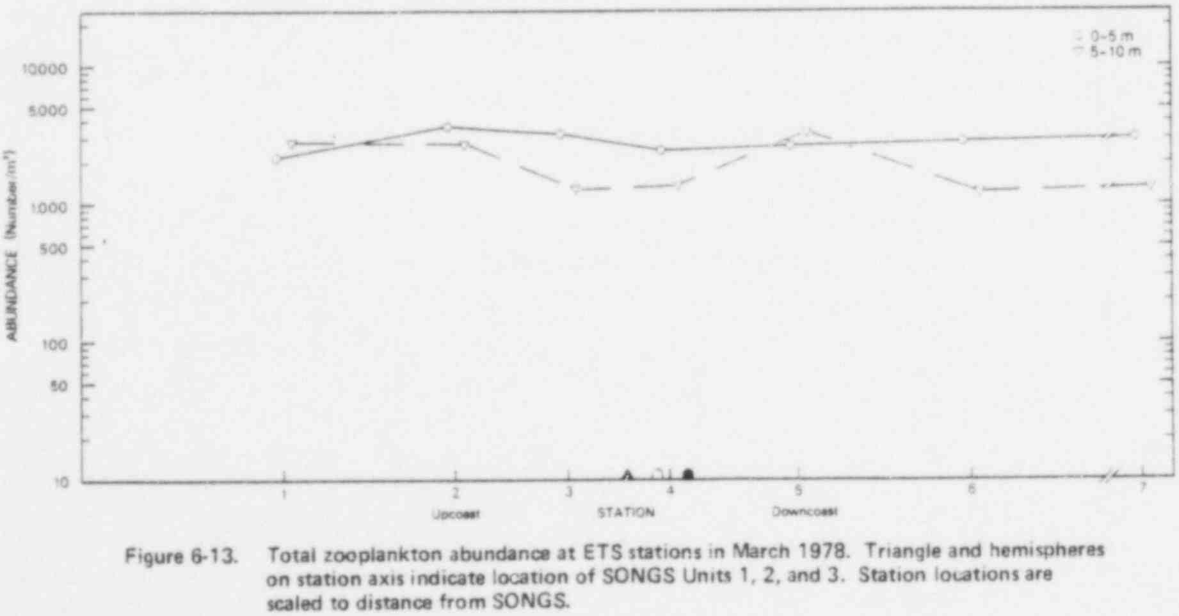

Figure 6-13. Total zooplankton abundance at ETS stations in March 1978. Triangle and hemispheres on station axis indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS.

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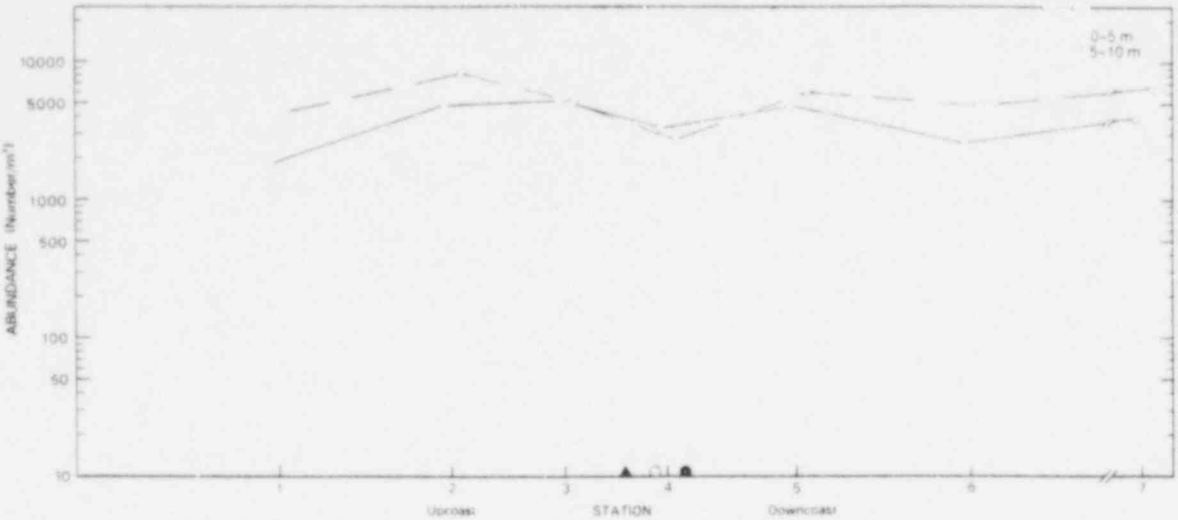

Figure 6-14. **Total zooplankton abundance at ETS stations in May 1978. Triangle and hemispheres on station axis indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS.**

was inconsistent. In September abundances ranged from 276 to 13,873/m^3 with a modest trend towards higher abundances at the 15 and 30-m stations than at the 10-m stations, but no patterns appeared among stations along the three isobaths (Figure 6-16). A consistent trend in abundance was not apparent in either depth stratum. Total zooplankton abundance ranged from 203 to 11,506/m^3 in November. Greater abundances occurred at the 10 and 15-m stations than at the 30-m stations, although no striking patterns of distribution were evident within any group of stations (Figure 6-17). Abundance appeared generally greater in the deeper stratum for the 10 and 15-m stations but not for the 30-m stations. Total abundances were lowest in July for the 10 and 15-m stations, but general seasonal trends were otherwise not apparent, with the exception of the gradient of increasing abundance with distance from shore which was present in July and absent by November (Figure 6-2).

The results of the analyses of variance of the 1978 total zooplankton abundance data appears in Table 6-1. Significant differences were present among the three days of each survey of the combined ETS and PMP programs. Significant differences ($p < 0.01$) were detected in depth distribution of total zooplankton for the September and November surveys, with higher abundances in the lower stratum except for 30-m stations in November. Differences among the stations grouped by isobath were significant for all three surveys. In September a significant upcoast-downcoast relationship was found. Significant interaction effects, however, were obtained between depth and isobath for the November survey, and transect and isobath in September.

Mean abundance of select zooplankton taxa during each of the 1978 surveys is presented in Table 6-2. The rank order abundance of these taxa for the year and comparisons with previous surveys is given in Table 6-3. Acartia tonsa, Acartia copepodites, and Paracalanus parvus copepodites and adults in 1978 were the most abundant components of the zooplankton.

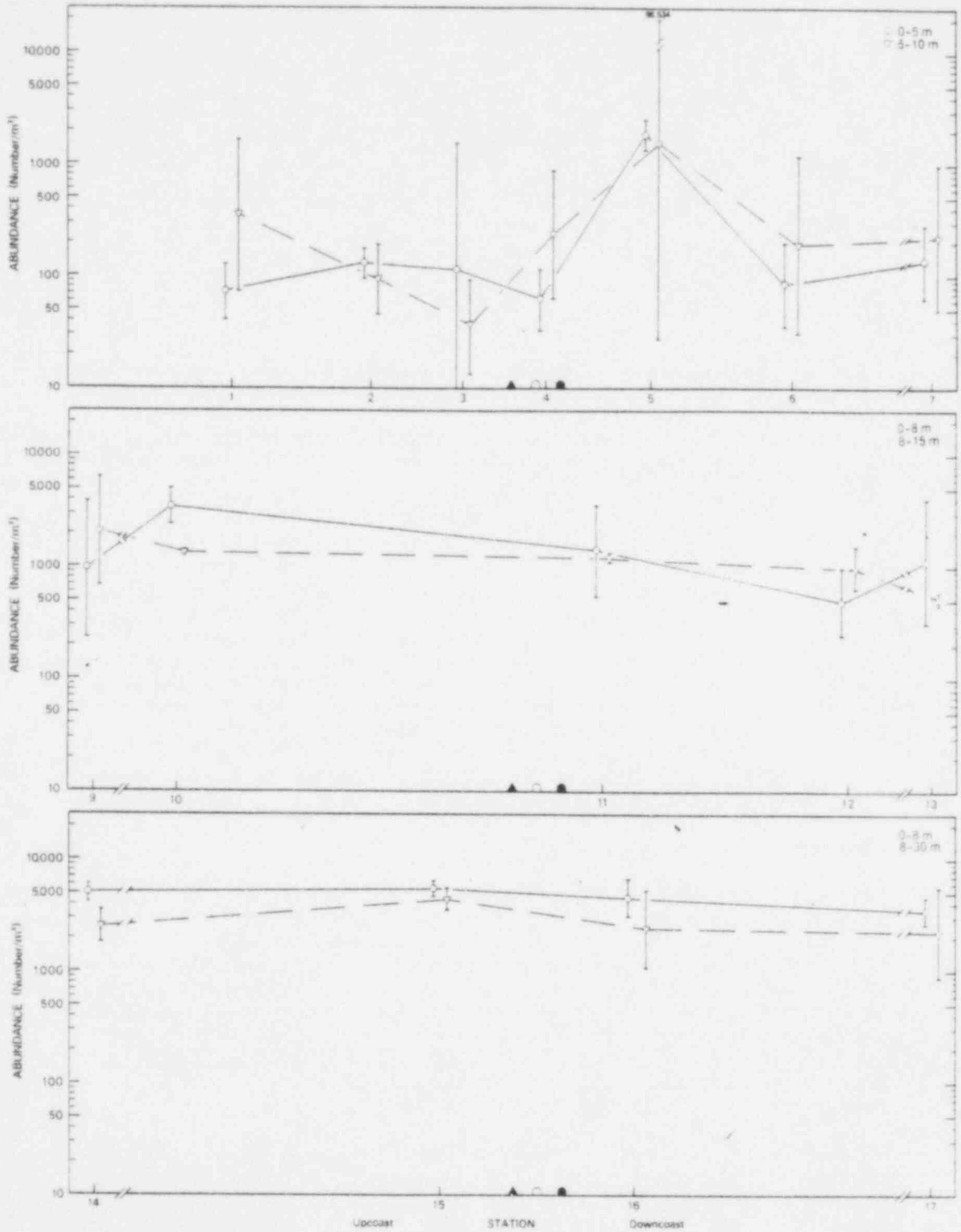

Figure 6-15. Total zooplankton abundance (geometric mean and 90% confidence interval) for each station in July 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

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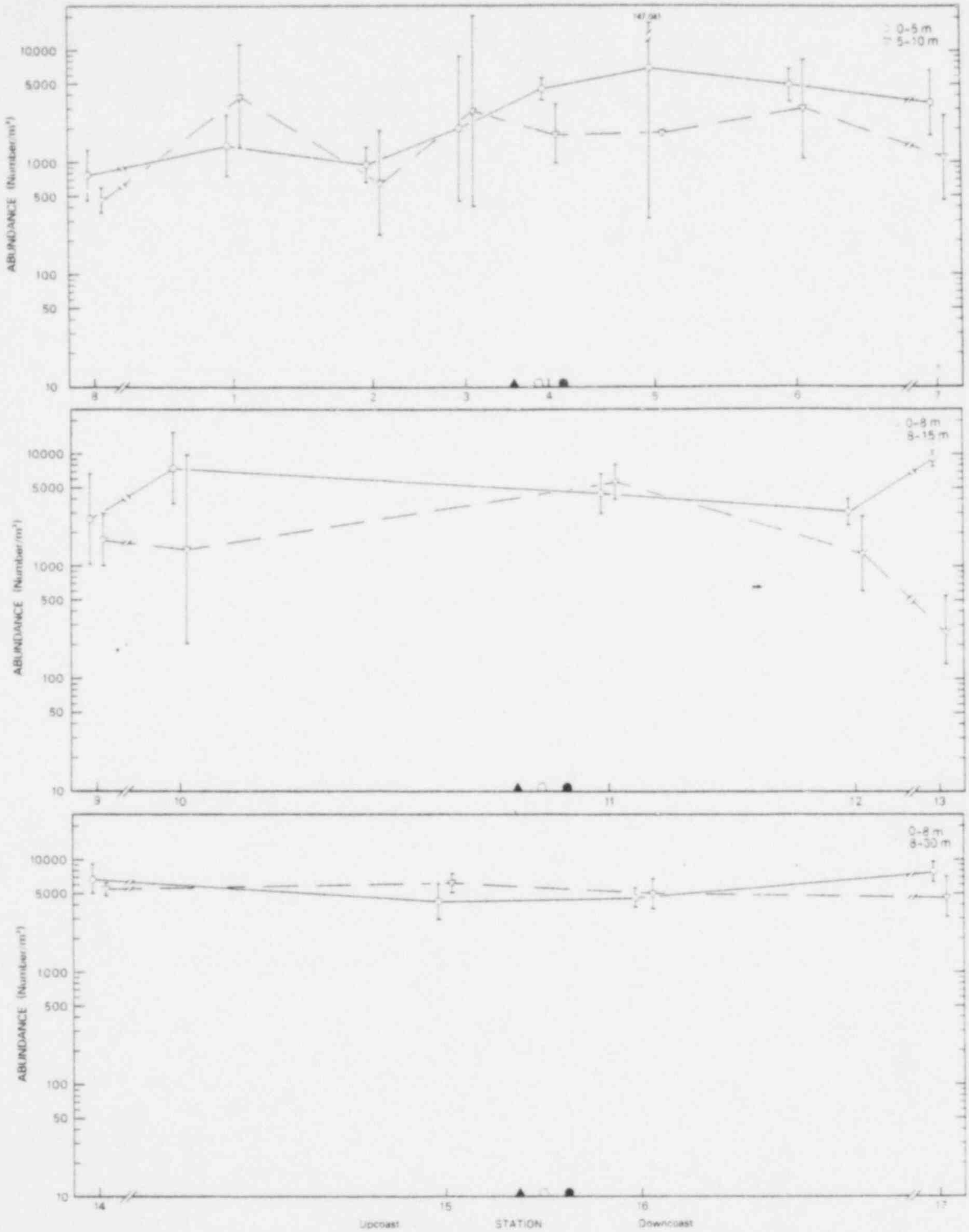

Figure 6-16. Total zooplankton abundance (geometric mean and 90% confidence interval) for each station in September 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

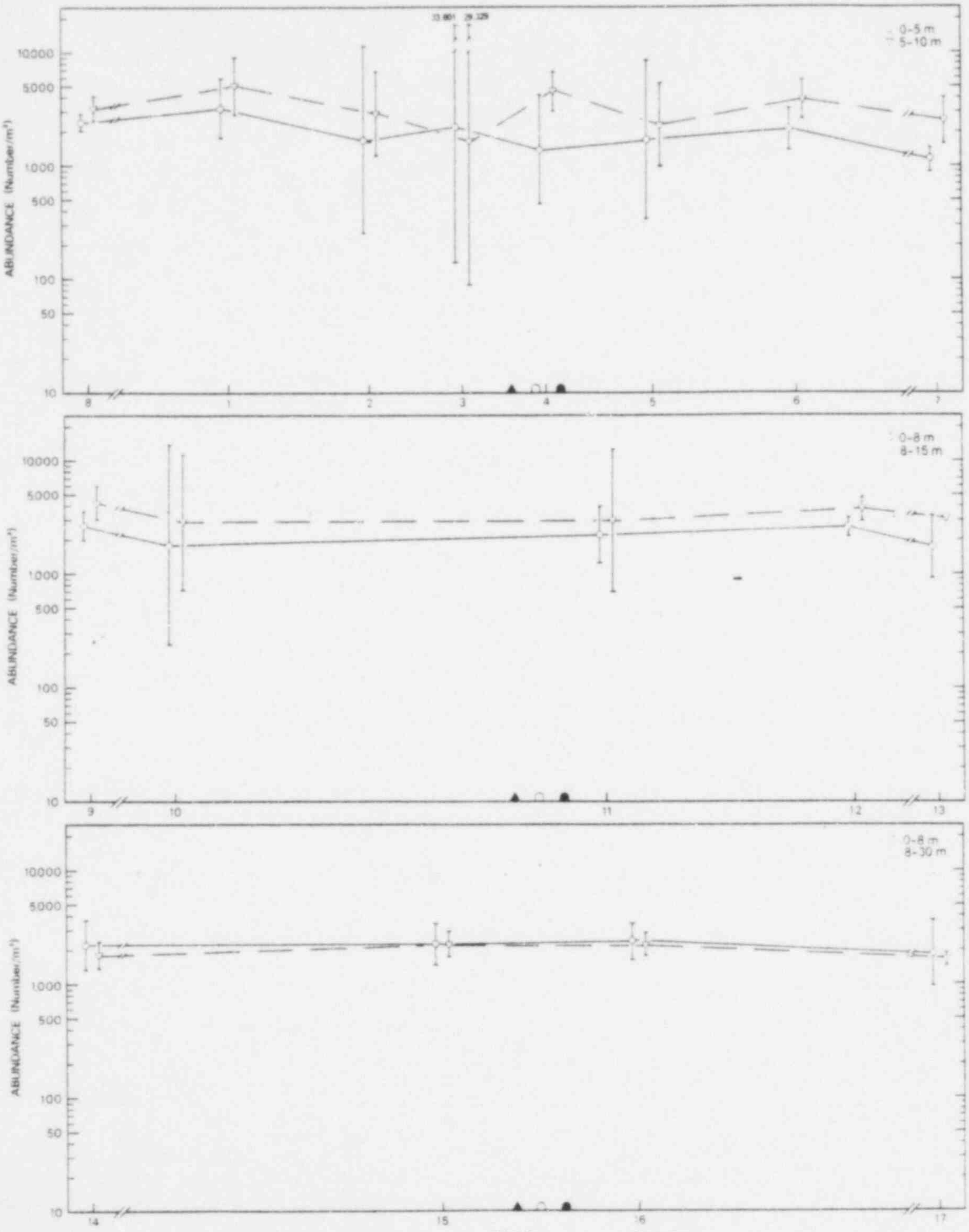

Figure 6-17. Total zooplankton abundance (geometric mean and 90% confidence interval) for each station in November 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others we e sampled on three days.

Table 6-2. Mean abundance (no./m3) of select taxa by survey for 1978.

Taxa	March	May	July	Sept	Nov	Annual Mean
A. tonsa copepodites	369.8	2679.3	321.1	580.2	634.5	613.0
Acartia tonsa	104.1	97.2	123.3	263.0	222.0	194.6
Penilia avirostris	222.9	12.4	67.7	98.0	76.1	84.4
P. parvus copepodites	242.3	481.8	370.3	1094.5	114.8	514.0
Sagitta spp.	38.7	275.4	31.2	62.6	91.7	71.6
Corycaeus anglicus	297.7	57.0	72.7	142.9	249.4	158.9
Cyphonautes larvae	172.8	119.6	59.1	44.8	87.3	71.7
Paracalanus parvus	84.5	165.8	163.5	395.7	91.9	209.3
Labidocera trispinosa copepodites	44.9	28.8	8.7	66.5	213.4	92.3
Podon polyphemoides	0	0	25.0	84.8	434.0	167.1
Euterpina acutifrons	104.4	30.4	95.0	39.5	54.3	62.7
Clausocalanus spp.**	-	-	349.4	-	-	-

* Means of first two surveys based on data from seven 10-m stations; means of July and the last two surveys based on data from 16 and 17 stations, respectively, from 10, 15, and 30-m isobaths.

** Although not on the select taxa list, Clausocalanus spp. was enumerated in July due to its high abundance.

Table 6-3. Rank order of abundance of select taxa collected off SONGS, from 1975 to 1978.

Taxa	Rank				Annual Mean (no./m^3)			
	1975*	1976	1977	1978**	1975*	1976	1977	1978**
A. tonsa copepodites	1	1	1	1	2105	797	1005	613
Acartia tonsa	5	3	3	4	98	480	164	195
Penilia avirostris	-	2	4	8	-	523	151	84
P. parvus copepodites	3	9	2	2	127	89	253	514
Sagitta spp.	2	7	5	9	148	98	118	72
Corycaeus anglicus	7	4	9	6	60	165	62	159
Cyphonautes larvae	8	6	6	10	59	102	114	72
Paracalanus parvus	9	5	8	3	55	108	87	209
Labidocera trispinosa copepodites	4	8	10	7	110	98	56	92
Podon polyphemoides	10	10	7	5	21	75	94	167
Euterpina acutifrons	6	11	11	11	63	64	52	63

* No surveys were conducted in January and March 1975.

** January 1978 survey not completed due to persistently inclement weather. First two surveys of year conducted as previous years. Last three surveys added stations on 15-m and 30-m isobaths farther offshore.

\- P. avirostris not present in 1975.

Biomass

Biomass determinations were conducted for the July, September, and November surveys. Raw data tables of dry weight zooplankton biomass, not available at the time that the Annual Operating Report, San Onofre Nuclear Generating Station, Volume II, Biological Data-1978 (LCMR, 1979a) was printed, are presented in Appendix D. Inspection of graphical presentation of these data reveals no distinct pattern of horizontal or vertical distribution of zooplankton biomass (Figures 6-18, 6-19, 6-20). Higher values in the lower stratum were generally observed at the 15-m stations in all three surveys. Patterns at the other isobaths were inconsistent with the exception of the 30-m stations in November, where higher values were recorded from the upper stratum. Peak zooplankton biomass values were recorded during the September survey.

Analysis of variance of zooplankton biomass data for the July survey detected a significant difference between the groups of 10, 15, and 30-m stations (Table 6-1). During July a strong gradient of increasing biomass with distance from shore was observed. In September an upcoast-downcoast (transect) versus isobath interaction was significant. In November, the transect and isobath effects as well as the isobath-depth interaction were significant (Table 6-1).

COMMUNITY STRUCTURE

Absolute and relative abundance data have been reported for each of the select species for each sample in Volume I: of this report (LCMR, 1979a). Inspection of Heip's evenness values calculated for each zooplankton sample does not show any distinct pattern.

PHYSICAL PARAMETERS

Since physical parameters of water masses often influence the nature and abundance of the planktonic community, temperature and transmissivity-depth profiles were obtained each time a plankton station was occupied. These parameters are ones potentially affected by plant operations and also important to plank- organisms.

Temperature

Temperature-depth data obtained during plankton cruises are listed in LCMR (1979a). Wide fluctuations in temperature o-curred both among days of a survey and during survey days. Surface temperature ranged from 15.8 to 16.7°C during the March survey and 17.9 to 18.5°C in May. There were no strong thermal gradients during these surveys, as evidenced in a drop of about 1.0°C at the bottom of the 10-m water column in March and a 1.0 to 2.0°C decrease in May. Generally, strong vertical thermal gradients were noted during the July and September surveys. In July, some temperature data indicated the presence of a fairly isothermal surface layer 8 to 10 m in thickness followed by a thermocline with a temperature decrease of up to 6°C in 6 m at some stations. Other data indicated a relatively steady decrease in temperature with depth. Surface temperatures ranged from 17.1 to 21.3°C. In September, data collected along the 10 and 15-m isobaths revealed a nearly isothermal mixed layer which extended almost to the bottom. Along the 30-m contour, temperatures steadily decreased to more than 10°C cooler than the surface. Surface temperatures ranged from 16.4 to 21.5°C. November surface temperatures ranged from 16.8 to 18.8°C. Temperatures were fairly uniform with depth, with a maximum decrease of 2.8°C at a 30-m station.

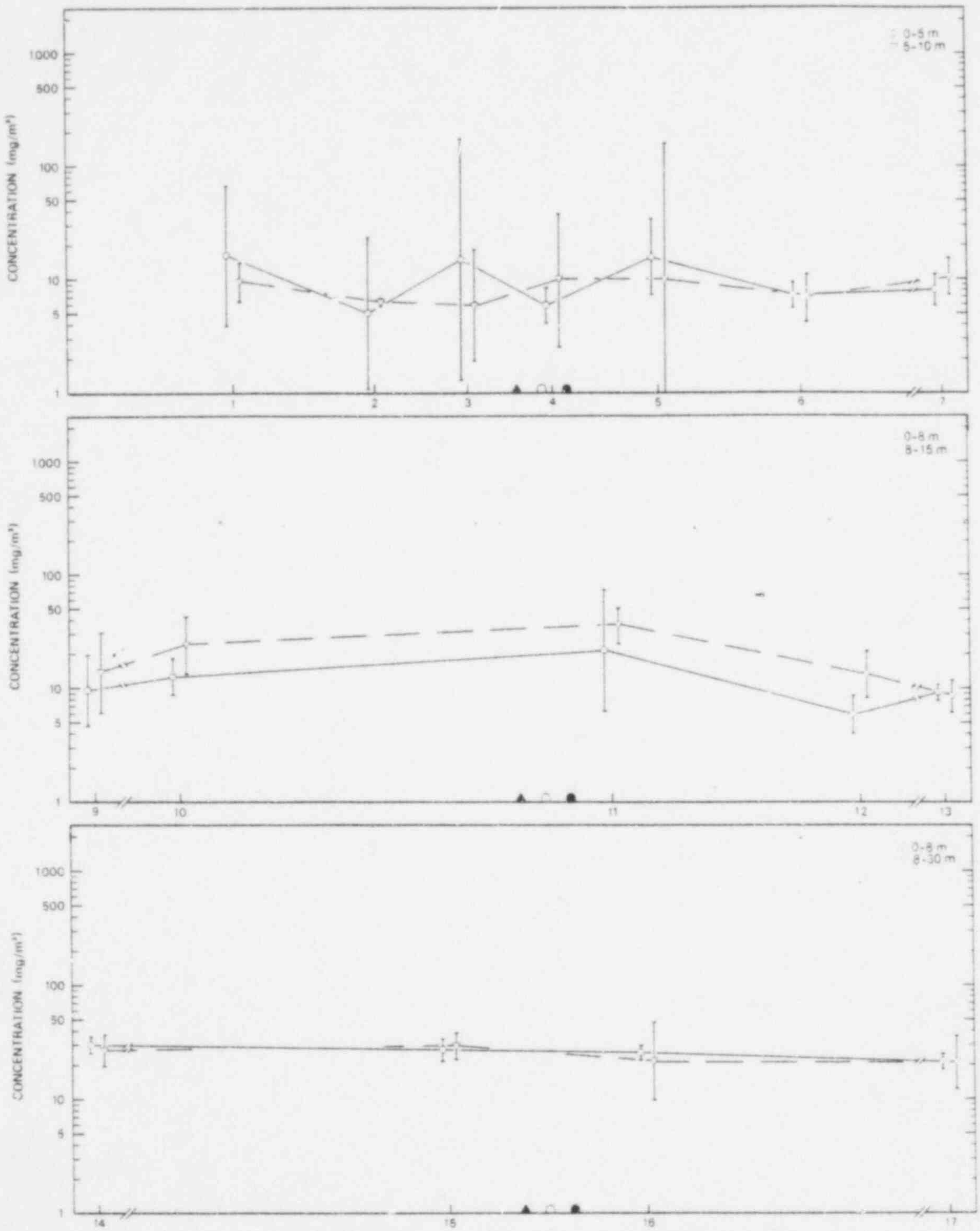

Figure 6-18. Zooplankton dry weight biomass (geometric mean and 90% confidence interval) for each station in July 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

POOR ORIGINAL

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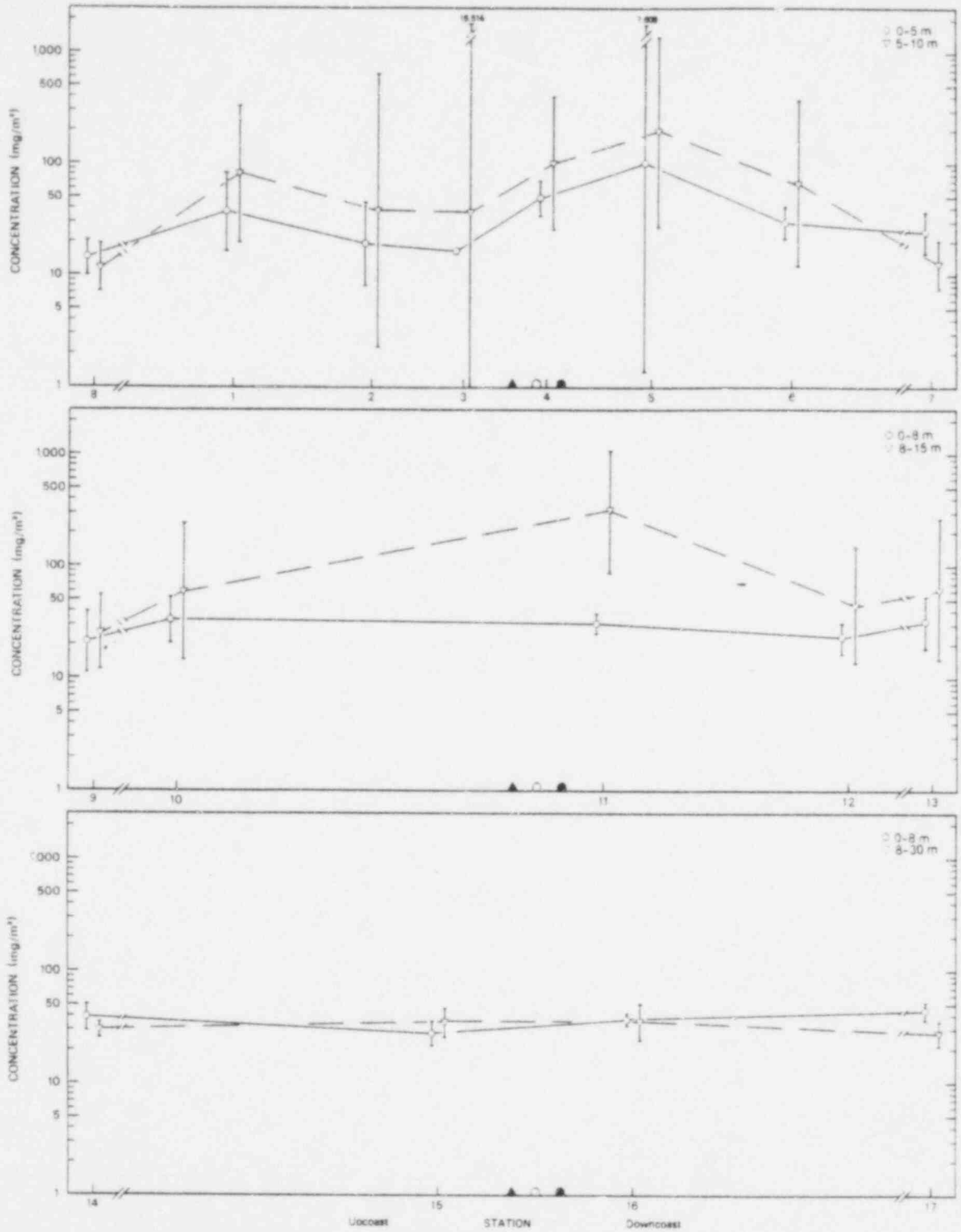

Figure 6-19. Zooplankton dry weight biomass (geometric mean and 90% confidence interval) for each station in September 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

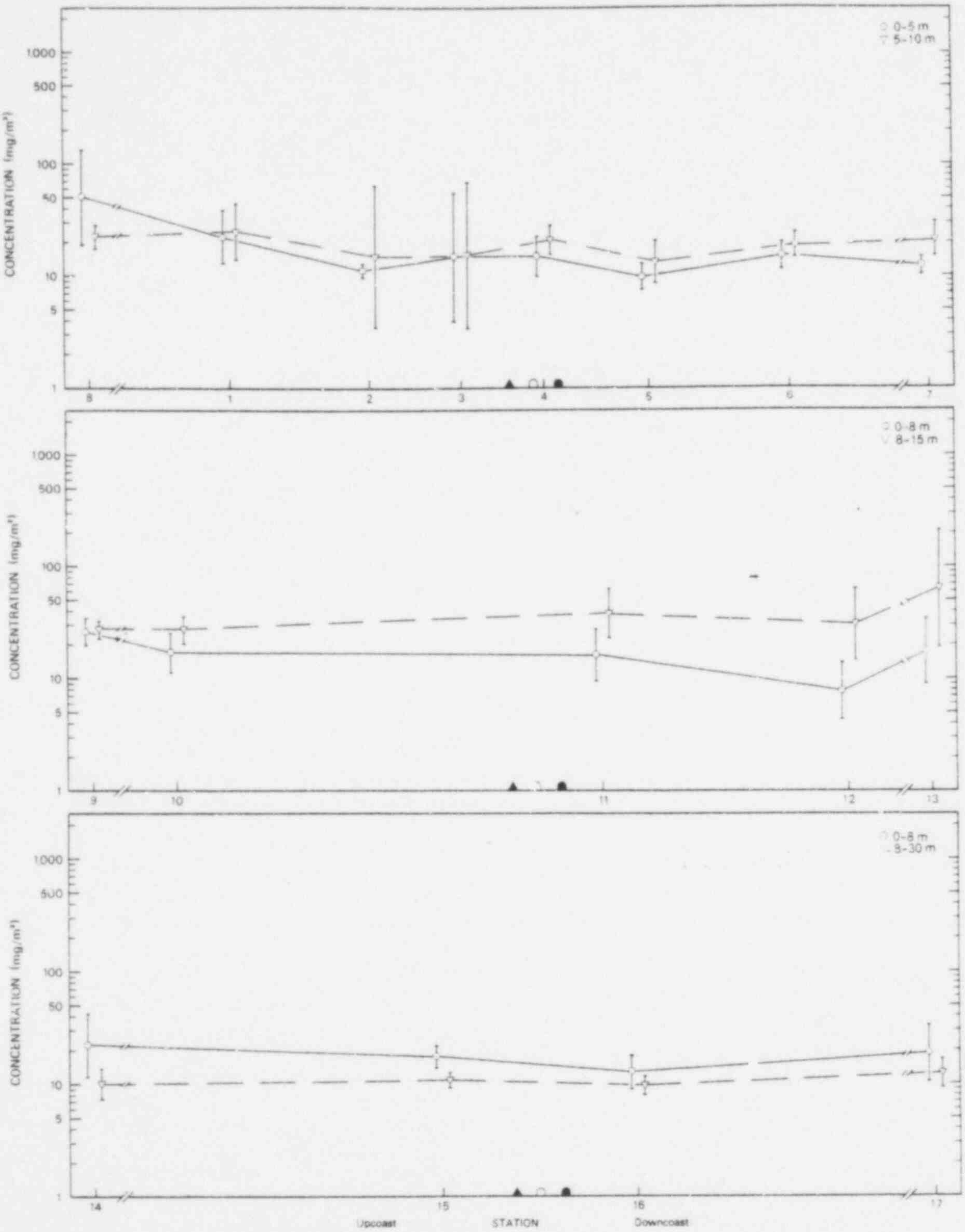

Figure 6-20. Zooplankton dry weight biomass (geometric mean and 90% confidence interval) for each station in November 1978. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

Transmissivity

Transmissivity-depth data beginning with the July survey were presented in LCMR (1979a). Large fluctuations occurred from day to day and station to station. In July transmissivity ranged from 0 to 66%, 0 to 72%, and 0 to 70% for the 10, 15, and 30-m stations. September transmissivity values ranged from 2 to 64%, 0 to 74%, and 0 to 90% for the 10, 15, and 30-m stations. In November, the values at these groups of stations ranged from 45 to 74%, 0 to 80%, and 54 to 70%, respectively. Generally, transmissivity was observed to increase proceeding offshore from the 10 to the 15 and 30-m stations, while decreasing with depth. Transmissivity values approaching zero percent transmittance were not uncommon near the bottom. Lenses of both clear and turbid water occasionally occurred in the water column. Transmissivity was higher and more uniform, in general, during the November survey than in either July or September.

Current Velocity

Gross current speed as measured by a sub-surface drogue at each station were reported in LCMR (1979a). During the single survey day in March, all measured currents were in a downcoast direction at approximately 10 cm/sec (0.2 knots) while in the May survey the currents were generally upcoast at a speed of approximately 8 cm/sec (0.15 knots). Commencing with the combined program in July, measurements were taken each day along three isobaths on the three survey days. During the July survey at the nearshore (10-m isobath) stations average current speeds decreased from 30 cm/sec (0.6 knots) to less than 10 cm/sec (0.1 knots) in the six day time period over which the survey was completed. Speeds at offshore (15 and 30 m) stations maintained a relatively constant level with a fairly high average of 23 cm/sec (0.4 knots). A downcoast flow was present on all days of the July survey. The September survey was characterized by slower flow with greater tidal influence than July. Most of the measured directions were onshore or downcoast, with a few upcoast measurements. Average current speed increased with distance from shore: 3, 6, and 16 cm/sec (0.06, 0.12, 0.32 knots), along the 10, 15, and 30-m isobaths. Velocities increased slightly and were more strongly directed downcoast during the latter portion of the three day survey. In general, the lowest current speeds recorded during the plankton surveys were in November. As in the previous survey, average current speeds increased with distance from shore: 3, 4, and 6 cm/sec (0.06, 0.08, 0.10 knots) along the 10, 15, and 30-m isobaths. Current direction was erratic, especially at low speeds, but generally with a net downcoast flow.

DISCUSSION

This section addresses specific topics that pertain to the establishment of the preoperational baseline data for Units 2 and 3, and the assessment of the effects of SONGS Unit 1 on the plankton resources in the vicinity of the generating station. Each topic is discussed in terms of spatial and temporal patterns of occurrence and abundance (or concentration) observed in the study area. The sampling design, method of data collection, results, analysis, and interpretation of the data from the programs presented in this chapter have been oriented to examine the nature and extent of naturally occurring plankton resources in the study area. Incorporated within this sampling and analytical scheme are specific analyses which evaluate whether or not there is any significant effect of Unit 1 operation on these plankton resources.

The statistical model described below and employed to evaluate the distribution of the biological parameters is subject to some constraints for 1978 resulting from additions to the program. Data from the combined ETS-PMP program in the latter half of 1978 were amenable to statistical analysis whereas evaluation of data from the March and May ETS surveys was limited to inspection of graphical representations of data. Stations 2, 3, and 5 were not included in the statistical model because they were sampled only on one of the three days of each survey. Station 8 was not added to the sampling program until September, therefore the transect in which it is located could not be used in the statistical model in July.

The model used for hypothesis testing takes into account the following factors: samples collected in the same day nested within days, the days within a survey, isobath on which stations were located, depth stratum from which samples were collected, and onshore-offshore transects. The last factor considers upcoast vs downcoast patterns and treats onshore-offshore lines of stations as transects. For analytical procedures of hypothesis testing, stations were grouped into four transects as depicted in Table 6-4. Transect 4 was not used in the primary analytical model employed because no representative 30-m station was present. A preliminary series of analyses, using five transects, but only stations on the 10 and 15-m isobaths, showed that much more information was gained than was lost if the transect containing only two stations was deleted. The factor "transect", measuring variation among groups of onshore-offshore aligned stations, revealed fewer instances of significant differences than other main effects. An important feature of the model employed is that short term variability (i.e., between days) has been included. The fact that nearly every analysis carried out showed significant difference between days, points out the highly transitory nature of the nearshore plankton populations off San Onofre. This feature was present for all biological parameters studied, except biomass, and indicates that patchiness may greatly affect the interpretation of data collected on a single day, as well as spatial and temporal patterns.

In the following paragraphs, topics concerning the data base gathered in the plankton program are discussed. Each is then discussed in terms of the results of 1978 observations, comparisons with past data, and implications regarding SONGS Unit 1 operations and future Units 2 and 3 operations.

SPATIAL AND TEMPORAL PATTERN OF PHYTOPIGMENT DISTRIBUTION

Chlorophyll a

Phytoplankton forms the base of food webs in the sea. It is therefore of great importance as a limiting factor for the support of all higher trophic levels. Factors influencing phytoplankton communities that may be altered by

Table 6-4. Stations grouped by isobath and transect included in the statistical model employed in the analysis of variance of ETS-PMP data.

Isobath	Depth	Stations				
		Transect 5	Transect 4	Transect 3	Transect 2	Transect 1
1	10 m	8	1	4	6	7
2	15 m	9	10	11	12	13
3	30 m	14		15	16	17

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SONGS operation are temperature, redistribution of nutrients, and light. Elevated water temperatures resulting from cooling water discharge may enhance or limit the growth of phytoplankton. Phytoplankton growth may also be influenced by redistribution of inorganic nutrients by the SONGS cooling water systems. Light is another limiting factor for phytoplankton growth. Redistribution of turbidity by SONGS operations could alter the quality and quantity of light available to the phytoplankton near SONGS. Redistribution of phytoplankters into different vertical strata by entrainment of bottom water by the discharge of the generating station cooling water system may also affect the quantity and quality of the phytoplankton communities near the generating station. For these reasons there is considerable ecological importance in examining phytoplankton biomass in the waters adjacent to the SONGS complex.

The significant isobath differences seen in the three surveys carried out for the combined ETS and PMP studies demonstrate the persistent onshore-offshore gradient of chlorophyll a characteristic of most nearshore marine environments. In each survey, chlorophyll a concentrations decreased with distance from shore. This pattern has been shown to occur throughout the southern California Bight region (Eppley et al., 1978) including nearby areas upcoast (Dana Point) and downcoast (Del Mar) from SONGS. Since this is the first year of this program, it cannot be stated with certainty that year-to-year variation in this pattern could not occur. However, previous studies (Barnett and Sertic, 1978) have also demonstrated an onshore-offshore gradient of chlorophyll a concentration in the region of SONGS; therefore, there is no reason to expect that this is other than a natural and persistent phenomenon. All isobath values were significantly different from one another with the exception of July in which the 10 and 15-m stations were not significantly different from each other. The biological significance of the concentration gradient is unknown at this time, but the explanation for higher chlorophyll values near shore may be a function of increased turbidity causing lower light levels, and not necessarily greater abundances of phytoplankton. Phytoplankters are known to compensate for low light by increasing the amount of chlorophyll per cell (Odum, McConnell, and Abbott, 1958). While other explanations are possible, there are insufficient data to resolve this question. During 1978, two peaks, one in March and a second in November, probably reflect spring and autumn phytoplankton blooms. The 1978 results are somewhat different from previous years in that the highest values occurred in November, while the highest values observed in the previous ETS studies usually occurred in the spring, based upon the inshore group of stations (LCMR, 1976d, 1977b, 1978c). The March values may represent the beginning or end of a spring bloom of phytoplankton and the November observations could have occurred during the peak of a bloom. The eight week time interval between scheduled plankton surveys is long enough for a phytoplankton bloom to occur without detection of the peak period of abundance.

There was not a consistent pattern in upcoast-downcoast chlorophyll a distribution during the period considered. No differences were detected in July. In September the upcoast transect (Transect 5) was significantly higher than Transect 2 but was not different from the extreme downcoast transect (Transect 1). In November chlorophyll a concentrations were significantly higher in the upcoast transect than the downcoast one. Currents during each of these surveys were downcoast and apparently were not a factor in the inconsistent upcoast-downcoast pattern.

Analysis of the initial three combined ETS-PMP surveys has identified definite trends in the distribution of chlorophyll a in the study area. Temporal

patterns of distribution and concentration, along with evaluation of the persistence of those patterns, will be better defined as more data is accumulated in the expanded study area.

Phaeopigment

Since phaeopigments are a degradation product of chlorophyll, a pattern similar to that of chlorophyll *a* with regard to spatial and temporal distribution is usually observed. This was generally the case for phaeopigment values observed off San Onofre in 1978. Statistically significant differences in phaeopigment concentration during July and November resulted from 10 and 15-m stations having higher concentrations of phaeopigment than the 30-m stations. This pattern of distribution would be expected considering the previously discussed relationship between chlorophyll *a* and phaeopigments. Although not significant, the pattern of onshore-offshore distribution described for July and November was also present in September, but not as well defined. The survey to survey variation noted for phaeopigment concentrations, paralleled those of chlorophyll *a*.

An upcoast-downcoast (transect) pattern similar to that seen for chlorophyll *a* in November was also present for phaeopigments. However, there was a significant interaction between onshore-offshore (isobath) and upcoast-downcoast (transect) effects. This resulted from the stations forming two broadly overlapping groups with regard to upcoast-downcoast and onshore-offshore distribution of phaeopigment. Phaeopigment concentrations at Stations 8 and 9 were significantly higher than at Stations 13, 16 and 17, but the remaining stations had intermediate phaeopigment concentrations which were not significantly different from either the highest or lowest. Since the group of stations with intermediate values contained stations from each transect and each isobath, no definitive distributional pattern can be delineated.

The seasonal pattern of phaeopigment concentration closely parallels the seasonal pattern observed for chlorophyll *a* during 1978 because it is measuring a different parameter of the same phytoplankton population. Excessively high phaeopigment concentrations not associated with high chlorophyll *a* concentrations, a condition which might suggest deteriorating phytoplankton populations or heavy grazing by zooplankton, were not observed in the study area. The concentrations of phaeopigment were of the same general magnitude as previously reported from the study area (LCMR, 1976d, 1977b, 1978c). The November peak noted for both chlorophyll *a* and phaeopigment was unique to 1978. It was not clearly associated with any gross climatic or oceanographic pattern in the area. Although SONGS 1 had been offline for refueling and maintenance for seven weeks during September and October, it was operating at nearly full load for ten days prior to the November plankton survey.

SPATIAL AND TEMPORAL PATTERN OF ZOOPLANKTON DISTRIBUTION

Total Zooplankton Abundance

Biomass is a measure of "how much" zooplankton is present, whereas abundance is a measure of "how many" organisms are present in a specified volume of water. Although it does not take into account the taxonomic composition of the community, total abundance of organisms is a useful gross measure of spatial and temporal changes in population sizes.

Of the three surveys containing offshore stations, the pattern of total zooplankton abundance was well defined with regard to onshore-offshore variations only in July. During that survey the 10, 15, and 30-m groups of stations were significantly different, showing a gradient of increasing abundance with distance offshore (Figure 6-2). The same pattern with regard to isobath was observed in September, but a significant interaction between isobath and transect (upcoast vs downcoast) was found. This resulted from Station 8 being significantly different from other stations with respect to the spatial distribution of total zooplankton. Zooplankton abundance at Station 8 was much lower than at other stations, but the reason for this cannot be delineated. This seems unrelated to other data gathered at the same station, during this survey, and is probably due to patchiness in zooplankton distribution. In November an interaction between isobath and depth existed. The group of 15-m stations was similar to the lower stratum 10-m stations whereas the 30-m stations were similar to the upper stratum of both the 10 and 15-m stations. The upper stratum 15-m stations showed an affinity for both groups. This appears to have resulted from an interaction of factors including an onshore-offshore gradient and vertical depth stratification of the zooplankton. The species composition may also vary among isobaths and depth strata.

Year to year variation can be compared only for the 10-m stations. The magnitude of numbers of organisms and ranges of fluctuations is similar for the four years over which the stations have been sampled. The abundance observed in 1978 deviates from previous years in that lower abundances in July, and higher abundances in November were observed. This may be due to the fact that previous years sampled only the 10-m isobath. Also, there was a peak of chlorophyll a in November, which, if present for a period of time prior to the November survey, may have indicated that a food source in the form of unusually high phytoplankton concentration was present which may have resulted in higher zooplankton production. Similarly, the lack of a major spring phytoplankton bloom could account for lowered zooplankton abundance later in the year during the July survey. Year to year fluctuations in the benthic invertebrate communities may also influence total zooplankton abundance by releasing planktonic larvae in large numbers over a relatively short period of time.

Differences in abundances of select taxa in 1978 compared to previous years (Table 6-3), are probably due, in part, to natural variability as well as the fact that, commencing with the July 1978 survey, data were collected from 15 and 30-m stations in addition to the 10-m stations. It can be seen that *Acartia tonsa* and *Acartia* copepodites have remained among the most abundant components of the zooplankton. The increased abundance of *Paracalanus parvus* and *P. parvus* copepodites in 1978 reflects the greater abundance of this species at the 15 and 30-m stations.

Zooplankton Biomass

Although closely related, biomass measurements of zooplankton may differ from the total number of organisms. A large number of very small organisms could easily yield a lower biomass value than fewer organisms with a larger individual size. For this reason, zooplankton biomass is very important for food chain considerations since, simplistically, it forms the link between the primary producers, phytoplankton, and the secondary consumers, e.g., fish.

The significantly greater biomass present in July proceeding offshore from the 10 to 30-m isobath corresponds to the onshore-offshore gradient of zooplank-

ton abundance seen on this survey. The September transect-isobath interaction resulted from a complex grouping of stations in which each contained 10 of the 12 stations considered in the analysis. Stations 7 and 8 had the lowest biomass and 5 and 11 had the highest. The remaining 8 stations had intermediate values and were not significantly different from one another. No consistent pattern with regard to zooplankton biomass existed between surveys.

A significant difference among transects was detected in November. The transect with the highest mean biomass was significantly different than the lowest mean biomass. However, the two transects with intermediate values were not significantly different from either the highest or the lowest. Since the high and low biomass means were not at the extremes of the station pattern, it is not possible to delineate a clear pattern of distribution of biomass with regard to upcoast-downcoast variability. A fairly complex isobath with depth interaction was also significant in November for biomass. The biomass in the lower stratum of the 15-m stations was significantly higher than any other group of observations in November. The remaining isobath-depth stratum combinations formed two broadly overlapping groups with no clear pattern.

Since biomass has been measured on three surveys commencing in July 1978, a few temporal comparisons can be made. In general terms, the biomass parallels zooplankton abundance. This indicates that no major changes in the size of organisms comprising the zooplankton occurred in different surveys. Biomass was highest during the September survey and lowest during the July survey, except for the 30-m stations, where the low of the three surveys was in November. Some deviations from the pattern of total zooplankton abundance may be attributable to contamination of samples by small amounts of detritus suspended in the water column, particularly near the bottom.

VERTICAL STRATIFICATION OF PLANKTON

Both zooplankton and phytoplankton are known to occupy specific zones within the water column. Seasonal, and/or diel vertical migrations may vary from species to species and within the same species (Longhurst, 1976). The operation of SONGS may potentially result in the vertical translocation of water masses and the plankton contained therein. Such changes may disrupt the community structure and/or productivity of areas affected by SONGS operations. It is therefore desirable to carry out analyses on zooplankton and phytoplankton with regard to their vertical distribution within the water column and delineate any features of the community structure which may be altered by SONGS operations.

Significantly greater chlorophyll a and total zooplankton abundance was detected in the lower strata in September. Significant depth-isobath interaction occurred in November for these parameters and has been previously discussed. Significantly higher phaeopigment concentrations in the lower depth stratum were found in all three surveys subjected to statistical analysis and also noted in March and May. No significant depth difference was detected in any survey for zooplankton biomass. Although not significant, a trend towards higher values of chlorophyll a and total zooplankton abundance also appeared in July. The significant difference between strata in September may have resulted from a well defined thermal gradient present at the time. This gradient was also well defined in July, but was completely lacking in November. Deviations from the general pattern occurred in March and May when only the 10-m stations of the ETS program were sampled. Chlorophyll a concentrations were

higher in the upper stratum in March than in May, but phaeopigment values were mixed, with most of the higher values recorded in the lower stratum during both surveys. Total zooplankton abundance was higher in the upper stratum in March, but higher in the lower stratum in May. Since these values are based on a single sample collected on one-day surveys, they cannot be compared directly to the results of the combined ETS-PMP program.

Higher chlorophyll a concentrations in the lower stratum may reflect greater overall phytoplankton concentrations (biomass or abundance) or a response of the phytoplankton to lower light intensity in deeper water (Yentsch and Ryther, 1957; Odum, McConnell, and Abbott, 1958). The cells in the lower stratum may contain more chlorophyll a than those in the upper stratum even though the number of cells is similar. Previous studies at the ETS 10-m stations have found similar results to those seen in 1978 for chlorophyll a (LCMR, 1977b). Higher concentrations of phaeopigment at depth may be explained by the sinking of nonliving particles including dead phytoplankton cells and zooplankton fecal material. The higher abundance of zooplankton at depth may be attributable to a tendency for certain taxa to selectively remain in the lower stratum during daylight. Previous studies (LCMR, 1976d; 1977b; 1978c) have found such trends for the 10-m ETS stations. The general pattern for biological parameters examined with regard to depth distribution is similar to observations made for the 10-m ETS stations in the preceding years 1975 to 1977.

SONGS UNIT 1 EFFECTS

There was no pattern with respect to the distribution of any plankton parameter and distance from the generating station. Since no consistent pattern of upcoast-downcoast variation in chlorophyll a or phaeopigment could be delineated, there was apparently no clear relationship between SONGS Unit 1 operations and the observed differences. The same was true of zooplankton biomass and abundance. The lack of clear patterns of upcoast-downcoast variability in concentrations with depth indicates that the operation of SONGS Unit 1 had no detectable effect on the vertical distributional patterns of chlorophyll a, phaeopigments, total zooplankton abundance, or zooplankton biomass at the ETS-PMP plankton stations. The November peak noted for both chlorophyll a and phaeopigment was unique to 1978. It was not clearly associated with any gross climatic or oceanographic pattern in the area. Its widespread occurrence over the study area indicates it was probably not related to SONGS Unit 1 operations.

Based on the analysis of the 1978 data, all indications are that the variability inherent within the plankton component of the ecosystem far exceeds any differences attributable to Unit 1 operations.

UNITS 2 AND 3 PREOPERATIONAL BASELINE OBJECTIVES

Implementation of the combined ETS and PMP plankton sampling program in July 1978 has resulted in the gathering of more extensive plankton samples from the SONGS study areas than previously obtained. Analysis of data has revealed spatial and temporal patterns of distribution of phytopigments and zooplankton that contribute toward establishment of baseline data for future assessments of the effects of Units 2 and 3.

Gross temporal patterns are similar to observations conducted for the ETS sampling program. Distributional patterns tend to be fairly well defined for spatial variability with onshore-offshore gradients and depth differences impor-

tant in July and September but less obvious in November. Thermal stratification within the water column during July and September may influence the vertical distribution of the plankton. The data base of the combined ETS-PMP program does not yet span an entire year, so temporal patterns cannot be addressed at this time, but will be addressed next year when sufficient data have been obtained.

SUMMARY

Five bimonthly plankton surveys were conducted in 1978. The January survey could not be completed because of persistently inclement weather. The second and third ETS surveys were carried out at seven stations along the 10-m depth contour. The combined ETS-PMP plankton studies began with the July survey and continued with the September and November surveys. The combined ETS-PMP sampling program encompassed a more extensive study area, including sampling along the 15 and 30-m isobaths. Plankton was sampled from two depth strata during daylight hours using a Lockheed designed pump system. Plankton samples were integrated throughout each depth stratum. Select taxa of zooplankton were identified and enumerated. Chlorophyll a and phaeopigment concentrations were measured from whole-water samples. An analysis of the data and a comparison with 1975 to 1977 results indicated the following.

1. Chlorophyll a concentrations were highest in November and March. The November peak differs from previous years but may represent an autumn phytoplankton bloom. Significant differences in onshore-offshore distribution of chlorophyll a were observed with higher values consistently present at the 10-m stations and decreasing seaward. No consistent pattern of upcoast-downcoast distribution of chlorophyll a was observed.

2. Phaeopigment concentrations showed a similar pattern of spatial and temporal distribution to chlorophyll a. Phaeopigment concentrations were generally lower at the offshore 30-m stations than at the 10 or 15-m stations. No consistent pattern of upcoast-downcoast distribution of phaeopigment was observed.

3. Total zooplankton abundance was lowest in July and highest in September. Zooplankton abundance was significantly greater at the 15 and 30-m stations in July, but well defined onshore-offshore patterns were not present in September or November. No consistent pattern of upcoast-downcoast distribution was observed for total zooplankton abundance.

4. Zooplankton dry weight biomass was lowest in July and highest in September, paralleling the total abundance data. No consistent pattern in either onshore-offshore or upcoast-downcoast distribution was observed for zooplankton biomass.

5. Zooplankton species composition and rank order of abundance for select taxa was similar to that observed in previous studies of 1975-1977. Deviations in 1978 may be attributed to the inclusion of additional stations farther offshore in the combined ETS-PMP studies.

6. Significantly higher values of chlorophyll a, phaeopigments and total zooplankton abundance were observed for the lower depth stratum. No obvious pattern of depth distribution was observed for zooplankton biomass.

7. Significant day to day variation was observed within a survey for each parameter measured except biomass.

8. No patterns of distribution or abundance (or concentration) were observed that could be related to the operation of SONGS Unit 1.

9. The inherent variability within the planktonic community offshore SONGS far exceeds any differences attributable to Unit 1 operations.

PLANKTON ENTRAINMENT SPECIAL STUDY

Section 4.3 of the Unit 1 ETS requires that a study plan to categorize and determine effects of plankton entrained within the circulatory water system be submitted for NRC approval.

San Onofre Unit 1 is also subject to a FWPCA Section 316(b) demonstration which is administered through the NPDES permit by the California Regional Water Quality Control Board (CRWQCB), San Diego Region. A study plan to a 316(b) demonstration has been submitted to EPA and the CRWQCB, San Diego Region and approved. That study plan included a methods development phase, now nearing completion, which will result in a detailed plan for conducting the 316(b) entrainment study.

In keeping with the EPA-NRC memorandum of understanding and to avoid redundant effort or delay of study implementation due to multiple agency approval and reporting, a licensing amendment request to delete the ETS 4.3 will be submitted to the NRC. The 316(b) study plan will form the basis for the licensing amendment request.

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CHAPTER 7

INTERTIDAL

A. SANDY INTERTIDAL

The intertidal zone adjacent to the San Onofre Nuclear Generating Station (SONGS) consists primarily of sand beaches interspersed with, and periodically covering, small areas of cobble. This intertidal sand habitat stretches south uninterrupted from San Mateo Point to Oceanside uninterrupted. The coastline faces southwest and is exposed to the full force of oceanic swells from the west and south. Intertidal sands are consequently, a high energy environment for those few species occupying them; the constant wave resculpturing of the beaches producing substrate instability, and a naturally stressful habitat.

Studies of the impact of construction associated with SONGS Units 2 and 3 on the sandy intertidal habitat and its biota were begun in 1974 by the Lockheed Center for Marine Research (LCMR, 1974). This monitoring effort continued on a quarterly basis through mid 1976. In December 1976, a modified study plan was undertaken by Marine Biological Consultants, Inc. (MBC, 1978).

The data and analysis presented in this report are results of the second year of intertidal monitoring with present methodology. Field surveys were conducted in February, May, August, and November of 1978. Construction of the cooling water intake and discharge conduits for SONGS Unit 2 and Unit 3 was in progress throughout 1978, as was the shallow-water disposal of dredge spoils.

Raw data were presented in Section II of the SONGS Annual Operating Report, Volume III, Construction Monitoring Program (MBC, 1979) and are not included here.

Biotic parameters presented and discussed include: the number, density, and distribution of species in the intertidal community; community trophic structure and diversity; species groupings at the study sites; and the population structure of the dominant organism, the sand crab Emerita analoga. These biotic parameters are correlated to abiotic factors in the study area, and analyzed to reveal construction related effects.

METHODS

Prior to the initiation of intertidal surveys, the +8 ft tidal elevation at each transect was located by surveying from permanent benchmarks of known elevation. All intertidal heights were recorded as feet above Mean Lower Low Water (MLLW).

During each quarterly survey, beach profiles were measured at each of the transects. The profiles were made using a surveyor's self-leveling level. Profiles were determined from the +8 ft elevation down to the lowest tidal level of the survey day. Collection levels of samples for grain size and biological analysis were determined during beach profiling.

Five transects were occupied during each survey (Figure 7-1). Transects AA and EE were located 1,187 m northwest and southeast of the midpoint between the Units 2 and 3 dredge lines. Transect BB was 236 m northwest, and Transects CC and

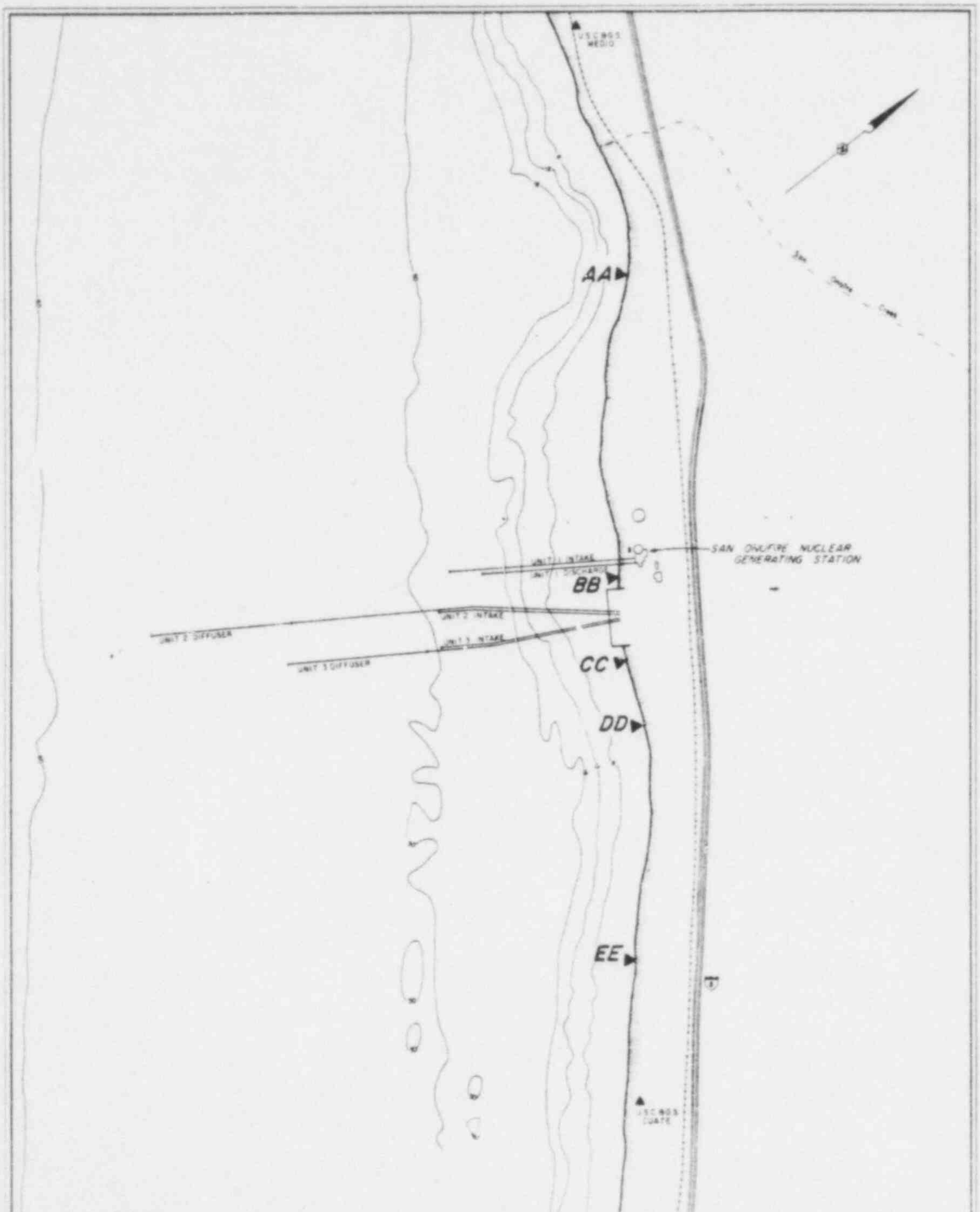

Figure 7A-1. Intertidal transect locations

Units 2 and 3 dredge lines. Transect BB was 236 m northwest, and Transects CC and DD were 236 and 472 m southeast of the midpoint, respectively. At each transect, five replicate biological core samples were collected from each of seven tidal elevations (levels) at 0 to +6 ft above MLLW. The 15.24 cm diamater by 30 cm (5 liters) cores were collected from the transect centerline and at 3 m and 6 m to each side.

The number of core samples necessary to adequately represent the sandy intertidal community was determined from a test collection of 25 replicates in December 1976 using rate of species accumulation and percent detectable change measures as criteria. At least 80% of the species at the site were collected in the first five cores, and this level of replication was adopted.

Samples were screened in the field through a 1.0 mm mesh sieve and the retained organisms initially preserved in 10% buffered Formalin-seawater. The preserved organisms were returned to the laboratory for identification and enumeration. Reproductive condition was determined whenever possible. All specimens were transferred to 70% isopropyl alcohol in the laboratory for permanent storage as voucher specimens.

Along each transect, core samples for sediment grain size analysis were collected at 0, +2, +4, and +6 ft tidal elevations. Sediment cores were collected to a depth of 30 cm except when cobble would not allow core penetration to this depth. Estimates of wave period, height, and direction as well as water temperature were also recorded.

Grain size distributions at each level were determined by mechanical sieving through different size mesh. The retained portions were weighed and proportionally related to the total sample weight. The mesh sizes used were -2.25, -1.5, -0.5, 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 phi units (phi = $\log_2$ x diameter in millimeters). A thorough description of grain size statistical parameters and their derivation was presented in Chapter 5.

DATA ANALYSIS

Two analytic techniques were applied to the intertidal data; classification and correlation.

Classification Analysis

This technique defines a habitat in terms of species presence and abundance (Clifford and Stephenson, 1975). Areas with similar biota are assumed to constitute similar micro-environments.

Classification analysis groups entities by specific joint attributes. Two classifications were performed. First, the samples were classified by their species composition and abundance (normal analysis) which resulted in the clustering of similar sites. The species were then classified by their occurrence and abundance at the sites, which clustered species with similar distribution patterns (inverse analysis). In both classifications, flexible sorting strategy was used to generate dendrograms from a Bray-Curtis dissimilarity matrix. The raw data were transformed by square root to reduce the effect of Emerita dominance and standardized as a percentage of each species' maximum abundance (Boesch, 1977).

Results of the site and species classification analyses were combined into two-way coincidence tables (Clifford and Stephenson, 1975) using the symbolic format proposed by Smith (1976). These tables provided a basis for objective detection of patterns in community distribution.

Correlation Analysis

Pearson's product-moment correlation coefficient (r) (Sokal and Rohlf, 1969) was used to examine the relationship between selected abiotic and biotic variables. As this is a parametric test (Siegel, 1956) only the rank order of abiotic correlations with each biotic variable was considered meaningful. This parametric measure was used instead of available non-parametric tests to maximize the amount of information considered in the correlation.

RESULTS

SPECIES COMPOSITION

A total of 29 taxa were identified from the 700 five liter cores collected in 1978. Arthropods and annelids, represented by 13 and 9 species, respectively, comprised 92% of the fauna. Two other phyla, Mollusca and Nemertea, were represented by one taxon each. One species, the sand crab Emerita analoga, was more widely distributed, and an order of magnitude more abundant than any other taxon (Table 7A-1).

Thirteen taxa ranked among the five most abundant species during one or more surveys (Table 7A-2). Four species ranked among the first five in more than one quarter: Emerita analoga, Hemipodus borealis, Pisione remota, and Excirolana kincaidi. Emerita and Hemipodus were consistently the most abundant species ranking first and second in each quarter, and in the year as a whole. The small polychaete, Pisione remota ranked third in February, and fourth in November and overall. The isopod Excirolana kincaidi ranked fourth in February, third in August, and sixth for the year.

Collection of relatively large numbers of the beach hopper species Orchestoidea minor and O. columbiana in May ranked them among the top five for the

Table 7A-1 Intertidal transect summary table for 1978 collections by survey.

	Transect AA	Transect BB	Transect CC	Transect DD	Transect EE	All Transects
February 1978						
Number of Species	3	4	3	4	3	8
Number of Individuals	55	26	6	19	41	147
Number of Emerita	52	17	1	3	16	89
% Individuals: Emerita	94.5	65.4	16.7	15.8	39.0	60.5
Species Diversity	0.11	0.42	0.38	0.41	0.47	0.52
May 1978						
Number of Species	6	5	11	9	7	16
Number of Individuals	19	84	371	276	73	823
Number of Emerita	6	71	337	198	48	660
% Individuals: Emerita	31.6	84.5	90.8	71.7	65.8	80.2
Species Diversity	0.71	0.26	0.20	0.45	0.42	0.38
August 1978						
Number of Species	12	2	4	5	3	17
Number of Individuals	47	202	145	311	121	826
Number of Emerita	25	201	142	290	111	770
% Individuals: Emerita	53.2	99.5	97.9	93.2	91.7	93.2
Species Diversity	0.75	0.01	0.07	0.08	0.14	0.15
November 1978						
Number of Species	5	7	6	11	4	17
Number of Individuals	44	88	24	60	73	289
Number of Emerita	29	80	6	23	56	194
% Individuals: Emerita	65.9	90.9	25.0	38.3	76.7	57.1
Species Diversity	0.41	0.20	0.56	0.80	0.30	0.56

Table 7A-2. Rank, percent of relative abundance (%) specimens, and percent replicate occurence of the five most abundant species overall and by survey.

Month	Rank	Species	%[1]	Cum. %[a]	% Occur[b]
Feb	1	Emerita analoga	60.5	60.5	29.7
	2	Hemipodus borealis	21.8	82.3	13.7
	3	Pisione remota	8.8	91.1	2.3
	4	Excirolana kincaidi	3.4	94.5	2.3
	5	Nemertea, unid.	2.[illegible]	97.2	2.3
May	1	Emerita analoga	80.4	80.4	37.7
	2	Hemipodus borealis	6.3	86.7	21.1
	3	Orchestoidea minor	4.7	91.4	13.7
	4	O. columbiana	2.7	94.1	9.1
	5	O. benedicti	1.9	96.0	9.1
Aug	1	Emerita analoga	94.2	94.2	84.4
	2	Hemipodus borealis	2.4	96.6	14.1
	3	Excirolana kincaidi	0.6	97.2	3.7
	4	Nepthys californiensis	0.5	97.7	3.0
	5	Dispio uncinata	0.4	98.5	2.2
	5	Microspio acuta	0.4	98.5	2.2
Nov	1	Emerita analoga	66.8	66.8	41.7
	2	Hemipodus borealis	13.5	80.3	19.4
	3	Donax gouldii	5.9	86.2	4.6
	4	Pisione remota	3.8	90.0	4.0
	5	Saccocirrus papillocercus	2.4	92.4	1.1
Year 1978					
	1	Emerita analoga	82.6	82.6	46.2
	2	Hemipodus borealis	6.9	89.5	17.3
	3	Orchestoidea minor	1.9	91.4	3.6
	4	Pisione remota	1.3	92.7	2.1
	5	Orchestoidea columbiana	1.1	93.8	2.6

[a] Percent of collected specimens

[b] Percent occurrence in replicates

year, although their density was much lower in other quarters. Other taxa relatively abundant during a single survey were: Nemertea, unid. in February; the beach hopper Orchestoidea benedicti in May; the polychaetes Nepthys californiensis, Dispio uncinata, and Microspio acuta (as Nerinides acuta previously - MBC, 1978) in August; the bean clam Donax gouldii, and the archiannelid worm Saccocirrus papillocercus in November.

Over 60% of the collected species had restricted vertical distributions (Table 7A-3). All of the five most abundant species were, however, found in the upper, mid, and lower beach biotic zones described by Dahl (1952). The majority of the species with vertically limited distributions were restricted to the lower beach and represented subtidal species occurring intertidally in low density.

SPECIES DISTRIBUTION

The number of taxa collected per survey ranged from 8 in February to 17 in August and November. No single transect was markedly more species rich than the others throughout the year (Figure 7A-2). The average species number ranged from 4.3/survey at Transect EE to 6.5/survey at Transect AA. Although these extremes occurred at the farthest downcoast and upcoast transects, intermediate transect values did not follow a longshore gradient. Numbers of species were similar at all tidal heights, although the lowest levels (0 and +1) were richer and intermediate levels (+3 and +4) poorer in species than other levels when quarterly data was averaged over the year. Average values ranged from 4.0 species at level +3 to 7.75 species at level 0.

No consistent pattern in distribution of species numbers by transect and quarter was evident (Figure 7A-2). The number of species per transect averaged between three and five along most transects during most quarters. High species counts at Transect AA in August (11 species), Transect CC in May (10 species), and Transect DD in November (10 species) raised the annual average for these transects above those for Transects BB and EE.

A fairly consistent pattern of relative species richness at Transect DD emerged when species numbers per transect were examined by level (Figure 7A-3). The average number of species per transect/level was highest at Transect DD in three of the four survey quarters. Only in August did another transect (AA) average more species/level than Transect DD.

Several collections contained no organisms. Each transect, other than Transect CC, had one level vacant during one quarter (Figure 7A-3). There were four such occurrences along Transect CC, two in February (levels +2 and +4) and two in November (levels +4 and +5).

Species turnover between sampling periods was examined to measure qualitative stability of the SONGS intertidal community. Despite the low density and

aggregated occurrence of most species, a basic pattern was evident. Species were added to the community along all five transects between the February and May surveys when species turnover values ranged from 100% (Transect AA) to 267% (Transect CC) largely because of the number of additional species recorded in May. Between May and August, however, all transects except Transect AA exhibited a net species loss. Between August and November, this pattern reversed, with net species gain at all transects except Transect AA. Cumulative species change over the year was small or absent, with all transects except Transect BB showing annual species turnover percentages less than or equal to average inter-quarter values. Annual turnover at Transect BB was higher than the average inter-quarter turnover, but the difference was too slight (225% vs 178%) to demonstrate cumulative change conclusively. Seasonal composition changes were marked along Transect EE, where the average inter-quarter turnover (129%) was four times the net annual turnover (33%).

Table 7A-3. Vertical zonation patterns of intertidal species.

Distribution Height Independent	Level	Zone	Distribution Height Dependent
			High only
	+6		Excirolana linguifrons Orchestoidea pugettensis
		A	
	+5		C[illegible]
			Ex[illegible]olana kincaidi E[illegible] nr. kincaidi
	+4		[illegible]
Emerita analoga Orchestoidea columbiana		B	None
	+3		Overlap
O. benedicti O. minor Hemipodus borealis Pisione remota			Microspio acuta
	+2		
			Low only
Sporadic Occurrence Synchelidium micropleon Saccocirrus papillocercus Insecta, unid.	+1	C	Nemertea, unid. Nephtys californiensis N. ferruginea Scolopios armiger Paraonella platybranchia Dispio uncinata Archaeomysis maculata Eohaustorius washingtonianus Lepidopa californica Donax gouldii
	0		

A = upper beach B = mid beach C = lower beach

COMMUNITY DENSITY

Density is a measure of abundance per unit area or volume. The density values reported herein are abundance per five 5ℓ replicates (station density, or each level at each transect), or abundance per 35 replicates (transect density). Equivalent surface area is approximately 0.18 m^2 per five replicates or 0.9 m^2 per transect. Average densities per transect represent the average abundances at the seven intertidal levels sampled along each transect during each quarter. Emerita analoga, which comprised over 80% of the intertidal fauna over the year, so dominated the community (Figure 7A-2) that the data were re-analyzed excluding Emerita (Figure 7A-4) in order to summarize density trends for other community members.

A total of 2,085 specimens were collected in the 700 replicate cores taken in 1978, an average density of 15 per station (3 per replicate). Excluding Emerita, the total number of individuals collected was 372, an average density of 2.7 per station (0.5 per replicate).

Community density (Emerita excluded) by quarter averaged 18.6 per transect and ranged from 11.2 in August to 32.6 in May. Density by transect was greatest along Transect DD (38.0 individuals/quarter) and least along Transect BB (7.75 individuals/quarter). Quarterly densities ranged from 78 along Transect DD in May to 1 along Transect BB in August. Densities at Transect DD were higher than at all other transects except in February, when the community was densest along Transect EE (Figure 7A-4).

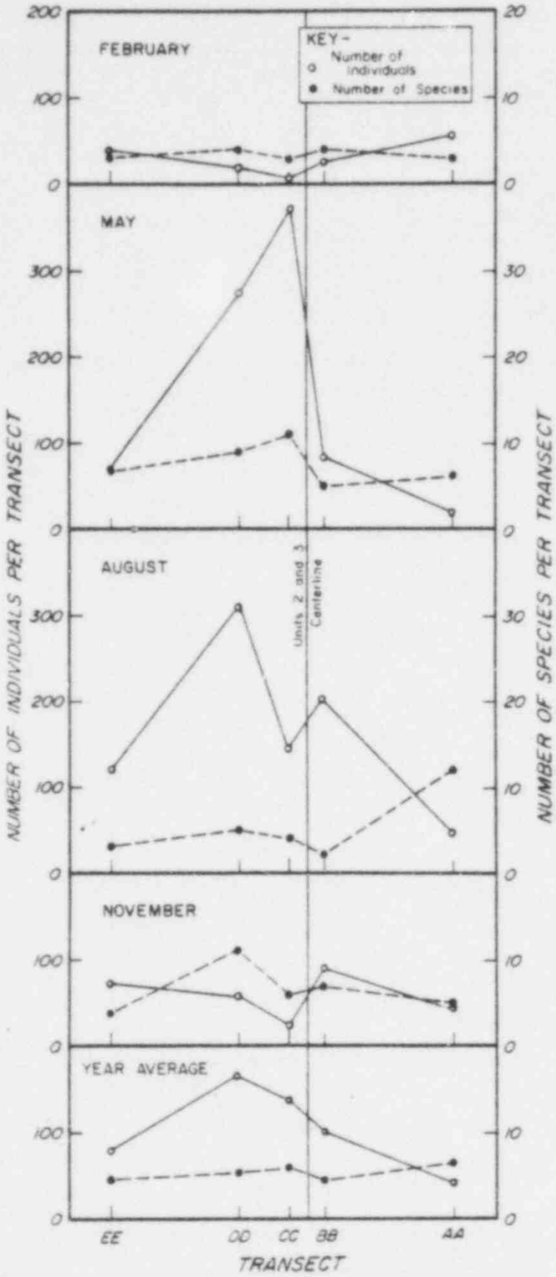

Figure 7A-2. Survey total and annual average number of individuals and species by transect.

Community density did not follow a trend of either increase or decrease with increasing tidal height over the sampling year, or in any quarter (Figure 7A-3). Density was generally somewhat higher at levels 0 and +4, and somewhat lower at level +3 than at other levels.

Inclusion of Emerita counts in density analysis did not change the overall pattern of highest density along Transect DD, although Transect AA replaced Transect BB as the transect with the lowest average density for the year (Figure 7A-2). The majority of the density differences with Emerita during each quarter were also related to consistently higher Emerita density along Transect BB than along Transect AA. A pattern of increasing density between Transect CC and Transect DD followed by decreasingdensity between Transect DD and Transect EE was present with or without Emerita inclusion during most quarters quarters.

DISTRIBUTION OF Emerita

The population density and distribution of Emerita analoga was separately examined. This species was numerically dominant in each quarter, and in the year as a whole (Table 7A-1). It was the most abundant organism along all transects except Transects CC in February and November, and Transect DD in February.

Emerita were encountered along all transects in all four quarters (Figure 7A-5), with the percentage of replicates in which the species occurred ranging from 2.9% along Transect CC in February to 100% along Transect BB in August. It occurred in 46.2% of the cores collected in 1978. Lowest density was observed in February, when 89 individuals were collected in 175 cores (0.5/replicate). Density increased to 662 (3.8/replicate) in May with collection of new recruits. Recruitment probably continued through June (Auyong, 1977) increasing density to 778 (4.5/replicate) by August.

Emerita were most abundant along Transect AA in February (52), Transect CC in May (338), Transect DD in August (300), and Transect BB (80) in November. Transect totals for the year increased along a downcoast gradient from Transect AA (112) to Transect DD (514), then declined to 231 at Transect EE.

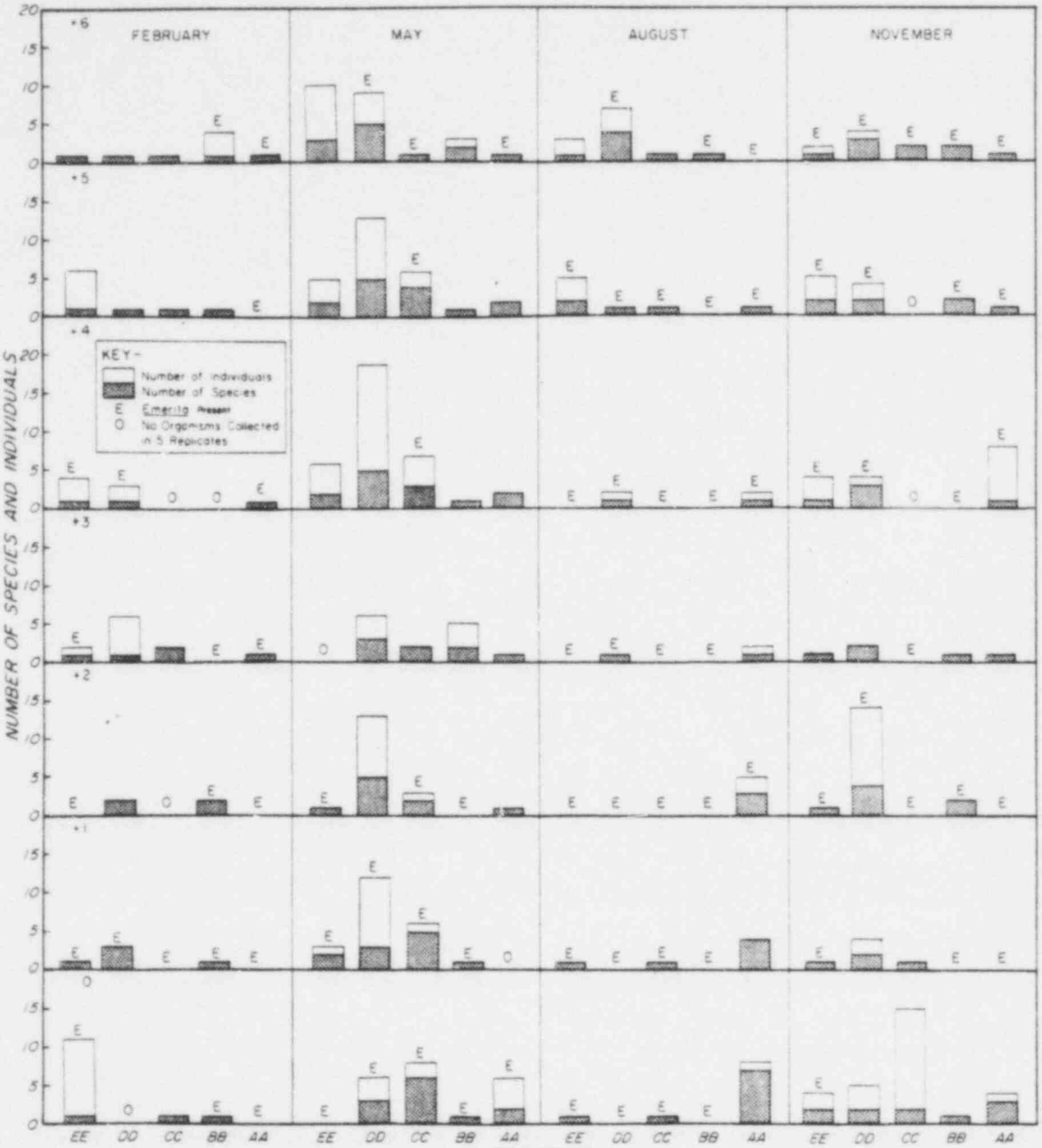

Figure 7A-3. Number of species and individuals other than Emerita by tidal level, transect, and survey month.

No pattern was evident in the vertical distribution of the population (Figure 7A-5). Percentage occurrence of Emerita in cores ranged from 8% along level 0 in November and level +6 in February, to 80% along level +1 in August. Abundances of Emerita were similar in May (660) and August (770), but the population was more evenly dispersed in August with individuals appearing in 84.4% of the cores vs. 37.7% of the cores in May.

Size frequency data (Figure 7A-6) indicated major recruitment occurred along Transects CC and DD between February and May, and along Transect BB between May and August. Minor recruitment occurred along Transects AA, DD, and EE between May and August. The presence of 0 to 5 mm size class individuals throughout the

year indicates sporadic or continuous low level recruitment outside the normal March-June spawning season (Auyong, 1977). Over-wintering individuals (5 to 10, and 10 to 15 mm size classes) were present along all transects in February, with the majority occurring along Transects AA and EE. Survival of young-of-the-year was poor along Transects CC and DD, after heavy initial settlement of these sites.

SPECIES DIVERSITY

Species diversity, as measured by the Shannon-Wiener Index H' was calculated to permit comparison with other studies (Table 7A-1). Such a comparison is most valid with reference to previous data from SONGS (MBC, 1978) collected by the same methods. H' values in Table 7A-1 represent actual transect diversity, and not mean diversity of the seven levels.

COMMUNITY TROPHIC STRUCTURE

Trophic analysis provides basic information on the functional organization of a community and reflects temporal changes in nutrient inputs into an area. Since change in species composition over time may reflect only the aggregate result of competitive interactions, analysis of trophic structure allows determination of the importance of observed faunal changes in the overall pattern of energy flow within the community. Such analyses have been commonly used both locally (i.e. Fauchald and Jones, 1977; Environmental Quality Analysts and Marine Biological Consultants, Inc., 1979a) and elsewhere (Dexter, 1969; Fedra, 1977).

Intertidal organisms encountered at SONGS were separable into different trophic groups based on the way they obtain food, the nature of food consumed, or a combination of both (Table 7A-4). Four basic trophic groups were represented in the community; raptorial carnivores, opportunistic omnivores, suspension feeding species, and deposit feeding species. These groups are not fully mutually exclusive as some species can obtain food in more than one way, or use more

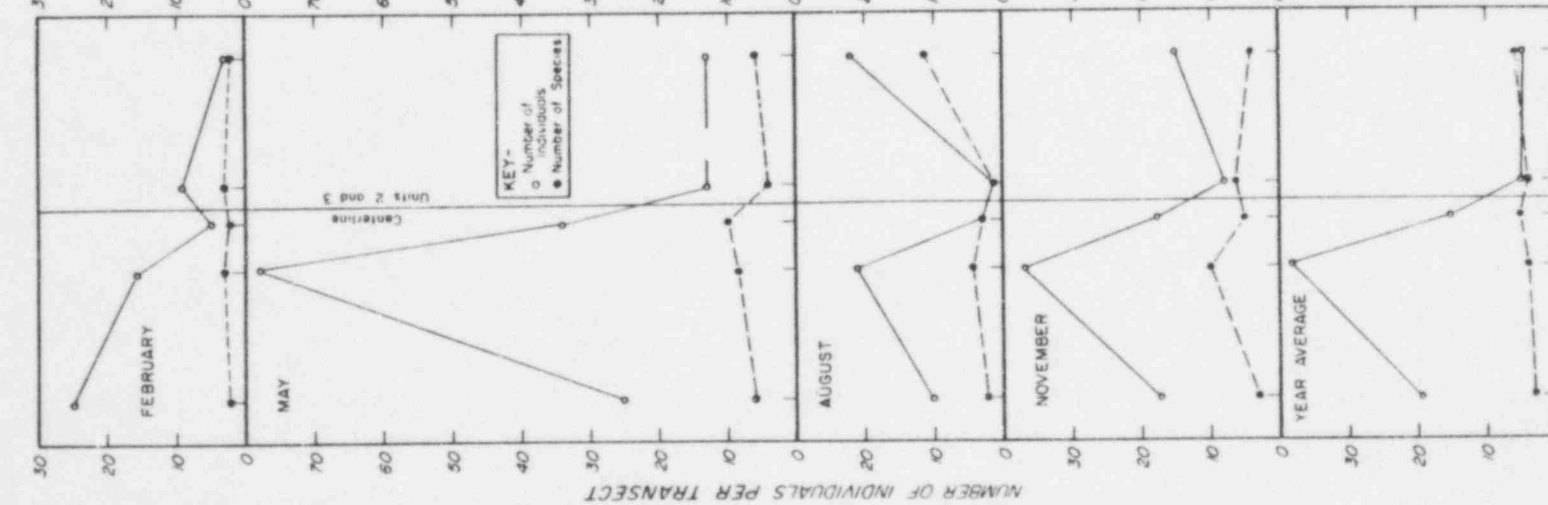

Figure 7A-4. Survey total and annual average number of individuals and species by transect (Emerita excluded).

POOR ORIGINAL

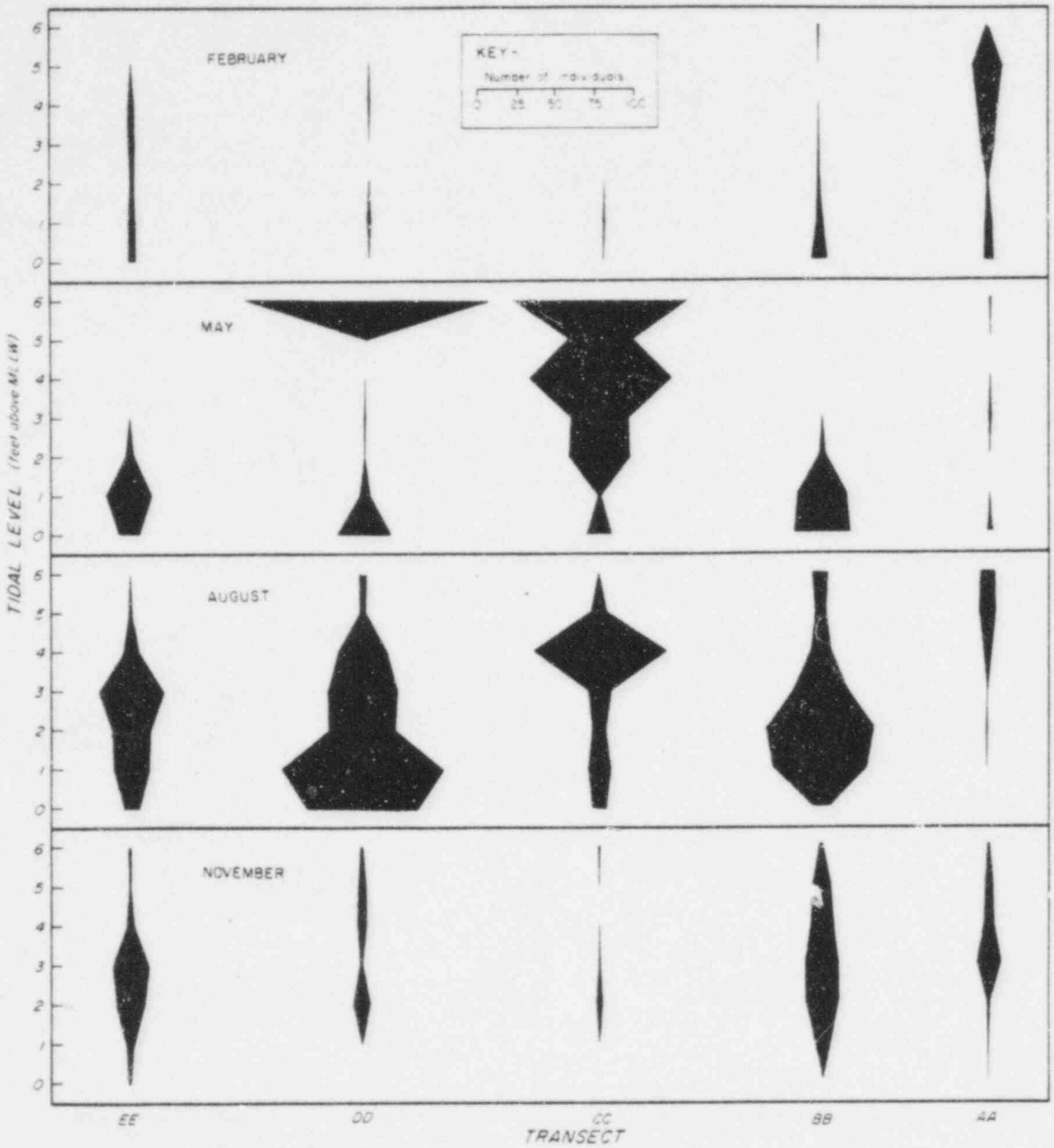

Figure 7A-5. Emerita density by tidal level, transect, and survey month.

than one type of food resource. Many spionid polychaetes (including Dispio uncinata and Microspio acuta, both occurring at SONGS) may, for instance, feed both by capture of particulates in the water column (suspension feeding), or by sifting through surface sediments for edible organic matter (deposit feeding). Similarly, Lepidopa californica feeds with equal ease on small living Emerita (carnivory) and on pieces of organic debris carried through the intertidal zone by tidal and current movements (omnivory).

Deposit feeding species were separated into two groups based on utilization of either surface or subsurface organic detritus as food. Surface deposit feeders generally sift through surface sediments and select organic particles. Subsurface deposit feeders are, however, much less selective and usually ingest the sediments, digest the organic constituents, and excrete the inorganic residue.

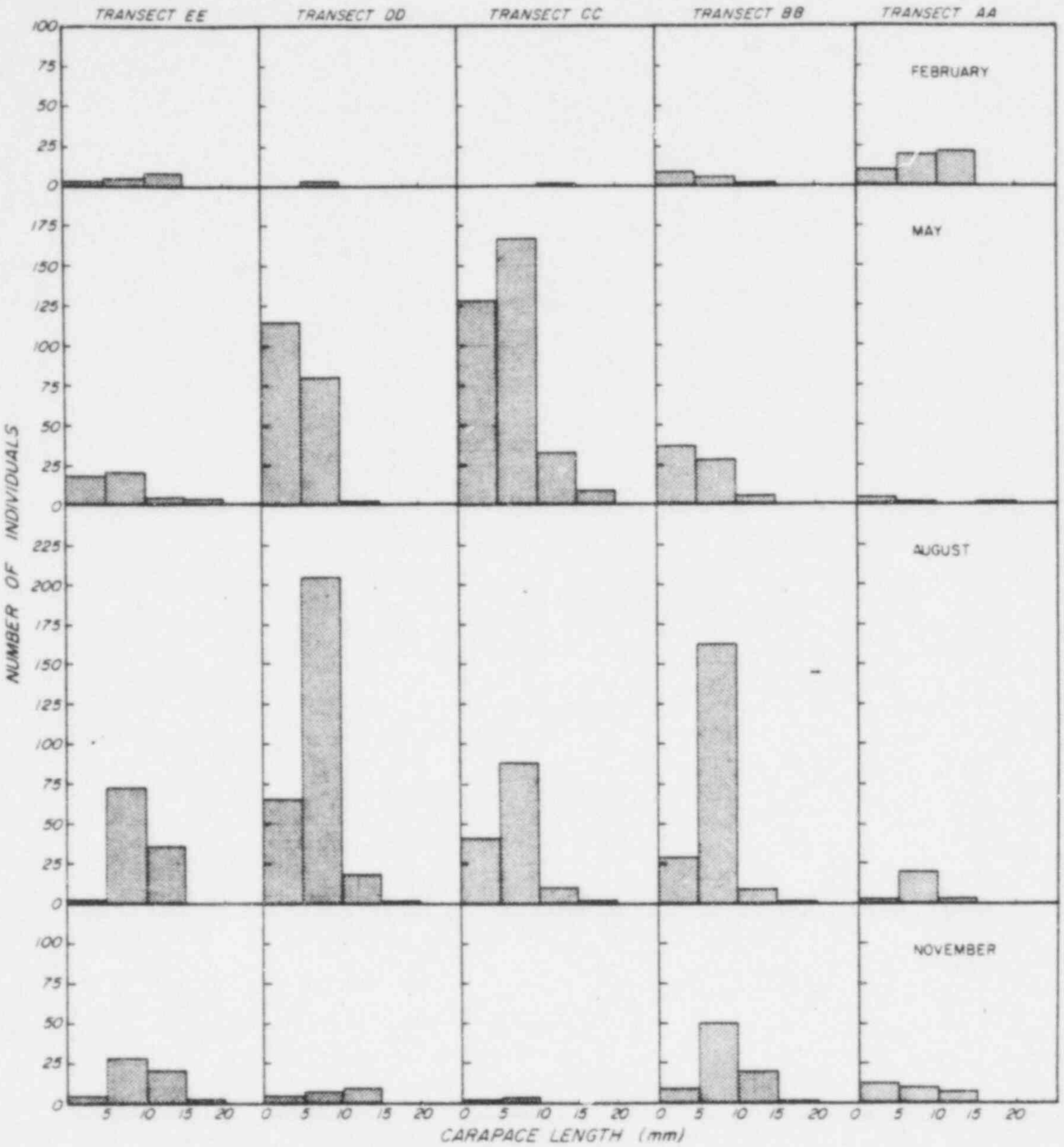

Figure 7A-6. Size-frequency distribution of Emerita by transect and survey month in 5 mm class increments.

Intertidal trophic structure was examined in terms of the percentage contribution of each trophic group to the community encountered along each transect. Percentage composition of species and numbers of individuals by trophic group were examined separately (Figure 7A-7).

All trophic groups were represented along all transects during at least some quarters. Only suspension feeders, however, were found along all transects during all quarters. Surface deposit feeders were the least consistent community members, appearing at only one transect (AA) during all four quarters, and in only one quarter at the remaining four transects. The greatest variability in species trophic composition occurred at Transect CC with no two quarters being similar in either number of trophic groups or relative group importance. Transects AA and BB were relatively stable, with absence of one or several trophic

groups noted during one or more quarters and constant minor adjustments in relative group importance. No trophic group clearly dominated the community, although surface deposit feeders were much less abundant than the other groups.

Suspension feeders averaged at least 55% of the individuals at each transect during the year. Their percentage contribution to the total catch was greatest along Transect BB (86%) and least along Transect DD (58%). Subsurface deposit feeders (represented primarily by Hemipodus borealis, the second most abundant species) were the second most abundant trophic group with average percentage contribution ranging from 2% (Transect BB) to 24% (Transect DD).

Table 7A-4. Trophic assignments of intertidal species.

Species Name	Trophic Group
Archaeomysis maculata	C
Dispio uncinata	SF/SDF
Donax gouldii	SF
Emerita analoga	SF
Eohaustorius washingtonianus	SF/SDF
Excirolana linguifrons	O
E. kincaidi	O
E. nr. kincaidi	O
Hemipodus borealis	SSDF
Insecta, unid.	unassigned
Isopoda, unid.	unassigned
Lepidopa californica	C/O
Microspio acuta	SF/SDF
Mysidacea, unid.	unassigned
Nemertea, unid.	C
Neomysis rayii	unassigned
Nephtys californiensis	C
N. ferruginea	C
Nephtys sp.	unassigned
Orchestoidea benedicti	O
O. columbiana	O
O. minor	O
O. pugettensis	O
Orchestoidea sp.	unassigned
Paraonella platybranchia	SSDF
Pisione remota	C
Saccocirrus papillocercus	C
Scoloplos armiger	SSDF
Synchelidium micropleon	SDF

C = Carnivore O = Omnivore SF = Suspension Feeder
SDF = Surface Deposit Feeder
SSDF = Subsurface Deposit Feeder

Annual average variation between transects was relatively small for suspension feeders, carnivores, and omnivores. Definite and opposing geographic distributional trends existed for surface and subsurface deposit feeders. Surface deposit feeders were uncommon at all transects downcoast of Transect AA, while subsurface deposit feeders comprised a markedly larger percentage of total individuals at Transects CC, DD, and EE downcoast of the construction trestles. This pattern was strongly developed in February, when the percentage contribution of subsurface deposit feeders averaged 61% at Transects CC, DD, and EE, and only 0.9% at Transects AA and BB (Figure 7A-7).

Site Classification

The five replicates at each level of each transect were considered a "site" in the quarter by quarter analysis (Figure 7A-8) providing 35 sites per quarter. In the combined analysis of the year's data, each site represents 35 replicates (5 at each of 7 intertidal levels) providing 20 transect/month sites (Figure 7A-9). Site and species groups defined by the classification were serially designated with numbers and letters, respectively. A letter denoting collection month (i.e. F for February) was added to groups in the quarterly dendrograms to provide a unique designation for each cluster.

Quarterly site classifications (Figure 7A-8) separated the sites into between 5 (August) and 9 groups (May). Group size and membership were extremely variable, which precluded tracing a single cluster between quarters. Little tendency was shown for sites to cluster either by transect, or by tidal zones or levels. Groups consisting of sites from a single beach zone (upper, middle, or lower beach, as defined in Table 7A-3) were more common than those containing only sites along a single transect. Groups 8M and 9M, which separated from other May sites at a high dissimilarity level, formed a large cluster containing 11 of the 14 sites along Transects C and D. This was the only grouping composed exclusively of sites from two transects. Clusters containing only vacant sites (5F, 4M, 8N) were also present in the dendrograms.

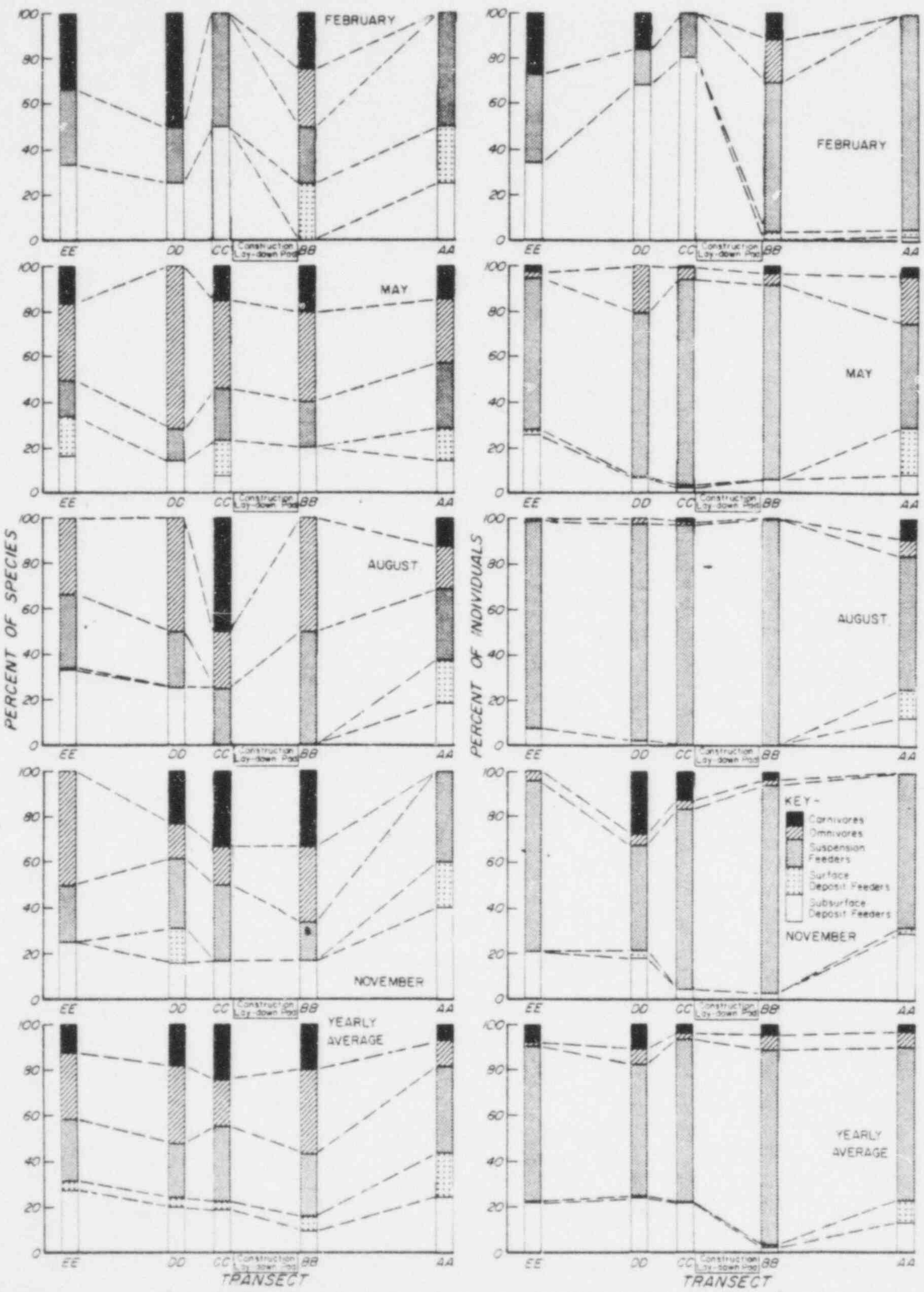

Figure 7A-7. Annual average and per survey trophic percent composition of species and individuals by transect.

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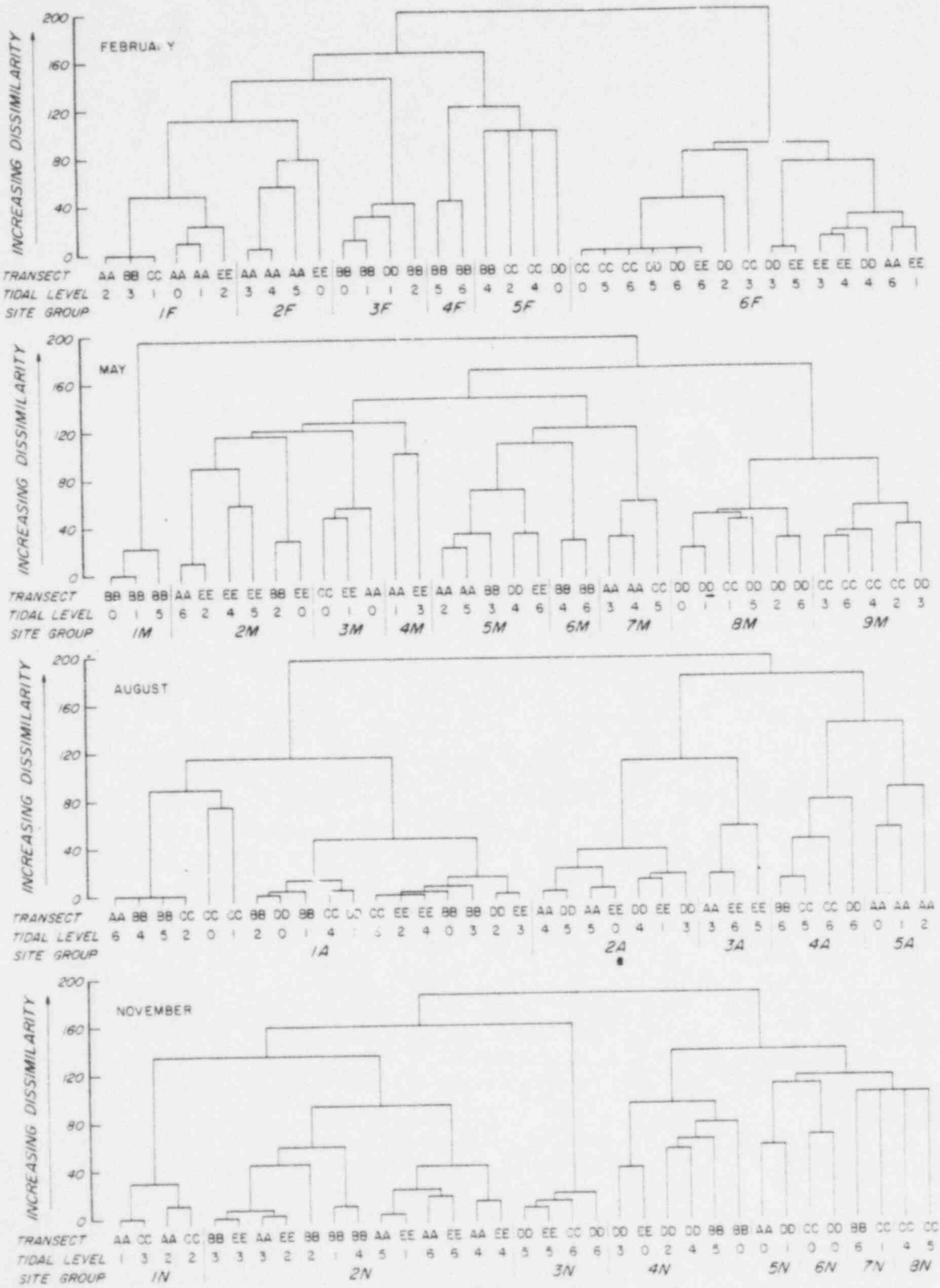

Figure 7A-8. Site classification by survey month.

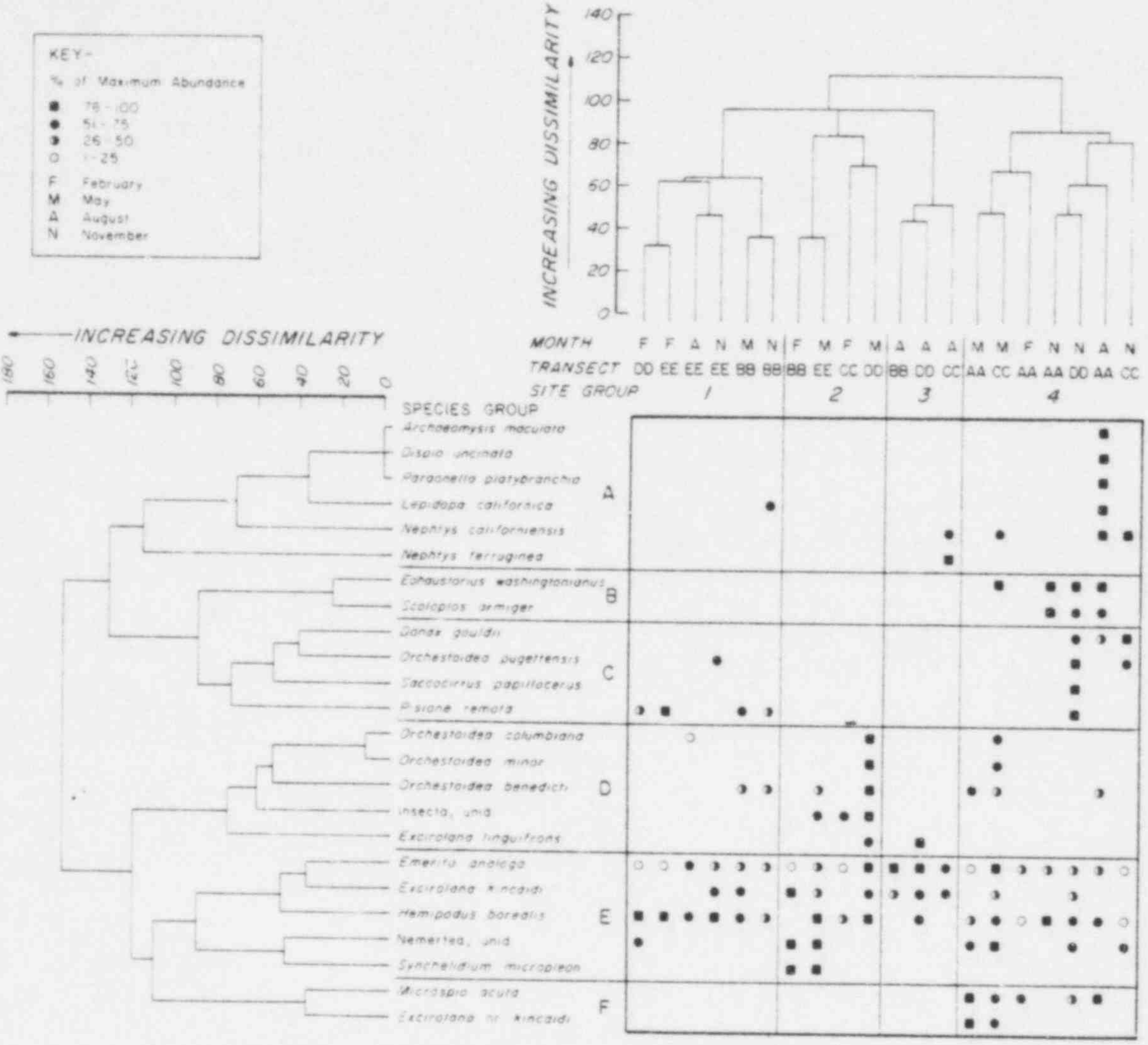

Figure 7A-9. Site and species classifications with resultant two-way table for the year.

The annual site dendrogram (Figure 7A-9) separated into four clusters. Some evidence of separation along both transect and month lines was evident, with group 4 (separated by the first dichotomy) containing Transect AA during each quarter, and group 3 containing Transects BB, CC, and DD in August. However, Transect AA was not the sole constituent of group 4, which also included Transects CC and DD from some quarters. Adjacent transects during the same quarter clustered infrequently, with group 3 being the best example. The first dichotomy separated Transect AA (group 4) from Transects BB and EE (groups 1, 2, and 3), with Transects CC and DD occurring in both main branches.

Species Classification

Records of all taxa were used in the species classification for the individual quarters (Figure 7A-10). Taxa such as *Orchestoidea* sp., Isopoda, unid., and *Nephtys* sp., were retained in the analyses to maximize the number available for classification. In the annual species classification (Figure 7A-9), where more species were available, five taxa (*Orchestoidea* sp., Mysidacea, unid., Isopoda, unid., *Nephtys* sp., and *Neomysis rayii*) representing single individual occurrences, were deleted prior to analysis. The first four probably represent repeat records of other taxa. The specimen of *Neomysis rayii*, a mysid shrimp not

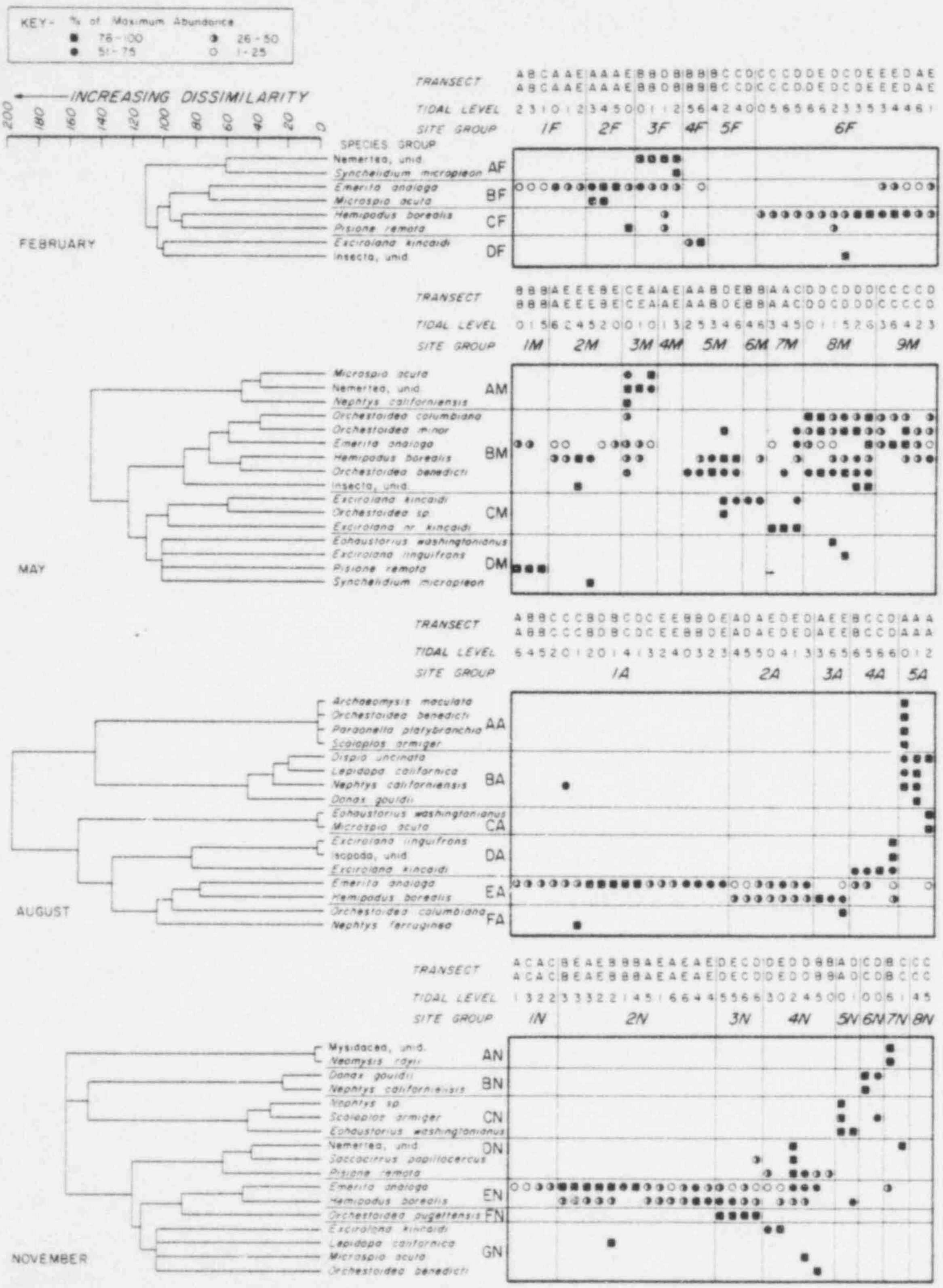

Figure 7A-10 Species classification and site group classification with resultant two-way tables by survey month.

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known to occur intertidally, was probably a fortuitous occurrence. Nemertea, unid. and Insecta, unid., although polyspecific taxa, were retained in the analysis since their individual members probably perform similar ecological roles.

In the quarterly species classifications, between four (February and May) and seven groups (November) were identified. As in the site classifications, species clusters varied between quarters in most cases. However, a cluster including Emerita analoga and Hemipodus borealis, the two most abundant and widely distributed intertidal species, was traceable throughout the year (BF, CF, BM, EA, EN). The dominant Emerita and subdominant Hemipodus formed the sole constituents of the cluster during August and November. Although classified in separable groups in February (BF and CF), the two species were still related at nearly the same dissimilarity level as in May and August. The cluster containing the two was most cohesive in November.

Less common species separated into clusters whose membership varied between quarters. Group memberships appeared to primarily reflect vertical zonation patterns (i.e. groups AF, DA, BN, CN, FN), although clusters with both transect and zone consistancy also occurred (AA, BA, CA). All consistent transect and zone groups characterized sites at Transect AA in August. At least two of the species clusters (DM and GN) were composed of species which occurred sporadically in low numbers, and were related to each other primarily by their lack of relation to other species.

Six clusters were formed in the annual species dendrogram (Figure 7A-9). Emerita and Hemipodus again clustered to form a dominant species group (E) which was represented in all site clusters. Group A consisted exclusively of uncommon lower zone species (characteristic of Transect AA in August). Group B consisted of two uncommon lower zone deposit feeders confined to site group 4. The four members of cluster C were more diverse, and included a density subdominant (Pisione remota) found in all three zones, a high intertidal omnivore (Orchestoidea pugettensis) found only in November, a low intertidal suspension feeder (Donax gouldii) found primarily in November, and Saccocirrus papillocercus (a carnivore occurring sporadically in most zones) also found primarily in November. Groups A, B, and C were separated at relatively high dissimilarity from Groups D, E, and F, which contained eight of the ten most abundant species. Many of these species occurred in all three beach zones, or in zone overlaps (Table 7A-3), but a few (i.e. Nemertea, unid., and Excirolana linguifrons) were of more discrete vertical distribution.

Two-way Tables

The two-way tables formed by the apposition of the site and species classifications show the patterns of occurrence and abundance of the species at the sites (Figure 7A-10). They represent the raw data matrix reorganized according to the normal and inverse classifications.

Most of the species occurrences in each quarter were clustered, although scattered records of the less common species occurred in all four quarters. Such scattered occurrences were least common in August, when Emerita dominance was most pronounced.

In February and November, one site cluster was defined by presence of Emerita only (1F and 1N). No other site groups were characterized by only a single species. Site clusters occupied by a single species group were uncommon, but at least one occurred in each quarter (1F, 9M, 2A, 1N, 6N). Most other site clusters included two species groups, some being differentiated only by differences in relative abundance or species occurrence i.e. 5M, 6M, 7M, each containing only species in clusters BM and CM.

A few instances of site group separation on the basis of suites of uncommon species occurred (3F, 3M, 5A, 5N, 7N), but no site or site cluster was consistently characterized by uncommon species throughout the year. Level 0 at Transect AA was differentiated by uncommon species in all surveys except February, and particularly strongly in August.

In the two-way table for the year (Figure 7A-9) none of the four site groups were defined by one species cluster, but group 4 contained representatives of all six species clusters, and maximum relative abundance and occurrence for four clusters (A, B, C, and F). Site group 3, containing Transects BB, CC, and DD in August, was defined by relative abundance of most cluster E species and a few species from groups A and D.

CORRELATION ANALYSIS

Correlations between abiotic and biotic variable distributions were tested to determine which abiotic factors were associated with the biotic differences (Table 7A-5). Biotic variables tested were 1) number of species, 2) number of individuals, 3) number of Emerita, 4) variable 2 minus variable 3, and 5) number of Hemipodus. Abiotic variables represented grain size (percent coarse sand, percent fine sand, and sorting coefficient), beach configuration (lower beach slope), and surf temperature. An additional test was performed on correlation between site stability (as measured by change in transect area between consecutive quarters) and faunal stability (as measured by change in each of the five biotic variables between successive quarters).

All biotic variables except Hemipodus abundance correlated significantly with several abiotic variables. Hemipodus abundance showed only a significant positive correlation with percent coarse sand. Both numbers of individuals and Emerita density were most significantly correlated with site stability. In both cases, the relationship was inverse which implies that as site changes between quarters became smaller, changes in community and Emerita density became greater. Based on the significance of their correlations, lower beach slope and surf temperature were also influential physical variables related to both community and Emerita density. Both were positively correlated with the two density variables.

Community density with Emerita excluded was also positively and significantly correlated with surf temperature. A less significant positive correlation with percent fine sand was also seen. Neither lower beach slope nor site stability were significantly correlated with community density once Emerita counts were omitted.

The number of species in the community was positively correlated with 1) percent fine sand, 2) surf temperature, and 3) lower beach slope (ranks based on the correlation significances).

Hemipodus was significantly correlated only with the percentage of coarse sand. This positive correlation suggests that Hemipodus was relatively independent of surface events, and its distribution primarily depended on availability of a preferred grain size.

Table 7A-5. Rank correlations of biotic and abiotic factors.

Biological Variables	Rank: Signed Physical Factor Correlations 1	2	3*
Number of Species	+B	+E	+D
Number of Individuals	-F	+D	+E
Number of Emerita analoga	-F	+D	+E
Number of Individuals other than Emerita	+E	+B	+D
Number of Hemipodus borealis	+A	-	-

Key to Physical Factors

A = % coarse sand B = % fine sand
C = sorting coefficient D = lower beach slope
E = surf temperature
F = change in transect area correlated with change in biological factors

* No more than three physical factors were significantly (@$P \leq 0.05$) correlated with any biological factor

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DISCUSSION

The sandy intertidal habitat, because of its physical rigor, is usually occupied by far fewer species than adjacent continuously submerged soft substrates of greater physical stability. This pattern was evident at SONGS, where the biota of the sandy intertidal (29 species, 20.7 individuals/m^2) was depauperate compared to that of the adjacent subtidal sediments (369 species, 3345.5/m^2). However, when compared with other high energy beach biota in the Southern California Bight (data from Straughan, 1977) the SONGS intertidal biota was relatively species rich.

The SONGS community exhibited seasonal cycles of species presence/absence, with only four species being numerically important year round. These species were considered characteristic of the SONGS intertidal community. *Emerita analoga* and *Hemipodus borealis*, which ranked first and second in abundance, respectively, for the year and in each quarter, were important in the SONGS intertidal community because of their consistent abundance. The presence of *Pisione remota* and *Excirolana kincaidi*, the two other species considered characteristic community members, among the February group of overwintering species indicated they are probably perennial constitutents of the community. Their lower ranks during some quarters reflected displacement by species whose population density was more strongly seasonal.

This suite of four species, which were numerous at SONGS throughout the year, differentiated the community at SONGS from others studied both north and south along the coast (Straughan, 1977). Both *Emerita* and *Hemipodus* are found at sites throughout the Southern California Bight, and their occurrence at SONGS was not unusual. *Pisione remota* and *Excirolana kincaidi*, however, did not occur at any of the 12 sites between Point Conception and San Diego examined by Straughan (1977). The SONGS intertidal community is thus separable in species composition from intertidal communities at other sites, but shares two major biotic characteristics: 1) depauperate fauna (compared to communities in less physically rigorous environments) and 2) numerical dominance by *Emerita analoga*.

PHYSICAL VARIABLES

As discussed in Chapter 5 and shown particularly Figure 5-4, the sandy beaches at SONGS are not static. Vertical profile changes of up to a foot were observed over a 24-hr period during surveys. Continual substrate movement creates a rigorous habitat for the biota of exposed sandy shores. All have either morphological, behavioral, or physiological adaptations which simplify the task of coping with a harsh physical environment. *Emerita*, for instance, has highly modified appendages for rapid digging (Weymouth and Richardson, 1912), and a behavioral response to changes in sand compaction which allow maintanence of position in the beach despite tidal fluctuations (Cubit, 1969).

Most abiotic variables of the sandy intertidal habitat including beach slope, beach width, and sediment grain size are reflections of wave climate. All sediment grain size and beach configuration measurements depend on the frequency and force of the waves, and the direction from which they approach. Only surf temperature is independent of wave climate.

Correlations Between Physical and Biological Factors

Because the sandy intertidal habitat is physically rigorous, the presence and abundance of its biota are assumed to be primarily physically controlled. It is thus of some interest to determine which physical factors exert the greatest

influence on which biotic distributions. A multivariate discriminant analysis similar to that applied to the subtidal infaunal (Chapter 8) would be the preferred analytic method. However, the collection of intertidal physical data at only four of the seven levels of biotic sampling rendered this approach inapplicable. The program was modified beginning with the February 1979 survey to allow collection of equivalent biotic and abiotic samples, and the resulting data will be analyzed with multivariate methods in subsequent reports. The less sensitive and less interpretable correlation method is used here to indicate which factors are probably of significance in determining biotic distributions.

The analysis indicated that no single abiotic factor was correlated with the majority of the biotic differences observed between sites. The biotic variables formed three groups based on the nature of their abiotic correlations. This separation suggests that variables in a group responded similarily to their environment and that each group represents a different type of response to abiotic variation. The groups formed were: 1) the deep-burrowing subsurface deposit feeder Hemipodus; 2) the mobile and highly seasonal community dominant Emerita (and community density, which was strongly dependent on Emerita numbers); and 3) the remainder of the community (number of species, and number of individuals other than Emerita).

The highly significant negative correlations between the stability of Emerita and community density and substrate stability probably resulted from the seasonal nature of Emerita recruitment: as the substrate became more stable in the spring following major winter profile changes, Emerita density became less stable with the beginning of its major recruitment. The correlation makes biological sense as recruitment during periods of increased substrate stability would intuitively seem likely to increase recruitment success. However, the seasonal regularity of the intertidal sediment accretion/erosion cycle strongly suggests that other seasonally co-varying factors were also involved.

EFFECTS OF WINTER QUARTER STORMS IN 1978

Transect AA was the transect closest to terrestrial organic and sedimentary inputs from San Onofre Creek, and from a storm drain situated near the landward terminus of the transect line.

Evidence of impact of heavy spring rains was not detected in major changes at Transect AA. Density in February was highest along Transect AA, and the number of species present along Transect AA was similar to all other transects. The possibility that such input may have subtly or indirectly influenced the community along Transect AA cannot be completely discounted however. Transect profile data, for instance, showed differences in the quarterly pattern of beach accretion and erosion along Transect AA, between 1977 (MBC, 1978) and 1978 (Figure 5-4). Data from a site monitored within approximately 50 m of Transect AA over a number of years (Shepard, 1950) show, however, that this site has displayed an inverted sand movement cycle of accretion in winter and erosion in summer for many years. Thus profiles in 1978 were fairly typical of the area and did not reflect appreciable modification of the cycle of sediment movement by terrestrial runoff or storm associated wave activity.

No evidence of storm runoff affecting intertidal sediment composition of Transect AA was visible in the February grain size analysis. Silt-clay fractions were absent along Transect AA, even on the long flat beach face at MLLW. Very fine sand concentrations were elevated at this tidal level in February, but the percentage of this size class was even higher along Transects BB and CC, far removed from terrestrial input sites (MBC, 1979). It is clear that any materials of the smaller size classes added by runoff either resided on the beach for a very short period and were removed prior to our sampling or were merely

transported across the intertidal zone. The latter is the more plausible explanation since storm conditions (Table 9-10) and the heavy rains and runoff associated with them, coincided with February intertidal sampling.

Lacking evidence of storm effects on either physical or biological parameters along Transect AA we must conclude that the winter quarter storms and heavy rainfall did not affect the intertidal macrobiota.

STABILITY OF THE SANDY BEACH AND ITS COMMUNITY

Physical changes in the sandy beaches at SONGS resulted from: 1) an annual pattern of natural seasonal variability, 2) the presence of the construction trestles, and 3) beach dispersal of dredge spoils. The sequence and magnitude of these changes differed at each site in 1978. The annual pattern of change in the beach was most similar at Transects AA and EE where gradual sand accretion occurred between December 1977 and August 1978. Between August and November 1978 the two sites developed differently, with slight net erosion at Transect AA and continued minor accretion at Transect EE. Changes in beach profile along Transects BB, CC, and DD between surveys were usually much more pronounced than those at Transects AA and EE (Figure 5-5). Transects in proximity to the construction laydown pad (BB, CC, and DD) were thus less physically stable than their upcoast and downcoast counterparts.

The much greater width of the beach at Transect BB, just upcoast of the laydown pad and construction trestles, reflected both 1) partial interruption of the predominantly downcoast longshore sand transport mechanism by the construction laydown pad, and 2) modification of the wave climate by reflection of south swells off the construction trestle (MBC, 1978). Both effects favored net accumulation of sand upcoast of the trestle along Transect BB. Such upcoast accretion around projecting obstacles which interrupt sand transport is typical of the Southern California Bight, and is invariably associated with net erosion on the downcoast side of the obstruction (Bascom, 1964). The net sand accretion along Transect CC between February and November reflected addition of sand through beach disposal of dredge spoils and translocation of beach sand during construction at a greater rate than natural downcoast sand transport removed it. Biological effects of net accretion along Transect BB and the overload of beach sand disposal along Transect CC were not pronounced. Physical instability at Transect CC may, however, have contributed to the large variations in trophic structure along the transect.

Although substrate stability along Transect AA may have been responsible for the relative trophic complexity of the biota there, no linear relationship between substrate stability and trophic complexity was demonstrable. For instance, the biota of Transect EE, which was as physically stable as Transect AA, was less trophically complex in August. Transects AA and EE did not, however, consistently group in either the quarterly or annual site classifications. Despite the similarity of their accretion-erosion cycle, and the relative stability of the two transects, the structure of their lower levels were considerably different. Beach slope at levels 0 and +1 at Transect EE did not differ markedly from higher tidal levels during any survey, while Transect AA exhibited a broad, flat, low tide terrace during each survey. This terrace was inhabited by a group of predominantly subtidal species, particularly during August. This group can be loosely traced from May through November (AM3M, AA/5A, BA/5A, and CN5N) despite changing memberships.

Beach sand disposal along Transect CC did not appear to adversely affect either the density or diversity of the intertidal community. Transect CC density values averaged higher than those at Transect AA, whether *Emerita* were included or excluded. Species diversity as numbers of species/transect averaged somewhat,

but not significantly, higher along Transect AA than at any other. Although initial Emerita recruitments were higher and subsequent survivorship lower along Transects CC and DD than along other transects, the ability of Emerita to move on the beach (Efford, 1965) makes it unlikely that substrate instability adversely affected the species.The addition of the stress caused by construction generated beach instability to the natural physical stress inherent in this high energy environment may, however, have contributed to increased mortality of Emerita despite its adaptations. The presence of over-wintering Emerita primarily along Transects AA and EE suggested this interpretation.

Effects on the intertidal biota of sand accumulation and the physical dissimilarity of Transect BB caused by interruption of the longshore transport system by the laydown pad and trestles were not apparent. Transect BB was never completely isolated from other sites in the classificaton by quarter, although several site groups (4F, 1M, 6M) contained mainly or exclusively sites along Transect BB. No such separation occurred in the annual classification, where Transect BB sites were allocated to three of the four site groups.

A consistent pattern of apparent community enrichment within 500 m (Transects CC and DD) downcoast of the construction trestle was seen in abundnce data (both with and without Emerita inclusion) throughout the year. Numbers of individuals were particularly large along Transect DD. The number of species was, however, increased only in May. It is likely that this increased abundance along Transects CC and DD was a result of natural population fluctuations. Because dredge spoil disposal has continued intermittently adjacent to Transect CC since May 1977, its effects should have been similar in all surveys during the period. No significant difference between numbers of individuals collected along Transects AA and EE and Transects CC and DD were noted in the 1977 data (MBC, 1978). We therefore interpret the increased density along Transects CC and DD as the result of successful recruitments of several species (particularly Orchestoidea spp.(and Hemipodus)at those sites. It is possible that particulate detrital material included in the water carrying the dredge spoils contributed to this recruitment success, but since neither Hemipodus nor the Orchestoidea species are suspension or surface deposit feeders, this is unlikely.

Despite a general lack of biotic data which paralleled substrate stability patterns, the study area was divisible into two semi-distinct areas on the basis of the biota. The division separated the transects into groups upcoast (AA and BB) and downcoast (CC, DD, and EE) of the trestle. The primary evidence on which this separation was density data (Emerita excluded) and trophic composition. Quarterly site classfications, however, support this division only in February.

The major changes in both abiotic and biotic variables between quarters reflect the dynamic nature of the sandy beach habitat at SONGS. The physical changes resulting from Units 2 and 3 construction activities are similar in kind and probably of lesser magnitude than the normal seasonal variations in this high energy environment. The responses of the biota to these physical changes are the same as those they exhibit in reaction to naturally occurring seasonal beach modifications. In consequence any biotic accommodations to the artificial physical changes resulting from SONGS construction activities are likely to be both minor, and easily reversible. The difficulty in detecting biotic effects of construction is a direct result of the similarity between the natural and construction-induced changes.

SUMMARY

The results of intertidal sand monitoring in 1978 may be summarized as follows:

1. All analyses showed that each site differed physically and biologically from each other site, despite basic similarities.

2. Changes in the beach profile at sites adjacent to the construction laydown pad and trestles were evident. These changes were probably a direct result of construction activities and the temporary structures associated with them.

3. It is not clear that physical changes resulted in corresponding modifications of the intertidal biota.

4. Species enrichment of the biota within 500 m downcoast of the trestle was evident, but did not appear related to construction activities.

5. Emerita recruitment was highest adjacent to the construction trestle, however reduction in substrate stability at those sites appeared to reduce Emerita post-recruitment survival.

6. Classification analysis showed the underlying similarity of the biota along all five occupied transects, and also pointed out a basic division of the study area into sites upcoast and downcoast of the construction trestles during February.

7. No evidence was found in the annual classification for the existence of a discretely different faunal assemblage at any one transect, in any part of the study area, or during individual quarters.

8. Heavy winter quarter storms had no apparent effect on the intertidal biota.

9. Comparisons with other exposed sandy beaches in the Southern California Bight indicated that the biota at SONGS, while basically similar, differed from that of other areas by the presene of Pisione remota and Excirolana kincaidi as characteristic community members.

10. The observed physical modifications associated with SONGS construction had no apparent effect on the intertidal biota.

11. Operation of SONGS Unit 1 had no apparent impact on the sandy intertidal biota.

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CHAPTER 7B

INTERTIDAL COBBLE

INTRODUCTION

This program has been established to maintain a surveillance of intertidal cobble areas which could be utilized to detect major changes in the biological community structure of the rocky cobble intertidal areas near the San Onofre Nuclear Generating Station (SONGS) and to determine if these changes may be related to (1) the operation of SONGS Unit 1 and/or the construction of Units 2 and 3, (2) variability due to natural processes (e.g., sand transport, storms, etc.), and (3) unnatural processes (e.g., human intervention).

This chapter presents a brief characterization of the SONGS intertidal cobble environment followed by a historical summary of studies conducted in the SONGS cobble areas. Data collection and analysis methodologies are described, and results and analysis of both 1977 and 1978 are presented. Data for both years is presented, compared to previous study results, and discussed in relation to possible SONGS effects. The 1977 data was included because the sampling design was the same as the 1978 design, and the 1977 data has not previously been discussed.

Raw data for the initial two surveys conducted under this program (13 October, 9 December 1977) is included in Appendix E. Raw data for 1978 was presented in the Annual Operating Report, San Onofre Nuclear Generating Station, Volume II, Biological Data-1978 (LCMR, 1979a). Raw data for the final two comprehensive ETS intertidal cobble surveys (15 February, 3 June 1977) is contained in the 1977 ETS Annual Operating Report, Volume II (LCMR, 1978a). The purpose of the present report is to analyze the 1977 and 1978 data bases and place the results in perspective with regard to historical studies of the area.

APPROACH

The sampling design is based on qualitative collection of data in the area near the SONGS discharge and a reference area outside the influence of SONGS selected to be representative of natural conditions. Consequently, the analysis of the data is directed at determining temporal trends, and similarities and differences between study and reference stations. Types of data considered are field observation notes, photographic records, and estimates of the two most abundant taxa at each station.

BACKGROUND

In order to place the study objectives and results into perspective, a brief description of the intertidal environment at SONGS is presented along with a historical review summarizing past and ongoing intertidal studies.

The cobble habitat upcoast and downcoast of SONGS consists of areas of sand, gravel, cobble, and a few scattered boulders. The intertidal cobble is limited to relatively small areas interspersed among the larger areas of sand beaches. In these areas, cobble occupies the lower ecological zones (3 and 4) and is not normally conspicuous from the beach. Exposure of the cobble occurs only during low

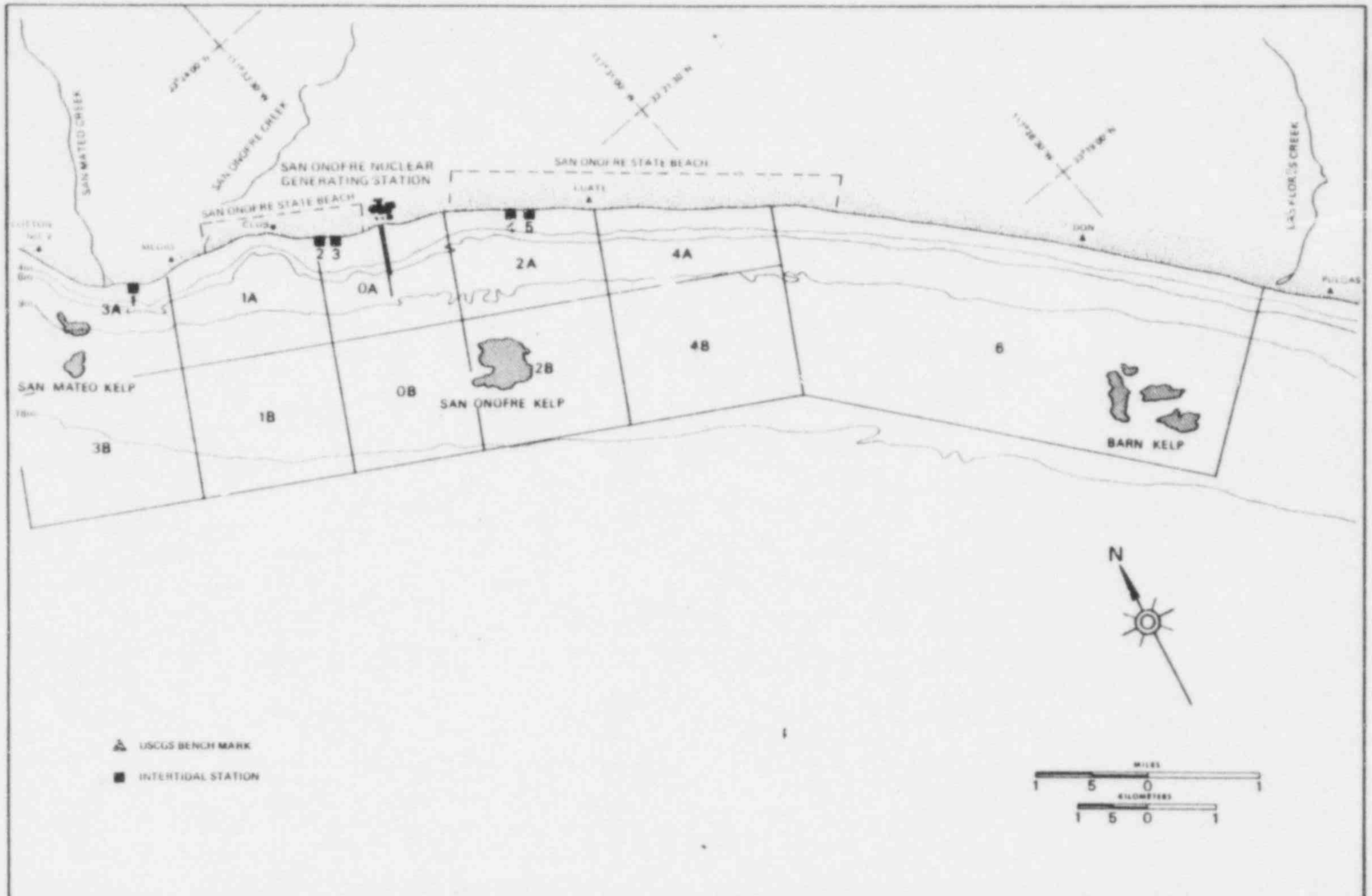

Figure 7B-1. ETS intertidal ... n locations at San Onofre Nuclear Generating Station.

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not sampled in February 1978 due to inaccessibility resulting from intense stor activity and nearby stream flooding. Lack of suitable tide conditions preventeu surveys during the second and third quarters of 1978.

The following taxa were the most abundant in fixed quadrats, based on percent coverage during 1977: Parvosilvosa (algal turf), Zonaria farlowii, erect coralline algae (e.g., Corallina/Haliptylon, Lithothrix spp., Jania spp.), and Phyllospadix spp. In 1978, Enteromorpha spp., Parvosilvosa, and the Corall na/Haliptylon algal complex were the most abundant taxa.

INTERTIDAL COBBLE STATION 2

During the 1977 surveys, four shallow excavations, probably the result of clamming, were noted in the vicinity of the fixed quadrats. All three fixed quadrats had been excavated prior to the February 1978 survey. This exposed 1/4 to 1/3 of the quadrat markers. Clammers were noted in the area. Shallow excavations were noted near all the quadrats during the November 1978 survey. During the February and December 1977 surveys, two quadrats were 95 to 100% covered with sand. Data from the remainder of the surveys in 1977 and 1978 showed that quadrats were covered by 1 to 0% sand.

Corallina/Haliptylon, Zonaria farlowii, Parvosilvosa, and Sargassum spp. were generally the most abundant algae in the quadrat areas in 1977 and 1978. Dictyota/Pachydictyon algae were abundant in the 1977 and 1978 June surveys. Ulva spp. was abundant only during the November 1978 survey.

INTERTIDAL COBBLE STATION 3

Clammers were observed in the area during all four 1977 surveys and in two of the three 1978 surveys. The amount of sand covering the quadrats was 53 to 70% during the December 1977 survey and 100% during the November 1978 survey. During all other 1977 and 1978 surveys, sand coverage in the quadrats varied from 2 to 50%.

Zonaria farlowii was one of the two most abundant species in all quadrats during all surveys wh... obble substratum was exposed, except at one quadrat during one survey. The algae Sargassum spp., Corallina/Haliptylon, Dictyota/Pachydictyon, Parvosilvosa, and Endocladia spp. were also abundant at various times.

INTERTIDAL COBBLE STATION 4

No clammers were noted during the 1977 and 1978 surveys. However, overturned boulders and cobble exposing bedrock were evident in fixed quadrat 3, indicating that some clamming activity had occurred. During the February, June, and December 1977 surveys, sand cover in the quadrats varied from 15 to 60%. The sand/cobble beach interface was seaward of the fixed quadrats during the October 1977 survey, which precluded sampling as all quadrats were covered with sand. All three 1978 surveys had sand cover in the quadrats which varied from approximately 5 to 30%.

The algae Zonaria farlowii, Parvosilvosa, Corallina/Haliptylon, and Dictyota/Pachydictyon were usually among the abundant taxa. Laurencia spp. was recorded among the two most abundant taxa in one fixed quadrat during the November 1978 survey.

INTERTIDAL COBBLE STATION 5

No clammers or persons other than survey personnel were noted in the cobble area during the 1977 and 1978 surveys. Fixed quadrat 2 (Q-2) contained freshly disturbed cobble in February 1977 and shallow excavations were noted in the cobble area near Q-2 in November 1978, indicating that clam digging activities had occurred. The sand/cobble interface had advanced seaward of Q-1 in October 1977, covering the quadrat with sand. This interface was about even with Q-1 in February 1978 and about 3 m inshore of the fixed quadrat line during the November 1978 survey. On June 23, 1978 it was noted that the tidepool shoreward of the cobble bed was filled in with sand. This indicates that the sand/cobble interface was quite variable in location throughout the year at this station.

Erect coralline algae, generally the Corallina/Haliptylon algal complex, were usually the most abundant areal coverage organisms, ranging ' a maximum abundance of 80% cover. Occasionally Parvosilvosa was the most abundant organism, with coverage ranging to a maximum of 46%. Phyllospadix spp. was noted among the two most abundant organisms in the December 1977 and the June and November 1978 surveys. Mytilus spp. was noted in November 1978 as the second most abundant organism in one fixed quadrat.

DISCUSSION

The biotic changes observed between sampling periods at intertidal stations did not appear to follow recognizable seasonal trends. Variations in rank order of abundance of species within a station over the 1977 and 1978 period can be attributed to normal seasonal variations in abundance. Generally, a total of six taxa accounted for the two most abundant taxa for all stations during each survey, out of the maximum possible diversity of 30 taxa for all stations. The between station diversity within a survey increased appreciably during the November 1978 survey when the total of the two dominant taxa in each of three quadrats at the five stations consisted of 10 taxa. The variability that was present may be attributable to a variety of factors including natural seasonal differences in abundance of populations due to recruitment, long-term fluctuation in populations, and mortality. Comparison of 1977 and 1978 data with historical intertidal data from the SONGS area indicated that the most abundant taxa in areal coverage were those that were reported as common in the nearby geographical area and had been previously noted in studies of the station areas (LCMR, 1975).

Photographs of each quadrat for all surveys from February 1975 until November 1973 and other station data indicate that percent sand increased during winter and decreased during summer at all stations except Station 1. This indicates that new areas of cobble surface were exposed to settlement of intertidal organisms during the summer at all but Station 1. The November 1978 survey photographs show the presence of a large amount of small, bare cobble at all stations except Station 3 which was completely sanded over. The previously mentioned high diversity between stations indicates the possibility of mortality or disruption of previous populations due to the instability of the substratum. Similar results have been found in other studies (Osman, 1977) which indicated that intermediate sized rocks (1 to 10 dm^3) remain stable long enough to establish a community, but not long enough to allow a few taxa to establish dominance. Storm wave induced cobble movement (noted even in 10 m of water by diving biologists), fresh water runoff, beach slope, erosion, sedimentation, heterogeneity of

cobble size, temperature effects on biota, human intervention, and other factors may have been components in the intertidal habitat instability. For example, San Mateo and San Onofre creeks, in the area adjacent to Station 1, were flooded during the February 1978 survey. Also, human intervention and sand inundation were documented at the intertidal stations.

The observed variations in sand coverage were probably naturally occurring seasonal fluctuations in sand deposition, but not all variations were indicative of the expected winter-summer beach sand transport in response to seasonal changes in wave length and height (Shepard, 1963; Speidel, 1975). Generally, summer months were periods of increased high intertidal sand coverage, leaving cobble habitats relatively free of sand at all stations except Station 1 (Figure 7B-2). Winter months showed general seaward movement of the sand/cobble interface with increased levels of sand in the quadrat areas at these stations. The limited Station 1 observations indicated a summer-winter reversal of the expected sand cover, which was higher in the summer period and lower in winter months. At no time during the 1977 and 1978 surveys did the Station 1 quadrat area appear to be sanded over completely, but the eleven-month period with no surveys reduced the data base for the reference area. This data loss, due to adverse weather and tidal conditions, precludes comparisons of physical and biological factors with other stations for those periods. An additional factor, which is considerably less probable because of the distance from SONGS, deals with the transport of residual sand from SONGS Units 2 and 3 construction activities.

Sand accretion on intertidal cobble for periods of varying durations has been frequently noted in reports on the SONGS area from 1963 until the present. Such processes act to define or limit the biological populations (McKnight, 1969; Connell, 1972). Populations of biota resistant to factors such as sand accretion and shifts in the substratum, whether natural or by human intervention, such as Zonaria farlowii (Dahl, 1971) and erect and crustose coralline algae, are usually the most abundant in the study areas. Increasing accretion of sand in areas is followed by decreasing abundance of macrobiota (MBC, 1978). This

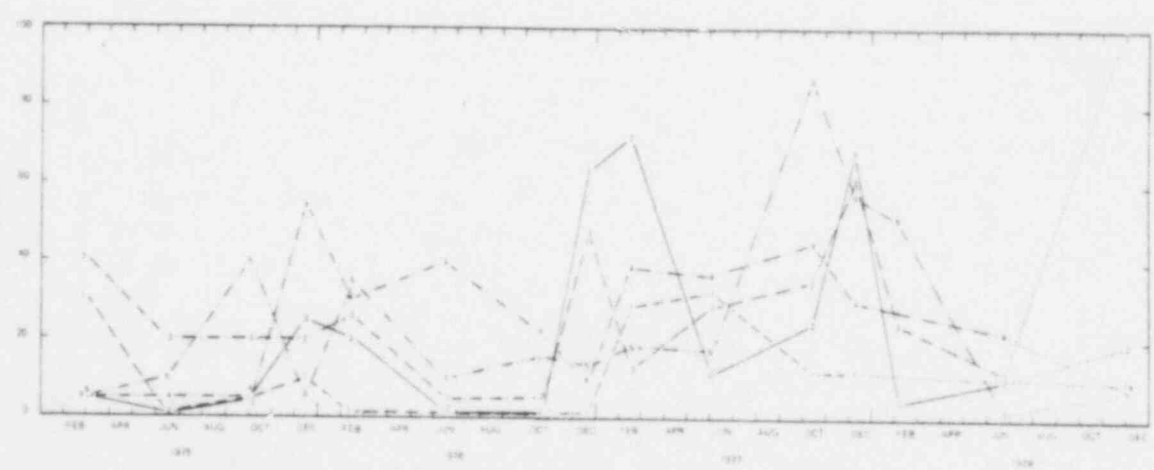

Figure 7B-2. Mean percent sand present in three fixed $0.25\text{-}m^2$ quadrats at ETS intertidal cobble stations in ecological Zone 4 from February 1975 to November 1978. Data from February 1975 to June 1976 obtained from photographs. All other data are field estimates. Intermittent data are indicated by the dotted line (....). Numbers on lines indicate station numbers.

phenomenon was obvious in this study as reflected by the reduced percentages of visible dominant biota in the quadrats where sand cover was noted.

Clamming or digging activity, as noted in previous reports (Parr, 1973; LCMR, 1977b) continued in all five cobble station areas under study, with the greatest activity observed in the more accessible cobble areas near Stations 2 and 3. Human intervention at Station 1 was present, but not directly in the quadrats. Station 2 quadrat biota was totally disturbed by digging activity prior to the February 1978 survey; however, by November 1978 the areal coverage of quadrat biota was again similar to biota from surrounding areas. Biota recorded in Quadrat 3 at Station 4 indicated continued disturbance after the initial excavation to bedrock in late 1976, with little refilling of the excavation with cobble substratum noted until November 1978 (see the data summary footnotes in Appendix E).

Although the Station 1 area was selected partially because it was outside the predicted area of influence of the thermal plume, it was apparently within the +1°F isotherm from the SONGS Unit 1 discharge on 2 May, 4 May, 6 July, and 3 November, 1977 (BC, 1978). However, there were no major changes in biota noted after these periods. Data in the Annual Operating Report, San Onofre Nuclear Generating Station, Volume I, Oceanographic Data-1978 (BC, 1979) did not indicate the Station 1 area to be within the influence of Unit 1 thermal plume during the 1978 surveys. There is no evidence that biotic changes at Station 1 were due to Unit 1 operations. During the 1977 and 1978 period, Stations 2 and 3 were frequently within the +1°F isotherm, as were Stations 4 and 5. Biotic changes that occurred at these stations were similar to the changes at Station 1, indicating that they were probably not influenced by the generating station.

A more detailed comparison of data gathered from the intertidal cobble quadrats with historical information collected before the ETS program is not warranted due to differences in station locations, sampling efforts, and the mixed quantitative and qualitative nature of historical studies. The results from more extensive ETS intertidal cobble studies conducted from 1975 to mid-1977 did not indicate the need to continue a more extensive intertidal cobble monitoring plan because factors such as the effect of human intervention, sand accretion, and other natural environmental variables, which affect the dynamic intertidal cobble communities in the SONGS area, were impossible to separate from the potential effects of San Onofre Unit 1. Based on the collected and referenced data, there is no evidence that the operation of SONGS Unit 1 influenced the intertidal cobble biota significantly, which is in agreement with previous findings.

SUMMARY

Intertidal surveys to sample macroorganisms on cobble substrata were conducted quarterly, weather conditions and tide levels permitting, during 1977 and 1978. Surveys were conducted in February, June, and November 1978 at five stations. No acceptable low tides (lower than -0.6 ft MLLW) occurred during the third quarter of 1978; therefore, sampling was not conducted. The intertidal data analyzed include the results of the 1977 surveys which had not previously been reported. The 1977 intertidal surveys occurred in February, June, October, and December. The intertidal sampling design was developed to monitor the intertidal area for major changes in biota and substrata attributable to the operation of SONGS Unit 1. The sampling consisted of identification and estimation of the abundance of the two most abundant organisms and the amount of

sand cover within three 0.25-m^2 permanently located quadrats at each of five stations. Four of the stations were within the predicted extent of the 1°F thermal plume. A qualitative analysis of the 1977 and 1978 data, and a comparison with previous intertidal studies in the area indicated the following.

1. Comparison of data collected at all cobble stations in 1977 and 1978 surveys with historical data indicated that the most abundant taxa in areal coverage were those that have previously been reported as common in the geographical area and noted in past studies of the station areas.

2. The observed variability in biota may be attributable to a variety of factors including natural seasonal differences in abundances of populations due to recruitment, mortality, and long-term fluctuations in populations.

3. Sand inundation and human intervention, resulting from recreational activities such as intertidal walking, clamming, and surfing, at all stations remained the only directly observable community altering factors in the intertidal cobble quadrats.

4. A review of photographs and other station data indicated that new areas of cobble surface were exposed to settlement of organisms, especially during winter months at Station 1 and during summer months at the remaining stations. Wave induced cobble movement, beach slope, fresh water runoff, sedimentation, erosion, size heterogeneity of cobble habitat components, and other factors probably contributed to this change in substratum exposure.

5. The Station 1 intertidal cobble area was probably within the +1°F influence of SONGS Unit 1 discharge during 2 May, 4 May, 6 July, and 3 November 1977. No noticeable biotic changes were noted. During 1978, Station 1 was not reported within the +1°F isotherm. The most pronounced biotic change that occurred at this station was apparently related to substratum instability and not to SONGS Unit 1 operation.

6. Stations 2 and 3 were within the +1°F isotherm more frequently than the other stations. Variation in biological factors due to generating station operation was not discernible. The most visible biotic changes that occurred were caused by sand inundation, apparently due to natural winter-summer beach processes and possibly to winter storms.

7. Based on data collected, there was no evidence that the operation of SONGS Unit 1 or construction of SONGS Units 2 and 3 caused major changes in the intertidal cobble biota. This is in agreement with previous findings.

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CHAPTER 8

BENTHIC INFAUNAL

INTRODUCTION

The San Onofre sublittoral area is composed of both rocky and sandy benthic habitats. The sandy soft bottom environment is an extensive habitat and supports an extremely diverse community (MBC, 1978; Diener and Parr, 1977). The community is composed primarily of invertebrate species from the Mollusca, Annelida, and Arthropoda. These species exhibit not only individual and population characteristics, but also play a definite functional role in the trophic structure and flow of energy through the marine ecosystem. The soft bottom benthos live in or on the bottom sediments and are intimately dependent on the specific physical-chemical nature of this environment for food and habitat (Rhoads, 1974). Several authors have reported selectivity on the part of benthic organisms as to the grain size of sediments they live in or consume (Gray, 1974; Johnson, 1971; Lie and Kisker, 1970). McCave (1974) suggests that sediment grain size is the most important factor, however sediment porosity, permeability, and oxygen content (all related to grain size) may also be influential in controlling community composition. Bottom stability, which is influenced by the nature of the sediments as well as biological and physical environmental factors has also been cited as a key factor controlling benthic communities (Oliver and Slattery, 1973; Rhoads and Young, 1970).

The construction of Units 2 and 3 and the emplacement of intake and diffuser lines offshore represent potential sources of impact on the benthic infaunal community. Dredging and resulting sediment suspension related to conduit installation impact the benthic habitat to some degree. The primary goal of the Construction Monitoring Program is to define the extent and severity of any impacts on the benthic infaunal community. Because Unit 1 is operating adjacent to construction activities, impacts related to jetting, resuspension and modification of sediments (following heat treatment and expulsion of debris) as well as entrainment of meroplankton by Unit 1 are also considered here. In addition, the program establishes baseline pre-operational community data to serve as a basis for comparison with data gathered once Units 2 and 3 become operational.

Previous Studies

Monitoring of the marine environment in the vicinity of SONGS dates back to the fall of 1963 before Unit 1 became operational. Bendix Marine Advisers, Inc., conducted the initial surveys and in 1971 their efforts continued under the name Intersea Research Corporation. In 1972 surveillance temporarily ceased and was begun again under the Unit 1 Environmental Technical Specifications (ETS) monitoring program. Subtidal soft bottom communities were examined initially by Lockheed Center for Marine Research in their ETS studies of 1974, but later became one aspect of the Sand Disposal Monitoring Program related to construction of Units 2 and 3 (LCMR, 1975a,b, 1976). Soft bottom community study was continued with revised methods by Marine Biological Consultants, Inc., in 1976. The first report was released in 1978 (MBC, 1978).

MATERIAL AND METHODS

Data were collected quarterly during March, June, September, and November 1978. Biological collections were made at stations located on the 6, 9, and 15 m isobaths of six offshore transects. Two of the six transects were established as references, one upcoast and one downcoast of the construction area. The remaining four treatment transects flank the axis along which dredging and conduit emplacement proceed (Figure 8-1). Selection of the transect positions, both treatment (B, C, D, E) and reference (A and F) was based on the premise that all stations within 500 m (transects B, C, D, E) of an imaginary line halfway between the Units 2 and 3 conduit lines would be subject to perturbation during some portion of the construction period. The upcoast (A) and downcoast (F) reference transects were well outside this area of potential construction influence being 4 and 5 times this distance (500 m) away. Comparisons between reference and treatment areas aid in determining any construction related impacts.

BIOLOGICAL SAMPLING

At each station replicate 1ℓ sediment samples were removed by biologist-divers. Samples were collected at a distance of 3 m from the permanent monument using a hand-operated 10 cm by 10 cm by 10 cm box core (Figure 8-2). The sampling site was rotated 90 degrees with respect to the monument during each survey to preclude any effects of previous sampling, and the divers exercised special care to minimize disturbance of sediments in the sampling area.

The number of core samples necessary to adequately represent the infaunal biota was determined from a test collection of 20 replicates and from analysis of 1977 data using information loss, species accumulation, and percent detectible change measures as criteria. Optimum levels of replication were determined to be 5 replicates/station along the 6 m isobath, and 12 replicates/station along the 9 m and 15 m isobaths.

ABIOTIC SAMPLES

The physical-chemical aspects of the benthic habitat directly influence species distribution patterns. Several abiotic characteristics of the benthic environment were measured and analyzed. The methods of sample acquisition and physical analysis are detailed in Chapter 5. The features considered in the benthic data analyses include: 1) substrate depth; 2) water clarity; 3) sedimentation rate; 4) sedimentation quantity; 5) sediment size and size distribution characteristics; 6) sediment temperature; and 7) sediment organic carbon content.

DATA ANALYSES

Benthic infaunal data were presented in Section II of the Construction Monitoring Program Annual Operating Report, Volume III (MBC, 1979) and are not included here. Data analyses included both statistical and non-statistical treatments. Graphical methods of data reduction and presentation were utilized in the examination of geographical and annual patterns in community diversity, numbers of individuals, biomass, and trophic structure. Multivariate analytical techniques were employed to synthesize community distribution patterns and explore the relationships between these patterns and abiotic features.

Classification Analysis of Biological Data

Classificatory techniques (Clifford and Stephenson, 1975) were employed in the analysis of subtidal benthic infaunal data. The analysis permitted the presence and abundance of species to define areas in which they live. The

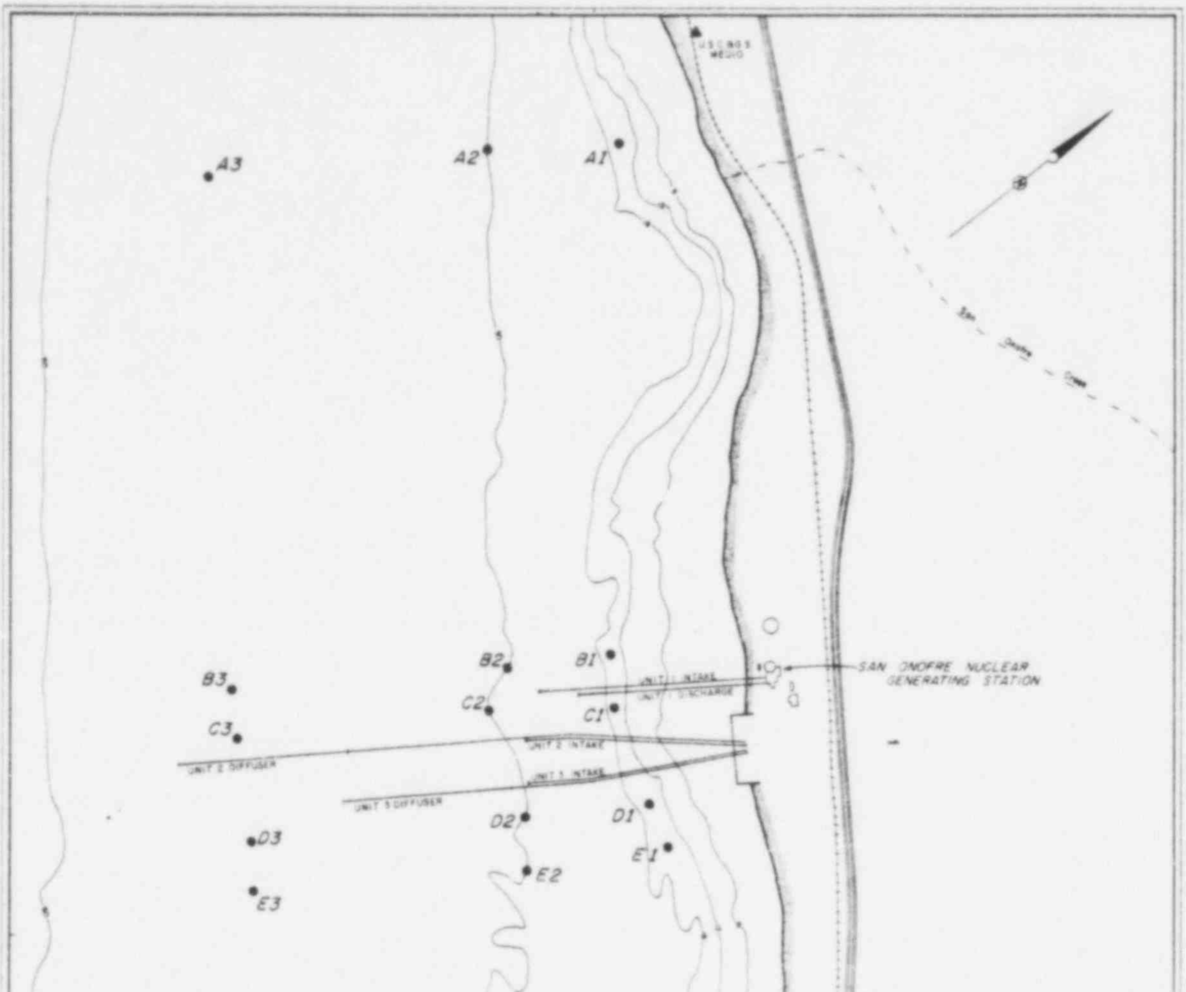

Figure 8-1. Benthic infauna station locations.

operative assumption being that optimal areas within a given environment were inhabited by greater abundances of particular species. Areas with similar biota (both in species composition and abundance) were assumed to provide similar microenvironments in terms of physical-chemical features. Areas which supported modified species assemblages were assumed to provide different or altered sets of environmental features.

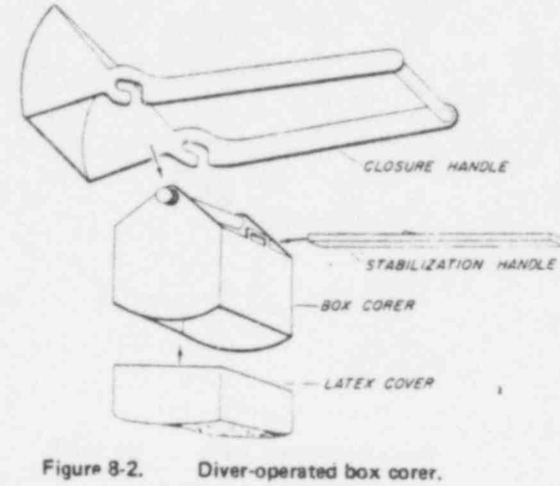

Figure 8-2. Diver-operated box corer.

Two classification analyses were performed in which entities were grouped by specific joint attributes. The sampling stations (entities) were classified by similarity of their species composition (attributes). This was the "normal" analysis of Clifford and Stephenson (1975). The "inverse" analysis classified the species (entities) with respect to their distribution among the sampling stations (attributes). The analyses considered all species that occurred more than once in a survey (quarter sampling).

The classification analysis involved three basic procedures. The first was the calculation of an inter-entity distance (similarity) matrix derived from the "Bray-Curtis" index (Clifford and Stephenson, 1975). The second procedure, commonly referred to as sorting, clustered the entities hierarchically into a dendrogram. The strategy employed in this study was "flexible" (Lance and Williams, 1966). The dendrograms from both the normal and inverse analyses were finally combined into a two-way coincidence table (Clifford and Stephenson, 1975). The relative abundance values of each species were replaced by symbols (Smith, 1976) and entered into the body of the two-way table, which displayed patterns of species occurrences that were subsequently interpreted.

All data were standardized by square root and species maximum prior to analysis (Smith, 1976), to reduce the excessive influence of abundant species.

Multiple Discriminant Analyses

Variables representing relevant abiotic characteristics of the subtidal benthic habitat were measured at all infaunal stations. These measurements reflected differences in the physical-chemical nature of the benthic habitat, the input of dredging and construction related materials, and the availability of food resources. They included:

- Substrate Depth
- Sediment Organic Carbon
- Sediment Temperature
- Water Clarity
- Sedimentation Rate
- Change in Sediment Height (Sea bed Elevation)
- Sediment Factors (Sediment Size and Size Distribution Characteristics)

Multiple discriminant analysis (Hope, 1969; Cooley and Lohnes, 1971; Green, 1971; Smith, 1976) was employed to determine which abiotic features were associated with community differences. Multiple discriminant analysis required the predefinition of groups. The groups were defined by the normal classification analysis. Discriminant analysis produced a linear combination of measured vari-

ables which maximized the differences between groups (i.e. variables which account for the maximum amount of variance between groups). The linear combinations describe a new discriminant axis which was composed of elements from the original variables. The proportion of each element's contribution to the discriminant axis was indicated by the absolute value of the coefficients of separate determination (Hope, 1969; Smith, 1976) and were expressed as percent of the axis total. The higher the coefficient of separate determination, the more influence the variable had on the formation of the discriminant axis.

The analyses were employed to elucidate patterns in the ecological data and were not used to produce mathematical probabilities describing distribution patterns. Statistical assumptions necessary to test the significance of group separation by this analysis were not met by the data. However, in several analyses, separation was complete with no overlap between groups. In instances where some overlap between groups remained, visual determination of adequate group separation was made (Bernstein et al., 1978).

Principal Components Analysis

The composition of sediments at SONGS was complex and ranged from coarse gravel-sized to clay- sized particles (MBC, 1978). Synoptic measures such as mean grain size may not truly represent the sediment features that animals are selecting for. Subcomponents of the sediment size range (e.g. the fine clay or silt-sized particles) may be the actual features influencing biological distribution patterns (Nichols, 1970).

To summarize the patterns in sediment variables and to reduce them into a form suited to discriminant analysis, the data were subjected to principal components analysis (PCA) and a varimax rotation (Harman, 1960; Orlocci, 1967; Cooley and Lohnes, 1971).

A reduction of sediment variables streamlines data handling and interpretation while eliminating certain problems inherent in analyzing many potentially redundant variables. The disadvantages of large variable lists include:

1. Methods which utilize an inverse matrix, such as discriminant analysis, become unstable (or impossible to calculate) as the number of variables approaches the number of samples used in the analysis.

2. Methods utilizing an inverse matrix are also adversely sensitive to high intercorrelations between variables.

3. Interpretation can be more difficult when the variables are considered separately.

The PCA defines low dimensional space containing most of the patterns in the data. Axis scores were used as variables in the discriminant analysis to describe the various independent trends (each axis of interest equal to one sediment factor variable).

The relationships between the axis scores and the original sediment size variables were shown in the factor matrices, which contained the correlations between each variable and the axis in question. The patterns of correlations with each axis were valuable in interpreting a more general sediment factor defined by the axis in question.

Varimax rotation was employed to make the patterns of correlations in the factor matrix more pronounced and interpretable. This rotation attempts to rotate the space so that the variable correlations for an axis are either close to zero

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or very far from zero (i.e. maximize high and low correlations and minimize middle level correlations, thus making the correlational patterns distinct). After the varimax rotation, the axis score are no longer necessarily independent.

RESULTS

BENTHIC INFAUNAL COMMUNITY COMPOSITION

The infaunal communities surveyed during this program were highly variabile among the stations in species composition and abundance (MBC, 1979). Over 22,950 infaunal organisms were collected during the year including 369 taxa representing 16 phyla (Table 8-1). The number of individuals ranged from a low of 2,302 in March to a high of 8,146 in November. The total number of taxa recorded by survey followed a similar trend and increased from a low of 163 in March to a high of 231 in November. These taxa were not all equivalent as some were identifiable only to phylum, although the majority were identified to species. The number of taxa is an approximation of the true number of species because it includes overestimations and underestimations. Some specimens cannot be identified to species because of immaturity, or fragmentation during sampling which results in overestimation through introduction of "artificial" taxa such as Tellina sp. These small clams were probably juveniles of T. modesta that had not yet developed the necessary anatomical characteristics that allow their taxonomic separation from other Tellina species known from the study area. Underestimation arises from two sources: unstable taxonomy currently under revision, e.g. Hemichordata, unid., and the necessity for excessively time consuming laboratory treatments such as serial sectioning which precludes species determinations, e.g. Nemertea, unid. Both sources introduce taxa which may or may not represent more than one species. Although the magnitude of overestimations and underestimations cannot be quantified, the reported number of taxa is the closest approximation of species totals available at this time.

The phyla Arthropoda, Annelida, and Mollusca accounted for greater than 91% of all the taxa encountered (Table 8-1, MBC, 1979). They encompassed individual species which included most major feeding types and habitat requirements, although detailed natural history information is lacking for a majority of the species.

DIVERSITY OF THE BENTHIC INFAUNAL COMMUNITY

Table 8-1. Phyletic composition of the benthic infaunal community.

Phylum	Number of Taxa	Percent
Arthropoda	130	35
Annelida	125	34
Mollusca	83	22
Echinodermata	11	3
Cnidaria	8	2.2
Sipunculoidea	2	0.5
Porifera	1	0.3
Platyhelminthes	1	0.3
Nemertea	1	0.3
Nematoda	1	0.3
Phoronida	1	0.3
Ectoprocta	1	0.3
Branchiopoda	1	0.3
Hemichordata	1	0.3
Chaetognatha	1	0.3
Chordata	1	0.3
Total Phyla	16	
Total Taxa	369	
Total percent		~100

The number of species reported for a station represents the cumulative value for all replicate 1ℓ samples collected at that station. Since the optimal sample size was determined previously, the cumulative species diversity value is a reflection of the total diversity of an area.

In this section, only taxa which were identified to species level were used in diversity determinations (a conservative approach). The only exception was in cases of morphologically distinct taxa, which represent undescribed species. These taxa were assigned a morphotype designation, e.g. Ogyrides sp. A, and were included in the species diversity counts.

Table 8-2. Numbers of benthic infaunal species collected at each station during all sampling periods.

Isobath	Station	Survey Mar	Jun	Sep	Nov	Mean for Year
6 m	A	19	21	16	20	19.0
	F	14	21	24	20	19.8
reference $\bar{X}$		16.5	21	20	20	19.4
	B	14	22	19	17	18.0
	C	24	24	22	29	24.8
	D	5	21	18	22	16.5
	E	27	23	19	20	22.2
treatment $\bar{X}$		17.5	22.5	19.5	22	20.5
9 m	A	23	40	33	46	35.5
	F	36	36	44	42	39.5
reference $\bar{X}$		29.5	38.0	38.5	44	37.5
	B	27	34	44	38	35.8
	C	34	35	49	52	42.5
	D	18	34	46	37	33.8
	E	29	37	47	46	39.8
treatment $\bar{X}$		27	35	46.5	43.3	37.95
15 m	A3	35	46	62	52	48.8
	F3	36	52	57	60	51.2
reference $\bar{X}$		35.5	49	59.5	56	50
	B	49	51	58	74	58.0
	C	38	47	50	58	48.2
	D	39	48	49	51	46.8
	E	24	46	52	53	43.8
treatment $\bar{X}$		36.8	48.3	54.7	58.0	49.2

The number of species found at a station during each survey are listed in Table 8-2 and graphically presented in Figures 8-3 and 8-4. The number of species generally increased proceeding offshore from the 6 m to the 15 m isobath stations. The mean number of species at all stations increased throughout the survey year. The increase was much more pronounced at the 9 m and 15 m isobaths than the 6 m stations.

The mean number of species found at 6 m reference stations ranged from a low of 16.5 species collected during March to a high of 21.0 species in June. The mean number of species recorded from the 6 m treatment stations ranged from a low of 17.5 in March to a high of 22.5 in June. The mean number of species found at the 9 m reference stations ranged from 29.5 in March to 44.0 species in November. The mean numbers of species recorded from the 9 m treatment stations ranged from 27.0 in March to 46.5 species in September. The mean number of species found at the 15 m reference stations ranged from 35.5 in March to 59.5 in September. The mean number of species recorded for the 15 m treatment stations ranged from 37.5 in March to 59.0 in November.

The annual mean number of species found at the 6 m isobath stations ranged from 16.5 at Transect D to 24.8 at Transect C (Table 8-2). The annual mean number ranged from 33.8 at Transect D to 42.5 at Transect C. The lowest mean number of species recorded for the 15 m isobath stations was 43.8 at Transect E, while the highest mean was 58.0 species recorded from Transect B.

NUMBER OF INDIVIDUALS

The mean number of individuals/ℓ of benthic infauna was highest at the 6 m isobath stations (Table 8-3). The number of individuals/ℓ generally increased through the year at all stations. However, occasional exceptions were noted, e.g. the number of individuals at Station B2 decreased from 35.3 in September to 17.4 in November. The mean number of individuals/ℓ found at the 6 m isobath stations ranged from 11.8 in March to 62.4 in November. The mean number of individuals supported at the 15 m isobath stations ranged from 15.7 in March to 46.3 in November. The annual means for the number of individuals/ℓ reflected the patterns of abundance for the individual survey months. The annual mean abundance of species at the 6 m isobath ranged from 25.8 at Station F to 49.5 at Station C. The annual mean number of individuals at 9 m isobath stations ranged from 17.2 at Station D to 40.5 at Station F. The annual mean number of species found at 15 m isobath stations ranged from 20.5 at Station F to 47.9 at Station F.

BIOMASS

Biomass is used as a summary value to characterize the total amount of living material at a station and is expressed as total wet weight of whole organisms in grams/ℓ. Whole organism weights include the weight of the inorganic

portions of the shells, tests, and carapaces of mollusks, echinoderms, and arthropods. The presence of a single large organism may cause extreme deviations in the values.

Mean biomass within each isobath generally increased throughout the survey year (Table 8-4). Mean biomass at the 6 m isobath stations ranged from 0.11 g/ℓ in June to 0.20 g/ℓ in November. The mean biomass at the 9 m isobath stations ranged from 0.12g/ℓ in March to 0.19 g/ℓ in November. The mean biomass at the 15 m isobath stations ranged from 0.15 g/ℓ in March to 0.29 g/ℓ in November. The mean biomass generally increased proceeding offshore with annual means for the 6 m, 9m, and 15 m isobaths of 0.16, 0.18, and 0.20 g/ℓ, respectively.

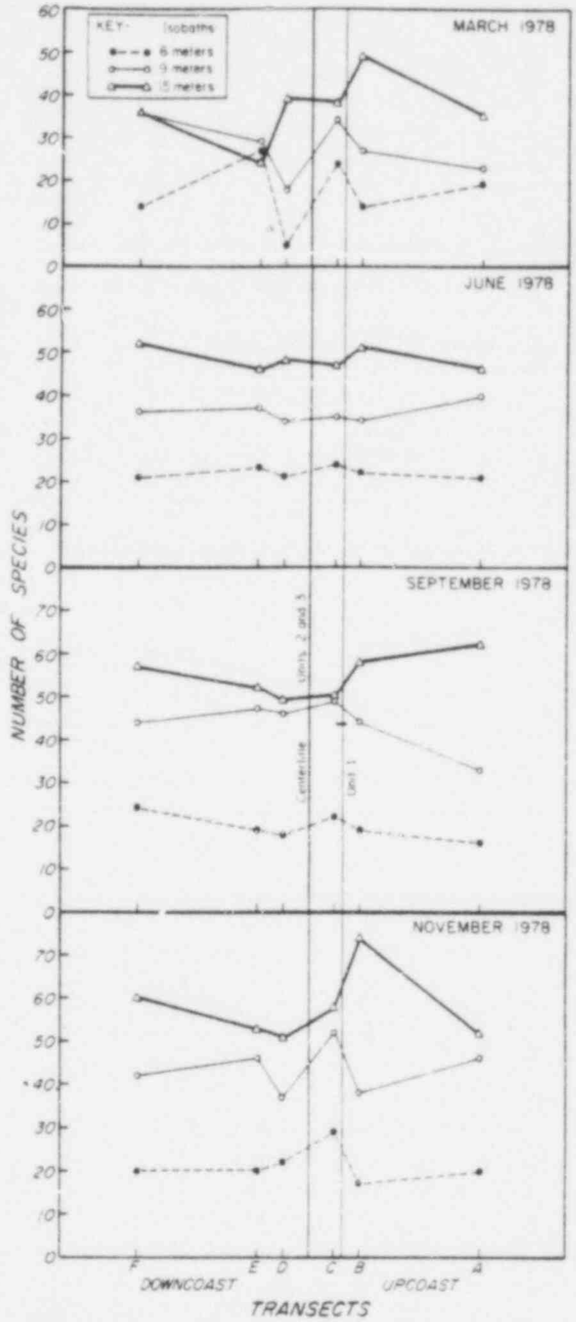

Figure 8-3. Number of benthic infaunal species found at each station during each survey period.

COMMUNITY TROPHIC STRUCTURE

Species collected during the four surveys were categorized according to feeding mode and food source. These categories include: surface deposit feeder, subsurface deposit feeder, filter feeder, omnivore, and carnivore. Placement within a category was based on either literature records or inferred by taxonomists from the basic morphology of feeding apparatus. Approximately 1% of the species could not be trophically classified. Species which have more than one feeding mode were counted in each category (Appendix F).

The number of species in each feeding category increased proceeding offshore. This pattern persisted throughout the year. The annual mean number of filter feeders found at the 6 m, 9 m, and 15 m isobath stations was 5.7, 9.8, and 12.2 species, respectively (Table 8-5). The annual mean number of carnivores found at the 6 m, 9 m, and 15 m isobath stations was 4.5, 10.8, and 11.2 species, respectively. The annual mean number of omnivores found at the 6 m, 9 m, and 15 m isobath stations was 1.8, 4.6, and 4.1 species, respectively. The annual mean number of deposit feeders found at the 6 m, 9 m, and 15 m isobath stations was 15.2, 26.2, 32.9 species, respectively.

PATTERNS IN BENTHIC INFAUNAL COMMUNITY DISTRIBUTION

Intercommunity similarity analyses were performed using classificatory techniques (Clifford and Stephenson, 1975). Each survey period was analyzed

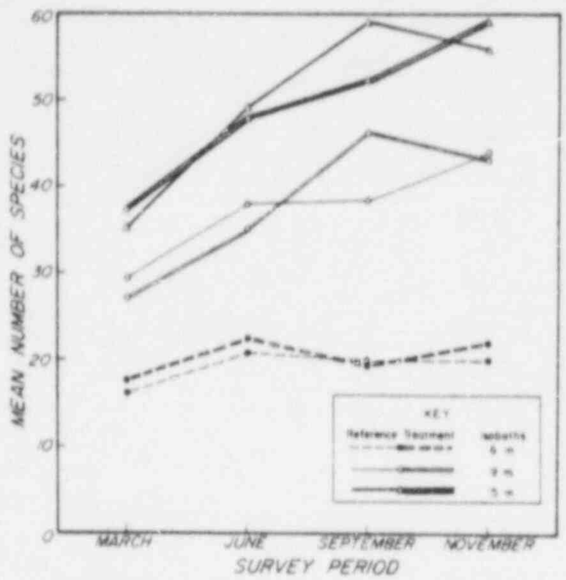

Figure 8-4. Mean number of benthic infaunal species found at reference and treatment stations throughout the year.

separately. Analyses were also performed with 1) data partitioned by isobath rather than Transect and 2) all survey months combined. These provided very little additional information and, therefore, are not discussed here.

The classification analyses produced normal (station) and inverse (species) dendrograms which were arranged in a two-way coincidence table. The normal dendrograms contain clusters of localities based on similarity of faunal composition. The inverse dendrograms contain clusters of)ecies with similar distribution patterns among stations. The two-way coincidence tables summarize faunal composition and abundance and contain symbols (Table 8-6) representing relative abundances based on the maximum abundance for each species.

The site groups which result from the normal analysis are labelled with arabic numerals for easy reference in subsequent discussions of the similarity analysis results (Figures 8-5 through 8-8). Species groups are similarly labeled with letters for reference. In order to interpret the species composition of a secific group, it is necessary to refer directly to the two-way table (Figures 8-5 through 8-8). The phylum of a particular species is as listed in the data report master species list (MBC, 1979).

The normal classification dendrogram for March exhibited one primary and two secondary divisions resulting in four clusters of stations. The primary dendrogram division separated groups 1, 2, and 3 from station group 4. Secondary dendrogram divisions in turn separated station groups 1, 2, and 3 from each other (Figure 8-5). Station group 1 contained the 15 m isobath Stations C3, D3, and E3. Station group 2 was composed of 15 m isobath Stations A3, B3, F3, and the 9 m isobath Station F2. Station group 3 was composed entirely of 9 m isobath stations A2, B2, C2, D2, and E2. Station group 4 included all 6 m isobath stations A1, B1, C1, D1, E1, and F1.

Table 8-3. Mean number of benthic infaunal individuals by station and survey.

Isobath	Station	Survey 1	Survey 2	Survey 3	Survey 4	Annual Mean
6 m	A	12.2	37.0	55.2	78.2	45.7
	B	3.8	32.8	100.8	24.6	40.5
	C	23.8	26.8	69.4	78.0	49.5
	D	1.8	20.2	41.2	91.2	38.6
	E	20.8	26.2	44.0	60.4	37.9
	F	8.6	17.8	35.0	41.8	25.8
Isobath $\bar{X}$		11.8	26.8	57.6	62.4	39.6
9 m	A	9.6	65.3	25.4	19.5	29.9
	B	8.6	18.7	35.3	17.4	20.0
	C	11.8	19.3	34.3	28.5	23.4
	D	6.6	27.1	21.2	13.8	17.2
	E	9.8	31.3	30.1	31.4	25.6
	F	15.1	24.1	30.0	92.8	40.5
Isobath $\bar{X}$		10.3	30.9	29.4	33.9	26.1
15 m	A	10.9	30.8	24.8	15.8	20.6
	B	18.9	27.9	35.7	109.3	47.9
	C	17.4	35.4	25.2	29.3	26.8
	D	16.7	36.2	26.9	38.7	29.6
	E	10.8	46.3	23.1	45.4	31.4
	F	19.4	30.8	22.9	39.5	20.5
Isobath $\bar{X}$		15.7	34.6	26.4	46.3	33.9

The March survey inverse analysis produced six species groups labeled A through F (Figure 8-5). Species group A contained species unique to station group 1. Group B species were scattered between station groups 2 and 3 primarily in medium to high relative abundances. Species in groups C and D occurred primarily in station groups 1 and 2 with medium to high relative abundances. Species group E was

ubiquitous, with most members occurring in all station groups. Species in group F characterized the 6 m isobath station group 4 in relatively high abundances, but were also scattered among many of the stations.

Table 8-4. Benthic infaunal biomass (g/l) by station and survey.

Isobath	Station	Survey Mar	Survey Jun	Survey Sep	Survey Nov	Annual Mean
6 m	A	0.47	0.09	0.11	0.13	0.20
	B	0.02	0.07	0.18	0.16	0.11
	C	0.07	0.07	0.16	0.20	0.13
	D	0.02	0.11	0.09	0.19	0.10
	E	0.32	0.21	0.09	0.26	0.22
	F	0.09	0.12	0.30	0.25	0.19
Isobath $\bar{X}$		0.17	0.11	0.16	0.20	0.16
9 m	A	0.33	0.19	0.08	0.14	0.19
	B	0.06	0.15	0.11	0.14	0.12
	C	0.10	0.23	0.22	0.18	0.18
	D	0.06	0.14	0.16	0.08	0.11
	E	0.08	0.41	0.15	0.18	0.21
	F	0.10	0.13	0.30	0.42	0.24
Isobath $\bar{X}$		0.12	0.21	0.17	0.19	0.18
15 m	A	0.08	0.14	0.27	0.13	0.16
	B	0.43	0.12	0.16	0.48	0.30
	C	0.10	0.14	0.22	0.31	0.19
	D	0.14	0.20	0.16	0.20	0.18
	E	0.06	0.19	0.13	0.31	0.17
	F	0.08	0.23	0.18	0.33	0.21
Isobath $\bar{X}$		0.15	0.17	0.19	0.29	0.20

The normal classification dendrogram from June exhibited one primary and two secondary divisions resulting in four clusters of stations. The primary dendrogram division separated groups 1, 2, and 3 from group 4. Two secondary divisions in turn separate groups 1, 2, and 3 from each other (Figure 8-6. Station group 1 was composed of 15 m isobath stations A3, B3, and F3. Station group 2 included 15 m isobath Stations C3, D3, E3, and the 9 m isobath Station A2. Station group 3 contained 9 m isobath Stations B2, C2, D2, E2, and F2. Station group 4 included all 6 m isobath Stations A1, B1, C1, D1, E1, and F1.

The June inverse analysis contained five species groups (A through E in Figure 8-6). Species group A contained species which characterized station group 1 in relatively high abundance. Several group A species including Glottidia albida and Cyclaspis nubila occurred at other stations in medium or low abundances. Species in group B characterized the 15 m isobath stations of groups 1 and 2 in relatively high abundances. Lumbrineris tetraura, Euphilomedes carcharodonta and other member species also occurred in the 9 m isobath stations, although in medium or low abundances. Diastylopsis tenuis, Goniada littorea, and Haploscoloplos elongatus were ubiquitous. Group C species occurred predominantly at the 15 m isobath stations, and in high abundances particularly at group 2 stations. Species of group D characterized the inshore 6 m isobath stations of group 4 in high relative abundances. Some other member species including Spiophanes bombyx and Amastigos acutus occurred at other stations in lower abundances. Apoprionospio pygmaeus and Paraphoxus epistomus were ubiquitous, but were not abundant at the 6 m isobath stations. Species of group E were scattered among all stations without apparent pattern.

Table 8-5. Annual mean number of benthic infaunal species by isobath and feeding mode.

Level (m)	Survey	Filter Feeder	Total Carnivore	Omnivore	Deposit Feeder
6	1	4.8	4.3	0.7	12.0
	2	6.2	4.0	1.2	16.8
	3	5.7	4.5	2.5	12.8
	4	6.2	5.2	2.7	19.2
$\bar{X}$		5.7	4.5	1.8	15.2
9	1	5.3	8.2	2.5	19.8
	2	11.8	7.8	3.2	26.2
	3	11.7	11.0	5.7	27.0
	4	10.3	16.3	7.0	31.8
$\bar{X}$		9.8	10.8	4.6	26.2
15	1	6.6	8.5	3.2	28.2
	2	12.5	10.3	4.0	33.5
	3	13.2	12.5	5.0	33.2
	4	16.5	13.5	4.3	37.0
$\bar{X}$		12.2	11.2	4.1	32.9

The normal classification dendrogram for September exhibited one primary and one secondary division resulting in three station clusters (Figure 8-7). The primary dendrogram division separated station groups 1 and 2 from group 3. The secondary division in turn separated group 1 from 2. The three station groups correspond to the three isobaths sampled. Station group 1 was composed entirely of 15 m isobath Stations A3 through F3. Station group 2 contained all 9 m isobath Stations A2 through F2. The inshore station group 3 included all 6 m isobath Stations A1 through F1.

Table 8-6. Key to abundance symbols and terms used in the two-way coincidence tables.

Descriptive Term	Symbol	Percent of Maximum Abundance
High	■	76-100
Medium	●	51-75
Low	◑	26-50
Very low	○	1-25

The September inverse analysis produced six species groups (Figure 8-7). Species of group A occurred in high abundances at Stations A3, B3, and F3 of station group 1, and were practically absent from stations of groups 2 and 3. Species group B characterized stations in groups 1 and 2. Group B species were represented in high abundances in station group 1 and slightly lower abundances in station group 2. Species of group C occurred in medium to high abundances in the 15 m isobath stations of group 1. Species of group D were scattered among all the stations and display no well-defined distribution patterns. Species of group E predominated at the 6 m isobath stations of group 3. Many group E species occurred in the 9 m isobath stations of group 2, but at relatively lower abundances Apoprionospio pygmaeus, Diastylopsis tenuis and Nephtys caecoides were ubiquitous, but decreased in relative abundance with increased depth. Species of group F occurred inconsistently at group 1 and 2 stations.

The normal classification dendrogram for November exhibited one primary and one secondary division resulting in three clusters of stations (Figure 8-8). The primary dendrogram division separated station group 1 from groups 2 and 3. The secondary division in turn separated group 2 from 3. The three station groups corresponded primarily to the three isobaths sampled. Station group 1 included all inshore 6 m isobath stations A1, B1, C1, D1, E1, and F1. Station group 2 included 15 m isobath Stations A3, B3, C3, D3, and F3. Station group 3 was composed primarily of 9 m isobath Stations A2, B2, C2, D2, E2, and F2, but also contained 15 m isobath Station E3.

The November inverse analysis produced five species groups (Figure 8-9). Species of group A were found in high relative abundance at stations in groups 2 and 3, and were generally absent from 6 m isobath stations (group 1). Group B species characterized the 6 m isobath stations of group 1. Many of these species occurred at the 9 m isobath stations of group 3, although in lower relative abundances. Apoprionospio pygmaeus, Nephtys caecoides, and Paraphoxus epistomus were ubiquitous, but displayed highest relative abundances at the 6 m isobath stations. Species of group C characterized the 15 m isobath stations of group 2. They also occurred at two stations (E2 and C2) of station group 3 but were conspicuously absent from station E3. Species group D characterized the 9 m and 15 m isobath stations of station groups 2 and 3 with relatively few of the species inhabiting any of the 6 m isobath stations. Species of group E predominated at the 15 m isobath stations of group 2. These species were found in relatively high abundances and, except for occassional representatives which occurred at 9 m isobath stations, exhibited a limited distribution pattern.

RELATIONSHIP BETWEEN BENTHIC INFAUNAL COMMUNITY DISTRIBUTION PATTERNS AND THE PHYSICAL-CHEMICAL ENVIRONMENT

Multiple discriminant analysis was employed to identify the most important abiotic features associated with biotic distributions. The variables examined in the analyses and their abbreviations are listed in Table 8-7.

The variables considered in the discriminant analysis provide separately or in combination food and habitat resources for the infaunal community. Single variables may supply combinations of resources for selected species. For example, sediment constitutes both habitat and food for deposit feeding polychaetes. Discriminant analysis produces linear combinations of abiotic variables (axes) which best separate the station groups predefined by the classification analysis. The relative importance of a variable in the construction of a discriminant axis

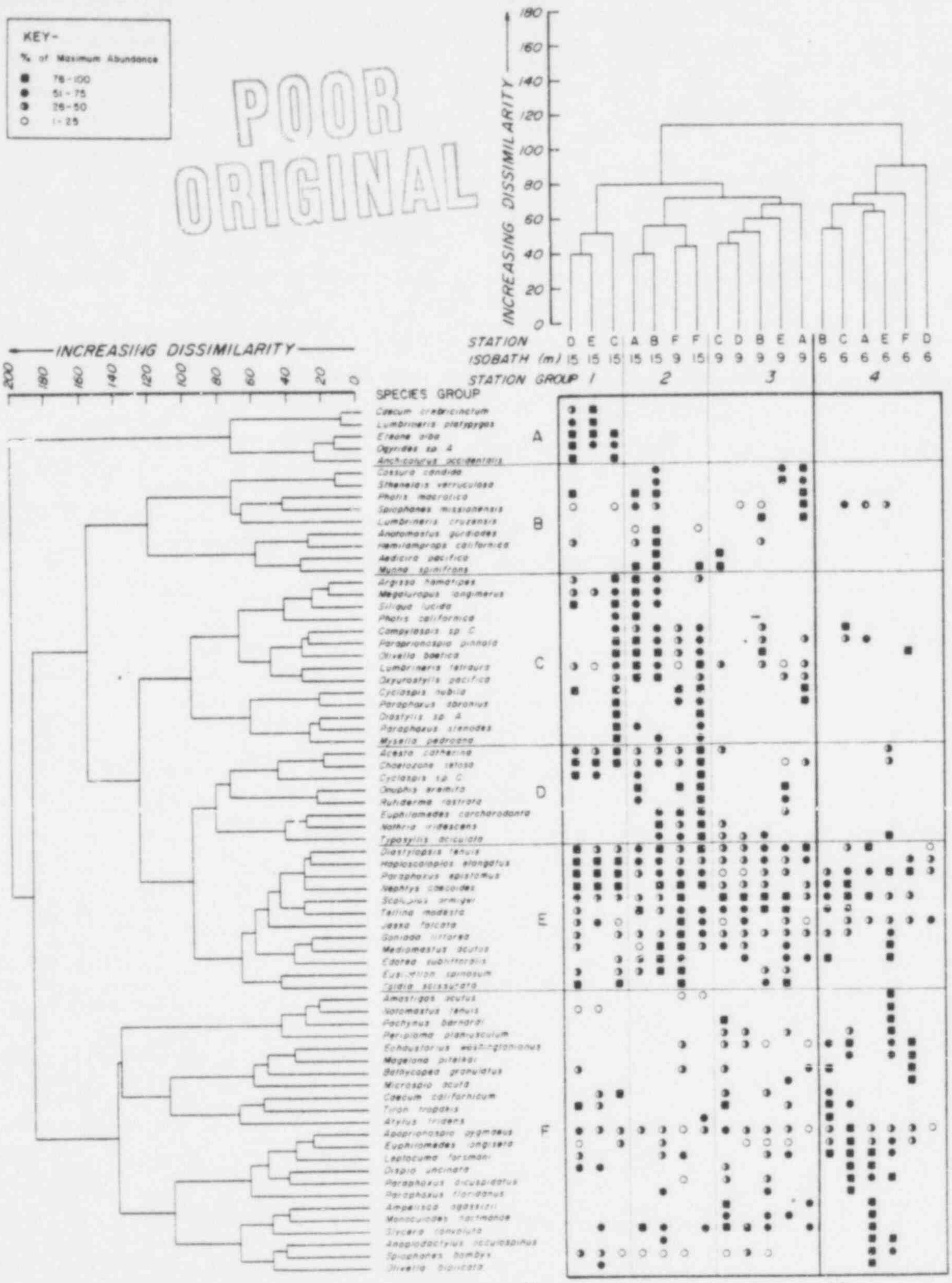

Figure 8-5. March classification results. Normal and inverse dendrograms with resultant two-way table.

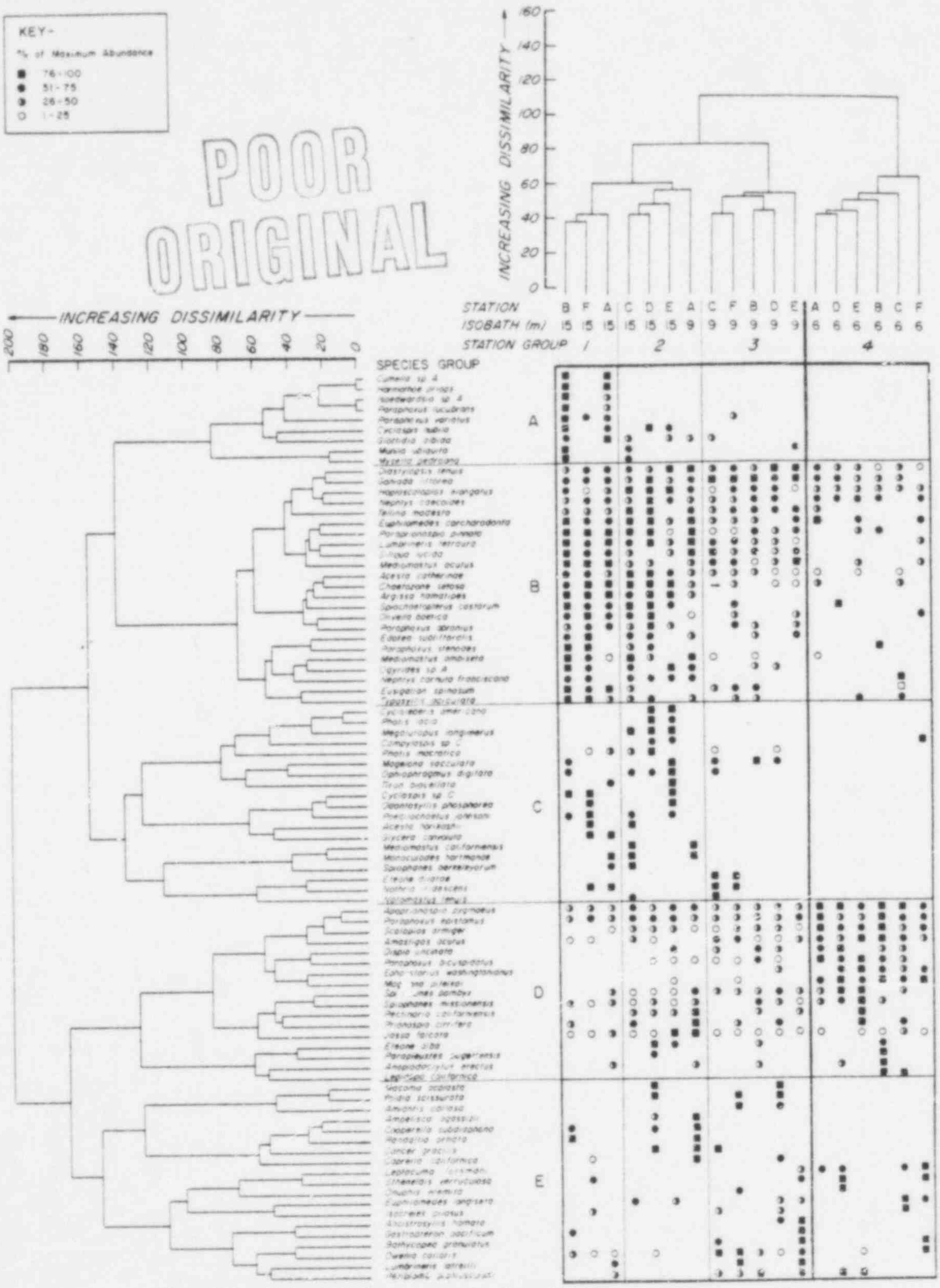

Figure 8-6. June classification results. Normal and inverse dendrograms with resultant two-way table.

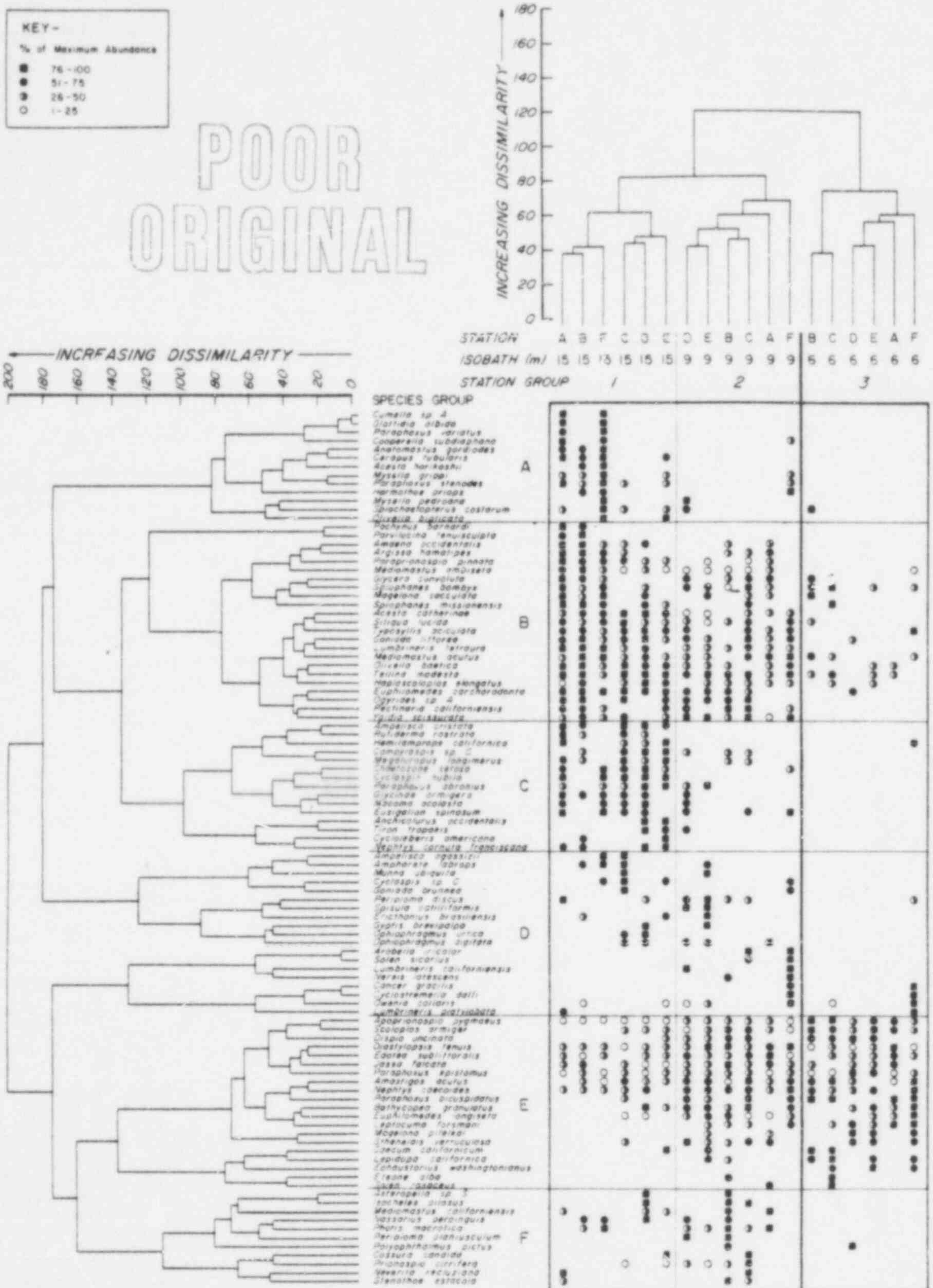

Figure 8-7. September classification results. Normal and inverse dendrograms with resultant two-way table.

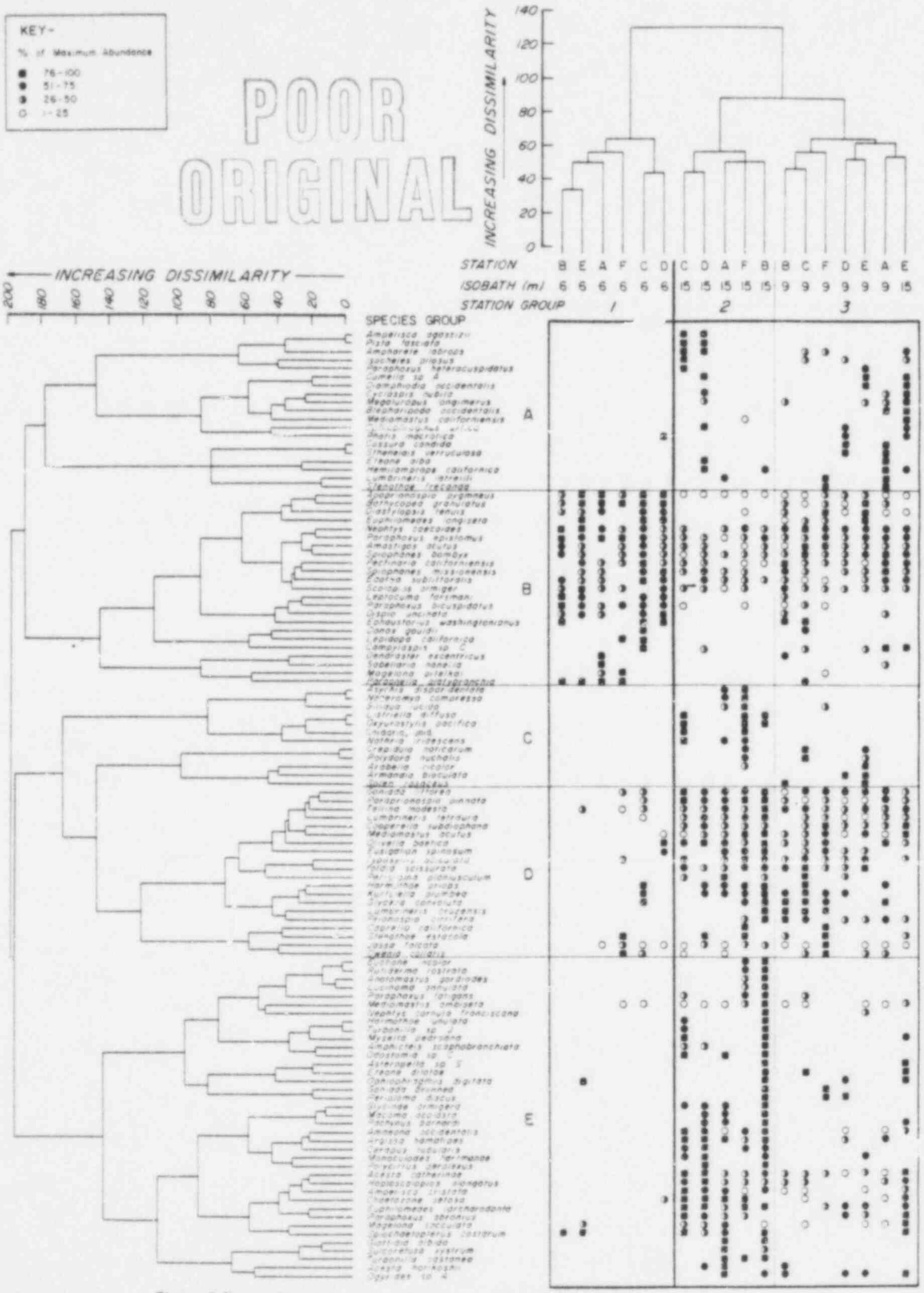

Figure 8-8. November classification results. Normal and inverse dendrograms with resultant two-way table.

is indicated by the magnitude of its coefficient of separate determination (Table 8-8). The most important variables are indicated on the discriminant axes which depict group separations (Figures 8-9a through d). Group means for all abiotic variables considered are listed in Table 8-9. A vector diagram is presented on each discriminant figure (Figure 8-9a through d). The vectors indicate the direction of increase of the important abiotic variables. The correlation of sediment textural features with the sediment factor variables considered in the discriminant analyses are listed in the Factor Matrix (Table 8-10). Sediment features positively correlated with an axis increase in the direction indicated by the corresponding vector arrow. Those sediment features negatively correlated with the sediment factor increase in the opposite direction and are indicated on the figures by a dashed line. The direction of increased numbers of species is also indicated on the vector diagrams. The important variables are interpreted in relation to the community structured and distributional differences.

Table 8-7. Variables considered in the multiple discriminant analyses.

Variable	Abbreviation
Species Diversity	H
Depth	D
Total organic carbon	TOC
Sediment temperature	ST
Water clarity	WC
Sedimentation rate	SR
Sediment height	SH
Change in sediment height	ΔH
Sediment factor 1	SF1
Sediment factor 2	SF2
Sediment factor 3	SF3

Two discriminant axes adequately separated the four station groups from the classification analysis March 1 data (Figure 8-9a). Axis 1 accounted for 74.9% of the variance between groups while axis 2 accounted for 23.2% (Table 8-11). The most important variables on the first axes were depth, water clarity, and sediment factor 3 (Table 8-10). Very fine sand was positively correlated with sediment factor 3, while medium and coarse silt were negatively correlated with sediment factor 3. The most important variable on the second axis was Sediment Factor 1. Although the coefficients of separate determination for total organic carbon and sediment factor 2 were slightly elevated (Table 8-8) their values at each of the stations display no distinct patterns. Sediment factor 1 was composed of highly correlated coarse sediment size features including medium gravel, fine gravel, granules, and very coarse sand. These features were responsible for separating station group 1 apart from other 15 m isobath stations of group 2 (Figure 8-9a). The faunal differences at this station reflected the modified

Table 8-8. Coefficients of separate determination from the discriminant analyses. (The magnitude of those elements underlined indicates their relative importance in the formation of the discriminant axes.)

Abiotic Variables	Axis 1	Axis 2	Abiotic Variables	Axis 1	Axis 2
March			September		
Total Organic Carbon	0.3	10.5	Total Organic Carbon	6.4	7.0
Sediment Temperature	1.4	3.6	Sediment Temperature	5.2	1.1
Depth	26.6	3.6	Depth	47.3	4.8
Water Clarity	9.6	5.2	Water Clarity	17.6	6
Sediment Height	2.7	0.2	Sedimentation Rate	0.4	5.1
Sediment Factor 1	0.7	62.3	Sediment Height	6.7	5.4
Sediment Factor 2	3.6	9.8	Change in Sediment Height	0.2	3.5
Sediment Factor 3	55.2	4.6	Sediment Factor 1	2.6	0.6
			Sediment Factor 2	13.2	20.6
			Sediment Factor 3	0.3	45.4
June			November		
Total Organic Carbon	4.0	29.5	Total Organic Carbon	3.9	1.4
Sediment Temperature	6.6	4.7	Sediment Temperature	3.2	55.5
Depth	51.0	3.4	Depth	51.9	7.3
Water Clarity	6.7	10.5	Water Clarity	10.7	5.3
Sedimentation Rate	16.1	30.4	Sedimentation Rate	0.4	4.8
Sediment Height	6.4	1.4	Sediment Height	1.1	0.2
Change in Sediment Height	0.4	5.3	Change in Sediment Height	0.5	1.4
Sediment Factor 1	0.2	8.8	Sediment Factor 1	25.6	9.6
Sediment Factor 2	7.0	1.8	Sediment Factor 2	1.8	1.6
Sediment Factor 3	1.5	4.1	Sediment Factor 3	0.9	12.8

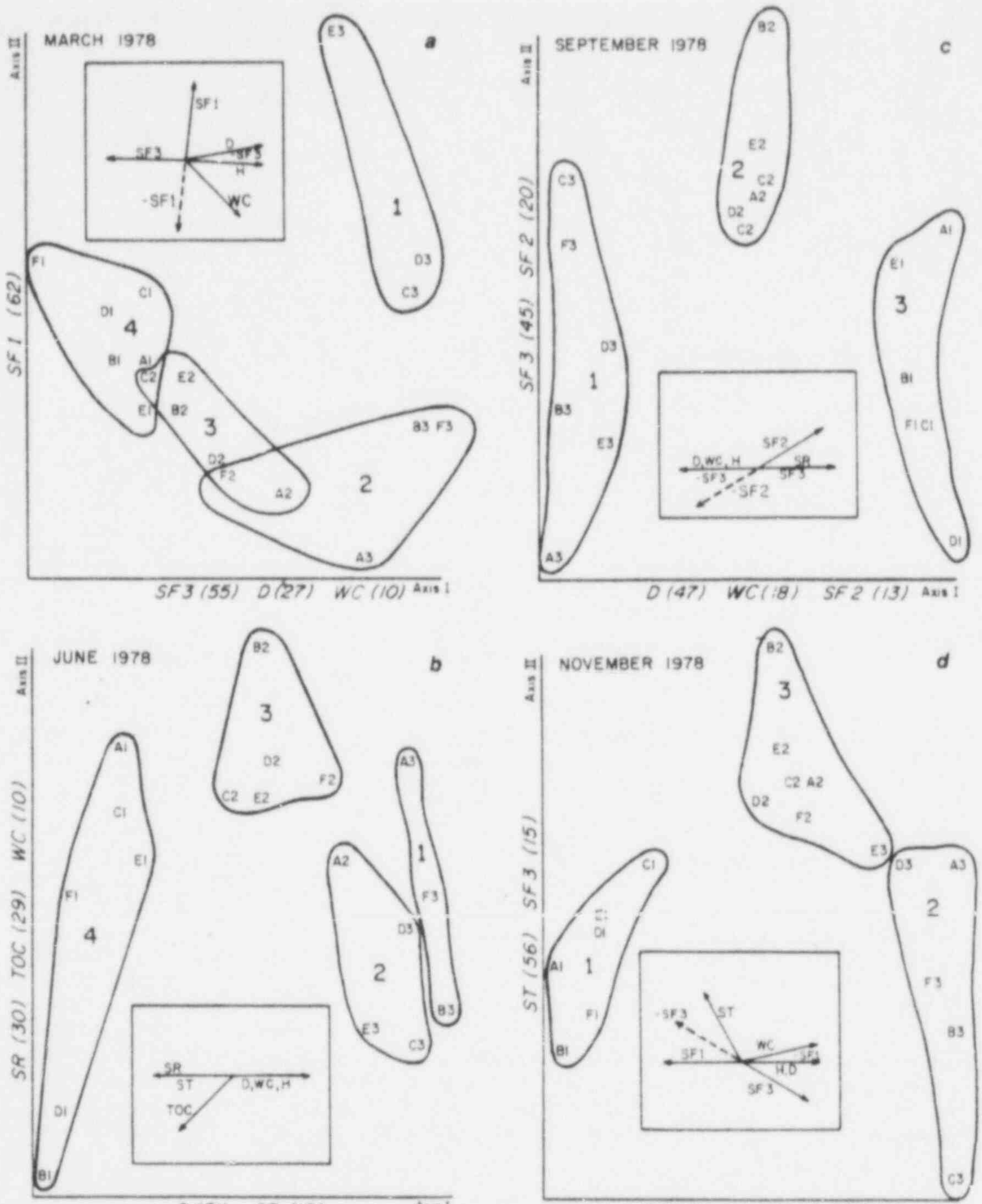

Figure 8-9. Discriminant analysis axes illustrating station group separation features. (See results text Relationship Between Benthic Infaunal Community Distribution Patterns and the Physical-Chemical Environment, and Table 8-7.)

sediment regime. Vectors (Figure 8-9a) indicates that species diversity increased with greater depth, water clarity, and increased quantities of medium and coarse silt.

Two discriminant axes separate the four station groups from the classification analysis of June data (Figure 8-9b). Axis 1 accounted for 95.1% of the

Table 8-9. Group means from discriminant analysis of abiotic variables.

Abiotic Variables	Site Groups* 1	2	3	4	Abiotic Variabiles	Site Groups* 1	2	3
		March					September	
Total Organic Carbon (%)	0.164	0.158	0.159	0.160	Total Organic Carbon (%)	0.18	0.17	0.14
Sediment Temperature (°C)	13.92	14.14	14.38	14.53	Sediment Temperature (°C)	17.60	17.98	18.40
Depth (m)	11.47	11.35	10.63	10.16	Depth (m)	11.99	10.97	9.84
Water Clarity (m)	5.14	5.20	4.83	4.53	Water Clarity (m)	6.13	5.48	4.71
Sediment Height[a]	130.03	129.46	127.67	126.92	Sedimentation Rate[a]	507.22	639.18	810.84
Sediment Factor 1	0.15	-0.13	-0.07	-0.01	Sediment Height[a]	118.32	113.22	107.07
Sediment Factor 2	-0.04	-0.07	-0.02	0.07	Change in Sediment Height[a]	8.24	8.17	8.48
Sediment Factor 3	-0.12	-0.11	0.00	0.06	Sediment Factor 1	0.08	0.02	-0.05
					Sediment Factor 2	-0.31	-0.03	0.27
					Sediment Factor 3	-0.10	-0.04	0.07
		June					November	
Total Organic Carbon (%)	0.14	0.14	0.14	0.16	Total Organic Carbon (%)	0.14	0.17	0.16
Sediment Temperature (°C)	14.52	14.64	14.98	15.48	Sediment Temperature (°C)	16.76	16.59	16.69
Depth (m)	12.58	12.35	11.69	10.80	Depth (m)	9.97	12.77	11.60
Water Clarity (m)	7.06	6.93	6.14	5.36	Water Clarity (m)	6.38	8.92	7.95
Sedimentation Rate[a]	633.36	683.29	785.95	1036.95	Sedimentation Rate[a]	767.65	428.53	538.08
Sediment Height[a]	132.58	131.21	129.60	125.91	Sediment Height[a]	109.19	114.74	112.58
Change in Sediment Height[a]	-3.48	-3.11	-3.43	-2.32	Change in Sediment Height[a]	-1.70	3.89	1.66
Sediment Factor 1	-0.16	-0.08	-0.11	0.07	Sediment Factor 1	0.38	-0.36	-0.04
Sediment Factor 2	0.26	0.18	0.03	-0.19	Sediment Factor 2	-0.09	0.09	0.03
Sediment Factor 3	-0.05	-0.03	0.02	0.02	Sediment Factor 3	-0.20	0.20	-0.02

* From Classification Analysis

[a] = centimeters

variance between groups while axis 2 accounted for an additional 4.2% (Table 8-11). The most important variables on the first axis were depth and sedimentation rate (Table 8-8). The most important variables on Axis 2 were sedimentation rate, total organic carbon, and water clarity. Sediment temperature also displayed a pattern corresponding to station group separation, although its coefficient of separate determination was not dominant on any axes. The vector diagram (Figure 8-9b) showed that species diversity increased with greater depth, water clarity, lower sediment temperatures and decreased sedimentation.

Two discriminant axes separated the three station groups derived from the classification analysis of September data (Figure 8-9c). Axis 1 accounted for 98.7% of the variance between groups while axis 2 accounted for the remainder (Table 8-11). The most important variables on the first axis were depth, water clarity, and sediment factor 2 (Table 8-8). Sediment factor 2 represented the positively correlated variables fine and very fine sand as well as the negatively correlated variables medium and coarse silt, and mean grain size of the sediments (Table 8-10). The most important variables on the second axis were sediment factor 3, sediment factor 2, and sedimentation rate. Sediment factor 2 represented the positively correlated variable fine sand and the negatively correlated variable sediment distributional kurtosis. The vector diagram indicated that species diversity was higher at stations with greater depth, water clarity, medium and coarse silt, lower sediment temperatures, and finer sediment size (Figure 8-9c).

Two discriminant axes separated the three station groups from the classification analysis of November data (Figure 8-9d). Axis 1 accounted for 97.6% of the variance between station groups while axis 2 contributed the other 2.4% (Table 8-11). The most important variables on the first axis were depth, sediment factor 1, and water clarity (Table 8-8). Sediment factor 1 represented the positively correlated variables fine and very fine sand and the negatively correlated variables medium silt and coarse clay as well as finer sediments in general (greater mean phi) (Table 8-10). The most important variables on the second axis were sediment temperature and sediment factor 3. Sediment factor 3 represented the positively correlated variables coarse gravel and coarse clay as well as sediment distributional kurtosis (Table 8-10). The vector diagram indicated that

Table 8-10. Sediment factors derived from principal components analysis. Underlined values represent high correlations with the sediment factor.

Sediment Characteristics	Phi Size	Sediment Factors 1	2	3	Characteristics	Phi Size	Sediment Factors 1	2	3
		March					September		
Medium gravel	-3	0.94	-0.11	-0.07	Granule	-1	0.87	-0.28	0.28
Fine gravel	-2	0.94	-0.11	-0.07	Very coarse sand	0	0.94	0.04	-0.15
Granule	-1	0.82	0.09	0.19	Coarse sand	1	0.79	0.09	-0.19
Very coarse sand	0	0.95	0.09	0.00	Medium sand	2	0.16	-0.07	0.12
Coarse sand	1	0.97	0.02	-0.10	Fine sand	3	0.00	0.56	0.72
Medium sand	2	0.94	0.04	-0.09	Very fine sand	4	-0.15	0.84	-0.13
Fine sand	3	0.07	0.13	0.10	Coarse silt	5	0.11	-0.93	-0.19
Very fine sand	4	-0.46	0.16	0.84	Medium silt	6	-0.05	-0.69	-0.08
Coarse silt	5	-0.18	0.05	-0.84	Fine silt	7	-0.09	-0.17	-0.08
Medium silt	6	-0.16	-0.70	-0.57					
Fine silt	7	-0.13	-0.94	-0.08	Mean phi	-	-0.07	-0.80	-0.49
Very fine silt	8	-0.10	-0.96	0.11	Sorting	-	0.39	-0.29	0.19
Coarse clay	9	0.12	-0.82	0.05	Skewness	-	-0.35	-0.03	0.10
					Kurtosis	-	0.04	-0.07	-0.95
Mean phi	-	-0.60	-0.50	-0.31					
Sorting	-	0.41	-0.78	-0.18					
Skewness	-	-0.04	-0.76	-0.07					
Kurtosis	-	-0.09	-0.15	0.02					
		June					November		
Very coarse gravel	-5	0.08	-0.16	-0.86	Very coarse gravel	-5	-0.08	-0.02	0.98
Medium gavel	-3	0.35	-0.18	0.06	Granule	-1	0.17	0.95	-0.06
Granule	-1	0.87	-0.09	0.12	Very coarse sand	0	0.12	0.95	-0.10
Very coarse sand	0	0.82	-0.13	0.11	Coarse sand	1	-0.01	0.98	-0.11
Coarse sand	1	0.74	-0.16	0.11	Medium sand	2	0.04	0.97	-0.10
Medium sand	2	0.90	-0.15	0.16	Fine sand	3	0.87	0.16	-0.15
Fine sand	3	0.57	-0.61	-0.02	Very fine sand	4	0.62	-0.59	-0.20
Very find sand	4	-0.65	-0.63	-0.02	Coarse silt	5	-0.92	0.06	0.27
Coarse silt	5	-0.16	0.93	-0.03	Medium silt	6	-0.72	0.03	-0.18
Medium silt	6	-0.12	0.84	-0.31	Fine silt	7	-0.33	0.20	0.10
Fine silt	7	-0.39	0.39	-0.61	Very fine silt	8	-0.35	-0.16	0.36
Very fine silt	8	-0.16	0.33	-0.88	Coarse clay	9	-0.08	-0.02	0.98
Coarse clay	9	-0.05	0.07	-0.98					
					Mean phi	-	-0.76	-0.58	0.15
Mean phi	-	-0.71	0.52	-0.13	Sorting	-	0.16	0.81	0.25
Sorting	-	0.97	-0.08	-0.00	Skewness	-	-0.07	0.17	0.19
Skewness	-	0.31	0.03	-0.11	Kurtosis	-	-0.24	-0.15	0.92
Kurtosis	-	-0.09	0.70	-0.06					

the species diversity increased with greater depth, water clarity, the quantity of coarse clay, medium silt, and generally finer sediments (Figure 8-9d).

DISCUSSION

DIVERSITY, NUMBERS OF INDIVIDUALS, AND BIOMASS OF THE BENTHIC INFAUNAL COMMUNITY

Table 8-11. Amount of variance accounted for by each discriminant axis.

Survey	Axis	Percent Variance	Cumulative Percent Variance
Mar	1	74.9	74.9
	2	23.2	98.1
	3	1.9	100.0
Jun	1	95.1	95.1
	2	4.2	99.3
	3	0.7	100.0
Sep	1	98.7	98.7
	2	1.3	100.0
Nov	1	97.6	97.6
	2	2.4	100.0

Three interrelated community parameters, species diversity, the numb'r of individuals, and biomass, were examined on a station by station basis. The survey grid provided a framework within which patterns in these parameters could be assessed relative to the construction activities of Units 2 and 3. The dominant biotic pattern, which was not modified by construction activities, was increase in the number of species with depth. An enhancement effect was generally evident in the three community parameters at the treatment

stations upcoast of the construction line, while a depression was noted for the treatment stations downcoast of the construction activities (Figure 8-10a,b,c). These patterns persisted throughout the year.

The simplest measure of species diversity is a count of the number of species (Pianka, 1966; Cody, 1974). This method was selected in preference to a diversity index, e.g. Shannon Wiener index, because it does not infer ecological importance based on species abundance (Hurlbert, 1971). Another problem alleviated by the use of species counts is the inability of indices to accommodate colonial or encrusting species which cannot be enumerated. Perhaps the most compelling reason for utilizing species counts is that they provide a biologically meaningful basis for interpreting diversity differences. The presence of a species infers its occupation of a multidimensional niche (Hutchinson, 1957). An area with greater species diversity implies either more efficient use of the available niches or an area with a greater number of potential niche resources or both.

A large range of benthic infaunal species diversity values was recorded between stations and survey periods. The lowest number of species (5) was recorded from Station D1 during March while the highest (74) was recorded at Station B3 during November (Table 8-2). Graphing the data (Figures 8-4 and 8-10a) revealed distinct patterns in species diversity values which were related to station position as well as survey period.

Graphing of species diversity by isobath at reference and control stations (Figure 8-4) revealed the dominant pattern of increase in diversity proceeding offshore from the 6 m to the 15 m isobath stations. This pattern persisted throughout the year. Other authors (Lie and Kister, 1970; Parr and Diener, 1977; MBC, 1978) have reported similar results for exposed open coast environments similar to or at SONGS.

Throughout the year, species diversity values at treatment stations paralleled those at reference stations

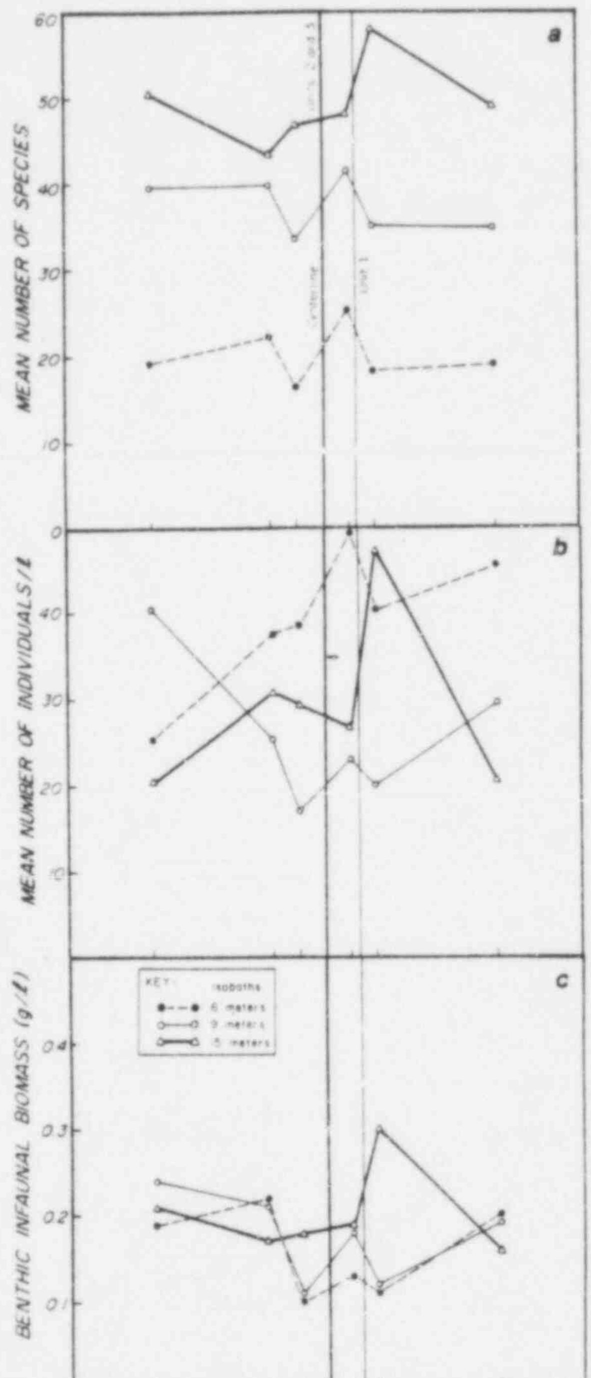

Figure 8-10. Summary graphs for entire year illustrating the a) number of species, b) number of individuals, and c) biomass of the benthic infaunal species of each feeding type from each survey.

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(Figure 8-4), and in general increased at all 9 m and 15 m isobath stations. However, the 6 m isobath stations do not display a similar trend with the number of species remaining fairly constant through the year after a small increase in the second survey.

A similar pattern was noted for all depths combined in 1977 (MBC, 1978), but the increase was noted only between March and September with a diversity decrease in December.

The number of species found at reference and control 9 m and 15 m stations differed somewhat in the September survey. The mean number of species was higher at the treatment stations than at reference stations for the 9 m stations, while the opposite was true for the 15 m isobath stations (Figure 8-4). No explanation for these seemingly contradictory results is advanced at the present time.

The number of species at each station during each survey are displayed in Figure 8-3. These data are summarized for the entire year in Figure 8-10. and the patterns of species diversity revealed during each survey were well illustrated in this summary graph. The species diversity increase proceeding offshore was again illustrated by these data (Figure 8-10). In addition, a notable enhancement in the number of species occurred at stations upcoast of the centerline dividing Units 2 and 3 and adjacent to the Unit 1 discharge and intake lines. This increase in the number of species appeared at the 6 m and 9 m stations of Transect C and the 15 m station of Transect B. A depression in the species diversity was apparent at the D transect 6 m and 9 m isobath stations and the C, D, and E 15 m isobath stations. The enhancement and depression of species numbers was probably affected by several factors. There was close agreement between the patterns of some physical-chemical parameters and species diversity. The closest agreement was with water clarity (see Chapter 5, Figure 5-9) and the relationship suggests that stations with greater water clarity support higher species diversity, while those with depressed clarity support lower numbers of species. Decreased water clarity at Transect D stations was a result of their downcoast proximity to the dredgeline for Units 2 and 3 (Brown and Caldwell, 1979).

The pattern of mean change in sediment height (Figure 5-10) also displayed a close correspondence to the patterns of species diversity. Stations located along Transect C generally experienced an increase in sediment height by accretion through the year, while those stations located along Transects D and E generally decreased in sediment height through erosion. These changes were probably the result of localized modification of hydrographic features in the area related to trestle placement. However, site specific current data were not available for this discussion.

Differences in water clarity and sedimentation which corresponded to species differences were localized and within 236 m (both sides) of construction related activities.

Another variable which exhibited a less consistent pattern correspondence to species diversity patterns was the amount of organic carbon in the sediments (see Chapter 5, Figure 5-11). Those stations with elevated organic carbon levels generally supported greater numbers of species while those with low or depressed levels contained fewer species. Elevated carbon levels appear related to Unit 1 operation. Periodic heat treatment and expulsion of fouling organisms has been suggested as a source of organic enrichment (Diener and Parr, 1977).

The annual mean number of individuals/ℓ at each station are graphically displayed in Figure 8-10b. Overall, more individuals/ℓ were collected along the 6 m isobath than at the 9 m or 15 m isobaths. The 9 m isobath treatment stations contained the lowest numbers of individuals but, the reference stations contained

slightly higher numbers of individuals (Figure 8-10b). The number of individuals found at the 15 m treatment stations was intermediate between the 6 m and 9 m isobaths. The 15 m reference stations supported fewer individuals than treatment stations on the same isobath. As with the species diversity values, some enhancement and depression of biota in terms of the numbers of individuals/ℓ was apparent at the treatment stations (Figure 8-10b). A sharp increase in the number of individuals upcoast of the dredgeline occurred at 6 m, and 9 m stations of Transect C and at the 15 m station of Transect B. Adjacent to the dredgeline downcoast, the number of individuals decreased at the 6 m and 9 m isobath stations of Transect D, and a similar depression at the 15 m isobath station of Transect C. Although these patterns resemble those displayed by the number of species, they were not always well defined. Irregularities occurred at the reference transects, where the numbers of individuals at specific stations was not consistent.

Benthic infaunal biomass (grams/ℓ) of all organisms at each station was tabulated by survey (Table 8-3) and presented graphically for the entire year (Figure 8-10c). No consistent relationship between biomass and depth at the reference transect stations was revealed. The highest biomass was recorded from the 6 m isobath community of Transect A while the 6 m community of Transect F had the lowest biomass. The treatment stations generally displayed an increase in community biomass proceeding offshore to the 15 m isobath. There was an enhancement and depression in the biomass pattern, adjacent to the dredgeline and Unit 1 discharge and intake structures. The 6 m and 9 m stations along Transect C and the 15 m isobath station of Transect B had elevated biomass levels while the 6 m and 9 m isobath stations of Transect D and the 15 m station of Transects C, D, and E had depressed biomass.

The three community parameters discussed above were interdependent and therefore a high amount of correspondence among the patterns was expected. The patterns of enhancement and depression of community parameters persisted throughout the year. The correspondence of these patterns with those in water clarity, sedimentation, and organic carbon content of the sediments suggests that these factors influenced the species patterns thoughout the year. Water clarity, sedimentation, and depressed organic carbon levels appear to be influenced primarily by the dredging activities and pipeline emplacement for Units 2 and 3. However, organic enrichment associated with the enhanced areas probably was related to the operation of Unit 1.

Many species colonize from larval recruits transported into an area by currents and water masses. Substrate suitability is influenced by many factors. Erosion adjacent to the trestle and decreased water clarity may directly inhibit larval recruitment. Crisp and Ryland (1960) and Williams (1965) noted the importance of sediment texture to larval settlement. Similar observations were made relating larval selection to 1) contour of the substrate surface (Crisp and Barnes, 1954), 2) sediment particle size (Wilson, 1952), and 3) current strength and turbulence near the substrate (Crisp, 1955; Crisp and Meadows, 1963). Each of these factors is modified by the local patterns of accretion associated with dredging activities. Recruitment is probably altered as a result.

COMMUNITY TROPHIC STRUCTURE

The benthic infaunal community at SONGS relied on several sources of energy among which are plankton, sediment organics, terrestrial and aquatic detrital material, and local macrophyte populations. None of the species collected during the subtidal infaunal sampling directly utilized the sun as an energy source

(primary production), but all were ultimately dependent on the organic materials manufactured by primary producers.

Species diversity increased throughout the year (Figure 8-3) and this pattern of increase was reflected in the numbers of species in each feeding type (Figure 8-11). The deposit feeding species exhibited the largest numerical increase, 7 species, a rise of 35%. However, the greatest percentage increase was noted in the filter feeders which rose by 109% from a mean of 5.5 in March to 11.5 in November. These results indicate that the entire community was expanding and that successful recruitment was occurring, however, the observed growth may be a portion of a larger scale temporal cycle. Further, the fact that all feeding types are not increasing with an equal representation (percentage) suggests that a community trophic shift is taking place. The significance of this shift can only be interpreted when placed in perspective by a comparison of several years data. This will be completed in the future.

The number of deposit feeders increased proceeding offshore (Figure 8-12d). Sanders (1968) described a similar pattern in a study of Buzzards Bay, Massachusetts. This increase was in part associated with the greater quantities of silts and clays, which bind organics, in deeper water sediments. The number of deposit feeders followed the enhancement/depression pattern described for species diversity in general. Upcoast of the dredgeline and adjacent to Unit 1 intake and discharge structures a general increase in the number of deposit feeders occurred at all stations (Figure 8-12d). Immediately downcoast of the Units 2 and 3 dredgeline (6 m and 9 m stations of Transect D) and at the 15 m station of Transect C the number of deposit feeders decreased. This pattern may be the response to the patterns of enrichment and depletion of sediment organics in these areas. There was also a high correspondence between the depressed numbers of species and decreased water clarity and increased sediment erosion as discussed previously.

Consistent with the pattern for deposit feeders and in contrast to the findings of Sanders (1968), the number of filter feeders increased with depth (Figure 8-12a). Filter feeding species

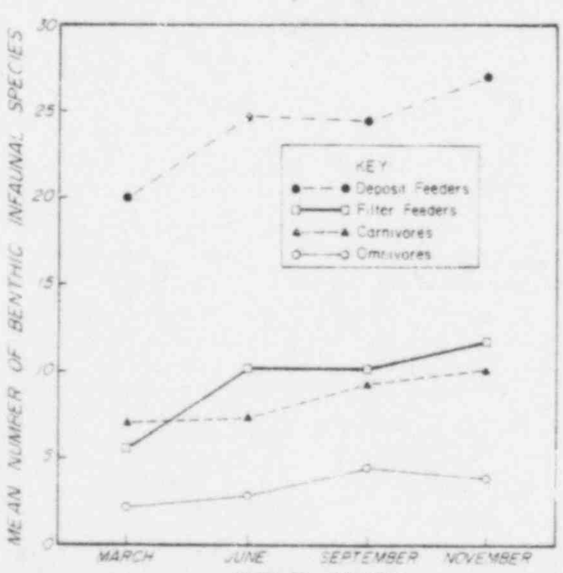

Figure 8-11. Number of benthic infaunal species of each feeding type from each survey.

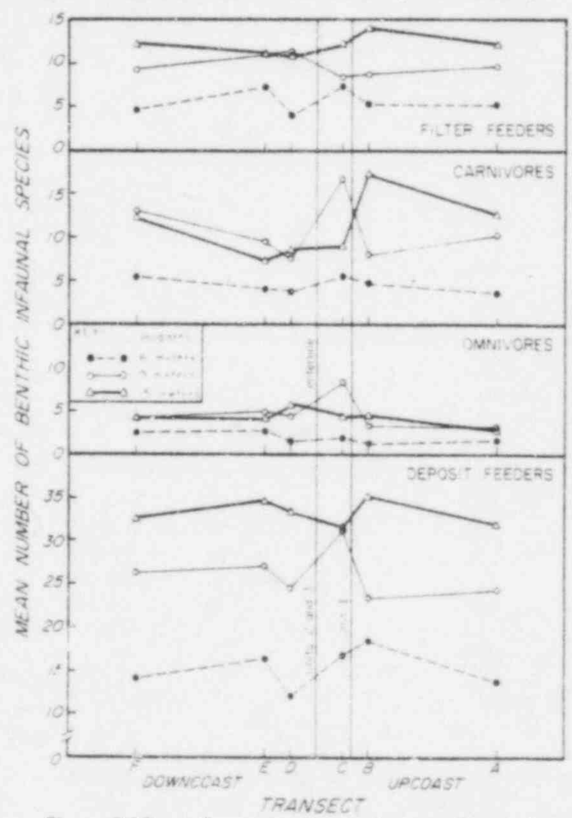

Figure 8-12. Summary for entire year by station of the number of benthic feeders.

POOR ORIGINAL

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as a group have been described as characteristic of sandy substrates (Sanders, 1968; Rhoads and Young, 1970). However, the number of species found in silt-clay dominated offshore sediments at SONGS exceeded those found in the sandy inshore sediments. The number of filter feeding species display a weaker pattern of enhancement/depression near the SONGS Units 2 and 3 dredgeline and Unit 1 line than the deposit feeding species. More species were found at the 6 m Transect C and 15 m Transect B stations, while fewer species were found at the 6 m and 15 m Transect D stations. The pattern of filter feeder abundance at the 9 m isobath is somewhat reversed. A slight depression in the number of species occurred at Transect C, and elevated species numbers were recorded at Transects D and E. No explanation is advanced here to explain th'· reversal.

The fewest carnivore species were recorded at the inshore (6 m) stations (Figure 8-12b). The number of species at the 15 m isobath stations upcoast of the Unit 1 conduits was higher than that for the 9 m station on the same transect. This pattern was reversed below the Units 2 and 3 dredgeline where the number of carnivore species was higher at the 9 m than at the 15 m isobath stations. The pattern of enhancement and depression of species numbers upcoast and downcoast of the construction and operation activities was again evident in the number of carnivore species.

Few omnivorous species occurred in the benthic infaunal samples (Figure 8-12). The inshore (6 m) isobath stations contained the lowest number of species. The 9 m and 15 m stations supported similar numbers of species. The pattern of enhancement/depression of species numbers was less ev dent within the omnivores than in any other feeding type. There was an elevated number of omnivr es at the 9 m transect C station. The elevated omnivore levels may compliment ne low number of filter feeders at this station.

PATTERNS IN BENTHIC INFAUNAL COMMUNITY DISTRIBUTION

Community classification analyses (Clifford and Stephenson, 1975) revealed distributional patterns of characteristic species and station assemblages. They were: 1) clusters of stations whose communities displayed distinct onshore-offshore patterns corresponding to a depth gradient, 2) secondary divisions within the 15 m isobath station groups during Surveys 1 and 2 which indicated faunal discontinuities, 3) groups of species whose distribution and highest abundances characterized specific isobaths, and 4) several species which were ubiquitous and whose distributions were not restricted by depth. The patterns (except 2) above persisted throughout the year.

The normal analyses of all four survey's data revealed a distinct onshore-offshore pattern of station similarity (Figures 8-5 through 8-8) corresponding to the depth gradient. The results indicated that stations within an isobath contained similar faunal assemblages which remained distinct throughout the year. The 9 m and 15 m isobath faunas were more similar to each other than either was to the inshore 6 m isobath community. This was indicated by the dendrogram affinities which associated the 6 m station groups to the 9 m and 15 m isobath group at a greater level of dissimilarity (Figures 8-5 through 8-8).

An important feature of the station dendrograms (Figures 8-5 through 8-8) was the high internal consistency within a station group, i.e. close similarity of the stations with respect to community composition. There was also the significant absence of intragroup divisions separating "reference" and "treatment" stations. Further, no aberrant groups of stations appeared that were totally distinct from the major groups discussed above. These results suggest that communities while varying within an isobath, display a high degree of internal consistency and an absence of major discontinuities in the presence and abundance of dominant community members.

The station dendrograms for the March and June surveys contained four station groups (Figures 8-5 and 8-6). In both surveys two station groups resulted from secondary divisions within the 15 m isobath station group which indicated faunal differences existed. The March station dendrogram group 1 apparently differed from group 2 primarily in the presence of five species (Group A, Figure 8-5) Caecum crebricinctum, Lumbrineris platypygos, Eteone alba, Ogyrides sp. A, and Anchicolurus occidentalis, which were found in high relative abundance and only at group 1 stations. The differences exhibited by the two 15 m isobath station groups of the June survey (Figure 8-6) were associated with the nine species of group A which characterized site group 1 in high abundance and were all but absent from the other stations.

Although the normal classification generally grouped stations by depth occasionally a station would cluster outside of its respective depth group, e.g. Station A2 in station group 2 of the March survey (Figure 8-5), or Station E3 in station group 3 of the November survey (Figure 8-8). Since station groups represent clusters of stations with similar species composition, a shift in species makeup must have occurred in which the faunal composition of the odd station resembled that of other stations at a different isobath. This phenomenon was apparently short lived with the stations that had shifted groups returning to their previously shared group in the following survey. Group reversals were confined to the 9 m and 15 m isobath stations, which as mentioned previously, were similar in community composition.

The species groups from the inverse classification revealed abundance patterns that characterized the various stations and which persisted through the year. However, species additions and deletions modified the communities slightly through the year. Since the number of species included in these analyses was high, subsequent discussions will cite selected species which display particular patterns, and not iterate a list of all species displaying a particular distribution.

The inshore 6 m isobath stations were characterized by species groups with a rather limited number of species. These species were most abundant at the 6 m isobath stations and/or they were found only at inshore stations. The inshore species included: the polychaetes Apoprionospio pygmaeus, Magelona pitelkai, Dispio uncinata, Paraonella platybranchia; the amphipods Paraphoxus bicuspidatus, P. floridanus; and the cumacean Leptocuma forsmani.

The midshore 9 m isobath stations were also characterized by species groups whose members were restricted to these stations or exhibited their greatest abundance at mid-depths. These species included: the polychaetes Cossura candida, Scoloplos armiger, Nephtys caecoides; the amphipods Stenothoe frecanda, Photis macrotica; the cumacean Diastylopsis tenuis; and the mollusk Yoldia scissurata.

Unique species groups and species displaying their highest relative abundance at 15 m isobath stations included: the polychaetes Chaetozone setosa, Glycinde armigera, Amaeana occidentalis; the mollusks Turbonilla castanea, Odostomia sp. C; the amphipods Argissa hamatipes, Monoculodes hartmanae; the cumaceans Oxyurostylis pacifica, Diastylopsis tenuis; and the ostracod Euphilomedes carcharodonta.

As discussed above, most of the species encountered in the benthic subtidal collections displayed a definite distribution pattern and occur in communities which characterized distinct depth environments. Some species, however, were ubiquitous although they may occurred in highest relative abundance at only one depth. Among these species are: the polychaetes Apoprionospio pygmaeus, Scoloplos armiger; the cumacean Diastylopsis tenuis; the bivalve mollusk Tellina modesta; and the amphipod Paraphoxus epistomus.

The fact that species exhibit definite (and often highly restricted) distribution patterns is not purely a matter of chance. Physiological, food, and habitat requirements dictate where an organism will live, and once the proper environment has been pioneered other factors such as interspecific and intraspecific competition may influence localized distribution and abundance (Connell, 1972; Dayton, 1971).

RELATIONSHIP BETWEEN COMMUNITY DISTRIBUTION PATTERNS AND THE PHYSICAL-CHEMICAL ENVIRONMENT

Multiple discriminant analysis (Green, 1971; Smith, 1976) was employed to determine which abiotic features of the benthic environment were associated with community distribution patterns. The most important physical-chemical features varied between survey periods, but dominant features persisted (Figure 8-8a through 8-8d). These include: 1) the importance of depth in community distribution, 2) the importance of silts and clay to communities at the 9 m and 15 m isobath stations, 3) the association of coarser sediments, with the differences in communities occupying the 15 m isobath stations, 4) the importance of sand to 6 m isobath communities, and 5) the the covariance in increased sedimentation, water clarity, and species diversity.

Depth was the dominant environmental feature associated with community distribution patterns. Depth exerts its influence on community composition and abundance directly and indirectly. As a habitat variable, depth translates into a pressure factor to which organisms must be adapted (Hoar, 1966). Indirectly, depth influences many other niche dimensions in the benthic environment. In the open coast environment there is an inverse relationship between water movement and depth (Shepard, 1963). Turbulence decreases proceeding offshore and the environment within which sedimentation processes operate, becomes a turbulence continuum (Shepard, 1963). Substrate stability follows this same continuum. The increase in species diversity proceeding offshore at SONGS parallels this continuum and a similar phenomenon has been documented for other areas by many authors (Rhoads and Young, 1970; Lie and Kisker, 1970; Gage and Geekie, 1973).

The sedimentation environment provides a framework for integrating the important sediment factor variables (from the discriminant analysis) with community distribution patterns. The effects of grain size are of fundamental importance in explaining observed community differences, since both food and habitat resources are provided by this substratum. The deeper stations (9 m and 15 m) and associated communities were characterized by sediment factors representing the finer sediments e.g. coarse silt, fine silt, and coarse clays. These sediments were deposited in an environment with reduced water movement compared to inshore stations. Communities in deeper water contained more deposit feeding species in higher relative abundance than those in shallow water (Table 8-6, Figure 8-11). Similar associations of benthic species which were dependent on the clay and silt-clay components of the sediment were described by Nichols (1970) and Sanders (1968).

The communities occupying the 15 m isobath stations differed during the March survey period (Figure 8-5). The discriminant analysis revealed significant differences in the sediment regimes of the station groups (Figure 8-9a). While all stations contained high proportions of silt and clay, station group 1 (E3, D3, C3) localities also contained high proportions of very coarse sand, medium gravel, fine gravel, and granules (Figure 8-9a, Table 8-11). This coarse material is apparently from the underlying San Mateo formation and was exposed by surve or current scouring. Apparently in response to this substrate modification, and increased sediment heterogeneity a faunal change occurred which included the appearance of species of group A (Figure 8-6).

The sand component characterized the inshore (6 m) station sediment regime. Greater relative water movement at this shallower depth apparently winnowed out the finer silts and clays leaving a well sorted sediment regime of fine and very fine sand. Low levels of silts and clays rather than the presence of sand probably account for reduced numbers of deposit feeders found within the 6 m isobath (Nichols, 1970). The association between high energy sand regimes of the inshore environments and specific communities have been noted by several authors (Sanders, 1958; Lie and Kisker, 1970; Gage and Geekie, 1973). However, the filter feeder dominated community described by Sanders (1958) was not found at SONGS. Filter feeder diversity increased with depth as did the diversity of deposit feeders (Table 8-6, Figure 8-12a). Moreover the diversity of filter feeders was always subordinate to that of deposit feeders, particularly at the inshore stations.

Sedimentation rate was an important variable associated with community differences in the June and September surveys (Figures 8-9b and 8-9d). The highest sedimentation occurred at the 6 m isobath stations. The primary origins of deposited materials were: 1) sediments transported from the seabed and nearby rivers by currents and surge, and 2) suspended sediments released by dredging activities (Figure 5-2). With the present monitoring scheme it is impossible to determine the percentage of input from each of these sources. However, one of the heaviest periods of dredging and sediment release preceeds the second benthic survey (Figure 5-2). The total dredge displacement of sediments during this period exceeded 65 x 10^3 yards and probably contributed substantially to the inshore sedimentation. Increased sedimentation may affect the community by selecting for species which are more mobile or whose respiratory and feeding structures do not foul easily. However, this process is probably occurring even when there is no dredging.

Water clarity was associated with community distribution patterns. However, the patterns suggested by this variable should be viewed with caution since the data were limited to four measurements per year and may not have accurately characterized ambient water clarity conditions. In addition, Secchi disk readings measure water clarity above the substrate and not at the sediment water interface. Community diversity was highest where water clarity was the greatest. The mechanism(s) by which water clarity affects community distribution and diversity is not known. However, turbidity may affect larval settlement and recruitment (Crisp, 1955). Proceeding offshore water clarity increased. This variable, as with sedimentation, was influenced by natural as well as construction related inputs. Water clarity was depressed near the area of highest dredge discharge (Brown and Caldwell, 1979), which occurred on different isobaths during each survey (Figure 5-9, Figures 8-9a through d).

Other factors such as sediment temperature and organic carbon content were important variables in the June and September surveys and were associated with community patterns. The sediment temperature patterns were regular during both surveys with the highest temperatures recorded at the 6 m stations and the lowest temperatures at the 15 m isobath stations. This pattern is consistent with most coastal marine environments where the colder waters occur at greater depths. No other distinct patterns of temperature and community distribution patterns were recorded. However, temperature measurements at benthic stations were limited, being made only once during each survey period.

The organic carbon content of the sediments from the June survey period were higher than those at deep stations and were associated with community differences. Greater inshore organic levels corresponded to the period of increased species diversity (Figure 8-3) and may have contributed to this increase by providing additional food for deposit feeding species. The source of the organics is unknown, but both storm runoff and some input from dredging probably contributed much of the material.

In general community composition and distribution patterns were controlled by depth, sediment composition, water clarity, sedimentation, sediment temperaature and organic carbon content of the sediments. Depth was the only factor which was not influenced by SONGS construction and operation. The remaining factors were modified from ambient levels by input from SONGS Units 1, 2, and 3. The community analysis indicated that the distribution patterns of characteristic benthic species were not significantly altered by SONGS construction and operation activities. However, community parameters of diversity, numbers of individuals, and biomass at stations immediately adjacent (within 236 m) upcoast and downcoast of the SONGS Units 2 and 3 construction were modified compared to reference stations.

SUMMARY

The benthic infaunal community in the vicinity of SONGS was investigated as part of the monitoring program related to construction of Units 2 and 3. The parameters examined were species diversity, abundance, biomass, trophic structure, distribution characteristics, and relationships to various habitat variables. The analysis revealed:

1. Elevated species diversity, numbers of individuals, and biomass at stations upcoast and immediately adjacent to the Unit 1 discharge and the construction areas for Units 2 and 3 discharge and intake structures. These patterns were probably related to SONGS operation and construction.

2. Lower species diversity, numbers of individuals, and biomass at stations downcoast and immediately adjacent to the construction areas for Units 2 and 3 discharge and intake structures. These patterns were probably related to SONGS construction activities.

3. Increased species diversity proceeding offshore from the 6 m to the 15 m isobath stations. This patterns was consistent with natural distributions observed by other authors.

4. Numerical dominance of the benthic infaunal community by deposit feeding species.

5. Patterns of enhanced and depressed species numbers in deposit feeders, filter feeders, carnivores, and omnivores which generally parallelled those patterns described for species diversity (1 and 2 above).

6. A general increase in the number of species at all trophic levels throughout the survey year (March through November), which may be part of a multi year cycle.

7. Community modifications at the 15 m isobath stations possibly corresponding to sediment modification by storm activity preceeding the March and June surveys.

8. Community distribution patterns characterized by:

   a. Groups of stations whose communities displayed distinct onshore-offshore patterns corresponding to a depth gradient.

   b. Groups of species whose distribution and highest abundances characterized specific isobaths.

   c. Species which were ubiquitous to all areas sampled.

9. An association between depth, sediment composition, water clarity, sedimentation, organic carbon content of sediment, and species distribution patterns. The important factors associated with community distribution patterns were influenced by both natural and construction related activities. It was not possible to separate their relative input.

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CHAPTER 9

SUBTIDAL COBBLE - UNITS 1, 2, AND 3

INTRODUCTION

The hard substrata benthos offshore of the San Onofre Nuclear Generating Station (SONGS) was the focus of three Southern California Edison (SCE) programs in 1978. These include the benthic study portions of the Unit 1 Environmental Technical Specifications (ETS) program initiated in March of 1975, the Units 2 and 3 Preoperational Monitoring Program (PMP) initiated in July 1978 and the Construction Monitoring Program (CMP) initiated in December 1976.

The objective of the Unit 1 ETS program is to determine the operational effect(s) of Unit 1 on the marine resources in the vicinity of the generating station. The objective of the PMP benthic study is to provide baseline data for use in determining the nature, extent, and significance of the operational effect(s) of Units 2 and 3 on the species composition, distribution, and abundance of the macroorganisms associated with subtidal cobble. The purpose of the CMP hard substratum benthic study is to assess the environmental effects of sediment dispersal on the nearfield cobble habitats associated with the San Onofre Kelp Bed during construction and dredging operations for the Units 2 and 3 intake and diffuser-discharge conduit system.

The 1978 biological data utilized in this analysis report was previously presented in the Annual Operating Report, San Onofre Nuclear Generating Station, Volumes II (LCMR, 1979a) and III (MBC, 1979). Physical oceanographic data utilized in this report was presented in Volume I (BC, 1979). The tabular data previously submitted included all the qualitative and quantitative biological and physical oceanographic data collected at sampling stations during 1978. Additional data sampled during previous years, for each program, is utilized to identify general temporal patterns or trends.

The following clarifications and definitions are presented with respect to each of the benthic programs considered. The benthic marine resources with regard to the ETS, PMP, and CMP benthic programs include all macroorganisms occupying hard substrata from a depth of less than 3 m to approximately the 14-m isobath. A list of local subtidal macroorganisms and their relative importance with respect to the San Onofre area is presented in tabular form and is discussed in the Final Environmental Statement for SONGS 2 and 3 (AEC, 1973). The vicinity of the discharge for the ETS benthic study is roughly defined as a rectangular area centered on the Unit 1 discharge extending approximately 1 km up- and downcoast and 0.5 km in- and offshore of the discharge. This rectangle includes Zone OA ETS Benthic Stations 1, 2, 3, and 4 (Figure 9-1).

The area in the vicinity of the Units 2 and 3 discharges or nearfield area for the PMP and CMP benthic studies is defined by a rectangle whose boundaries extend 1 km upcoast and downcoast of a point located between the terminus of the Unit 3 diffuser and the beginning of the Unit 2 diffuser, and inshore to the beginning of the Unit 3 diffuser and offshore 0.5 km from the terminus of the Unit 2 diffuser. The area acceptable for station location within the inshore-offshore boundaries is partially limited by the availability of hard substrata (IRC, 1977, 1978), by the extent of the predicted thermal plume (Koh et al.,

1974), and by the construction activities associated with dredging and conduit installation. The upcoast-downcoast boundaries are determined by the predicted areal extent of the thermal plume (Koh et al., 1974) and potential turbidity effects.

Collectively, all stations sampled by each program may be assigned to one of three groups. These groups include stations located on the nearshore isobath (10-12 m) without kelp canopies, stations on the offshore isobath (12-14 m) within areas of previously or presently existing kelp beds, and the stations on the offshore isobath without kelp canopies.

BACKGROUND

In order to place the present benthic programs and their objectives into perspective with regard to previous benthic studies at San Onofre, a brief description of the subtidal environment offshore SONGS is presented which includes a review summarizing past benthic studies at SONGS.

The area offshore San Onofre has been characterized as a region of moderate to heavy wave action, usually accompanied by naturally turbid offshore water conditions (Given, 1973). The region in the vicinity of SONGS is quite varied with respect to substratum composition. The natural processes of accretion and erosion of rock substrata by sand or silt limit and define the biological populations (Connell, 1972; Given, 1973; Valentine, 1973). The greatest proportion of rocky substrata offshore of SONGS is unconsolidated cobble and boulder with isolated areas of exposed bedrock and sandstone. The nearshore benthic environment within the SONGS study area (5 km and 10 km upcoast and downcoast) consists of a heterogeneous mixture of boulder, cobble, and sand substrata. The proportions of boulder, cobble, and sand vary depending upon the area considered (IRC, 1978). The San Mateo Point reference region 5 km upcoast of SONGS consists of relatively stable cobble-boulder substratum from the 18-m isobath to the shoreline (Figure I-3, LCMR 1978c). In contrast, the Don Light reference area 8 km downcoast from SONGS is largely sand with isolated patches of cobble occurring at the 10-12-m isobath (IRC, 1978; Figure I-5, LCMR 1978c). The area directly offshore of SONGS is a complex mixture of all three components (IRC, 1978; MBC, 1978; Figure I-4, LCMR 1978c).

Benthic biological studies of the marine environment at San Onofre began in 1963 and consisted of periodic monitoring programs. Methods for conducting quantitative subtidal benthic biological studies had not been fully developed at the initiation of the first monitoring programs at San Onofre; consequently, early investigations were basically qualitative. As improved methods evolved, benthic studies at San Onofre became quantitatively oriented. An independent evaluation of the methodology and results of the benthic biological data from 1964 through 1971 is presented by Given (1973) and Scanland (1973). These reports concluded that the artificial substratum and relief associated with the discharge structure increased the numbers and types of species comprising the biological community in the immediate vicinity of the discharge. No long-term detrimental effects attributable to the operation of Unit 1 were identified. However, it was noted in an early study (Given, 1973) that two cobble stations, one adjacent to the discharge and one located approximately 610 m downcoast of the discharge, were buried by sand and covered with a fine layer of silt after generating station operation began. Further, it was suggested that turbidity in the immediate proximity of the discharge reduced available light levels and inhibited algal growth (Given, 1973).

Generally, semiquantitative data were collected from 1963 until March 1975 when the existing Environmental Technical Specifications program was initiated (LCMR, 1975g). Implementation of the ETS benthic program included the permanent marking and delineation of station transects and quadrats, the incorporation of a sampling area delineated into distinct zones and kelp beds, taxonomic standardization, consistency in methods of recording enumerated and percent cover taxa, and quantitative data collection. The CMP and PMP sampling programs evolved from the ETS study design. These programs included kelp mapping utilizing an electronic positioning system and kelp health (nutrients) studies. The PMP study utilized previous ETS analyses, field reconnaissance, and sampling experiments to develop a paired station experimental design which employs a quantitative point contact sampling technique.

The ETS benthic sampling design does not attempt to identify expected biological effects immediately adjacent to the Unit 1 discharge, but emphasizes monitoring a larger area near Unit 1 for potential long-range spatial and/or temporal effects on organisms in these subtidal cobble-boulder habitats (Figure 9-1). The results, analyses, and interpretation of yearly ETS benthic survey data from 1975 to 1977 (LCMR, 1976b, 1977b, 1978c) have not identified or suggested any long-term spatial or temporal biological effects associated with the operation of SONGS Unit 1. Similarly, the CMP data collected during five quarterly surveys conducted from December 1976 to December 1977 (MBC, 1978) did not identify any biological effects to the San Onofre kelp bed macrobiota associated with diffuser-discharge conduit construction for SONGS Units 2 and 3.

In terms of nearfield effects, a relative increase in benthic invertebrate larval settlement on artificial hard substrata has been observed within 50 m of the discharge (Osman, 1978). Increased larval settlement on hard substrata was attributed to alteration of natural current conditions near the discharge (within 50 m) resulting from the mechanical entrainment of surrounding water. This mechanical entrainment exposed the nearfield hard substrata to greater densities and subsequent greater settlement of merozooplankton than would normally be expected under natural conditions (Osman, 1978).

The purpose of this report is to analyze and interpret the 1978 data collected by each of the three subtidal benthic programs, to identify any alterations in the marine environment and determine the significance of the effects which may be attributed to the operation of SONGS Unit 1 or construction activities associated with Units 2 and 3. The PMP study is specifically designed to describe the baseline conditions of the macrobiota offshore of SONGS Units 2 and 3.

METHODS

FIELD

A total of 23 subtidal cobble stations are sampled quarterly by the ETS, CMP, and PMP benthic programs. Collectively, these programs sample 16 cobble stations, eight stations each on the nearshore (10-m) and offshore (12-m) isobaths. Additionally, seven stations are located in three kelp beds or areas that recently (1975-1978) supported large stands of kelp on the offshore isobath. A map detailing the position of all stations with respect to SONGS 1, 2, and 3 is presented in Figure 9-1.

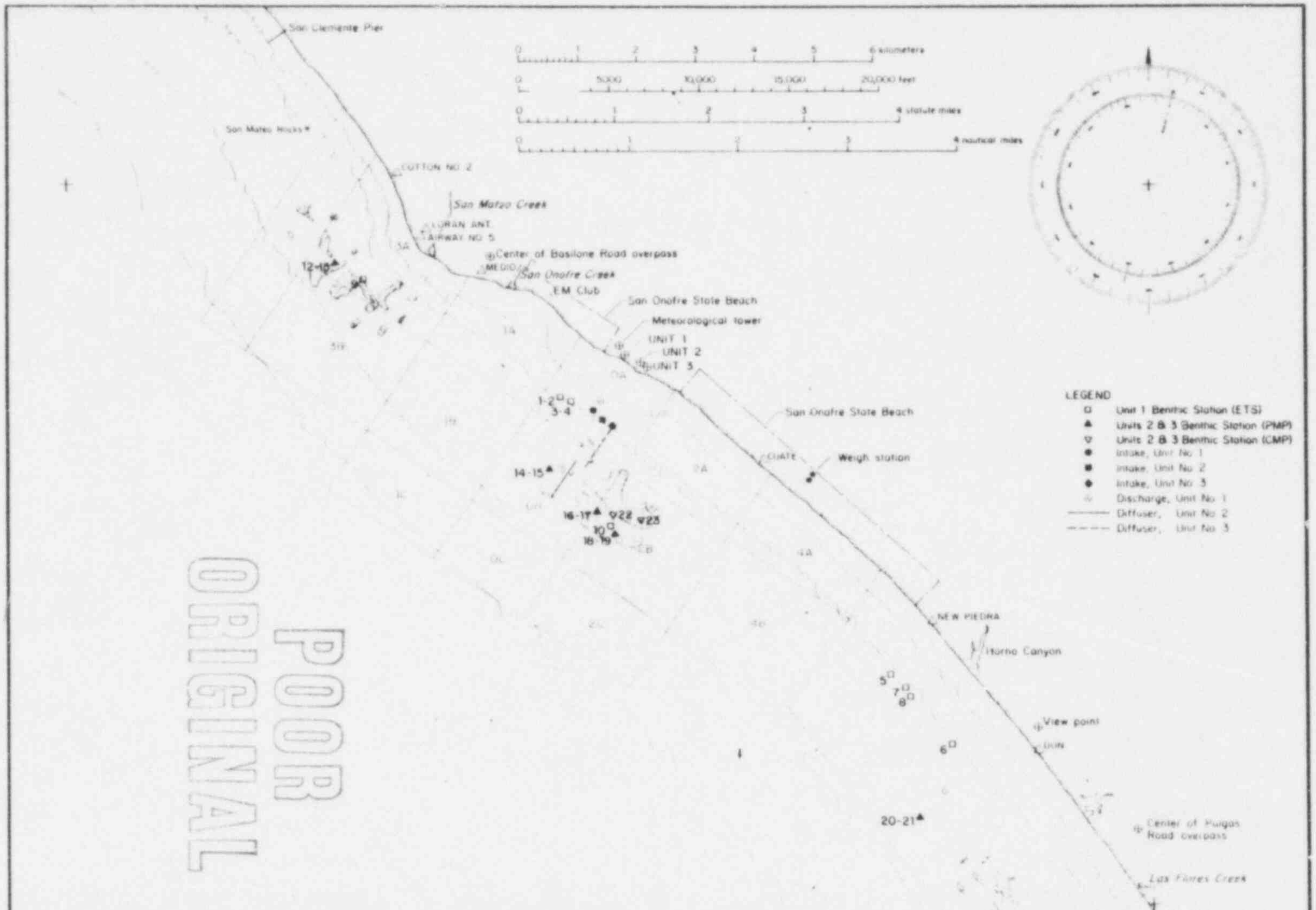

Figure 9-1. ETS, CMP, and PMP benthic station locations at San Onofre Nuclear Generating Station. Shaded areas represent the areal extent of the kelp canopies sampled in December 1978.

The ETS sampling design includes eight cobble stations located on the nearshore isobath and three kelp stations (SMK, SOK, and BK located in the San Mateo, San Onofre, and Barn kelp beds, respectively) on the offshore isobath (Figure 9-1). These eleven permanent benthic stations, marked with surface buoys, were established in areas of comparable substrata in February 1975 (LCMR, 1975). Four of the eight nearshore stations were established in Zone 0A near the discharge and four were established downcoast in the Zone 6 reference area. The placement of the inshore cobble stations was based on three considerations: (1) the location and availability of cobble substratum, (2) avoidance of the complicating factors associated with sampling the discharge riser and surrounding artificial substratum (rip-rap), and (3) avoidance of the SONGS Units 2 and 3 construction activities immediately downcoast of Unit 1. The four stations located approximately 9 km downcoast on the nearshore isobath were restricted to available areas of cobble and sandstone shelf. Each kelp bed station was originally established on substratum representative of the general area within the kelp bed. For identification purposes, the ETS inshore benthic stations are numbered consecutively from upcoast to downcoast. Stations 1 through 4 are located in Zone 0A and Stations 5 through 8 are located in Zone 6. Similarly, the ETS offshore kelp stations are numbered 9, 10, and 11 and include SMK, SOK, and BK, respectively.

The CMP benthic study added two stations within SOK in 1977 (MBC, 1978), which are located a short distance upcoast and downcoast of the ETS SOK station (Figure 9-1) on the offshore isobath. For this report the two CMP stations within SOK are referred to as Stations 22 and 23 (previously labeled SOK-U and SOK-D respectively; MBC, 1978).

Each permanent benthic station for the ETS and CMP studies is a band transect 10 m long and 1 m wide and is divided into ten, 1-m^2 quadrats. Organisms are identified in the field and are surveyed quarterly at each station using non-destructive sampling techniques. Conditions permitting (i.e., adequate visibility), marine biologists identify and enumerate solitary macroorganisms and make visual estimates of percent areal coverage of colonial and encrusting macroorganisms in each of the 10 quadrats at each station. These data are recorded on preprinted data sheets. Organisms for all benthic programs presented in this chapter are defined as those organisms living on the exposed portions of the hard substrata. In order to maintain consistency in data recording among biologists, the type of data to be reported for each organism is standardized and indicated on the data sheets. Conspicuous organisms which cannot be field identified are collected outside the sampling area and returned to the laboratory for taxonomic determination. Dominant habitat forming organisms which cannot be specifically identified are classified into higher taxonomic groups, such as unidentified hydroids or ectoprocts. Descriptive growth forms are also employed to identify taxa groups. For example, unidentified ectoprocts may be encrusting or erect. Another growth form classification is the algal group of Parvosilvosa. This growth form group includes all minute algae growing in dense patches on hard substrata (Neushul and Dahl, 1967). Bottom characteristics and relief of each quadrat are described. General oceanographic observations of surface and bottom water temperatures, visibilities, and surge conditions are recorded. Additionally, the following information is collected within the band transects at the kelp stations: (1) number of stipes on each individual kelp plant, counted 2 m above the bottom, (2) general conditions of the kelp plants (e.g., tattered fronds), and (3) kelp growth (e.g., new fronds).

Quarterly ETS surveys were conducted during 1978 on 1 February, 10-25 May, 14 July-25 August, and 16-26 October. Persistent storms during the first quarter of 1978 prevented ten stations from being sampled during the first survey. During the second quarter only three stations in Zone 0A and two kelp stations were sampled due to loss of the transect markers by sand inundation and/or storm-induced station buoy movement. During the third quarter, three stations could not be relocated after intensive searches utilizing an electronic positioning system, compass headings to known land marks, sextant angles, and extensive diver reconnaissance. These stations were re-established at new locations on similar substrata. These re-established stations included two reference stations in Zone 6 and the kelp station at Barn Kelp. During the third and fourth quarterly sampling periods all stations were sampled; however, no biological data were collected at two stations in Zone 0A and one station in Zone 6 because of extensive sand accretion. The two CMP stations located in SOK were sampled during 1978 on 11 April, 8 June, 21-22 September, and 27 November.

The PMP benthic program is designed to collect baseline data on the cobble communities located further offshore on approximately the 14-m isobath. The sampling design includes ten stations arranged in pairs allocated among two reference areas and the area near the Units 2 and 3 diffuser-discharge lines. The PMP sampling design evolved from the Unit 1 ETS program with data collection techniques developed from terrestrial studies. A brief narrative on the selection of station locations and sampling techniques is presented below.

Subtidal benthic reconnaissance and sampling investigations on cobble substratum were conducted from January to July 1978 to locate suitable station areas and collect preliminary data on sampling techniques. Reconnaissance dives were made on all cobble/boulder areas identified from side-scan sonar records (IRC, 1978) from San Mateo Point to the Barn Kelp Bed between the 13 and 15-m isobaths. Observations made during these dives identified areas that were similar with respect to cobble/boulder substrata, relief, and biological communities. As a result of these dives and a consideration of the study objectives, five station pairs (10 stations) were established to sample the representative cobble habitats (Figure 9-1). Station pair 12-13 is located in the upcoast reference area. Station pairs 14-15 and 16-17 are located upcoast and downcoast of the diffuser-discharges, respectively, and within the potential area of influence of the Units 2 and 3 diffuser-discharges. Station pair 18-19, located downcoast of station pair 16-17, is situated near the downcoast limit of the San Onofre cobble area within the SOK area. Station pair 20-21 is located approximately 9 km south in the downcoast Don Light reference area (Figure 9-1).

Each permanent PMP benthic station is a rectangle measuring 2 m x 3 m and station pairs are permanently marked with a surface buoy attached to a 907 kg anchor block. Each 6-m^2 station is sampled by a point contact sampling technique similar to methods utilized in terrestrial vegetation studies (Goodall, 1952; Winkworth, 1955; Greig-Smith, 1957) and adapted for use in the PMP benthic studies. Advantages of the point contact method for use in marine ecological studies have been reviewed by Carter et al. (1979) and include (1) the objectivity of the technique (i.e., no percent areal coverage estimation is required by the biologist), (2) estimation of the relative abundance of all taxa or substrata encountered for direct comparison by summing the number of contacts, (3) the ability to derive a quantitative, objectively collected, estimate of the ecological layering of each taxon (Dayton, 1975; Foster, 1975), and (4) the derivation of a statistical confidence interval which may be applied to the estimated abundance of each taxon or substratum type encountered.

938239

Benthic organisms at each station are sampled by two methods to generate temporal abundance patterns and spatial dispersion data. Dispersion statistics are a function of the variance to mean ratio, with values greater than one generally suggesting contagious or clumped populations. Values less than one suggest regular or evenly spaced populations (Elliott, 1971; Pielou, 1977). To collect these data, diving biologists utilize two reference (stationary) lines and one movable sampling line to sample each 6-m^2 station with 300 evenly distributed points (Figure 9-2). Data collected at each point include the identification of substratum type and macroorganisms present. Up to three levels of organisms, indicating layering in the community, are recorded. Additionally, four 0.125-m^2 square quadrats are randomly located within the 6-m^2 station area and are sampled with 60 evenly distributed points to observe small cryptic, clumped, or patchily distributed organisms. Data for both sampling elements (6-m^2 and 0.125-m^2) are recorded by individual biologists on task-specific data sheets. Designated solitary or motile organisms not sampled by the point contact technique, but observed to be conspicuous within the sampling area are enumerated. Conspicuous organisms that cannot be field identified are collected outside the sampling area and returned to the laboratory for taxonomic determination. General oceanographic observations on surface and bottom water temperatures, visibilities, and surge conditions are recorded.

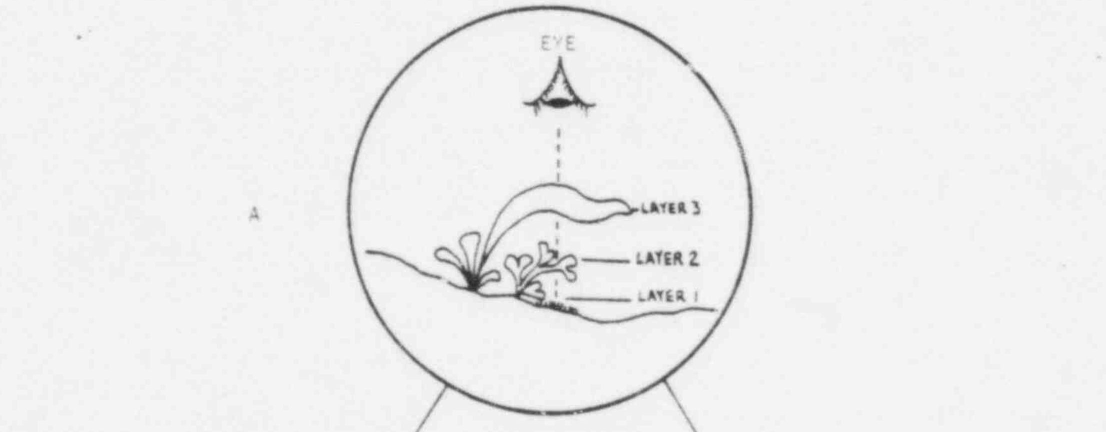

Figure 9-2. An illustration of multiple layering sampled at a single point (a) with examples of divers sampling evenly distributed points on a line (b) and within a quadrat (c) (after Carter et al., 1979).

Tagged colonies of the sessile anthozoan, Muricea, are measured semiannually. Data collected include measurements of maximum width and height, the species (M. californica or M. fruticosa), the substratum, planar orientation, and location (within or extralimital to the nearest benthic station) collected. Additionally, age of Muricea colonies in years may be determined using height measurements derived by Grigg (1974). Assuming that areas which periodically exhibit substratum movement would limit or restrict the growth or persistence of Muricea, height or age of colonies may be used to evaluate spatial and temporal substratum stability.

To effectively document changing substrata composition, wide area substrata reconnaissance is also conducted at each station pair. This task includes sampling four 30-m transects extending upcoast (300°), downcoast (120°), inshore (030°), and offshore (210°) from each station pair. Each 30-m transect line is divided into 100 equal sections denoted by numbered placards. After the transect line has been positioned by the diver, the substratum under each placard is identified as boulder, cobble, or sand. For the PMP benthic study the following functional substratum definitions are employed for boulder and cobble. Boulder is defined as rock substratum which is immovable by natural current conditions and/or which measures 26 cm or greater in greatest linear dimension. Accordingly, cobble is defined as rock substratum whose greatest linear dimension ranges between 1 and 26 cm and/or can be moved by natural bottom currents. By incorporating a component of mobility into the substratum definition, a cobble size rock which is permanently attached or wedged into a crevice would be identified as a boulder, because biologically the cobble would be a permanent substratum, similar to a large size boulder.

In association with the offshore station location and sampling efforts, numerous dead specimens of the chestnut cowry, Cypraea spadicea, were encountered and randomly collected in order to investigate a possible mass mortality due to burial by sediment. Maximum length of all Cypraea shells was determined and shells grouped according to the degree of erosion of the shell's nacreous layer. Class one shells are characterized by no erosion of the nacreous layer, and class two shells are characterized by a loss of surface sheen. Class three shells exhibit a loss of the nacreous layer. Shells were also examined for degree of development.

The sampling frequency of the PMP benthic surveys is quarterly. However, this program began in the second half of 1978; therefore, all stations were surveyed twice: 2-9 August and 31 October-8 November. Tagged Muricea colonies were measured during the October-November 1978 survey.

DATA ANALYSIS

Analysis of the ETS and CMP data was primarily a qualitative assessment of community and population estimates by tabular and graphical methods using density (no./m^2) and number of species. Although trends and patterns are noted, no rigorous statistical evaluation was used because of the limited data. The missing data points associated with early 1978 storms and the loss of cobble habitats due to accretion of sand diminished the potential 1978 data set by 50%. The nearshore isobath of cobble stations was most affected by the missing data points (a loss of 60% of the scheduled sampling points). Data loss at the ETS and CMP offshore kelp stations was 15%.

Analysis of the PMP cobble data was also primarily a descriptive treatment of community and population data by tabular and graphical methods. Statistical methods were generally not employed, since the 1978 data set comprises only two quarterly surveys. The sampling design for the PMP study is oriented toward identification of temporal patterns, and two surveys do not provide sufficient data to test the hypotheses the experimental design addresses. However, to elucidate community relationships among the PMP stations, normal and inverse classification analysis was performed using the Canberra metric dissimilarity index (Lance and Williams, 1966, 1967; Clifford and Stephenson, 1975). The untransformed data from all stations consisting of the total contacts for all taxa levels were used to generate station and species Canberra dissimilarity matrices. The quantitative Canberra coefficient is relatively insensitive to large or small attribute scores and represents a moderately objective coefficient in the numerical classification of ecological data (Boesch, 1977). The dissimilarity matrices were then subjected to an agglomerative, group averaging strategy (unweighted pair-group method using arithmetic averages; Sneath and Sokal, 1973) resulting in station and species groupings or clusters.

RESULTS

The results and analyses of the 1978 data presented below are grouped under two subject headings. The inshore cobble stations and the kelp stations offshore form one group. The offshore stations located on cobble substratum without kelp canopies form the other group.

INSHORE COBBLE AND OFFSHORE KELP STATIONS

Number of Taxa

The total number of taxa recorded during each survey at the inshore cobble stations is presented in Table 9-1. Within Zone 0A, near the discharge, the number of taxa sampled was consistently greatest at Station 1, with maximum numbers of taxa being sampled during the July-August survey period at both Stations 1 and 2. During the May survey two organisms were observed at Station 3, the erect anthozoan Muricea californica and unidentified onuphid polychaetes residing in homogeneous fine sand tubes. The sampling area at Station 3 was 100% sand. Tips of Muricea stalks above the substratum appeared healthy, with many opened polyps; however, the stalk portion below the sand apparently was moribund. Tubes of onuphid polychaetes had not been observed at Station 3 during any previous survey, and were probably recruited to the new sand habitat which

Table 9-1. Number of benthic taxa observed at the inshore cobble stations during 1978.

Survey	Station							
	Zone 0A				Zone 6			
	1	2	3	4	5	6	7	8
February	*	*	*	*	*	*	*	*
May	44	36	2	*	*	*	*	*
July	53	43	+	+	21	48	+	49
October	27	24	+	+	18	40	+	27

* Station not sampled, for details see page 9-6.

\+ No biological data collected, area observed to be 100% sand.

938242

resulted from sand deposition during the early 1978 storms. A minimum estimate of the increase in sand depth at Station 3 was 30 cm as revealed by sand height which reached the top of several transect markers. A 70% increase in sand cover was observed at Station 3 when the 1977 November and 1978 May sampling periods were compared.

Similar to Zone OA stations, the total number of taxa sampled at Zone 6 stations was also maximum during the July-August survey. Stations in Zone 6 exhibited a greater range in number of taxa during both surveys with Station 5 exhibiting the minimum number of taxa at a station in both zones during the last two quarterly surveys.

A comparison of the number of taxa sampled in Zones OA and 6 in 1978 with previous surveys is presented in Figure 9-3. The pooled data by zone for all stations on the inshore cobble isobath showed a general decrease in number of taxa during the 1978 sampling period, down to levels similar to those observed during the 1975 July sampling period.

Total number of taxa observed at each offshore kelp station during 1978 are presented in Table 9-2. Greater numbers of taxa were consistently recorded at SMK and BK stations. Both stations averaged 67 taxa/survey with the maximum number of taxa noted during the July survey. CMP Stations 22 and 23 averaged 53 and 52 taxa/survey, respectively. Maximum numbers of taxa were also noted at CMP Stations 22 and 23 during the summer (June) sampling period. The lowest numbers of taxa sampled were consistently recorded at SOK, which averaged 36 taxa/survey. Minimum numbers of taxa were consistently recorded at all stations during the April and May surveys.

The number of taxa observed at the offshore kelp stations since the initiation of the respective programs through 1978 is presented in Figure 9-4. Three stations, SMK, BK, and CMP 23, show a general pattern of increasing numbers of

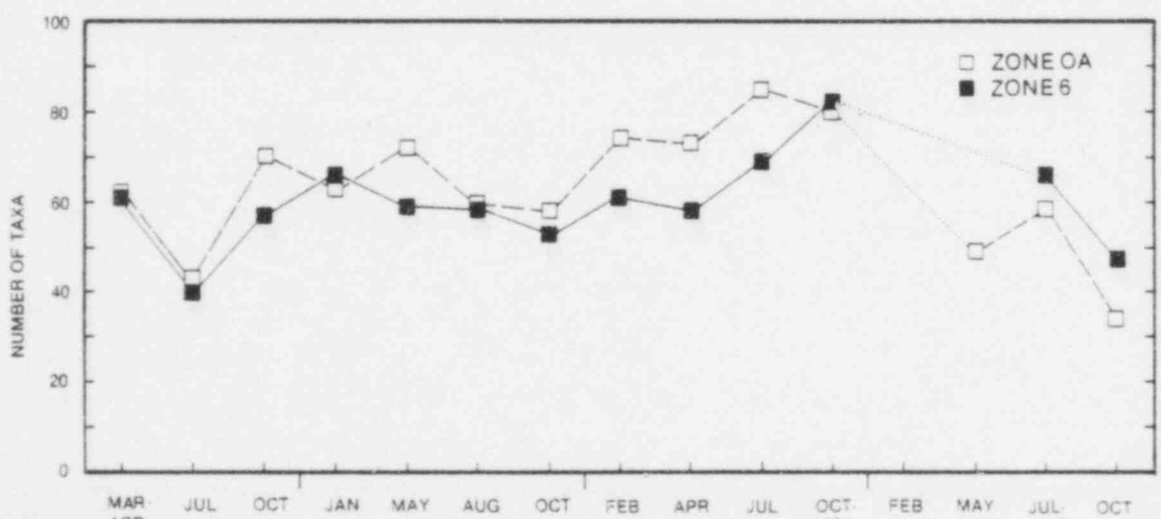

Figure 9-3. Number of benthic taxa observed at inshore cobble stations (1975-1978). Stations not sampled indicated by (.....). For details see page 9-6.

938243

Table 9-2. Number of benthic taxa observed at the offshore San Mateo (SMK), San Onofre (SOK), Barn Kelp (BK) stations during 1978.

Survey	Station				
	SMK ETS 9	SOK ETS 10	BK ETS 11	SOK CMP 22	SOK CMP 23
February	67	*	*		
April				50	37
May	63	33	*		
June				58	63
July	70	39	75		
September				48	57
October	66	36	59		
November				56	52

*Stations not sampled, for details see page 9-6.

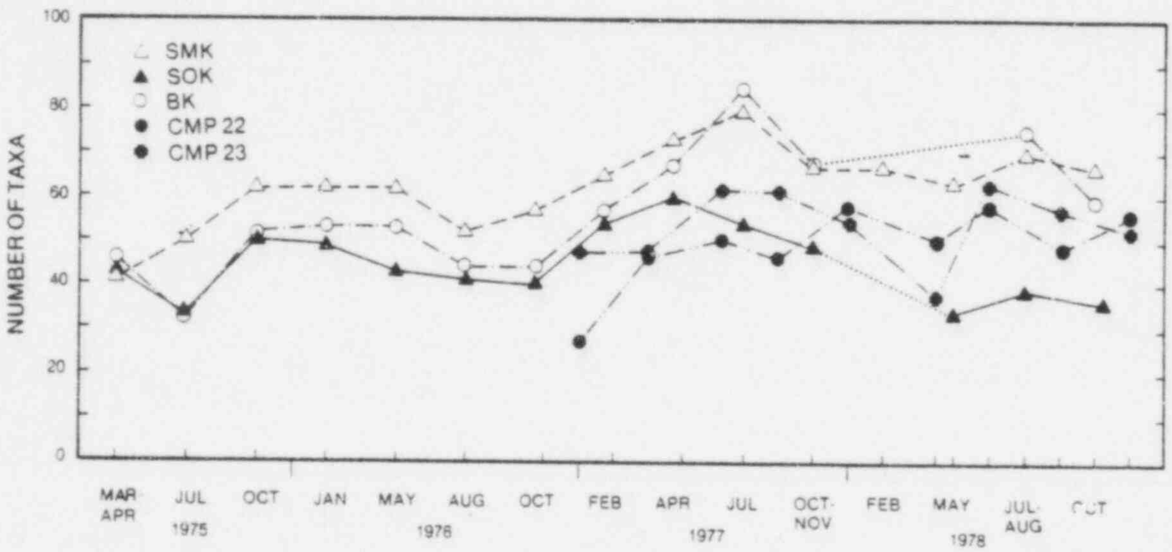

Figure 9-4. Number of benthic taxa observed at the offshore kelp stations (1975-1978). Stations not sampled indicated by (.....). For details see page 9-6.

taxa during the spring or summer in 1977 and 1978 followed by a decreasing trend in the fall or winter. Stations SOK and CMP 22 exhibited an increase in numbers of taxa from the late fall and winter of 1976 to the spring of 1977. Annual fluctuations in numbers of taxa at these stations after the 1977 spring sampling period were not apparent.

Data on juvenile and adult Macrocystis observed in each quadrat at each kelp station sampled during 1978 were recorded. Giant kelp plants (Macrocystis), including juveniles and adults, were encountered at SMK, BK, and CMP 23 during 1978. Dense numbers of juveniles were observed at SMK during the July survey, with fewer numbers being recorded during the October survey at SMK and BK. No plants were observed at CMP 23 or SOK. Moribund holdfasts were observed at all

stations at least once during the year. The data from the kelp bed surveys indicated that recruitment to the three kelp beds during 1978 occurred primarily during the late summer and fall, with little recruitment occurring between the December 1977 survey and the May 1978 survey. Generally, the live plants were in good condition, i.e., lack of tattered or faded fronds, or not covered with encrusting organisms.

Trophic Structure

All organisms observed during the benthic studies were assigned to trophic types which are defined in the glossary. In some cases an organism may occupy more than one trophic type. In these cases, the method by which an organism procures the majority of its food was designated as the trophic type. The trophic types and the methods of designating the type for each species are the same as those used previously for the ETS program (LCMR, 1978c). The number of trophic types sampled during 1978 at the inshore cobble stations is presented in Table 9-3, with the trophic types for each kelp station presented in Table 9-4. Primary producers and suspension feeders were the dominant trophic types at the inshore cobble stations, with suspension feeding organisms exhibiting a slightly higher annual mean number/station. The annual mean numbers of primary producers and suspension feeders sampled at Stations 1 and 2 were nearly identical to Stations 5, 6, and 8 (Table 9-3). Mean numbers of grazers, scavengers, and preda-

Table 9-3. Trophic composition as represented by the number of each trophic type present at the inshore cobble stations during 1978.

Trophic Type	Station						
	Zone 0A			Zone 6			
Survey	1	2	mean/station	5	6	8	mean/station
Primary producers							
May	12	12					
July/August	19	18	13.5	6	21	14	12.8
October	12	8		6	19	11	
Suspension Feeders							
May	20	16					
July/August	20	19	16.3	12	22	27	17.3
October	12	11		10	20	13	
Grazers							
May	3	1					
July/August	3	1	1.7	0	0	1	0.2
October	1	1		0	0	0	
Scavengers							
May	6	4					
July/August	6	3	4.2	1	3	4	2.0
October	2	4		1	1	2	
Predators							
May	3	3					
July/August	5	3	2.3	1	2	3	[illegible].2
October	0	0		1	0	0	

938245

Table 9-4. Trophic composition as represented by the number of each trophic type present at the offshore kelp stations during 1978.

Trophic Type	Station				
	SMK	SOK	BK	SOK	SOK
Survey	ETS 9	ETS 10	ETS 11	CMP 22	CMP 23
Primary Producers					
February	17	*	*		
April				11	11
May	23	5	*		
June				13	17
July/August	25	11	20		
September				15	17
October	23	8	18		
November				13	17
MEAN	22.0	8.0	19.0	13.0	15.5
Suspension Feeders					
February	30	*	*		
April				21	15
May	25	14	*		
June				24	23
July/August	27	16	33		
September				20	22
October	30	18	29		
November				21	22
MEAN	28.0	16.0	31.0	21.5	20.5
Grazers					
February	4	*	*		
April				6	3
May	4	5	*		
June				6	4
July/August	4	3	3		
September				4	4
October	4	4	2		
November				4	3
MEAN	4.0	4.0	2.5	5.0	3.5
Scavengers					
February	10	*	*		
April				6	6
May	6	6	*		
June				10	10
July/August	7	5	9		
September				5	6
October	7	4	6		
November				12	6
MEAN	7.5	5.0	7.5	8.2	7.0
Predators					
February	6	*	*		
April				6	2
May	5	4	*		
June				5	9
July/August	7	4	10		
September				4	8
October	2	2	4		
November				6	4
MEAN	5.0	3.3	7.0	5.25	5.75

*Station not sampled, for details see page 9-6.

938246

tors were higher in Zone OA, but exhibited greater variation within each trophic type.

Similar to the inshore cobble stations, the offshore kelp stations supported a higher annual mean number of suspension feeding organisms at each kelp station with both primary producers and suspension feeding organisms being dominant. Stations SMK and BK supported the greatest annual mean number of primary producers and suspension feeders. The lowest annual mean of each trophic type. with the exception of grazing taxa, was consistently recorded at SOK. Annual means for each trophic type similar to those found at SOK were recorded at San Onofre CMP Stations 22 and 23. Comparison of surveys reveals the general trophic composition at each kelp station showed little temporal variation for each trophic category with the exception of predators, which exhibited moderate variation among surveys.

Predominant Organisms

A total of 14 organisms were selected as predominant in 1978 (Tables 9-5 and 9-6). Predominant organisms are those which account for 5% of the total number of individuals or total percent-cover for the annual data, and occur in greater than 50% of the Zone OA and 6 station-survey combinations, or at each kelp station at least once during the year.

Inshore Cobble Stations. At the inshore cobble stations, the predominant organisms estimated in percent-cover accounted for 71% of the total percent-cover abundance, while the predominant organisms estimated by enumeration accounted for 81% of the total abundance of enumerated organisms (Table 9-5). Six of the predominant organisms sampled at the inshore cobble stations were present in all station-survey combinations sampled. Stations which were not sampled because of poor weather, station loss, or sand inundation, were not included in the determination of the frequency of occurrence or the estimate of mean abundance per m^2.

Only a single percent-cover organism selected as predominant in 1978, the chlorophyte *Bryopsis hypnoides*, had not been selected in previous years. Two enumerated organisms, *Chelyosoma productum* and *Styela montereyensis*, were also selected as predominant for the first time in 1978. Three groups of organisms whose abundance was estimated in percent-cover were previously selected for graphical analysis (LCMR, 1978c). Continuation of these graphs for 1978 data is presented in Figure 9-5a-c. The organism group of Parvosilvosa/unidentified rhodophytes (Figure 9-5a) shows a decreasing trend during 1978 in Zone OA, attaining the lowest level recorded during the ETS benthic program. Similar low abundances of this group in Zone 6 were also recorded during 1978. Another group, unidentified crustose corallines (Figure 9-5b), exhibited percent-cover estimates which also revealed a general decrease in comparison with previous surveys in Zone OA. In Zone 6, however, the July/August survey results revealed the highest mean percent-cover reported during the four-year study. In comparison with Zone OA levels, however, this value is low. The third group, *Rhodymenia*/*Gracilaria* (Figure 9-5c), also showed low levels of percent-cover for both zones and general decreasing abundance trends in comparison with previous years.

Two enumerated organisms which were previously selected for graphical analysis (LCMR, 1978c) are presented in Figure 9-6a-b. *Diopatra ornata* continued to exhibit little annual variation in either zone from 1976 to 1978. *Diopatra ornata* was, however, less abundant during the 1978 July/August and October

Table 9-5. Rank order of abundance of predominant benthic organisms sampled at the inshore cobble stations during 1978.

	Total Abundance	Relative Abundance (%)	Percent Frequency of Occurrence	1978 Rank	1975-1977 Rank
PERCENT COVER TAXA					
Ectoprocts, unident (encrusting)	90.2	18.6	100	1	2
Parvosilvosa	64.6	13.3	100	2	1
Crustose corallines, unident	54.8	4.6	100	3	4
Ectoprocts, unident (erect)	43.9	9.1	100	4	6
Bryopsis hypnoides	33.8	7.0	58	5	-
Hydroids, unident	29.5	6.1	100	6	3
Rhodymenia spp.	25.2	5.2	92	7	5
Total Predominant	342.0	70.6			
All other taxa	142.1	29.4			
Total all taxa	484.1				
ENUMERATED TAXA					
Cystoseira/Halidrys	30.7	18.2	92	1	3
Diopatra ornata	29.5	17.5	100	2	1
Chelyosoma productum	28.6	17.0	67	3	-
Muricea californica	17.4	10.3	92	4	2
Styela montereyensis	15.8	9.4	75	5	-
Total Predominant Taxa	122.0	72.5			
All other taxa	46.3	27.5			
Total all taxa	168.3				

Table 9-6. Rank order of abundance of predominant benthic organisms sampled at the offshore ETS kelp stations during 1978.

Taxa	Total Abundance	Relative Abundance (%)	Percent Frequency of Occurrence
Percent Cover Taxa			
Crustose corallines, unident.	155.2	23.4	100
Parvosilvosa	123.3	18.6	100
Rhodymenia spp.	80.7	12.2	89
Ectoprocts, unident. (encrusting)	48.2	7.3	100
Total Predominant Taxa	407.4	61.5	
All Other Taxa	256.1	38.5	
Total Taxa	663.5		
Enumerated Taxa			
Diopatra ornata	24.7	12.3	100
Macrocystis spp.	15.3	7.6	56
Lytechinus spp.	13.1	6.5	56
Styela montereyensis	11.7	5.8	78
Muricea californica	11.5	5.7	78
Total Predominant Taxa	76.3	37.9	
All Other Taxa	124.1	61.9	
Total Taxa	200.4		

surveys in Zone 0A than in past surveys (Figure 9-6a). The Zone 6 abundances of Diopatra observed during these two surveys were near the lowest levels previously recorded at these stations. Muricea californica abundance levels in Zone 0A were similar to those previously recorded (Figure 9-6b), but the mean number/m^2 in Zone 6 exhibited a considerable decrease by the July/August survey, with a further decrease in the mean number/m^2 noted in the October survey.

Offshore Kelp Stations. Nine organisms were selected as predominant in the three ETS kelp stations during 1978 (Table 9-6). The four percent-cover organisms chosen were also selected as predominant for the results of the three previous years (LCMR, 1978c). Of the five enumerated taxa, only one, Diopatra ornata, had been previously selected as predominant. The predominant percent-cover taxa accounted for 62% of the total percent-cover recorded while the enumerated taxa accounted for 44% of the total number of organisms counted at the kelp stations.

Graphs of three selected organisms observed at all offshore kelp stations whose abundances were estimated by percent-cover are presented in Figure 9-7a-c. The rhodophyte group of Rhodymenia/Gracilaria exhibited conspicuous peak abundances during the spring and summer surveys at stations SMK and CMP 23, respectively, during 1978 (Figure 9-7a). Variations in abundances of Rhodymenia/Gracilaria at SOK, BK, and CMP 22 during 1978 were similar to those observed during 1977. Both CMP 22 and 23 exhibited considerably higher abundances than SOK throughout 1978, a trend which was also noted during the final three survey periods in 1977. In comparison with data collected at all San Onofre kelp stations, unidentified crustose corallines at SMK and BK have consistently exhibited low abundances and little annual variation since the beginning of the 1977

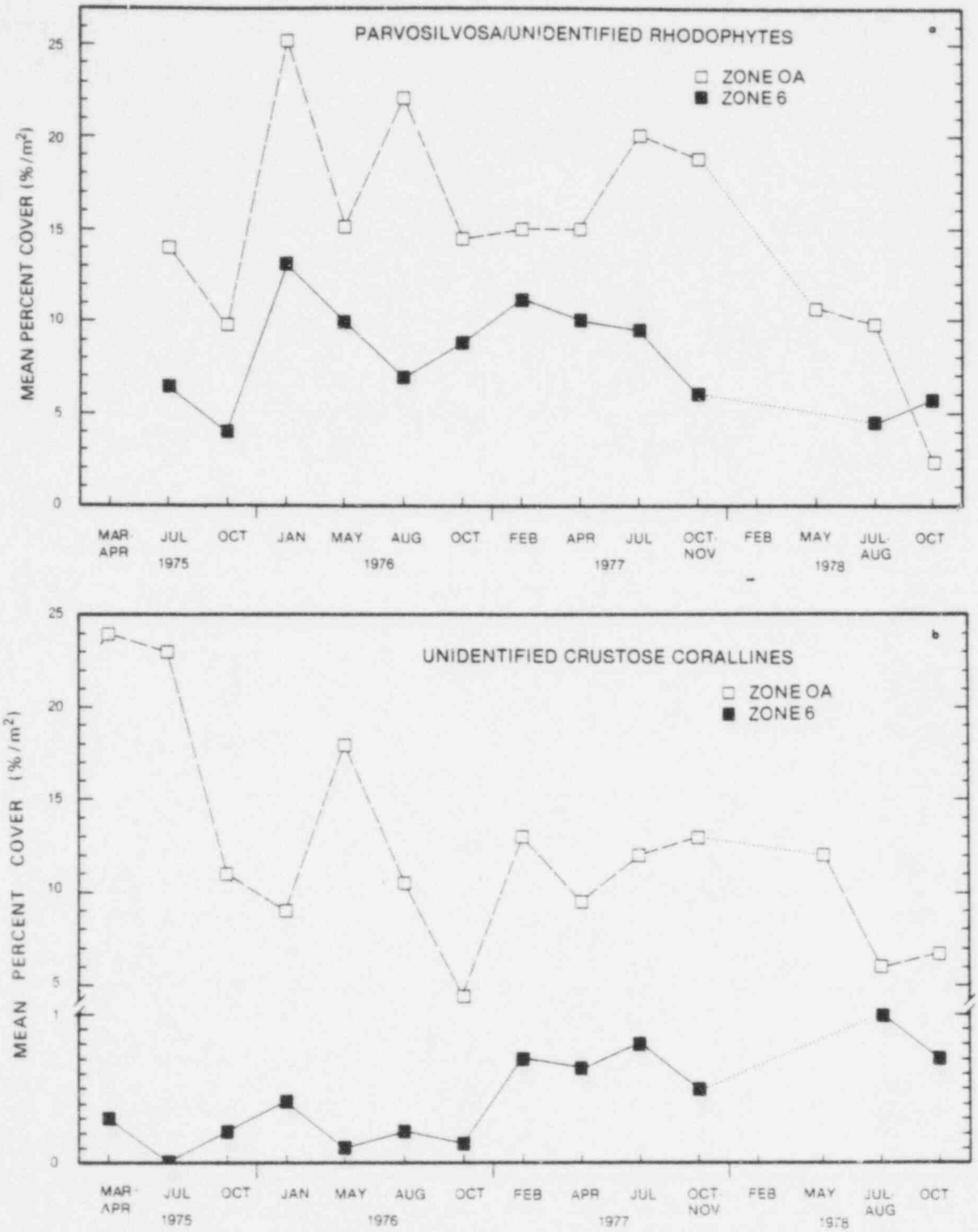

Figure 9-5a-c. Mean percent cover estimates of selected organisms sampled at inshore cobble stations (1975-1978). Stations not sampled indicated by (.....). For details see page 9-6.

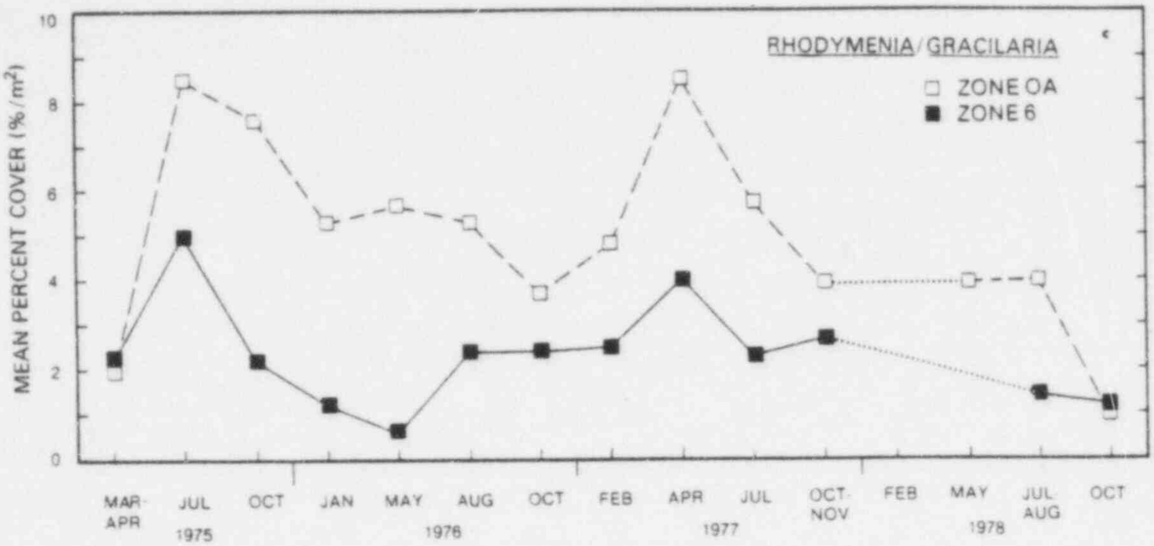

Figure 9-5. (Continued)

sampling period (Figure 9-7b). The functional group of Parvosilvosa/unidentified rhodophytes exhibited consistent levels of low abundance at BK with higher estimates at SMK and CMP 23 (Figure 9-7c). Similar abundance estimates were recorded at SOK and CMP 22 during both the 1977 and 1978 sampling periods. All San Onofre kelp stations have revealed a trend of increasing abundances of Parvosilvosa/unidentified rhodophytes since the 1978 summer sampling period.

Substrata Composition

Quarterly mean percentage estimates of sand cover for the cobble stations located in Zones OA and 6 from 1975 to 1978 are plotted in Figure 9-8. The composition of substrata at these nearshore cobble stations underwent dramatic changes in 1978. From 1975 to 1977, stations within Zone 6 exhibited high levels of mean percent sand cover compared to the low levels of sand cover in Zone OA. Results of the 1978 quarterly surveys revealed that substantial increases in sand cover had occurred at all inshore cobble stations in both zones.

Quarterly mean estimates of sand cover at all offshore kelp stations from 1975 to 1978 are plotted in Figure 9-9. From 1975 to 1978 kelp stations exhibited differential patterns of sand accretion and erosion. San Mateo kelp station has exhibited little variation in substratum composition since the initial sampling period in 1975. In contrast, SOK has exhibited considerable variation in mean sand cover ranging from over 60% in October 1975 to less than 30% in May 1976 and October 1978. Barn Kelp exhibited a pattern similar to SOK during the initial surveys until April 1977. Subsequent surveys at BK reveal little variation in sand cover except for an increasing trend exhibited during the final survey in 1978 at the relocated station. San Onofre kelp stations CMP 22 and 23 also exhibited differential patterns of sand cover with moderate variation between surveys. San Onofre kelp station CMP 22 has generally exhibited greater sand coverage than CMP 23 or SOK.

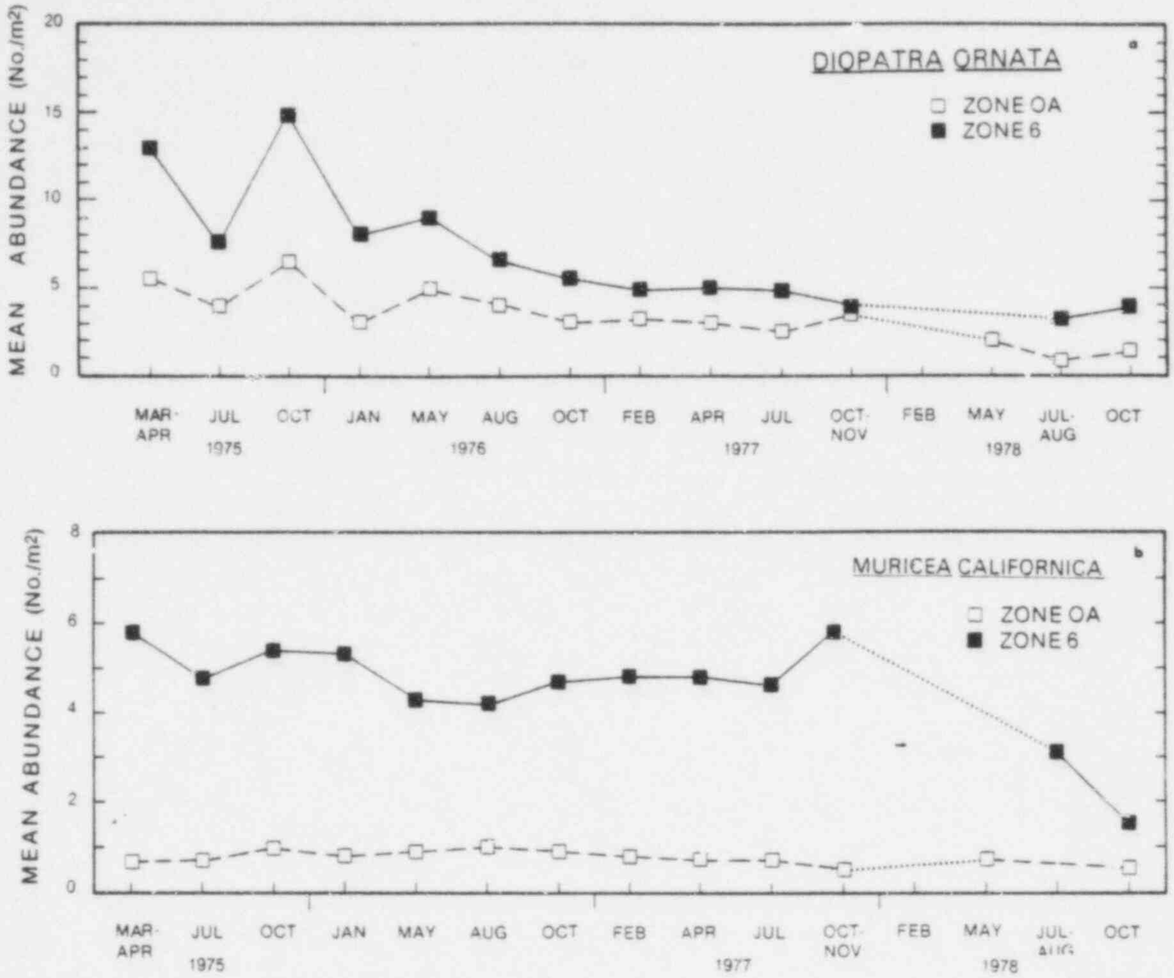

Figure 9-6a-b. Mean density/m^2 of selected organisms sampled at inshore cobble stations (1975-1978). Stations not sampled indicated by (.....). For details see page 9-6.

Diver observations during intensive station relocation efforts during the spring and summer of 1978 revealed that large regions were covered with sand within previous cobble station areas in Zone 6. Subjective estimates of increases in sand depth associated with 1978 storms on the inshore isobath averaged about 30 cm. Reconnaissance dives made on the offshore isobath in the vicinity of BK indicated conditions in this area were similar to those on the inshore isobath; however, accretion of sand was not as extensive, being deposited mostly between cobbles and in crevices, rather than burying the cobble substrata.

Mass Mortality

Concurrent with station relocation efforts and during the diver reconnaissance of areas for location of the PMP benthic stations, extralimital biological observations were recorded. Besides noting that many of the inshore and offshore cobble habitats had been buried, observations made during the summer revealed some of the cobble habitats were in the process of being eroded and ex-

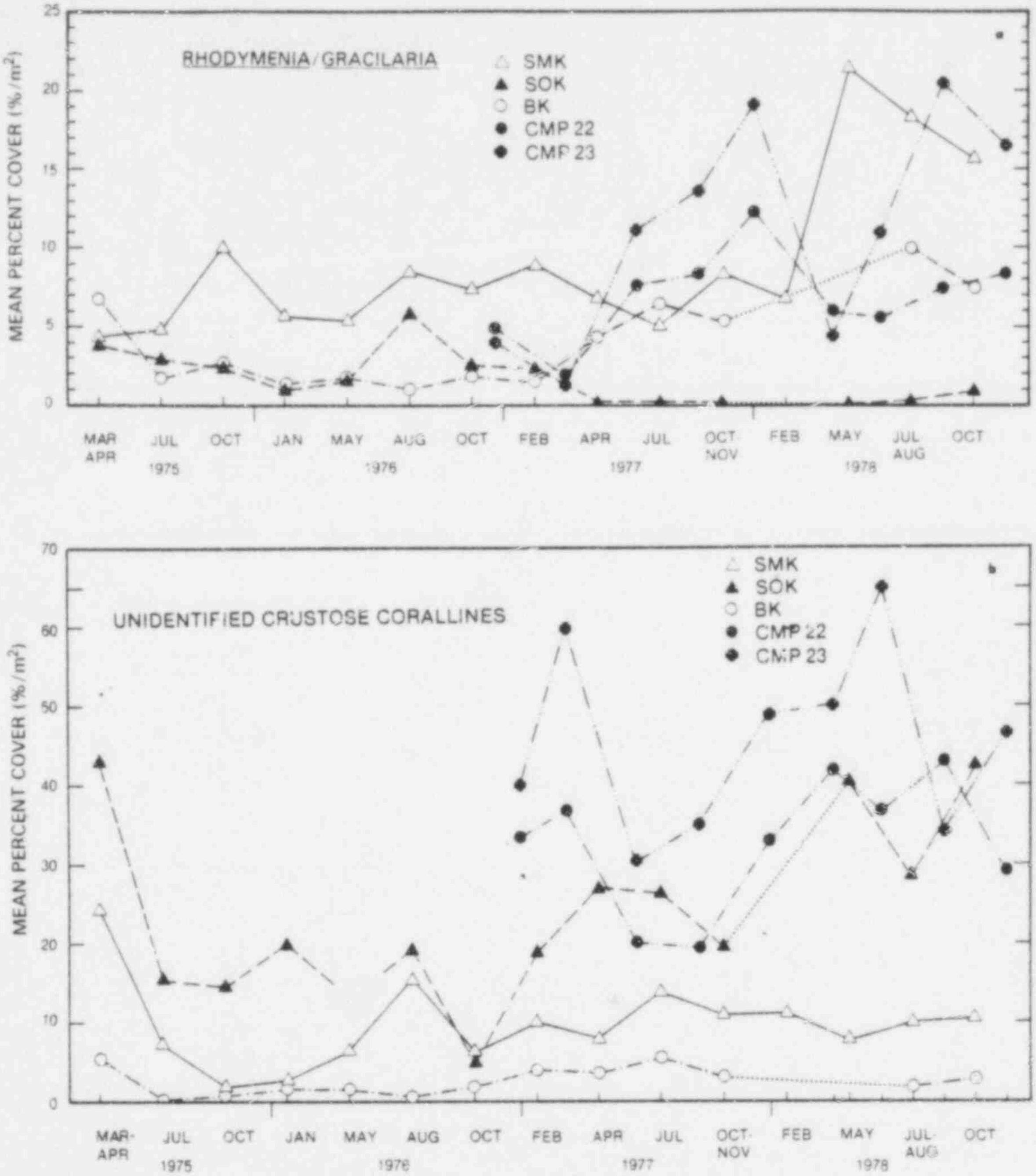

Figure 9-7a-c. Mean percent cover estimates of selected organism groups at offshore kelp stations (1975-1978). Stations not sampled indicated by (.....). For details see page 9-6.

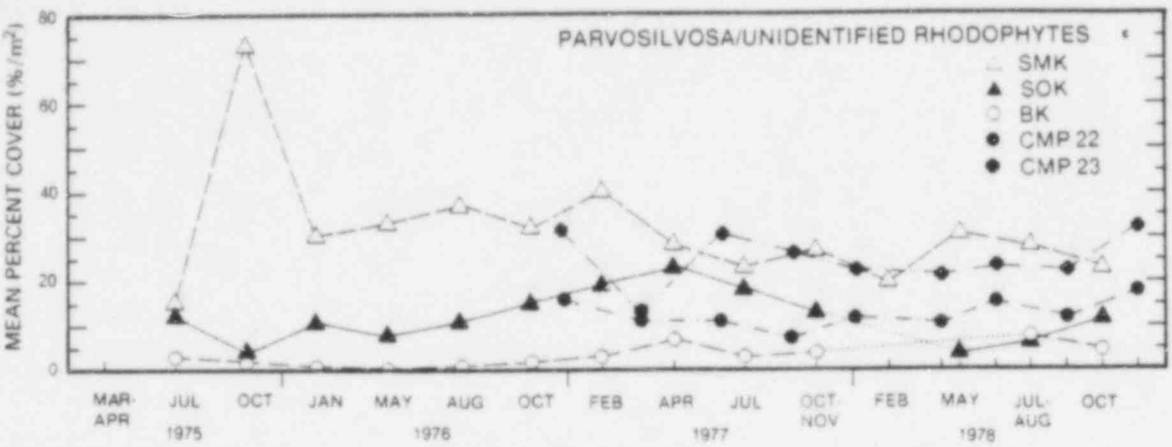

Figure 9-7. (Continued)

posed. During this period on both the inshore and offshore isobaths dead individuals of the chestnut cowry, Cypraea spadicea, were frequently encountered and many were collected. Because Cypraea is a member of the cobble habitat community and their shells, with and without the decaying animal, were particularly conspicuous, data on shell length and degree of shell erosion were collected to evaluate recent mortality. These data and a length frequency histogram are presented in Table 9-7 and Figure 9-10.

Mean shell length and range of the three Cypraea shell classes of erosion are very similar (Table 9-7). No single class can be differentiated by size from the others. A combined length frequency histogram (Figure 9-10) of all specimens collected closely resembled a normal distribution. The absence of skewness demonstrated the presence of several different size classes.

OFFSHORE COBBLE STATIONS

The sampling design for the offshore cobble stations (PMP study) utilizes two sampling strategies to generate baseline data for the offshore cobble habitats. These strategies include abundance estimates of the dominant organisms for detection of temporal patterns of variation by the point contact sampling of 6-m^2 area with 300 evenly distributed points. The second strategy subsamples the same 6-m^2 station area with four randomly placed 0.125-m^2 quadrats to generate dispersion data (in sensu Elliott, 1971) on the less conspicuous habitat forming organisms. These habitat forming organisms are functionally defined as the usurpers and providers of substratum and biotic space, i.e., secondary substratum (EPA, 1975) and may be cryptic and inconspicuous, clumped, and/or patchily distributed. These two sampling methods produce data specific to each technique and are presented independently in this section and considered collectively in the discussion with all the 1978 benthic data.

6-m^2 Quadrats

A summary of the 6-m^2 data generic to all stations including total percent hard substratum (cobble, boulder, shell debris) and total number of taxa observed is presented in Table 9-8. Total biological cover, biological cover con-

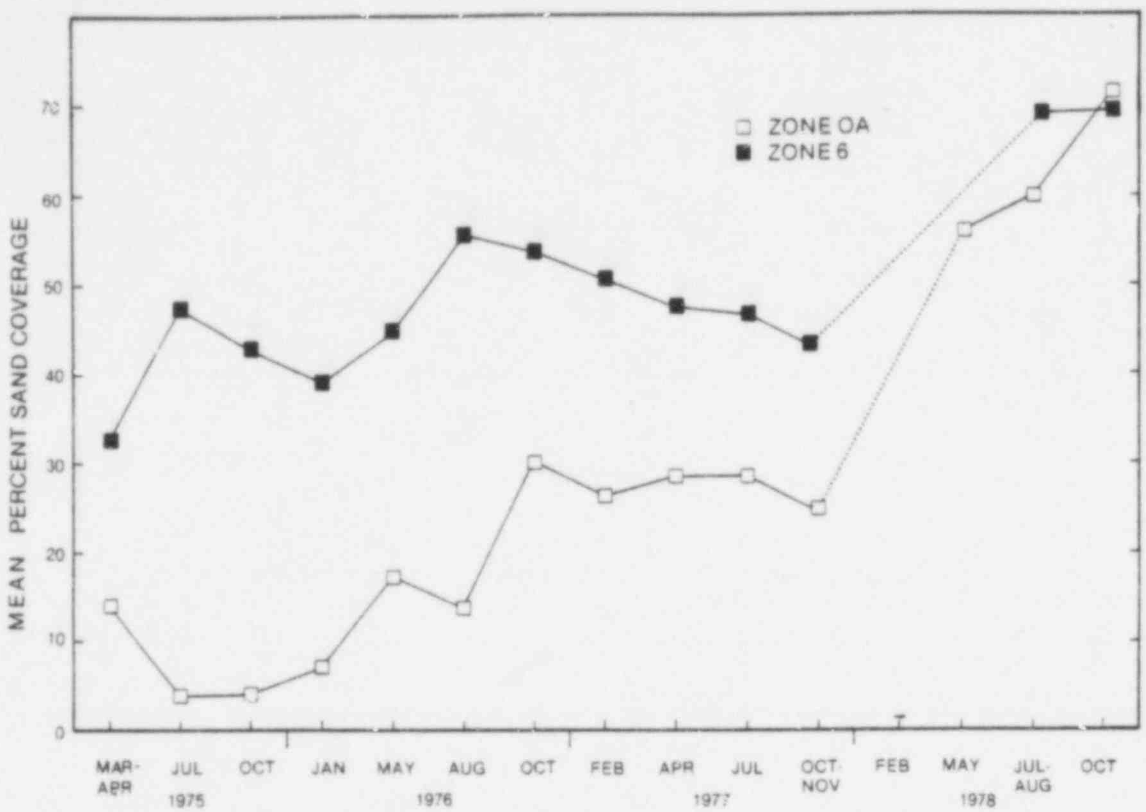

Figure 9-8. Mean percent composition of sand substratum sampled at the inshore cobble stations (1975-1978). Stations not sampled indicated by (.....). For details see page 9-6.

tributed by the five most abundant organisms, and the rank order of abundance for these organisms are presented in Table 9-9.

Total percent hard substratum measured within each paired 6-m^2 station ranged from a mean of 53.8% at station pair 20-21 to 92.2% at station pair 14-15 during the August survey period (Table 9-8). During the second sampling period, maximum within station pair hard substratum difference was 11% at station pair 14-15. Between survey comparisons of mean hard substratum estimates made at each station pair ranged from less than 1% at station pair 12-13 to a maximum of 10% at station pair 20-21, with a mean of about 5% for all station pairs.

During the October-November survey the wide area substratum reconnaissance task was initiated to detect large scale changes in substratum composition in the vicinity of each station pair (approximately 30-m radius). Results of this effort are presented in Table 9-10. Cobble substratum dominates the area surrounding station pairs 12-13, 14-15, and 18-19. The majority of the hard substratum at station pair 16-17 consists of boulders, and is surrounded by sand. Station pair 20-21 is composed of the least amount of hard substratum of any benthic station pair, and is surrounded by sand.

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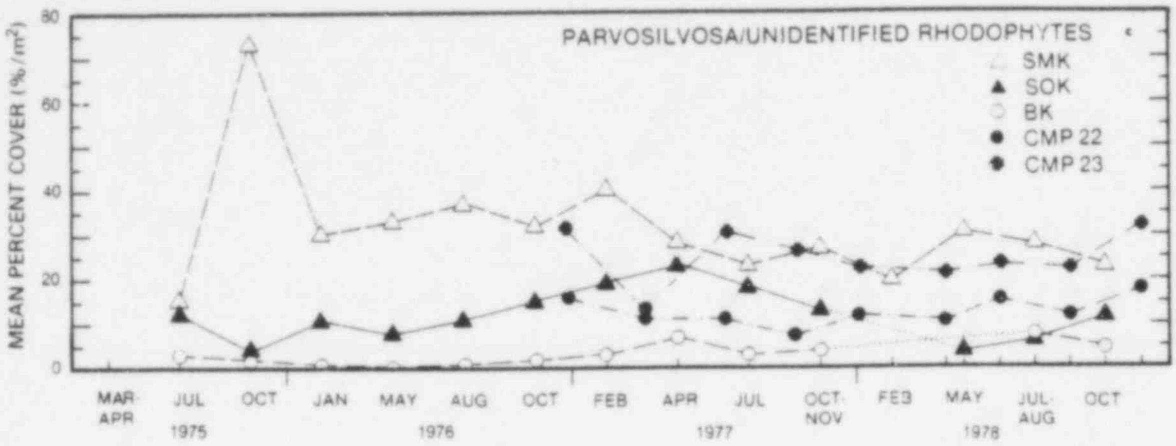

Figure 9-7. (Continued)

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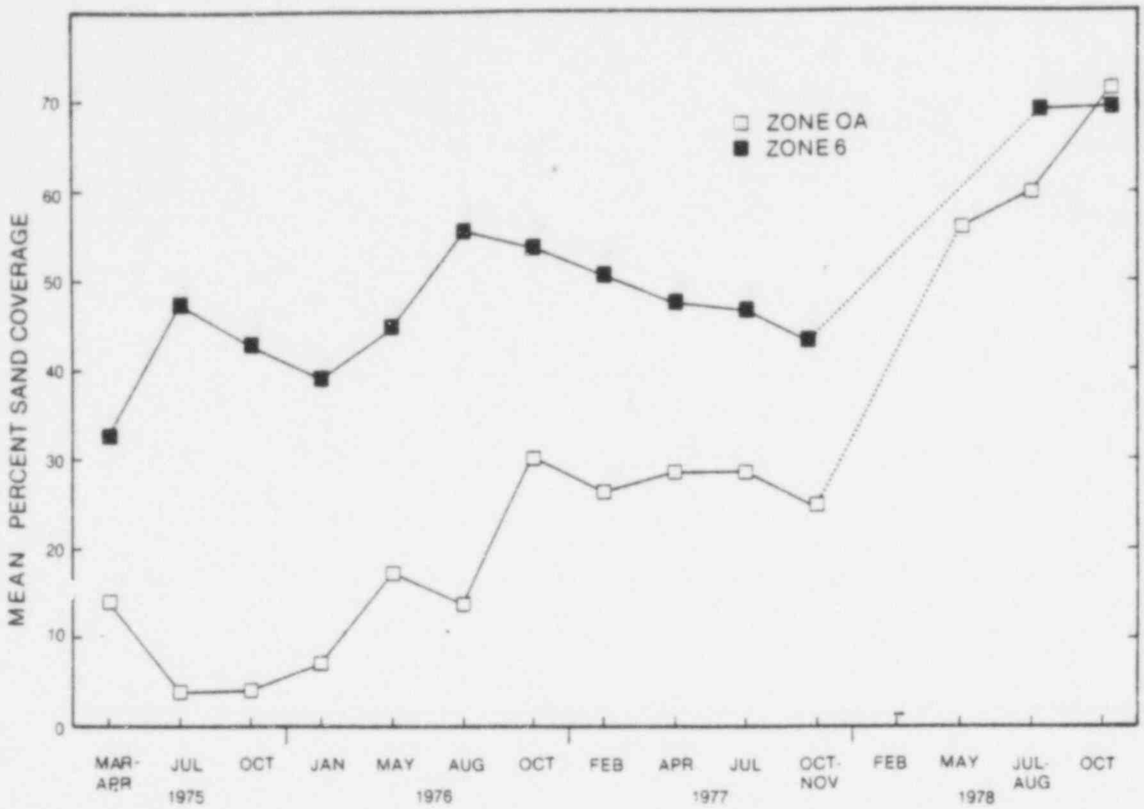

Figure 9-8. Mean percent composition of sand substratum sampled at the inshore cobble stations (1975-1978). Stations not sampled indicated by (.....). For details see page 9-6.

tributed by the five most abundant organisms, and the rank order of abundance for these organisms are presented in Table 9-9.

Total percent hard substratum measured within each paired 6-m^2 station ranged from a mean of 53.8% at station pair 20-21 to 92.2% at station pair 14-15 during the August survey period (Table 9-8). During the second sampling period, maximum within station pair hard substratum difference was 11% at station pair 14-15. Between survey comparisons of mean hard substratum estimates made at each station pair ranged from less than 1% at station pair 12-13 to a maximum of 10% at station pair 20-21, with a mean of about 5% for all station pairs.

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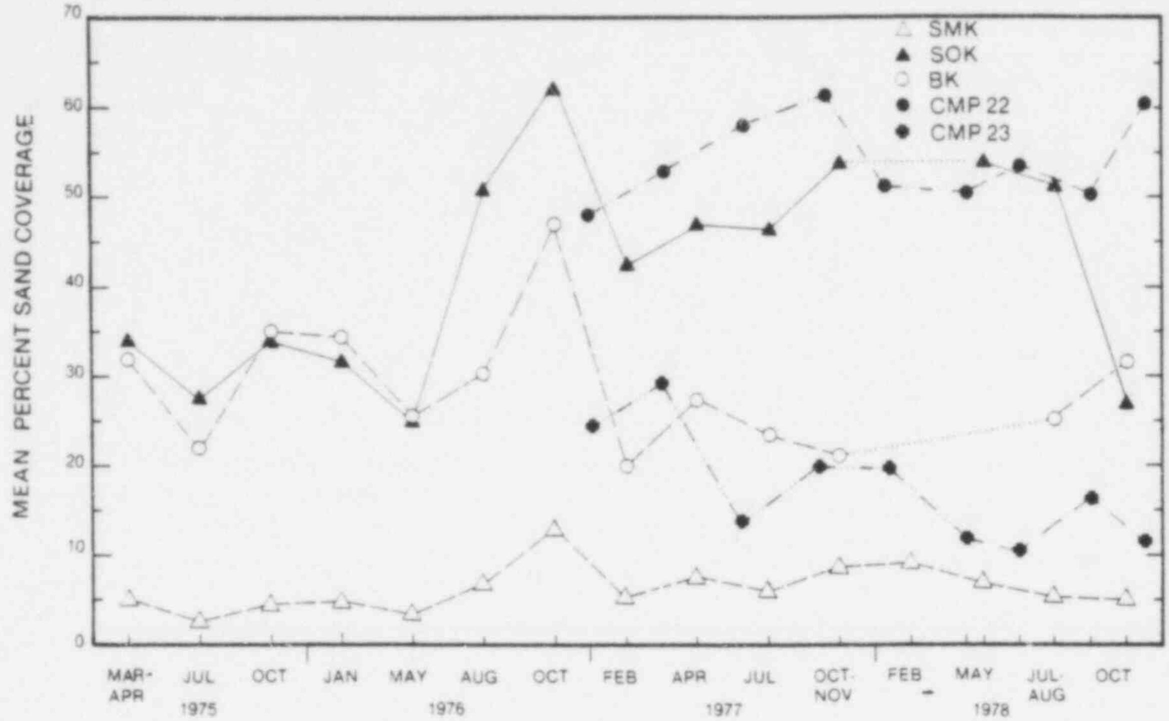

Figure 9-9. Mean percent composition of sand substratum sampled at offshore kelp stations (1975-1978). Stations not sampled indicated by (.....). For details see page 9-6.

Total number of taxa sampled ranged from 20 to 36 during the August survey and from 18 to 32 during the October-November survey (Table 9-8). Greatest variations between sampling periods were noted at station pairs 12-13 and 20-21 which exhibited decreases from the summer survey period. Minimum variation in number of taxa sampled between survey periods was observed at Station 14 and station pair 16-17, all located in the nearfield area of the SONGS Units 2 and 3 diffuser dishcarges.

Taxa which comprised the five most abundant organisms generally accounted for greater than 75% of the total biological cover and are considered to be the dominant taxa. These organisms and their rank order of abundance for the 6-m^2 sampling strategy during the two 1978 sampling periods are presented in Table 9-9. Fourteen organisms accounted for the five most abundant taxa sampled at each station during each sampling period. Parvosilvosa, an assemblage of algae with similar turflike growth formed the most abundant organism group sampled at station pairs 14-15 and 18-19, and Station 17 during both sampling periods (Table 9-9). Parvosilvosa was also included among the five most abundant taxa during each survey at each station. The foliose rhodophyte Rhodymenia spp. was abundant at station pairs 12-13 and 16-17, and Station 15 during each sampling period. The encrusting coralline algae complex was generally the second most abundant organism group sampled (Table 9-9) during both survey periods at station pairs 14-15, 16-17, and 18-19 which are all located within the San Onofre offshore cobble area.

Table 9-7. Cypraea spadicea shell organization according to degree of erosion. Specimens were randomly collected from cobble habitats on the 10 and 30-m isobaths during the 1978 sampling period.

Shell Characteristics	Class 1	Class 2	Class 3
Mean shell length (mm)	42.98	41.82	42.58
Sample size (n)	38	23	8
Range of shell lengths (mm)	52.67-30.39	51.65-31.38	46.64-37.38

Class 1 - Erosion absent, nacreous layer present
Class 2 - Erosion, and sheen absent
Class 3 - Shell fouled, broken, eroded

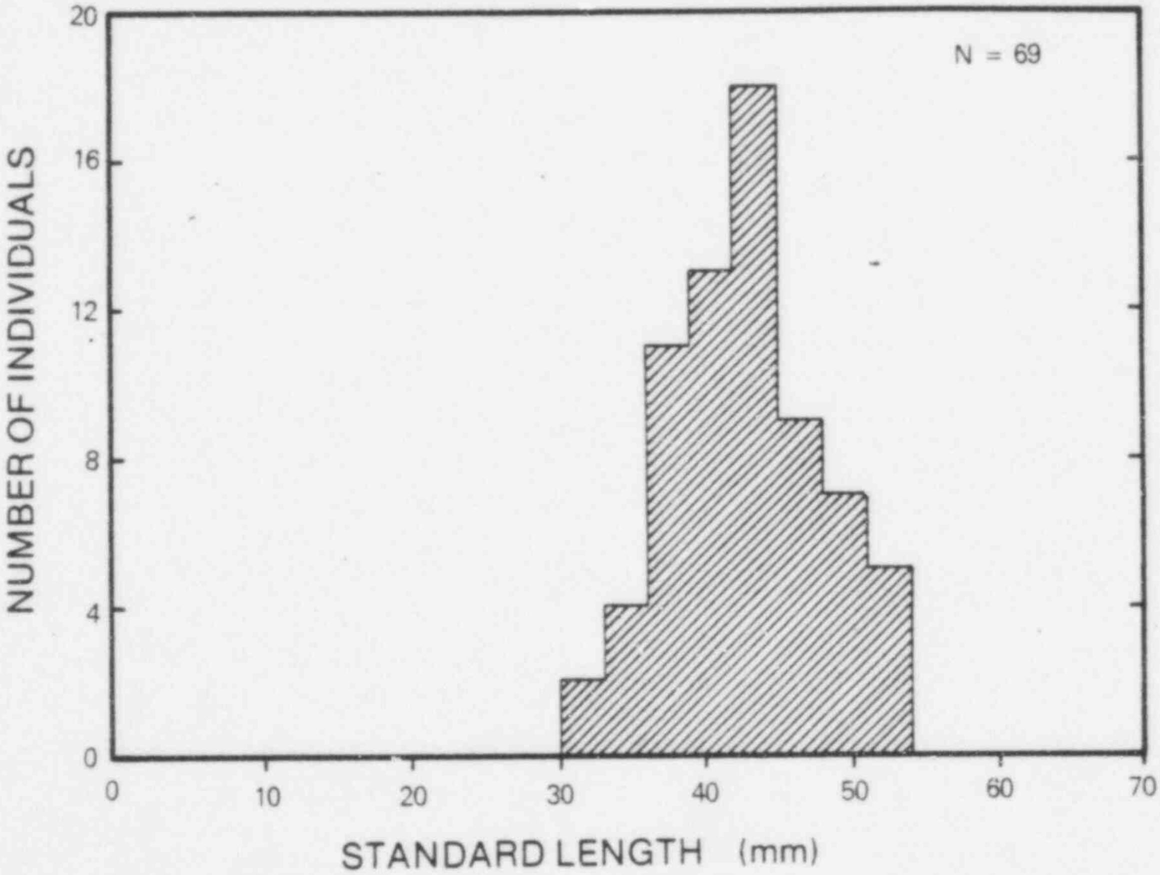

Figure 9-10. Length frequency histogram of dead individuals of Cypraea spadicea haphazardly collected at the inshore and offshore isobaths during 1978.

Organisms which apparently reflect functional responses to local environmental conditions (substratum, ambient current patterns) include the sessile, suspension-feeding invertebrates Muricea californica, unidentified ectoprocts, and unidentified hydroids (Table 9-9). These organisms were dominant during both sampling periods at station pair 20-21 and exhibit inconsistent and re-

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Table 9-8. Total number of taxa and hard substratum (%) sampled at each 6.0 m^2 offshore cobble station during 1978.

Station	Total Number of Taxa		Total Hard Substratum (%)	
	Aug	Oct - Nov	Aug	Oct - Nov
12	27	22	89.33	87.67
13	36	23	89.67	91.00
14	31	32	94.00	81.33
15	33	27	90.33	92.33
16	20	18	63.33	69.33
17	21	20	68.00	74.67
18	24	19	90.00	91.00
19	22	19	88.33	92.00
20	29	22	50.67	58.00
21	26	19	57.00	68.33

stricted occurrence patterns at all other stations. The restricted dominance pattern exhibited by unidentified crustose corallines in the vicinity of Units 2 and 3 discharges may also reflect a response to unstable substratum.

The total percent biological cover recorded at each station ranged from 60% to 202% during the August survey and from 72% to 175% during the October/November survey (Table 9-9). Total biological cover within each 6-m^2 sampling area greater than 100% is indicative of organism layering and was observed at all stations except station pair 20-21 during both surveys. Four stations (Stations 13, 14, 15, 18) showed decreases in total biological cover between surveys while five stations (Stations 12, 17, 19, 20, 21) showed increases. Percent biological cover decreases were greater than 25% at three stations (Stations 13, 14, and 15) with increases greater than 10% at three stations (Station 17, 20, and 21).

0.125-m^2 Quadrats

The mean number of taxa sampled by the four replicate 0.125-m^2 quadrats ranged from 6.8 to 13.5 during the August survey and from 6.0 to 13.8 during the October-November survey (Table 9-11). Five stations exhibited a decrease in mean number of taxa sampled while four stations revealed an increase between sampling periods.

Generally, those organisms which were ranked as one or two in terms of abundance for the 6-m^2 sampling effort were similarly ranked as a result of the replicate 0.125-m^2 sampling effort (Tables 9-9, 9-12, and 9-13). A comparison of the data collected by the 0.125-m^2 technique reveals little change in organism abundances between the two sampling periods at all stations except station pair 14-15. At station pair 14-15 during the August sampling period, the phaeophyte Desmarestia spp. and the rhodophyte organism group of Cryptonemia/Halymenia/Schizymenia were abundant, accounting for 134 and 122 contacts, respectively (Table 9-12). During the October-November survey period, only

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Table 9-9. Rank order of abundance of the five most abundant taxa at each offshore cobble station sampled with 300 points during August and October/November 1978.

Abundant Taxa	Stations 12 Aug	12 Oct-Nov	13 Aug	13 Oct-Nov	14 Aug	14 Oct-Nov	15 Aug	15 Oct-Nov	16 Aug	16 Oct-Nov	17 Aug	17 Oct-Nov	18 Aug	18 Oct-Nov	19 Aug	19 Oct-Nov	20 Aug	20 Oct-Nov	21 Aug	21 Oct-Nov
Coelosira/Lhampia															4.5	5				
Crustose Corallines, unident.					4	4	3	2	2	3	2	3	2	2	3	2				
Cryptonemia/Halymenia/Schizymenia					3		2													
Hildenbrandia prototypus									5	5										
Rhodymenia spp.	2	2	2	1		3	4	3	4	4	4	4				4			5.5	
Parvosilvosa		5	3	5	1	1	1	1	3	2	1	1	1	1	1	1	3	1	4	5
Desmarestia spp.					2	2	5	5												
Macrocystis spp.			1	2		5		4												
Pterygophora californica					5				1	1	3	2								
Astrangia spp.													4	3		3				
Hydroids, unident.	3			4							5		3		2		4	2	1	1
Muricea californica	1	1	4	3									5.5	5			1	3	5.5	3
Ectoprocts, unident. (erect.)	4	3													4.5		5	5	2	4
Ectoprocts, unident. (encr.)	5	4	5									5	5.5	4			2	4	3	[illegible]
Total Biological Cover	165.7	173.0	191.7	157.3	202.3	171.0	177.7	133.3	175.0	175.0	121.0	149.0	118.7	117.7	119.3	131.0	72.7	91.7	60.0	72.0
Cover, Top Five Taxa	108.0	123.0	159.3	119.3	152.3	133.7	136.7	99.0	153.7	160.0	107.3	134.7	107.0	106.7	94.7	120.3	52.7	72.3	43.0	51.3
Percent (%)*	65.2	71.1	83.1	75.8	75.3	78.2	76.9	74.3	87.8	91.4	88.7	90.4	90.1	90.7	79.4	91.8	72.5	78.8	71.7	71.3

* Percent of the total biological cover accounted for by the five most abundant taxa

POOR ORIGINAL

Table 9-10. Percentage of cobble, boulder, and sand substrata at each transect at each offshore station pair sampled during the 1978 October/November survey. Each transect is 30 m long and was sampled at 100 evenly spaced points.

Station Pair	Transect Heading (degrees)	Substrate (%) Cobble	Boulder	Sand
12-13	30	61	36	3
	120	72	22	6
	210	62	34	4
	300	63	27	10
	Total	258	119	23
14-15	30	59	30	11
	120	82	15	3
	210	43	49	8
	300	82	11	7
	Total	266	105	29
16-17	30	9	54	37
	120	26	46	28
	210	4	22	74
	300	14	11	75
	Total	53	133	214
18-19	30	34	46	20
	120	78	18	4
	210	62	35	3
	300	72	24	4
	Total	246	123	31
20-21	30	13	1	86
	120	Ø	Ø	100
	210	22	11	67
	300	Ø	3	97
	Total	35	15	350

Desmarestia spp. continued to be ranked as one of the five most abundant organisms and accounted for 22 contacts, a considerable decrease in total number of contacts from the summer sampling period (Table 9-13). Dispersion data on the five most abundant taxa sampled with the 0.125-m^2 sampling strategy during the two quarterly sampling periods are presented in Tables 9-12 and 9-13. An examination of the spatial dispersion patterns of these organisms reveals that most exhibited a contagious distribution (variance/mean ratio>1) during both survey periods. During the August sampling period, turf-like Parvosilvosa at Station 12 and unidentified crustose coralline algae at Station 18 exhibited regular dispersion patterns (variance to mean ratio<1) as did encrusting ectoprocts at Station 19 (Table 9-12). During the October-November sampling period, the algal growth form of Parvosilvosa at Stations 17 and 19, and encrusting ectoprocts and unidentified crustose corallines at Station 19 also exhibited regular dispersion patterns (Table 9-13).

Table 9-11. **Mean number of taxa sampled at each offshore cobble station utilizing four randomly located 0.125 m2 quadrats sampled with 60 points each during August and October/November 1978.**

Station Pair	Survey			
	August		October/November	
	$\bar{x}$	SE	$\bar{x}$	SE
12	12.3	1.11	13.0	0.71
13	13.5	1.04	13.8	2.87
14	11.8	1.32	10.0	0.91
15	8.8	0.95	11.0	1.47
16	7.5	1.55	7.5	0.50
17	11.3	0.85	9.0	0.41
18	9.8	2.15	6.0	0.71
19	10.0	1.08	6.3	0.48
20	8.8	0.63	9.5	1.32
21	6.8	0.48	8.0	1.22

Classification Analysis

Inverse and normal classification tables were generated to identify those organisms or groups of organisms associated with specific stations using data collected by the 6-m^2 sampling technique. Station groups generally clustered into pairs independent of survey period. Two major station clusters, Groups A and B are evident (Table 9-14). Generally, stations within Group A represent station pairs which are located upcoast, with Group B stations located downcoast of the Units 2 and 3 diffuser lines. An exception is the apparent "misclassification" (Boesch, 1977) of Station 18 which clustered with Station 12 at low levels of similarity within Group A during both survey periods. The clustering of Station 12 and 18 which are located upcoast and downcoast of the diffuser lines, respectively, reflects the reduced number of taxa sampled at Station 12 during the October survey period. A comparison of the number of taxa associated with station Groups A and B indicates that those stations upcoast of the diffuser lines, in general, support greater numbers of organisms than stations within station cluster Group B. This upcoast to downcoast taxa gradient is ostensibly associated with the availability as well as the motility (i.e., small cobble or boulder) of hard substrata at each paired benthic station.

Eighty-four benthic organisms or organism groups consisting of 36 algae, 48 invertebrates, and one secondary substratum (i.e., moribund Muricea holdfast) clustered into four groups (Table 9-14). Assemblages within Group 1 reflect the more ubiquitous taxa and include 16 algae and 22 invertebrates. Dominant taxa, with regard to general occurrence (constancy) include the foliose red algae, Rhodymenia spp., the algal assemblages of Parvosilvosa/unidentified crustose corallines, and the invertebrate assemblage of unidentified encrusting ectoprocts. These organisms exhibited a high degree of fidelity and were observed at all stations during each survey in considerable abundances (Table 9-14). Two taxa within species Group 1 exhibited station specific constancy. The barnacle Balanus spp. was sampled only at station pair 20-21 and the red alga Prionitis spp. was restricted to station pair 12-13. Additionally, two erect coralline

Table 9-12. The five most abundant taxa resulting from sampling four randomly placed 0.125 m^2 quadrats with 60 points each during August 1978. Total number of contacts is the sum of all quadrats.

Station	Taxa	Total Contacts	Mean	Standard Error	$s^2/\bar{x}$ Ratio
12	Rhodymenia spp.	167	41.75	3.50	1
	Macrocystis spp.	76	19.00	6.38	>1
	Parvosilvosa	46	11.50	1.26	<1
	Ectoprocts, unident. (encrusting)	33	8.25	2.29	>1
	Hydroids, unident.	32	8.00	2.20	>1
13	Muricea californica	71	17.75	3.59	1
	Hydroid, unident.	56	14.00	2.68	1
	Rhodymenia spp.	48	12.00	3.19	<1
	Parvosilvosa	46	11.50	4.91	>1
	Crustose corallines, unident.	21	5.25	1.60	1
	Ectoprocts, unident. (erect)	21	5.25	0.85	<1
14	Parvosilvosa	169	42.25	4.75	>1
	Cryptonemia/Halymenia/Schizymenia	93	23.25	11.46	>1
	Desmarestia spp.	21	5.25	3.68	>1
	Rhodymenia spp.	18	4.50	2.40	>1
	Crustose corallines, unident.	18	4.50	1.44	<1
15	Parvosilvosa	118	29.50	5.52	>1
	Desmarestia spp.	113	28.25	4.92	>1
	Cryptonemia/Halymenia/Schizymenia	29	7.25	2.46	1
	Rhodymenia spp.	27	6.75	2.95	1
	Callophyllis spp.	26	6.50	6.50	>1
16	Parvosilvosa	98	24.50	6.98	>1
	Pterygophora californica	60	15.00	15.00	>1
	Crustose corallines, unident.	58	14.50	2.87	>1
	Rhodymenia spp.	30	7.50	7.94	>1
	Hydroids, unident.	9	2.25	1.31	>1
17	Pterygophora californica	123	30.75	13.44	1
	Crustose corallines, unident.	100	25.00	4.65	<1
	Parvosilvosa	65	16.25	2.50	<1
	Rhodymenia spp.*	22	5.50	2.60	>1
	Chelyosoma productum	9	2.25	0.85	1
	Hydroids, unident.	9	2.25	0.85	<1
18	Parvosilvosa	83	20.75	5.02	>1
	Hydroids, unident.	75	18.75	6.86	>1
	Crustose corallines, unident.	62	15.50	1.85	<1
	Strongylocentrotus franciscanus	17	4.25	2.66	>1
	Rhodymenia spp.	11	2.75	1.89	>1
19	Parvosilvosa	103	25.75	2.75	1
	Crustose corallines, unident.	59	14.75	7.50	<1
	Hydroids, unident.	25	6.25	1.89	1
	Ectoprocts, unident. (encrusting)	10	2.50	0.29	<1
	Strongylocentrotus franciscanus	8	2.00	2.00	<1
20	Ectoprocts, unident. (encrusting)	36	9.00	4.02	1
	Ectoprocts, unident. (erect)	24	6.00	3.78	>1
	Crustose corallines, unident.	22	5.50	2.02	>1
	Cryptonemia/Halymenia/Schizymenia	19	4.75	4.11	>1
	Hydroids, unident.	17	4.25	1.70	1
21	Ectoprocts, unident. (encrusting)	59	14.75	7.11	<1
	Muricea californica	45	11.25	6.26	<1
	Hydroids, unident.	24	6.00	3.67	<1
	Ectoprocts, unident. (erect)	12	3.00	1.68	<1
	Rhodymenia spp.	9	2.25	0.63	<1

Figure 9-13. The five most abundant taxa resulting from sampling four randomly placed 0.125 m^2 quadrats with 60 points each during October/November 1978. Total number of contacts is the sum of all quadrats.

Station	Taxa	Total Contacts	Mean	Standard Error	$s^2/\bar{x}$ Ratio
12	Rhodymenia	125	31.25	5.12	>1
	Ectoprocts, unident. (encrusting)	78	19.50	2.33	>1
	Muricea californica	65	16.25	7.08	>1
	Ectoprocts, unident. (erect)	38	9.50	4.99	>1
	Crustose corallines, unident.	33	8.25	3.75	>1
	Parvosilvosa	33	8.25	3.00	>1
13	Muricea californica	87	21.75	7.69	1
	Rhodymenia spp.	76	19.00	7.65	>1
	Parvosilvosa	46	11.50	5.28	<1
	Ectoprocts, unident. (encrusting)	39	9.75	1.65	<1
	Ectoprocts, unident. (erect)	34	8.50	3.12	<1
14	Parvosilvosa	90	22.50	5.20	>1
	Crustose corallines, unident.	50	12.50	4.01	>1
	Rhodymenia spp.	31	7.75	5.45	>1
	Ectoprocts, unident. (encrusting)	26	6.50	3.29	>1
	Hydroids, unident.	17	4.25	2.17	>1
15	Parvosilvosa	167	41.75	3.68	>1
	Crustose corallines, unident.	52	13.00	4.14	<1
	Ectoprocts, unident. (encrusting)	24	6.00	2.94	1
	Desmarestia spp.	22	5.50	5.50	<1
	Rhodymenia spp.	9	2.25	1.65	1
	Poriferan unident.	9	2.25	0.48	<1
16	Crustose corallines, unident.	106	26.50	8.99	>1
	Parvosilvosa	92	23.00	11.67	>1
	Rhodymenia spp.	40	10.00	3.58	<1
	Ectoprocts, unident. (encrusting)	31	7.75	2.43	>1
	Ectoprocts, unident. (erect)	24	6.00	4.24	>1
17	Parvosilvosa	84	21.00	1.87	<1
	Crustose corallines, unident.	71	17.75	3.71	>1
	Rhodymenia spp.	24	6.00	2.16	1
	Hildenbrandia prototypus	21	5.25	1.49	<1
	Ectoprocts, unident. (encrusting)	16	4.00	1.08	<1
18	Parvosilvosa	113	28.25	6.36	<1
	Crustose corallines, unident.	62	15.50	4.94	<1
	Muricea californica	23	5.75	4.80	>1
	Rhodymenia spp.	17	4.25	2.02	>1
	Ectoprocts, unident. (encrusting)	10	2.50	1.55	>1
19	Parvosilvosa	121	30.25	3.21	1
	Crustose corallines	44	11.00	1.08	<1
	Ectoprocts, unident. (encrusting)	14	3.50	0.65	<1
	Astrangia spp.	13	3.25	1.31	1
	Patiria miniata	5	1.25	0.95	<1
20	Ectoprocts, unident. (encrusting)	64	16.00	6.84	<1
	Ectoprocts, unident. (erect)	40	10.00	4.14	<1
	Muricea californica	23	5.75	3.61	>1
	Hydroids, unident.	22	5.50	2.10	>1
	Rhodymenia spp.	14	3.50	1.32	>1
21	Ectoprocts, unident. (encrusting)	77	19.25	9.15	1
	Hydroids, unident.	39	9.75	2.46	>1
	Muricea californica	29	7.25	6.25	>1
	Ectoprocts, unident. (erect)	23	5.75	1.49	>1
	Parvosilvosa	7	1.75	1.11	<1

algae tended to show affinities for Group B stations. The erect coralline alga, Bossiella spp., was observed at station pair 16-17 and Station 20 during each survey period while it was represented by a single occurrence within Group A stations. Corallina/Haliptylon was observed at least once at all stations within the Group B station cluster while exhibiting a restricted occurrence pattern at station pair 12-13 within the Group A station cluster.

Group 2 consists of seven algae and nine invertebrates and exhibited a considerable affinity with station cluster Group A. Of the seven Group 2 taxa

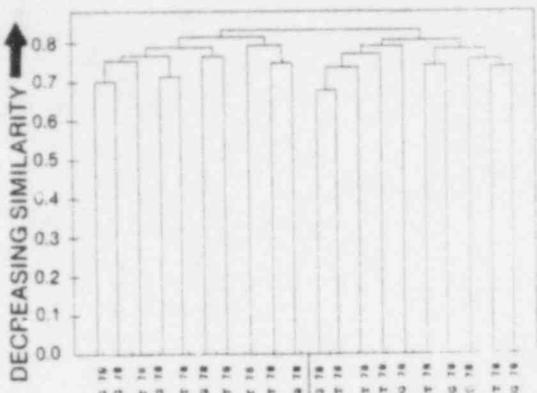
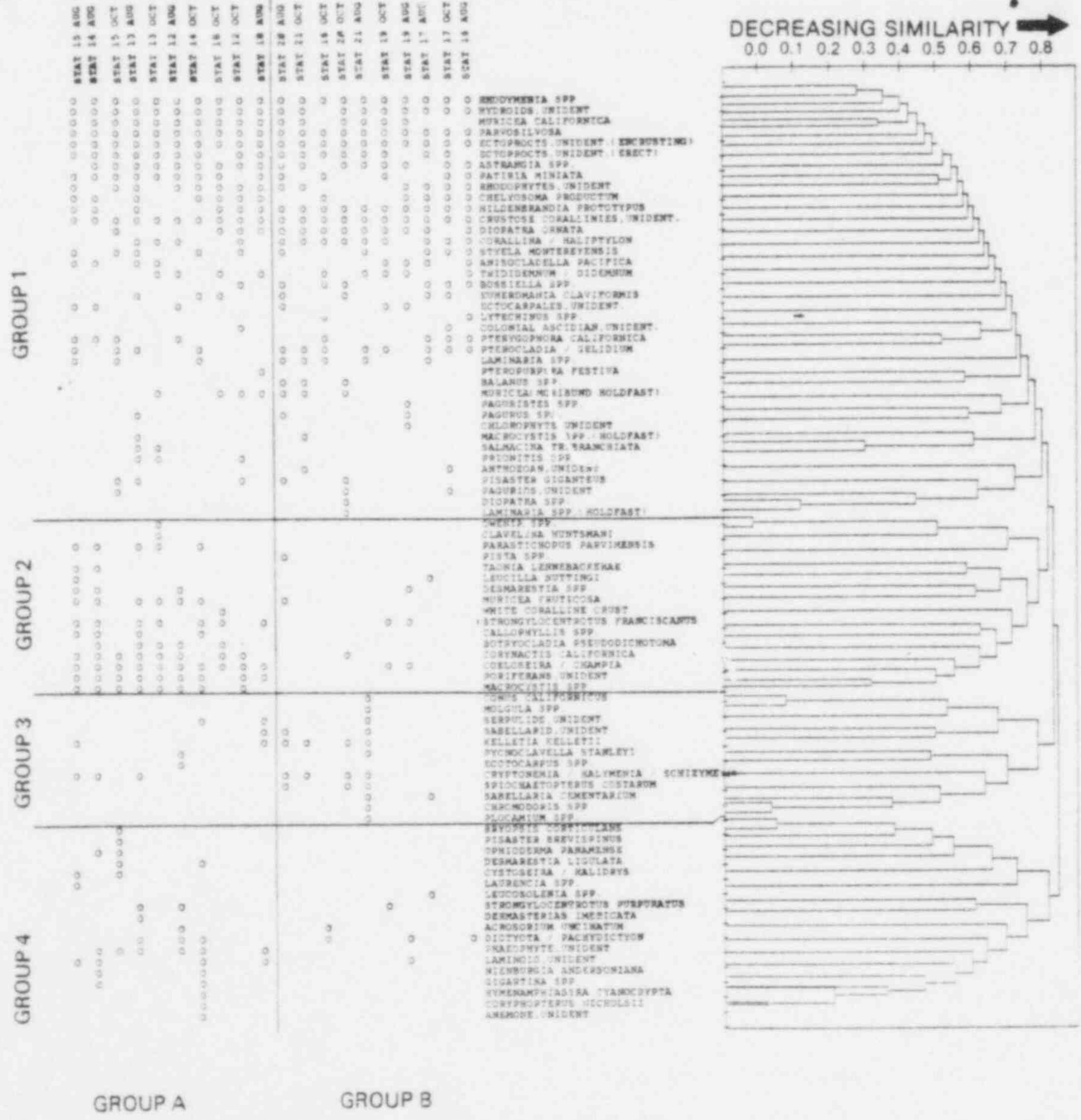


Table 9-14. Normal and inverse classification of 1978 benthic data from offshore cobble stations and resultant co-occurrence table.



associated with Group B stations, six are invertebrates. The brown kelp, Macrocystis spp. was observed to be restricted to Group A stations except for one occurrence at Station 18.

Group 3 assemblages accounted for three algae and nine invertebrates and showed a moderate affinity for Group B stations. With the exception of the brown filamentous alga, Ectocarpus spp., all Group 3 organisms were observed at Station 21 during the August survey. All Group 3 taxa within station cluster Group B were present at station pair 20-21, with the exception of the sedentary polychaete, Sabellaria cementarium.

Group 4 organisms consist of ten algae and eight invertebrates and exhibit an affinity for station cluster Group A. Of the five Group 4 taxa associated with station cluster Group B, three are algae and two are invertebrates. All were observed in low abundances during each survey. Except for the small sponge Leucosolenia spp., Group 4 organisms that were associated with station cluster Group B were common to station cluster Group A and exhibited low abundances during each survey.

Muricea Measurements

A summary of the mean heights of tagged Muricea colonies is presented in Table 9-15. A one-way analysis of variance was performed to test for a significant difference in mean heights (ages) among station pairs. Height (age) was observed to be significantly different among pairs and a Student-Newman-Keuls multiple range test (Sokal and Rohlf, 1969) was employed to identify similar pairs. The test indicated that Muricea heights at station pair 12-13 and station pair 20-21 were significantly greater, and thus older than at station pair 16-17. These results suggest that station pair 16-17 supports the youngest Muricea colonies followed by Stations 14, 15, 18, 19 which support intermediate aged Muricea, and Stations 12, 13, 20, 21 which support the oldest Muricea colonies (Table 9-15).

OCEANOGRAPHIC AND METEOROLOGICAL OBSERVATIONS

Three types of oceanographic data were collected on a bimonthly basis during 1978 oceanographic cruises. These included bottom temperatures, bottom transmissivity measurements, and water column Secchi disc observations (BC, 1979). Results of these bimonthly cruise efforts are presented in Table 9-16. Bottom temperatures (°C) were lowest during January and March surveys showing little variation, ranging from 15.? to 16.1. Warmest bottom temperatures during 1978 were recorded during the late summer (September) and fall (November) surveys. On a survey by survey basis, no spatial discrimination in bottom water

Table 9-15. Summary of age-height statistics of Muricea colonies measured during November 1978 at the offshore PMP cobble stations.

Age-Height Statistics	Station Pair 12-13	14-15	16-17	18-19	20-21
Mean Height (cm)	39.23	31.68	27.50	31.22	41.05
Standard Error (SE)	2.00	1.67	1.70	3.92	1.80
Sample Size (n)	35	20	14	9	10
Estimated Age (Years)	23.2	17.2	14.3	16.9	[illegible]

Table 9-16. Bottom temperatures, bottom transmissivity, and Secchi disc depths measured at the inshore oceanographic stations in Zone 0A and Zone 6 during six bimonthly oceanographic cruises in 1978.

Station	Bottom Temperatures (°C)					
	1/18/78	3/7/78	5/4/78	7/10/78	9/13/78	11/16/78
C2N	15.9	15.8	16.6	16.7	20.2	17.2
D2N	15.9	15.8	16.2	15.6	19.8	17.3
C22S	16.1	15.8	15.5	15.4	19.9	17.1
C24S	16.1	15.9	15.0	16.5	20.1	17.3

Station	Bottom Transmissivity (%)					
	1/18/78	3/7/78	5/4/78	7/10/78	9/13/78	11/16/78
C2N	0	0	0	0	0	45
D2N	0	0	0	1	16	61
C22S	0	0	0	0	0	15
C24S	0	0	0	0	0	18

Station	Secchi Disc Depths (m)					
	1/18/78	3/7/78	5/4/78	7/10/78	9/13/78	11/16/78
C2N	1.0	0.5	2.0	7.0	2.0	7.0
D2N	1.0	0.5	3.0	7.0	4.5	9.0
C22S	1.0	1.5	7.0	7.0	8.0	7.5
C24S	1.0	1.5	6.0	7.0	7.0	7.0

temperatures at the four stations sampled was discernible.

Bottom transmissivity measurements taken during the first four bimonthly sampling efforts were zero at all stations except for a 1% transmittance value noted at Station D2N during the July survey. The November sampling period revealed that bottom water clarity had improved substantially at all stations, with greatest light transmittance readings recorded at Stations C2N and D2N. Secchi disc extinction depths were 1.5 m or less at all stations during the January and March surveys. Generally, there were no apparent differences between stations in the January, March, July, and November surveys. However, during the May and September surveys water column clarity was considerably greater at stations downcoast of SONGS (C22S and C24S), than at stations near SONGS (C2N and D2N).

The high amount of precipitation in southern California was anomalous during 1978. Oceanside Harbor, 21 km downcoast of SONGS, received a total of 22.6 inches of rain (Table 9-17); more precipitation than any year since 1940, when slightly less than 25 inches of rainfall was recorded for the general southern California area (Pryde, 1977). Other recent periods of unusually heavy rainfall include 1965-66 and 1968-69 when 16 and 17 inches of rainfall were recorded, respectively (Pryde, 1977). Considering the historic 19 year (1959-1977) annual

Table 9-17. Total monthly rainfall during 1978 recorded at Oceanside Harbor.

Month	Inches	Month	Inches	Month	Inches
January	7.95	May	0.03	September	0.00
February	5.49	June	0.00	October	0.04
March	6.73	July	0.00	November	1.16
April	1.20	August	0.00	December	0.00
Annual Total	22.60				

mean precipitation has been 11.0 inches, the southern California area received over twice as much rainfall in early 1978 as would be expected during an average year.

DISCUSSION

The hard substratum studies currently being conducted offshore the San Onofre Nuclear Generating Station are designed to develop a baseline data set for future assessment of the potential effects of Units 2 and 3, and to detect significant physical and/or biological alterations associated with the operation of Unit 1 and/or construction activities associated with Units 2 and 3. The sampling design, method of data collection, results, analysis, and interpretation of the data from all programs presented in this chapter have been oriented to examine the general hypothesis that there are no significant environmental effect(s) on the biological communities associated with subtidal cobble habitat due to the operation of SONGS Unit 1 and construction activities for Units 2 and 3. For this discussion "significant environmental effects" is defined as any physical or biological change(s) attributable to SONGS activities which alters the factors under investigation to an extent which is considered to be ecologically significant.

Within the vicinity of the San Onofre Generating Station and with respect to the objectives of the subtidal cobble studies, there are three major factors which may alter the local marine environment and be detected by the sampling programs. These include the operation of SONGS Unit 1, the construction activities associated with Units 2 and 3 diffuser conduit installation, and naturally occurring variability stemming from both biological and physical events. Previous studies conducted since 1975 to evaluate the effects of SONGS operation have not detected or defined any immediate or long-term biological effects associated with the operation of Unit 1 outside the immediate nearfield area (LCMR, 1976b, 1977b, 1978c). Additionally, subtidal studies conducted since the fall of 1976 to evaluate the effect of Units 2 and 3 construction activities have not identified any deleterious biological effects on the cobble habitat within the San Onofre kelp area (MBC, 1978). However, significant ecological effects associated with a period of storms were observed and documented. As noted previously, the southern California area was subjected to abnormally high rainfall and unusually intense nearshore storm activity during the first quarter of 1978. Storm related phenomena such as terrestrial runoff resulted in dramatic and often catastrophic alterations of the subtidal cobble environments and their associated communities, particularly on the nearshore isobath. At the nearshore (10 m) stations within the vicinity of the Unit 1 discharge, extensive areas of cobble were inundated with sand as deep as 30 cm. This resulted in a considerable decrease in the total number of taxa observed among stations nearest the

938267

Unit 1 discharge in Zone 0A as two of the four stations were completely covered with sand and supported few visible organisms (Figure 9-3). Decreases in number of taxa were also observed at the inshore cobble stations downcoast in reference Zone 6 (Figure 9-3). Additionally, predominant groups of organisms such as Parvosilvosa/unidentified rhodophytes and Rhodymenia spp., both primary producers, exhibited substantial decreases in mean abundances in Zone 0A during 1978 (Figure 9-5). The onuphid polychaete, Diopatra ornata, an organism which normally inhabits sand. exhibited little temporal variation in abundance in both zones and apparently was not affected by the phenomena of sand accretion (Figure 9-7). Enumeration of the suspension feeding anthozoan Muricea at each station revealed a substantial decrease in mean abundance estimates from previous annual patterns observed in Zone 6 (Figure 9-7). This decrease is probably more closely associated with the establishment of two new Zone 6 stations following their loss than with the increase in the amount of sand in Zone 6.

Trophic composition between zones was similar (Table 9-3); however, comparison with mean numbers of trophic types with previous years (LCMR 1978c) reveals the average number of taxa within each trophic type decreased during 1978. This decrease is associated with the general reduction of numbers of taxa and decreases in density estimates of many organisms during the 1978 surveys. The general simplification (i.e., decreases in numbers of taxa and abundances) of the nearshore habitat appears to be directly attributable to the extensive accretion of sand in both the upcoast and downcoast areas studied.

There are three hypotheses which, when considered collectively, assist in explaining the nature of the sand accretion phenomena. First, the onshore movement of sand, including movement through kelp beds, from offshore deposits may be accomplished by long-period waves (Berry, 1977). The occurrence of this phenomen has been documented in the kelp beds near Santa Barbara (Ashley, Berry, and Fischer, 1975). Second, beach and cliff erosion may contribute to the offshore movement of sand. This type of movement is generally catastrophic, rapid, and visibly evident when it occurs (Kuhn, 1978). Third, and probably most important, is the deposition of sand in the nearshore areas via river and stream runoff. Heavy rainfall following years of light rainfall has been associated with the addition of sand to offshore subtidal areas (Berry, 1977). A major source of the addition may be from sand and silt built up in nearby creeks over the past nine years as rainfall apparently has not been heavy enough to provide a runoff sufficient to transport the sand out to sea during each year (Berry, 1977). There is little empirical data which documents the amount and final location of river and stream runoff during flood periods. Drake, Fleischer, and Kolpack (1971) in a study near Santa Barbara, documented sediment deposition from three rivers and small intermittent streams which accounted for greater than 80×10^6 metric tons of sediment introduced offshore during an intense one-month flood period in January-February 1969.

The increase of sand in the area of the nearshore SONGS cobble stations occurred within the same time interval as a series of rain storms which deluged the southern California coast in the winter of 1977-78 and spring of 1978. The heavy rainfall during the first three months of 1978 (Table 9-17) was sufficient to wash the sediments from several small vernal streams out to sea. The region upcoast and downcoast of the generating station has several streams (San Mateo, San Onofre, Las Flores, Las Pulgas, and Santa Margarita) which flooded during the early 1977-78 winter and 1978 spring. Considering that the streams in the vicinity of the generating station have probably not experienced flood conditions since 1969 when heavy rainfall and subsequent biological effects were

observed at SONGS (Given, 1973), there probably was sufficient time for the accumulation of a considerable amount of sediment. Given this pre-flood accumulation during the preceding years, it is reasonable to assume that the flooding which accompanied the winter and early spring storms made a significant contribution to the nearshore environment in terms of a major sand loading phenomena out to at least the 10-m isobath. This naturally occurring phenomena may be considered a catastrophic event with respect to the hard substrata habitats which were covered with sand. Further evidence for this hypothesis is found in the transmissivity profiles taken during the first three bimonthly cruises (BC, 1979). Transmissivity data collected at oceanographic stations near the benthic stations were zero at all depths except near the surface, which is indicative of a heavy load of suspended sediment (Table 9-16).

Additionally, storm waves, which generally have a short period, tend to suspend beach sand in the water and move it offshore. This has previously been noted in the San Onofre area (Spiedel, 1975). The storm waves which came from a southerly direction could have moved the stream runoff offshore of the beaches and deposited it on the subtidal areas. These combined effects most likely accounted for the sand inundation in both zones. An additional source of sand may have come from dredged material placed on the beach during present dredging activities for construction of Units 2 and 3; however, no specific evidence of dredge spoils settling on the nearshore or offshore cobble or kelp stations was detected during 1978.

Burial and subsequent mass mortality of marine benthic organisms due to weather fluctuations, vulcanism, and/or human intervention such as mining operations have been reported by several investigators (Engle, 1948; Hedgpeth, 19?7; McKnight, 1?59; Ryan and Heezen, 1976). These reports have dealt with sessile organisms (oysters) or organisms which are not highly motile (bivalves). However, motile invertebrates such as the chestnut cowry, *Cypraea spadicea*, may also be subject to mortality due to rapid and extensive burial by sediment.

The assemblage of cowry shells collected at the offshore kelp station SOK and other stations downcoast of SONGS did not consist of any single size class (Table 9-7), as indicated by the length frequency histogram (Figure 9-11). The total collection closely resembled a normal distribution (Figure 9-11). This reveals that the shells collected were not all large adults which may have died of natural causes. In addition, several different stages of development were evident in the shells collected, indicating juveniles were present. Darling (1965) has observed the growth of *Cypraea spadicea* and has noted several growth changes in the shells. The thickening of the shell, an absence of an apical swirl, and formation of ripple-like teeth at the labial and columellar shell edges may be indicative of adult transformation. The varied stages of shell development present in shells collected from the SONGS area further indicates that mortality was not associated with any one particular age group.

Fifty-five percent of the *Cypraea* shells collected exhibited no signs of erosion (Class 1 type shell, Table 9-11) suggesting these specimens died at about the same time. Only one individual in Class 1 exhibited evidence of predation (i.e., a small hole bored through the shell). The variable size classes and stages of development within these classes as well as uniform degrees of shell erosion suggest that the cowries represented by this collection died *en masse*, probably as a result of burial by sediment, rather than such natural causes as senescence or predation. Cowries in the Class 1 stage of shell erosion are probably those which were uncovered by sediment most recently. Shells

in the Class 2 category presumably were exposed earlier and hence are weathered to a greater extent. Shells in the Class 3 category may represent cowries which died of natural causes, because some of these shells are encrusted with bryzoans and clearly have been exposed longer than shells in Classes 1 or 2. These specimens were probably dead before the area was covered with sediment. The presence of Class 3 type shells may therefore be coincidental.

A consideration of all the benthic data collected during 1978 and a review of the sampling data from 1975 support the general hypothesis that there have been no significant ecological effects associated with the operation of Unit 1 or Units 2 and 3 construction activities on the inshore cobble habitats. In contrast, the natural phenomena of unusually heavy rainfall and concomitant storm activity were responsible for the catastrophic burial of many cobble habitats resulting in the mass mortality of many species of saxicolous organisms.

The kelp stations, with the possible exception of BK, appear to have been affected very little by the sand accretion which occurred at the inshore stations. Each station seemed to remain at levels similar to past years, except for SOK, which showed a large decrease in percent sand cover during the final 1978 benthic survey (Figure 9-9). This decrease represented a return to levels found during 1975 and early 1976.

Both SMK and SOK exhibited a relatively stable number of taxa (Table 9-2). The numbers at SMK were similar to those observed in previous surveys while the numbers at SOK were lower than all but one value previously recorded. CMP Stations 22 and 23 exhibited higher numbers of taxa than SOK with some levels as high as stations SMK and BK which have nearly always had more taxa.

The trophic composition of the kelp stations was relatively similar among all stations except for lower numbers observed at SOK during the 1978 sampling period (Table 9-4). The generally lower numbers of each trophic type as well as number of taxa noted during each survey are most likely related to two factors: abundance of hard substratum and habitat stability. Partial evidence for this hypothesis is found in Figure 9-7a,b which details the quarterly mean abundance estimates of two algae since 1975. The algal group of Rhodymenia/Gracilaria, a foliose algae with an erect growth form has consistently exhibited low mean abundance estimates at SOK since 1975. Intermediate abundance levels have been observed at CMP 22 for Rhodymenia/Gracilaria since 1976. In contrast, unidentified crustose corallines, which exhibit an encrusting growth form were observed in high mean abundances at San Onofre kelp stations during 1978. However, the algal group of Rhodymenia/Gracilaria also occurred in comparatively high abundances at CMP 23 and SMK.

Biological data collected at San Onofre kelp stations which show a causal relationship between hard substratum and organism abundance may be seen in Figure 9-10, which presents mean percent sand estimates for each survey at the offshore kelp stations. Until the final survey in 1978, percent sand composition at SOK was substantially greater than that observed at all other kelp stations except CMP 22. Since 1976 percent sand estimates at CMP 23 have been similar to SMK, i.e., comparatively low with greater amounts of hard substratum available to saxicolous organisms. The low estimates of sand cover at CMP 23 and SMK associated with comparatively high abundance estimates of Rhodymenia/Gracilaria suggest a negative relationship. This relationship predicts low estimates of Rhodymenia/Gracilaria at stations exhibiting high percent sand cover such as observed at CMP 22 and SOK (Figure 9-8). The general negative relation-

ship between increasing sand cover and decreasing organism abundance was also observed at the San Onofre area in 1977 (MBC, 1978).

The comparatively high abundance estimates of unidentified crustose corallines at all San Onofre kelp stations suggest that the San Onofre kelp area is rather dynamic with respect to cobble movement, sand cover, and/or sand accretion. The dominance patterns of unidentified crustose coralline algae at all stations within San Onofre kelp including the offshore cobble stations are well established (Figure 9-7b and Tables 9-6 and 9-9). As noted previously (LCMR, 1978c), crustose coralline algae may be substratum size specific (Adey, 1970) and corallines in general can be early colonizers (Johansen and Austin, 1970). Observations made during the 1978 sampling period suggest crustose coralline algae may function as a fugitive species (in sensu Hutchinson, 1951) by readily colonizing free space and persisting in a relatively unstable and harsh environment. Crustose coralline algae persisted on cobble substratum after burial of at least three to four months as evidenced by the pinkish color of recently exposed organisms. Similar observations have been made for unidentified crustose coralline algae in central California (M. Foster, personal communication). The dominance of crustose coralline algae in the San Onofre area may result from this general immunity to sand cover or scour. The functional adaptations of crustose coralline algae appear to be persistent slow growth and recruitment during periods of exposure alternated with the ability to withstand sand scour and periodic burial. During periods of sand scour or burial most, if not all, of the other organisms attached to the substratum are eliminated, resulting in free space for colonization during later periods of exposure. When cobbles are exposed after burial, spores of crustose corallines may quickly settle and/or the established area of crustose coralline may continue to grow. Given several periods of exposure and quiescence it is plausible that eventually crustose coralline algae could be present in considerable abundance.

Evidence for periodic cobble movement may be derived by examining the results comparing age and height of Muricea colonies at the respective offshore cobble station pairs (Table 9-15). The mean height of Muricea colonies associated with offshore cobble station pair 16-17 was observed to be significantly smaller ($p<.001$) than all other mean estimates derived from station pairs. Using the significant correlation between height and age of Muricea colonies established by Grigg (1974) to estimate mean colony age, it is apparent that the two station pairs located in the area of potential influence of Units 2 and 3 as well as San Onofre station pair 18-19 support comparatively younger colonies than San Mateo Point station pairs 12-13 and Zone 6 station pair 20-21. It is reasonable to assume growth and persistence of the sea fan Muricea is closely related to size and/or stability (mobility) of substratum. Muricea colonies tend to grow and branch in one plane which is oriented at right angles to the dominant current flow for feeding purposes (Grigg, 1972; Wainwright and Dillon, 1979). It follows logically that larger (older) colonies with greater surface area would have a greater drag. This would stress the area of attachment on the substratum or displace both the colony and substratum simultaneously. Consequently, detachment and abrasion rather than predation are the major causes of mortality of Muricea (Grigg, 1977). This mechanism of substratum movement is also well documented for kelp plants which settle and develop on cobbles (Rosenthal, Clarke and Dayton, 1974). It follows then, assuming a similar magnitude of water motion in all areas, that areas which support larger (older) colonies are also relatively more stable with respect to substratum. These observations suggest that substratum within the San Onofre kelp area in the vicinity of the offshore cobble stations is comparatively less stable than the upcoast and down-

coast reference areas.

The preoperational offshore cobble stations were sampled for the first time during the last two quarterly survey periods during 1978; therefore, temporal generalizations have not been considered. However, general comparative statements on species composition and spatial relationships between stations observed during the initial surveys are presented.

San Mateo station pair 12-13 and the upcoast station pair 14-15 located within the nearfield area of potential influence of Units 2 and 3, exhibited the greatest amount of hard substratum during both surveys (Table 9-8). In contrast, Zone 6 station pair 20-21 exhibited lowest hard substrata estimates in both surveys. The hard substratum estimates were positively associated with total biological cover at all station pairs. Total biological cover greater than 100% is indicative of biological layering. The greatest biological cover was sampled at station pairs 12-13 and 14-15 (Table 9-9). The San Mateo station pair revealed a relatively heterogeneous composition with algae and sessile invertebrates occurring in similar abundances (Tables 9-12 and 9-13). Overstory algae occurring in abundances greater than 100% were consistently sampled at upcoast nearfield station pair 14-15. In contrast, Zone 6 station pair 20-21, while exhibiting a similar number of taxa to San Mateo station pair 12-13 and the upcoast nearfield station pair 14-15 (Table 9-8), consistently had the lowest abundances sampled during each survey (Table 9-9). Further, Zone 6 station pair 20-21 consistently exhibited taxa dominated by sessile, suspension feeding invertebrates (Tables 9-12 and 9-13).

The lowest number of taxa was generally recorded at downcoast nearfield station pair 16-17 and San Onofre kelp station pair 18-19 during each survey. This may be attributed to the dominance of two or three algal groups at each station pair. At the downcoast nearfield station pair 16-17, the kelp Pterygophora californica and the algal assemblage Parvosilvosa were consistently encountered in abundances disproportionately greater than the densities of the other taxa sampled. Parvosilvosa and unidentified crustose corallines were dominant at San Onofre station pair 18-19 and also displayed abundances disproportionate to the other organisms sampled (Tables 9-12 and 9-13).

In summary, data collected at each station were more similar within station pairs than among station pairs. The five offshore station pairs, when considered as individual sampling units, may be biologically classified into four groups. San Mateo station pair 12-13 forms one group and exhibited a well-mixed species composition with sessile invertebrates and red algae tending to be most abundant. As biological layering suggests, the community in the San Mateo area is complex with competition for unoccupied hard substrata intense. Station pair 14-15, located approximately 500 m upcoast of the Units 2 and 3 diffusers, was dominated by evenly distributed algae, and constitutes another group. San Onofre station pairs 16-17 and 18-19, located approximately 0.7 km and 2.0 km downcoast of the Units 2 and 3 diffusers, respectively, were characterized by the dominance of two or three algae. With the exception of Station 17, which had extensive overstory of Pterygophora californica, this group of stations exhibited similar patterns of biological layering which consisted largely of unidentified crustose corallines underlying upright algae (e.g., Parvosilvosa and Rhodymenia spp.). Reference Zone 6 station pair 20-21 constitutes the fourth group and is located within a large expanse of sand approximately 9 km downcoast from the generating station. This station pair is dominated by evenly distributed sessile invertebrates.

A review of all benthic biological data collected during the first two quarterly preoperational surveys of the offshore cobble stations reveals that hard substratum was positively correlated with total biological cover. The more intense biological layering occurred at Stations 12, 13, 14, 15, and 16. Less intense layering was consistently observed at San Onofre stations 17, 18, and 19. Zone 6 station pair 20-21 never exhibited biological layering when the evaluation criteria was greater than 100% biological cover.

Subjective observations comparing the offshore and onshore cobble habitats without kelp canopies suggest the invertebrate species composition is similar, with algal diversity and abundance estimates tending to be greater in deeper water. The distribution and abundance patterns of these groups appear to be mediated by substrata composition and stability and bottom water motion (surge) associated with onshore swell movement. The nearshore cobble habitats experience greater bottom disturbance, resulting in the more frequent suspension of sand and detritus which reduces water transparency. This may partially account for the apparent increase in number of algae, particularly rhodophytes, observed at the offshore cobble areas.

Results of the 1978 biological data collected at the kelp stations and the offshore cobble stations suggest that the upcoast San Mateo and downcoast Barn Kelp areas are similar with respect to stability of substratum. However, the San Onofre kelp area is highly variable, exhibiting dramatic differences in substrata and organism composition over relatively short distances. Further, data collected in 1978 suggest that physical accomodations associated with sand scour and cobble movement may be expected to regulate community structure during years which experience moderate storm activity. During relatively benign periods, much of the exposed cobble areas may be biologically accomodated and develop quickly and become similar to the San Mateo or Barn Kelp areas.

With respect to the objectives of the benthic studies which this chapter addresses in detail, the intense evaluation of all the benthic data collected quarterly during 1978 and previous years reveals that no significant ecological effects associated with the operation of SONGS Unit 1 or Units 2 and 3 construction activity were detected or suggested at the offshore kelp or cobble stations.

SUMMARY

Diving surveys to sample macroorganisms on cobble substratum were conducted quarterly, weather permitting, at eight inshore cobble stations; five offshore cobble stations associated with the San Mateo, San Onofre, and Barn kelp beds; and ten paired stations located at offshore cobble areas. The objectives of these studies include collection of preoperational baseline data for Units 2 and 3, determination of the operational effects of Unit 1, and assessment of the environmental effects of Units 2 and 3 construction activities. During 1978 unusually heavy rainfall and persistent nearshore storm activity prevented ten stations from being sampled during the first quarterly survey and five stations from being sampled during the second quarterly survey. Nondestructive sampling techniques were employed at each station. The inshore cobble stations and the offshore cobble stations associated with kelp beds were sampled by diver-biologists who identified and enumerated all dominant macroscopic organisms observed within each 1-m^2 area along a 10-m long band transect at each station. The offshore cobble stations were sampled using a point contact method to esti-

mate mean abundances of organisms identified within one 6-m^2 and four 0.125-m^2 areas at each station. A detailed analysis of the 1978 data and a comparison with 1975, 1976, and 1977 results indicated the following.

INSHORE 10-M COBBLE HABITAT

1. Significant terrestrial runoff associated with persistent nearshore storms and abnormally heavy rainfall resulted in rapid and extensive sand inundation of numerous cobble habitats along the inshore (10-m) isobath. Extensive areas of cobble surrounding inshore ETS stations in the area near the discharge and at stations located in the downcoast reference area were completely covered by at least 30 cm of sand.

2. The rapid and extensive burial of inshore cobble resulted in substantial decreases in the total number of taxa sampled compared to previous surveys (1975, 1976, 1977). Additionally, considerable decreases in mean abundance estimates of historically dominant primary producing taxa including Rhodymenia spp. and the turf-like growth form of Parvosilvosa were observed on the inshore isobath.

3. Catastrophic burial of numerous cobble habitats resulted in mass mortalities of many saxicolous organisms. For example, mass mortality of the motile chestnut cowry, Cypraea spadicea, was attributed to the extensive and rapid burial of many cobble habitats.

4. No significant ecological effects associated with SONGS Unit 1 operation or construction activities of Units 2 and 3 were detected or suggested at the nearshore cobble stations.

OFFSHORE 14-M COBBLE HABITAT

1. The sand accretion phenomenon observed at the inshore (10-m) cobble stations was also noted in moderation on the offshore (14-m) isobath.

2. No significant ecological effects associated with construction activities of Units 2 and 3 were detected or suggested at the offshore cobble stations.

KELP BED COBBLE HABITAT

1. Relative stability of the substrata at five offshore areas near San Mateo, San Onofre, and Barn Kelp was evaluated. Results strongly suggest that the San Onofre kelp area is subject to frequent periods of cobble movement and sand scour, which ultimately affect the composition and constancy of the biological communities in the vicinity of the San Onofre kelp bed.

2. Encrusting coralline algae were observed in disproportionately high abundances at San Onofre kelp compared to San Mateo and Barn kelp stations. The higher abundance estimates at San Onofre kelp may be attributed to the functional adaptations of crustose coralline algae, which appear to exhibit persistent slow growth and recruitment during periods of exposure, alternated with the ability to withstand sand scour and burial. These adaptations to a relatively unstable and harsh environment may result in a competitive advantage over organisms sensitive to similar environmental perturbations.

3. Age estimates of the colonial anthozoan, Muricea californica, suggested that substrata movement has historically been significantly more dynamic at San Onofre Kelp station compared to San Mateo or Barn Kelp stations.

4. No significant ecological effects associated with the operation of SONGS Unit 1 or construction activities of Unit 2 and 3 were detected or suggested at the offshore kelp stations.

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CHAPTER 10

FISH

INTRODUCTION

The ongoing marine monitoring studies reported in this chapter are being conducted to meet objectives approved by the Nuclear Regulatory Commission (NRC) as stated in the Environmental Technical Specifications (ETS), Docket No. 50-206, Sections 3.1.2a(1) General Ecological Survey and 3.1.2a(2) Impingement of Organisms for San Onofre Nuclear Generating Station (SONGS) Unit 1 and the Preoperational Monitoring Program (PMP) for SONGS Units 2 and 3. Broadly stated, the ETS objective is to determine the effects of SONGS Unit 1 on the marine fish resources in the vicinity of the generating station. The PMP objective is designed to provide a baseline to determine the possible effects of SONGS Units 2 and 3 on the species composition, distribution, and abundance of fish inhabiting the receiving waters offshore of the generating station. These studies are also being conducted in compliance with the National Pollution Discharge Elimination System (NPDES) permit for SONGS Unit 1, which requires that results be reported to the California Regional Water Quality Control Board (CRWQCB), San Diego Region and the regional office of the Environmental Protection Agency. In addition, ichthyoplankton (fish eggs and larvae) is being investigated at San Onofre as a special study of the Preoperational Monitoring Program. The one-year study was initiated in May 1978 and will terminate in April 1979. Data and analyses will be presented in the 1979 Annual Operating Report to be submitted in 1980 per established reporting requirements.

All 1978 biological data analyzed in this report is presented in Volume II of the Annual Operating Report, San Onofre Nuclear Generating Station Biological Data 1978 (LCMR, 1979a); physical data analyzed in this report is contained in Volumes I (BC, 1979) and II of the 1978 Annual Operating Report.

This chapter presents the objectives of the combined ETS/PMP fish studies, the approach used to meet these objectives, and a review of past fish studies offshore SONGS. Methods of data collection and analysis are also included. Results are discussed in light of specific topics directed toward the combined fish program study objectives.

APPROACH

This chapter is organized into two sections, one dealing with fish in the receiving waters offshore of the generating station and the other with fish impinged by SONGS Unit 1. Sport and commercial fisheries catch data compiled by the California Department of Fish and Game two years after collection is usually presented in the annual analysis report; however, the Department of Fish and Game has not completed the compilation of 1976 data, consequently it will not be presented in this report.

The receiving waters section addresses topics related to the fish community and to populations of select fish species. Specific topics within the fish community cover variation in species composition, abundance, and diversity; while topics addressed for select fish species populations include variation of numerical abundance, size (age), and sex structure. The variation of these parameters

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in the community and population sections is examined through time and with depth within the potential area of influence and reference areas. The possible relationship between any variation in biological factors and variation in the physical environment is also examined.

The fish impingement section develops estimates of the number and weight of the total impingement catch, the impingement catch of select species, and analyzes size (age) and sex structure of select impinged species. Size and sex structure of impinged fish is compared with offshore fish data to determine if SONGS Unit 1 impingement is selective with respect to these factors.

BACKGROUND

In order to place the study objectives and results into perspective, a brief description of the environment offshore SONGS and past and ongoing ichthyofaunal studies is presented.

Receiving Waters

The available environment for fish offshore SONGS consists of the sea bottom and overlying water. The overlying water is characterized by current speeds typically ranging from 5 to 40 cm/sec and averaging 10 cm/sec. Currents near the coast vary in duration and speed as a result of wind and tide induced motions (EQA/MBC, 1973). Water temperatures generally decrease with depth. During the winter however, surface cooling and vertical mixing causes water temperature to become relatively uniform with depth, when it ranges from 13 to 16°C (BC, 1978). During the summer, surface warming creates a thermocline at mid-depth, while surface temperatures range from 17 to 22°C decreasing two to three degrees with depth (IRC, 1973; LCMR, 1976d; BC, 1979). Chemical nutrients and phytoplankton concentrations show a characteristically normal pattern for coastal waters. Nutrient concentrations are generally lower in surface waters than at greater depths, except during winter when vertical mixing results in a relatively uniform distribution throughout the water column (MBC, 1979). Turbidity is caused by suspended sediment particles, organic detritus, and plankton. High turbidity of inshore coastal waters is largely due to the increased turbulence and wave action stirring up and suspending bottom materials (Raymont, 1963). Turbidity in the San Onofre area increases nearshore and near bottom (LCMR, 1976d; BC, 1979). During the spring, upwelling of nutrient rich water from offshore generally increases productivity and may cause locally dense blooms of phytoplankton.

The sea bottom is composed of a complex of boulder, cobble, sand, and kelp substrata. The proportion of each type of substratum varies among areas and is subject to change due to sand accretion and erosion (see Chapter 9). The area directly offshore SONGS is a highly complex mixture of all four types (IRC, 1978; LCMR, 1978c; MBC, 1979). The reference area upcoast of SONGS at San Mateo Point is primarily cobble-boulder and kelp substrata surrounded by sand; the reference area downcoast from SONGS at Don Light is primarily sand with isolated patches of cobble and sandstone shelf (IRC, 1978; LCMR, 1978c).

Fish sampling offshore SONGS has evolved from semi-quantitative visual observations by divers to quantitative multi-gear sampling techniques. Quantitative data on fish populations prior to SONGS Unit 1 operations is limited. Seven subtidal visual transects made by divers from 1963 to 1968 produced a species list consisting of demersal species (Hickman, 1973). Similar observations were made during the initial operation (1968-1973) of Unit 1 although they were often limited in scope by turbid water.

Short term studies using samples caught by gill nets and otter trawls during late 1972 and early 1973 (Hickman, 1973) constituted the first quantitative analysis of SONGS fish populations. However, gill nets set for one hour near SONGS produced minimal information due to the short fishing period. Randomly placed 10 minute otter trawl hauls conducted in 1972 demonstrated the high variability of catches from fish populations in the SONGS area (Hickman, 1973) and provided the necessary abundance and length frequency data for a more complete description of fish populations.

In March 1975 the ETS gill net sampling program began. This sampling program included quarterly survey periods, use of experimental gill nets with various mesh sizes, and replicate sampling. Study sites included stations within the potential area of influence (Zone OA - SONGS) and a reference area (Zone 6 - Don Light approximately 7 km downcoast) (Figure 10-1). Preliminary studies of gill net catches were conducted to determine optimal fishing duration and locations of sample sites to best describe fish populations in the SONGS and Don Light areas based upon ETS requirements (LCMR, 1975g). These preliminary surveys indicated that nets set over cobble bottoms yielded substantially more fish than those set over sand, consequently sites for gill nets were limited to areas of cobble substrata. These studies also evaluated the effectiveness of gill nets in catching surface fishes, but since catch per unit effort was very low, gill nets were used primarily to sample fishes associated with the cobble substrata. Results of the ETS gill net fish sampling program for 1975 through 1978 indicate that (1) the queenfish, Seriphus politus and the white croaker, Genyonemus lineatus were the most numerically abundant fish captured in gill nets, (2) gill net catches in the potential area of influence (Zone OA) were numerically greater than gill net catches in the reference area (Zone 6), (3) there were no significant correlations between abundance in gill net catches and temperature or turbidity, and (4) the presence of substantially greater areal extent of cobble/boulder substrata and algal habitat in Zone OA may account for higher catches and greater number of species observed in Zone OA compared to Zone 6.

On 15-16 March 1978 a preliminary survey was conducted using an otter trawl to sample fishes associated with sand substrata (LCMR, 1978f). The results of this preliminary survey indicated that otter trawls effectively caught smaller fish over sandy areas and could be effectively used to partially complement gill net catches. On 30-31 March 1978, as part of the first 1978 ETS fish survey, a comprehensive 24-h investigation was conducted to evaluate variability of gill net and otter trawl catches, gill net orientation with respect to the coastline, and the suitability of San Mateo Point as an upcoast reference area. Additional gill nets were fished at stations further offshore in the potential area of influence for the Units 2 and 3 diffusers and inshore (30 ft) and offshore (45 ft) of San Mateo Point (Figure 10-1). Otter trawl samples were sequentially taken at the 20-ft, 40-ft, and 60-ft isobaths in the SONGS area for most of the 24-h period, however, a storm forced the discontinuation of trawling activities midway through the study. Analysis of gill net catches resulted in the use of two replicate gill nets per station (2 stations/isobath) fished perpendicular to the shoreline. Additionally, San Mateo Point was chosen as a suitable reference area based upon its bottom topography and species composition and abundance of fishes caught in gill net samples. Analysis of otter trawl catches resulted in the use of two replicate otter trawls per day for two consecutive days at each isobath. A more comprehensive fish sampling program combining the use of gill nets at inshore (30 ft) and offshore (45 ft) isobaths and otter trawls at 20, 40, and 60-ft isobaths in two reference and one test area evolved from this survey. Station locations and fishing techniques utilized in this survey applied to all subsequent

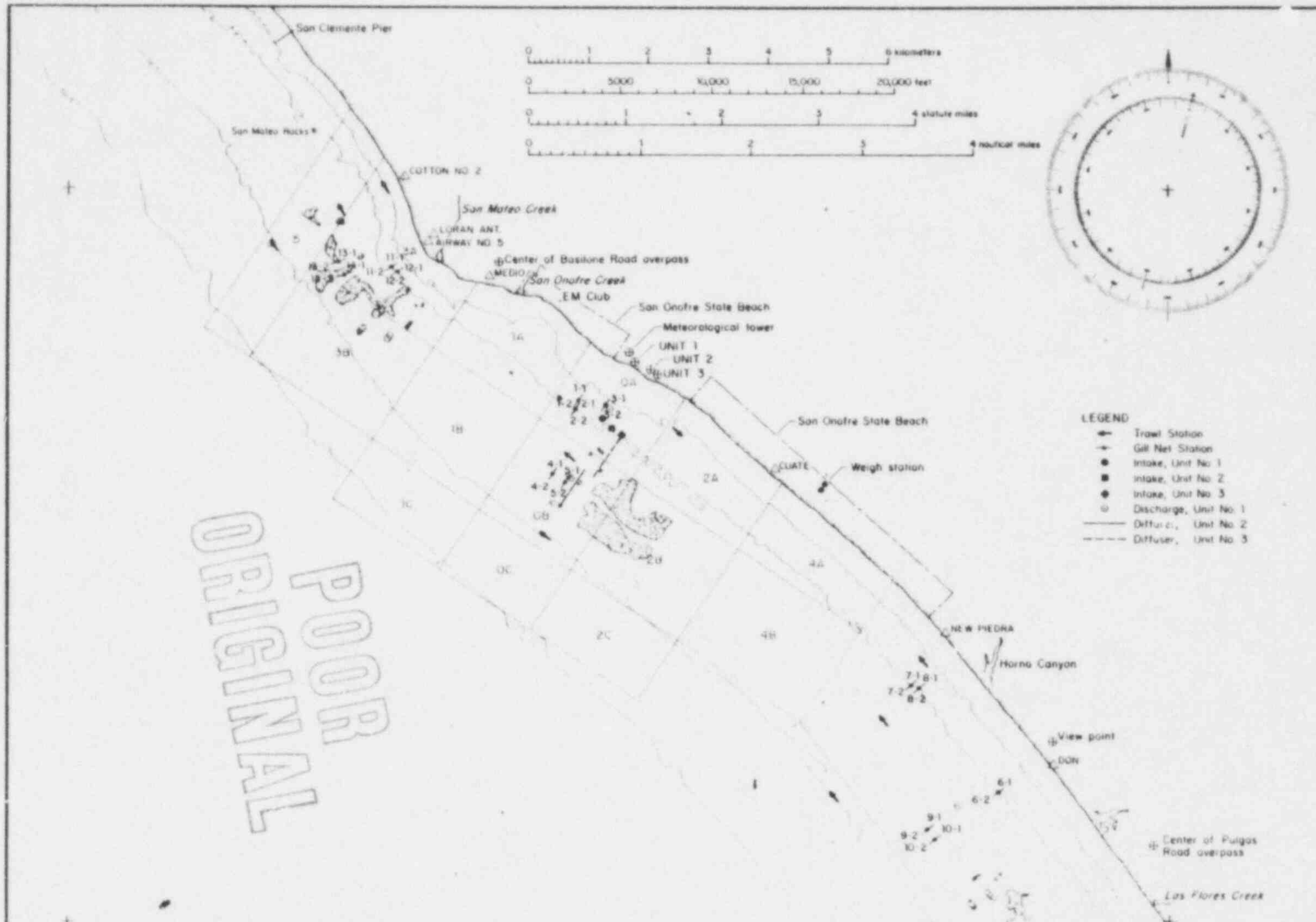

Figure 10-1. **ETS and PMP fish receiving water station locations at San Onofre Nuclear Generating Station. Shaded areas represent the areal extent of the kelp canopies sampled in December 1978.**

1978 fish surveys. This combined fish program is primarily designed to sample fish populations in areas outside of the area immediately surrounding the SONGS Unit 1 discharge.

The fish resources (species composition) in the SONGS region are characteristic of nearshore fish communities observed from Pt. Conception to the Mexican Border (Starks and Morris, 1907; Duffy, 1970). Owing to the complexity of the cobble-sand-kelp habitat offshore SONGS, a wide range of fish families are present. These include the sciaenids (croakers) represented primarily by Seriphus politus (queenfish), Genyonemus lineatus (white croaker), Cynoscion nobilis (white seabass), Roncador stearnsii (spotfin croaker), and Menticirrhus undulatus (California corbina), and the embioticids (surfperches) represented by Hyperprosopon argenteum (walleye surfperch) and Phanerodon furcatus (white surfperch). The latter five species constitute a valuable fishery resource (Frey, 1971). Additionally, these surfperch species are considered characteristic representatives of the fish community associated with kelp beds (Feder, Turner, and Limbaugh, 1974). Other members of the kelp bed fish community caught offshore SONGS include the serranid Paralabrax clathratus (kelp bass), the labrids Chromis punctipinnis (blacksmith) and Oxyjulis californica (senorita), and several species of the family Scorpaenidae (rockfishes).

Impingement

Comprehensive impingement studies began in July 1974 and continue to date. The objectives of the fish impingement program are to accurately define the magnitude of fish impingement and to relate this information to offshore fish populations. In-plant sampling during heat treatments and normal operations periods was initiated in 1974 to achieve these objectives. As part of ETS section 3.1.2a(2)B, a special study evaluating sampling duration and frequency under normal flow conditions was initiated in November 1974. This program required the collection and analysis of two to three continuous 24 h impingement samples per week. Historical impingement over three previous years (1975, 1976, 1977) has averaged approximately 243,380 individuals weighing an average of 24,363 lb per year. The abundant species impinged, by number, for these years are queenfish, walleye surfperch, white croaker, and white surfperch. This special study culminated in a report (LCMR, 1979b) recommending that an optimal allocation sampling scheme, based upon seasonal trends in impingement catch, be implemented at SONGS Unit 1.

The purpose of this report is to analyze and interpret the 1978 data collected by the combined ETS-PMP fish program, establish a baseline for determining the potential effects of Units 2 and 3, and to identify any ecologically significant alterations in the marine environment which may be attributed to the operation of SONGS Unit 1.

METHODS

The methods of collection and analysis of fish samples from the combined ETS and PMP fish in receiving water programs and the fish impingement study are described in this section.

RECEIVING WATER

Techniques for acquiring data in the field and laboratory and for statistically analyzing these data are presented.

Field

The field sampling strategy is of the "restricted systematic design"; whereby sampling sites are predetermined and it is assumed that the fish randomize themselves by moving in complex patterns relative to the sampling site (Venrick, 1978).

A detailed description of station locations and field methodology is given in ETS Fish Survey Procedures (SCE R&D/LCMR, Procedures EMP 25-5-35) and PMP Fish Survey Procedures (SCE R&D/LCMR, Procedures N-1-1/79). A general review of these procedures is presented below.

A total of 14 gill net stations were established at sites in an upcoast (San Mateo Point - Zones 3A, 3B) reference area, an area directly offshore of SONGS Units 1, 2, and 3 (SONGS - Zones 0A, 0B), and a downcoast (Don Light - Zone 6) reference area (Figure 10-1). Each gill net station consists of a pair of identical Marinovich experimental monofilament gill nets for replicate sampling. Each net measures 45.7 m long, 1.8 m deep and contains six 7.6-m panels of bar mesh with the following sizes: 22 mm, 25 mm, 38 mm, 46 mm, 53 mm, and 76 mm. All nets are set over mostly cobble substrata perpendicular to the shoreline and are retrieved 24 h later after fishing through the periods of greatest fish activity during dawn and dusk. Eight of the 14 stations (Station 1, 2, 3, 6, 7, 8, 11, and 12) are located on the 9-m (30-ft) isobath. The remaining six stations (4, 5, 9, 10, 13, and 14) are located on the 14-m (45-ft) isobath (Figure 10-1). Station 3 is located within 50 m of the SONGS Unit 1 discharge and Station 6 is located approximately 2 km downcoast of Stations 7 and 8 (Figure 10-1).

Otter trawl samples are collected over sand substrata at nine stations at depths of 6.1 m, 12.2 m, and 18.3 m (20, 40, and 60 ft) in Zones 6, 2A, 0B, 3A, and 5 (Figure 10-1). A 25-ft semi-balloon otter trawl is used to make two sequential 5-min trawls (i.e., a pair of replicate samples) at each station on two consecutive days during daylight hours (18 trawls/day for a total of 36 trawls/survey). Trawl samples are collected within the same 24-h period that gill nets are fished. Trawl stations are located at sites over sandy bottom in the same general areas as gill nets. Sites for stations were established to provide data for assessing the present effects of the SONGS Unit 1 discharge, as well as to provide baseline data for assessing possible future effects of Units 2 and 3 when they become operational.

Temperature and light transmissivity are measured at 1-m depth intervals from the surface to the bottom, once daily for the two days of the survey at each cluster of 9-m and 14-m gill nets.

Sampling with gill nets and otter trawls is conducted bimonthly. In 1978, combined ETS and PMP surveys were made on 30-31 March, 14-15 June, 15-16 August, 11-12 October, and 12-13 December. The 30-31 March survey was unique in that methods were developed during this survey using gill nets and otter trawls that were used in all subsequent surveys (see Introduction: approach section).

Laboratory

All fishes collected in gill net and otter trawl samples are identified, counted, and visually inspected for anomalies, diseases, and parasites. A group of select fish species has been studied more intensively with the onset of the

combined program. These species were selected because of their numerical dominance in SONGS Unit 1 impingement samples, their abundance offshore, and/or because of their value to local sport and commercial fisheries:

Seriphus politus	- Queenfish
Genyonemus lineatus	- White croaker
Roncador stearnsii	- Spotfin croaker
Cynoscion nobilis	- White seabass
Hyperprosopon argenteum	- Walleye surfperch
Phanerodon furcatus	- White surfperch
Paralabrax clathratus	- Kelp bass
Paralabrax nebulifer	- Barred sand bass
Paralabrax maculatofasciatus	- Spotted sand bass
Paralichthys californicus	- California halibut

Select species are identified, enumerated, measured, and sexed. Standard lengths (tip of the snout to the end of the vertebral column) of a maximum of 125 individuals per species from each gill net and otter trawl sample are measured. A subset of no more than 50 individuals per species are sexed (male, female, indeterminate) by examining their gonads or by noting secondary sexual characteristics when evident. Indeterminate fish are sexually immature, recently spawned, or damaged such that sex cannot be determined. General reproductive condition of fish is also noted.

Data Analysis

Gill net and otter trawl samples of fish from receiving waters are analyzed at community and population levels. Community level analysis involves species composition, relative abundances, and diversity; population analysis involves abundance, size (age) structure, and sex composition of select species populations.

Community level analysis compares species composition, relative abundance, and rank abundance through time and among depths within the potential area of influence and two reference areas. Rank abundances are based upon the mean catch of four replicate gill nets and two pairs of replicate otter trawls at each depth stratum within each area during five surveys in 1978. Only one pair of otter trawl samples was taken in all areas on 15-16 March 1978, therefore rank abundances for March otter trawls are based upon the catch of two, rather than four, trawl samples.

The evenness measure, J', of Pielou (1975) is used to describe the diversity of fish caught in gill nets and otter trawls. The index:

$$J' = \frac{H'}{\log S}$$

where H' = Shannon-Wiener diversity index

S = number of species

scaled from 0.0 to 1.0, measures evenness of the distributions of individuals among species in a sample or collection. It is maximal (1.0) if all species in the sample have the same number of individuals and it approaches zero as one

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species predominates in numbers. Thus, intermediate values indicate varying degrees of dominance by one or more species.

Analyses of offshore fish samples of selected species include abundance, length (age) frequency distributions, and sex ratios. Abundance data are presented as geometric means $\pm$ 90% confidence limits for gill net and otter trawl catches. Original values (x), whose distributions are skewed, are transformed to log (x + 1) to compute means and confidence limits, which are converted back to antilogs (geometric mean) for graphical presentation. The log (x + 1) transformation minimizes extreme values so variances are no longer correlated with means and tend to be homogeneous among samples. Valid use of parametric statistics, such as comparing means by confidence intervals, assumes that distributions of the variates approach normality; i.e., that variances are nearly independent of means and are nearly homogeneous. This assumption allows visual evaluation of significance by comparing mean abundances by overlap or non-overlap of their confidence interval within study areas, between depths, and through time.

Length frequency distributions presented as histograms are used to estimate the size (age) structure of the selected species populations. Modal length classes are compared within areas, between depths, and through time to follow relative seasonal variation in recruitment, growth and/or migration of the selected species.

Sex ratios of selected species are depicted as bar graphs for each depth and time within areas. The Chi square goodness of fit for replicated tests (Sokal and Rohlf, 1969) is used to test for significant departures from a 50:50 ratio of males to females among depths and within areas for each survey in 1978.

IMPINGEMENT

Heat Treatment

During each heat treatment, fish collected by the traveling screens and bar racks are identified, enumerated, weighed, and measured. In addition, all fish that are measured are also examined for disease and/or abnormalities. Sex ratios of ident species (Reference: letter of December 4, 1974 from J. E. Fitch, California Dept. of Fish and Game to A. R. Strachan, SCE) are estimated from subsamples when possible.

Normal Operation

During normal plant operation samples were taken weekly. The total weight and number of fish, by species, removed from the traveling screens and bar racks over a continuous period of 24 hours were monitored at least once per week during the first three weeks following heat treatment and twice per week thereafter, until the next heat treatment.

Data Analysis

Analysis of impingement catch involves (1) estimating the annual total and selected species catch, (2) describing the length frequency distributions of the selected species, and (3) estimating sex ratios of selected species.

The annual impingement catch in weight and numbers of fish is estimated as the sum of monthly means weighted by the total number of plant operational days

per month. An operational day is defined as two circulation pumps operating 24 hours/day. This sum, calculated from the monthly stratified samples, estimates total annual impingement under normal flow conditions. The standard error of the stratified sample mean is the sum of monthly values and is expressed as:

$$S(I) = \sqrt{\Sigma(N_h^2\ S_h^2/n_h)}$$

where $S(I)$ = standard error of total impingement

N_h^2 = total number of plant operational days in stratum h (month)

S_h^2 = sample variance of impingement catch in stratum h (month)

n_h = number of impingement samples in stratum h (month)

The total annual impingement estimate for Unit 1 is the sum of the estimated total impingement under normal flow, plus the total impingement during heat treatment.

Length frequency histograms are presented for Seriphus politus and Genyonemus lineatus, which consistently comprise the greatest part of the SONGS Unit 1 impingement catch (LCMR, 1978c). Analysis of length frequency samples for selected species taken under normal flow and heat treatment operations suggests that individuals of these species are impinged soon after entrapment rathar than remaining in the screenwell for a period of time (LCMR, 1978c). Histograms based on impingement samples describe length frequency distributions of these species taken for approximately the same dates (28, 29, 31 March; 13 and 14 June; 9, 10, 21, 22 August; and 12, 13, 14 December) as fish surveys in receiving waters. Since impinged fish were taken on a series of dates within which fish in receiving waters were sampled, length frequencies of impinged fish can be compared with those of fish sampled offshore.

Sex ratios of the selected species are presented as bar graphs. As above, comparisons are made between impingement and receiving water samples that were taken within a similar time period.

RESULTS

The results of the 1978 fish program include those pertaining to fish in receiving waters and impingement of fish. Fish in receiving water data include an analysis of the fish community as sampled by gill nets and otter trawls, followed by population analyses of the abundance, length, and sex ratios of select species.

Analysis of the annual impingement catch at SONGS Unit 1 includes a temporally stratified annual estimate of total fish and select species impingement and comparisons of length frequency and sex ratios of impinged select species with similar data from their offshore populations.

RECEIVING WATERS

Community Analysis

Analysis of the fish community sampled by gill nets and otter trawls utilized species composition, rank abundance, and diversity data. Total number of

species and individuals caught in the ETS program from 1975 through 1977 and for the combined ETS-PMP programs in 1978 are presented in Table 10-1. Species composition and rank abundances for gill nets and otter trawls are presented in Tables 10-2 and 10-3, respectively. Community analyses of species diversity of fish in gill net and otter trawl samples by Pielou's evenness measure (J') are presented in Figure 10-2 nd 10-3 for the San Mateo Point, SONGS, and Don Light areas.

A total of 89 species comprising a total of 55,997 individuals representing 39 families were caught using gill nets and otter trawls in 1978. Gill nets caught 10.7% (6,006 individuals) of the total catch and otter trawls caught the remaining 89.3% (49,991 individuals) (Table 10-1).

Gill Nets. Species composition and rank abundance of gill net catches in 1978 are presented in Table 10-2. Species listed in Table 10-2 have catches averaging at least one individual per net. This criterion was used to eliminate those species from the rank abundance table which were considered numerically unimportant for this analysis. Three species, queenfish *Seriphus politus*, white croaker *Genyonemus lineatus*, and walleye surfperch *Hyperprosopon argenteum*, comprised 78.9% of the total gill net catch. Queenfish were caught in all areas and at all depths in each survey and were numerically dominant throughout 1978, accounting for 42.7% of the total gill net catch. White croaker catch ranked second, comprising 31.0% of the 1978 gill net catch and were generally caught in all areas, depths, and surveys. Walleye surfperch catches made up 5.2% of the total catch, ranked third in overall gill net catch, and exhibited spatial and temporal catch distributions similar to queenfish and white croaker.

No temporal patterns in species composition or rank abundances of fishes caught in gill nets were found. Queenfish, white croaker, and walleye surfperch were the only species consistently caught throughout the year within each area; catches of all other species were variable.

Spatial patterns of fish species were evident within all areas. The apportionment of species among depths and areas forms a pattern reflecting the preferred habitat of certain fish. In addition to the three species mentioned above gill nets fished at the 30-ft isobath at San Mateo Point and at the 45-ft isobath at SONGS and San Mateo Point areas caught a group of fish commonly associated with kelp beds (Feder, Turner, and Limbaugh, 1974). This group included kelp bass, *Paralabrax clathratus*, halfmoon, *Medialuna californiensis*, white surfperch *Phanerodon furcatus*, black surfperch *Embiotoca jacksoni*, sheephead *Pimelometopon pulchrum*, and pile surfperch *Damalichthys vacca*. The presence of these species at these depths at SONGS and San Mateo Point reflect the presence of kelp nearby (within 1 km). Few of these species were caught in gill nets at the 30-ft SONGS site, or at the 30 or 45-ft isobaths in the Don Light area (Table 10-2)' suggesting the lack of kelp habitat in these areas in 1978.

Mean evenness (J') for the part of the fish community at San Mateo Point sampled by gill nets fluctuated relatively little throughout the year and varied concordantly between shallow (30 ft) and deep (45 ft) samples. In general, means were relatively high in fall and low in spring (Figure 10-2), indicating that catches perhaps contained relatively more individuals among a few species during the latter period. As indicated by standard deviations, however, variance of J' was highest when means were lowest for spring and summer shallow samples, indicating that the degree of dominance fluctuated most among these catches. Shallow and deep samples showed little difference in mean J'.

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Table 10-1. Total number of fish species and individuals sampled in the ETS program from 1975 to 1977 and for the combined ETS-PMP programs in 1978.

Category	1975[1]	1976[1]	1977[1]	1978[2]
Number of species	49	. 46	41	89
Number of individuals	3,206	3,383	3,216	55,997

[1]The 1975, 1976, and 1977 survey data are based upon quarterly samples of 12 gill nets.

[2]The 1978 survey data are based upon bimonthly gill net and otter trawl samples.

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Table 10-2. Rank abundance of fish species represented by an average catch of one individual per gill net in SONGS, San Mateo Point, and Don Light areas, during 1978.

	SONGS										San Mateo Point										Don Light									
	30 ft					45 ft					30 ft					45 ft					30 ft					45 ft				
	Mar	Jun	Aug	Oct	Dec	Mar	Jun	Aug	Oct	Dec	Mar	Jun	Aug	Oct	Dec	Mar	Jun	Aug	Oct	Dec	Mar	Jun	Aug	Oct	Dec	Mar	Jun	Aug	Oct	Dec
Seriphus politus	5.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	3.0	3.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	5.0	1.0	1.0	2.0	1.0	-
Genyonemus lineatus	7.0	-	2.0	2.0	3.0	2.0	3.0	5.0	2.0	-	3.0	2.5	3.0	8.5	-	2.0	3.0	2.0	10.0	-	2.0	2.0	2.0	2.0	4.0	2.0	2.0	1.0	2.0	-
Phanerodon furcatus	-	-	-	-	1.3	10.0	4.0	2.0	3.0	1.0	-	-	4.5	6.0	1.0	5.0	7.0	-	11.0	2.0		-	5.5	8.0	2.0	-	3.0	3.0	3.5	-
Hyperprosopon argenteum	8.5	6.5	3.0	-	5.0	13.0	2.0	4.0	4.0	5.0	4.0	2.5	2.0	3.0	4.5	6.5	-	7.0	13.0	-	4.5	-	3.0	-	-	4.0	5.5	4.0	6.5	-
Menticirrhus undulatus	4.0	6.5	-	6.0	8.0	7.0	6.5	-	-	-	5.5	5.5	-	-	-	8.5	-	-	13.0	-	4.5	3.0	5.5	3.0	3	3.0	4.0	5.0	4.0	-
Cheilotrema saturnum	10.5	9.0	-	-	6.0	7.0	5.0	-	5.0	2.0	8.0	4.0	10.0	10.0	2.0	11.5	-	5.5	3.5	-	7.0	-	-	-	6.0	5.0	-	-	-	-
Cynoscion nobilis	6.5	5.0	7.0	3.5	7.0	3.5	-	-	-	-	8.0	-	-	-	6.0	6.5	-	-	2.5	8.0	-	-	-	7.0	-	-	-	-	-	-
Embiotoca jacksoni	-	-	-	-	4.0	7.0	6.5	3.0	-	-	-	-	12.0	5.0	-	-	-	-	3.5	-	-	-	-	-	-	-	-	-	8.0	-
Paralabrax clathratus	-	-	-	-	-	7.0	-	6.0	-	-	-	-	-	11.5	-	8.5	4.5	-	6.0	3.0	8.0	-	-	6.0	-	-	5.5	-	9.5	-
Paralabrax nebulifer	-	-	-	7.0	11.0	13.0	-	-	7.0	3.0	-	-	12.0	4.0	-	-	-	-	5.0	10.0	-	-	-	-	-	-	-	-	5.0	-
Medialuna californiensis	-	-	-	-	-	3.5	-	-	6.0	-	-	-	7.0	2.0	-	-	2.0	-	-	6.0	-	-	-	-	-	-	-	-	-	-
Triakis semifasciata	1.5	8.0	-	4.5	9.0	-	-	-	-	-	-	-	-	13.5	-	11.5	-	-	7.0	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	-	-	-	-	10.0	-	-	-	-	-	8.0	-	-	-	-	-	-	-	-	-	4.5	-	-	5.0	1.0	-	-	-	-	-
Mustelus californicus	6.0	3.0	5.0	4.5	-	-	-	-	-	-	-	-	-	-	-	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	-	-	-	-	-	13.0	-	8.0	-	-	-	-	4.5	-	-	-	-	8.5	13.0	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	1.5	-	-	-	-	13.0	-	-	-	-	2.0	-	-	-	-	-	-	5.5	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsii	3.0	2.0	-	-	-	-	-	-	-	-	5.5	-	-	-	-	-	-	-	-	-	-	-	7.0	-	-	-	-	-	-	-
Sarda chiliensis	-	-	6.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5	-	-	-	-	4.0	-	-	-	-	-	9.5	-
Pimelometopon pulchrum	-	-	-	-	-	13.0	-	-	-	-	-	-	12.0			-	-	-	5.5	4.5	-	-	-	-	-	-	-	-	-	-
Chromis punctipinnis	-	-	-	-	-	-	-	-	-	-	-	-	6.0	-	-	1.0	-	-	-	3.0	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	-	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	2.0	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	-	-	4.0	-	-	-	-	-	-	-	-	-	9.0	-	-	-	-	-	-	-	-	-	-	4.0	-	-	-	-	-	-
Trachurus symmetricus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	-	6.0	-	-	7.0	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonii	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0	7.0	-	-	-	-	4.5	-	-	-	-	-	-	-	-	-	-
Rhacochilus toxotes	-	-	-	-	-	-	-	8.0	-	-	-	-	8.0	8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachyistius frenatus	-	-	-	-	-	-	-	-	-	-	-	-	-	13.5	-	11.5	-	-	-	-	4.5	-	-	-	-	-	-	-	-	-
Damalichthys vacca	-	-	-	-	-	-	-	8.0	-	-	-	-	14.0	11.5	-	-	-	-	-	10.0	-	-	-	-	-	-	-	-	-	-
Heterostichus rostratus	10.5	-	-	-	-	7.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hermosilla azurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.0	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes serranoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scomber japonicus	-	-	-	-	-	-	-	-	-	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mustelus henlei	-	-	-	-	-	-	-	-	-	-	-	5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Synodus lucioceps	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0	-	-
Xenistius californiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5	-
Scorpaena guttata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	-	-	-	-	-	-	-

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Table 10-3. Rank abundance of fish species represented by an average catch of one individual per otter trawl in SONGS, San Mateo Point, and Don Light areas, during 1978.

[illegible]

Table 10-4. Mean monthly number and weight of fish impinged by SONGS 1 during 1978.

Month	Total Fish		Queenfish		White Croaker		White Surfperch		Walleye Surfperch		Number of Operational Days per Month	Number of Samples per Month
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.		
January	1943	159	1305	52	57	7	52	5	261	29	30.9	3
February	2585	267	1826	110	120	15	3[illegible]	2	338	32	27.9	9
March	1603	107	1073	50	38	5	29	2	152	14	30.6	10
April	3782	196	3227	105	18	3	40	2	148	9	16.5	5
May	3023	204	2287	70	317	47	48	2	43	1	30.6	9
June	1088	97	751	42	137	6	42	1	76	13	29.1	11
July	1044	74	645	29	98	4	42	1	50	2	29.9	9
August	4764	270	1966	107	1661	89	50	1	171	14	31.0	7
September	472	36	128	6	8	2	2	0.1	19	1	16.6	2
October	-	-	-	-	-	-	-	-	-	-	*	*
November	380	16	213	4	5	0.1	2	0.1	17	1	26.9	8
December	465	26	307	6	20	1	3	0.1	20	1	30 8	8

*Generating Station offline.

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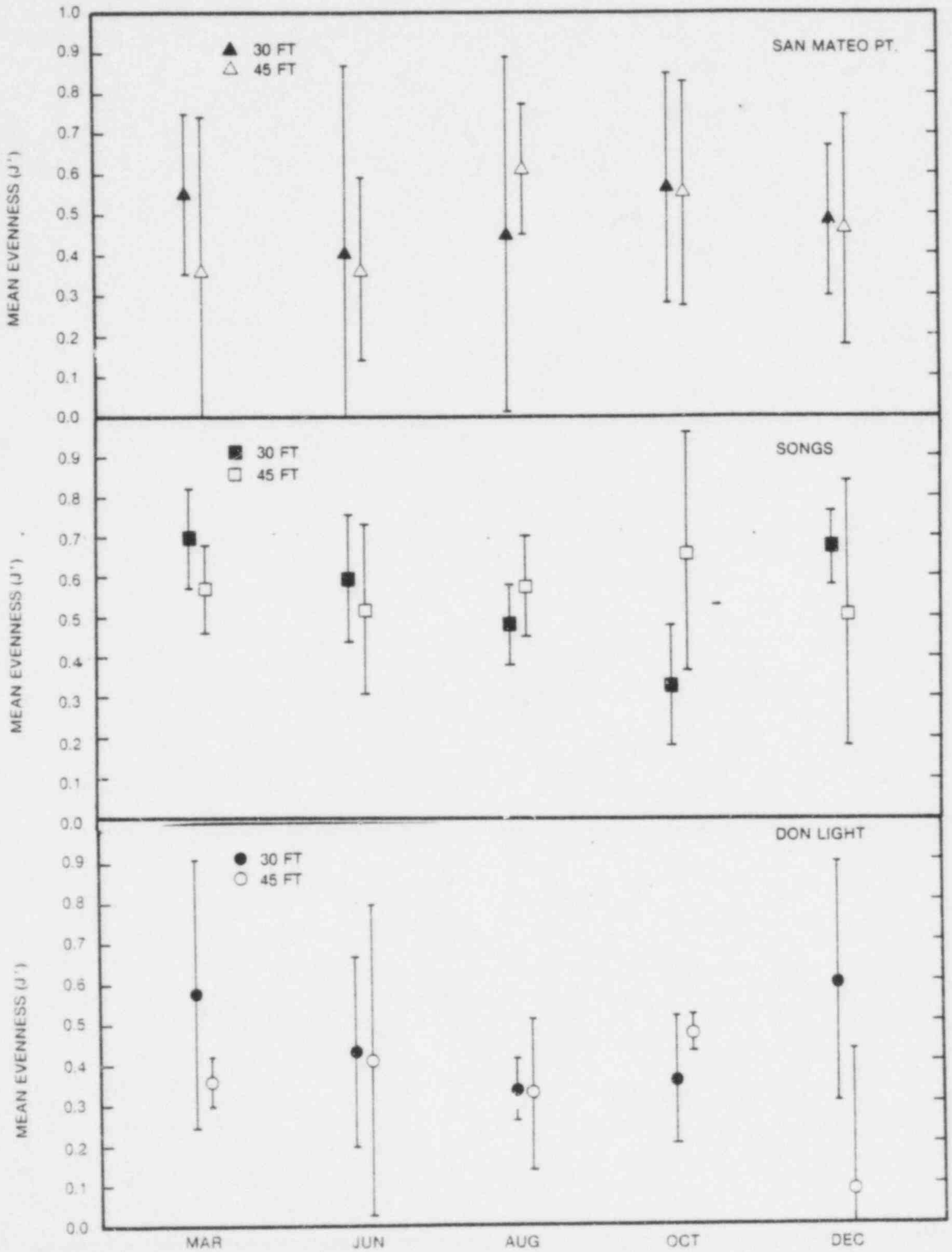

Figure 10-2. Pielou's mean evenness values calculated for gill nets set at 30 and 45 ft for each study area during 1978

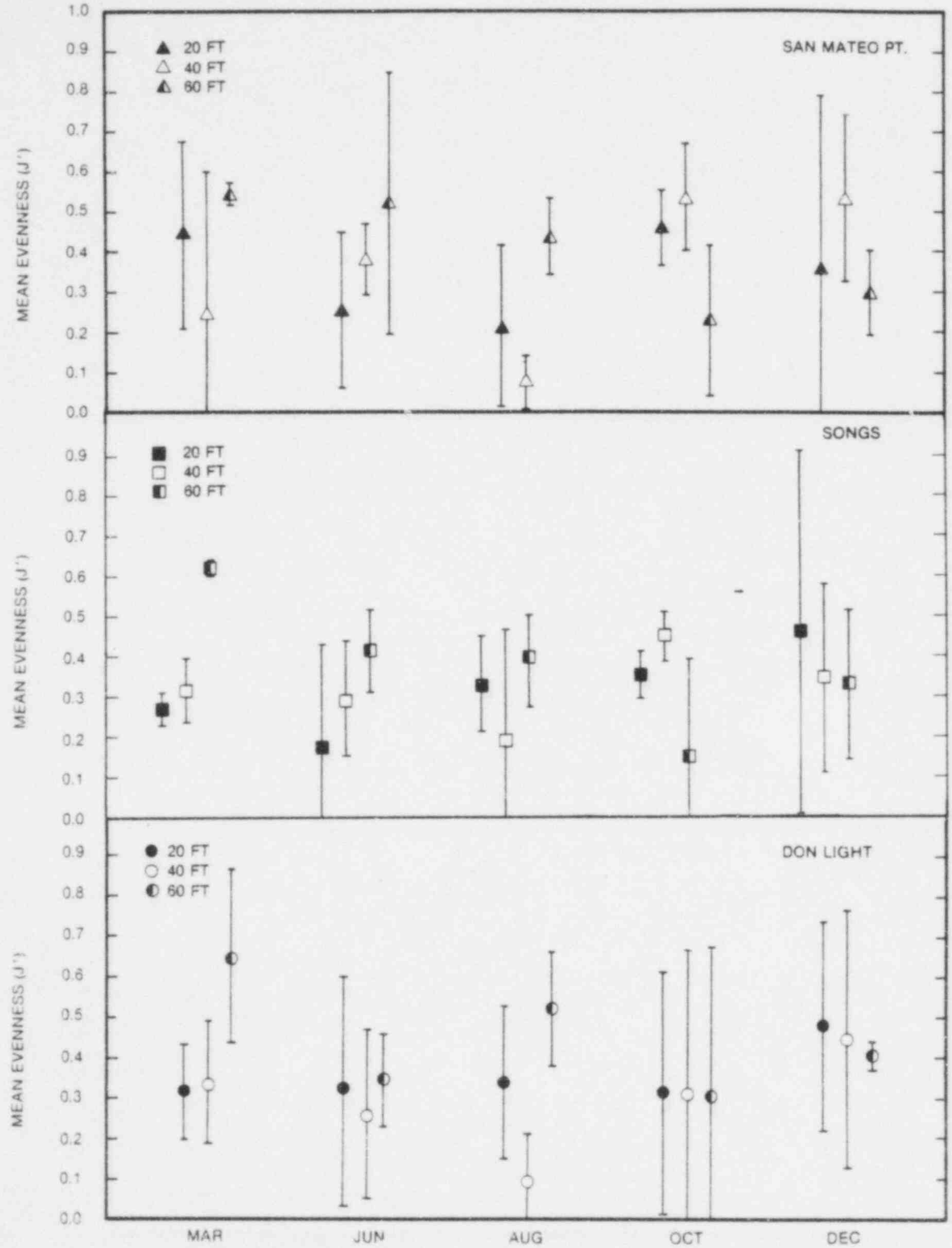

Figure 10-3. Pielou's mean evenness values calculated for otter trawls set at 20, 40, and 60 ft for each study area during 1978.

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Mean evenness fluctuated more widely in a different pattern among bimonthly samples from the Don Light reference area (Figure 10-2). Although means varied concordantly between deep and shallow samples throughout much of the year, they differed markedly in December, when shallow catches were dominated by a few species. Unlike those for the San Mateo area, Don Light means were lowest for summer samples, but like those for San Mateo, variances were relatively high for spring samples. Variances were also high for the disparate winter shallow and deep samples, indicating fluctuations in degree of dominance by a few species and perhaps relatively extensive movements of fish in and out of the area and between deeper and shallower habitats.

The seasonal pattern of sample evenness at the potential area of influence (SONGS) resembled that at the Don Light reference area more closely than that at San Mateo Point. Yet with the exception of fall and winter deep samples, variances of J' were generally lower than those for either reference area. This indicates that dominance-diversity relations of the SONGS fish community sampled by gill net may be relatively predictable, especially during spring and summer when other areas show shifts in dominance-diversity relations.

Otter Trawls. Species composition and rank abundance of otter trawl catches in 1978 are presented in Table 10-3. The three numerically dominant species included northern anchovy, queenfish, and white croaker. These three species accounted for 58.1% (29,025 individuals), 20.7% (10,332 individuals), and 12.2% (6,165 individuals) of the 1978 otter trawl catch, respectively. Together, these three fish species comprised 91.0% of the annual otter trawl catch.

Species composition for the fish community sampled with otter trawls generally fluctuated throughout the year among depths and areas (Table 10-3). A group of species composed of G. lineatus, speckled sanddab Citharichthys stigmaeus, shiner surfperch Cymatogaster aggregata, P. furcatus, S. politus, and northern anchovy Engraulis mordax recurred at all depths and areas. The sandy habitat sampled by otter trawls is preferred by the speckled sanddab (Ford, 1965); the remaining species in this group may also occupy this habitat although it may not be preferred (Feder, Turner, and Limbaugh, 1974).

Mean evenness for the part of the fish community at San Mateo Point sampled by otter trawl varied between shallow (20 ft) and intermediate depth (40 ft) samples, with lowest values in summer and highest in fall and winter (Figure 10-3). On the other hand, mean evenness of deep (60 ft) samples was lowest in the fall, indicating greatest dominance by few species. The greatest difference between deep and intermediate samples was in summer, when catches at intermediate depths showed greatest dominance. As in the other areas, the San Mateo Point deeper catches are more evenly distributed than shallow catches during much of the year. Like those of samples from other areas, variances were generally least in summer.

Mean evenness fluctuated in a similar pattern among bimonthly samples from the Don Light area, except that means of samples from intermediate depth were essentially invariant over much of the year (Figure 10-3). Unlike those for other areas, variances were relatively great for fall samples from all three depths, indicating that catches varied widely in their degree of dominance by common species.

The seasonal pattern in the SONGS area resembled that at both reference areas, although trends were less marked (Figure 10-3). Excepting the winter

shallow sample, the SONGS variance of J' was generally lower than those for either reference area. As it did for gill net samples, this pattern indicates that dominance-diversity relation of the SONGS fish community sampled by otter trawl may be relatively predictable, especially during spring and summer.

Population Analyses

Seriphus politus (Queenfish)

Abundance. Catch data for Seriphus politus collected in gill nets and otter trawls at San Mateo Point, SONGS, and Don Light are presented in Figures 10-4 through 10-6.

Figures 10-4, 10-5, and 10-6 depict predictable seasonal patterns of Seriphus abundances as represented in samples from gill nets set at 30 and 45-ft depths and in samples from trawls conducted at 20 ft. However, seasonal abundance patterns as represented by samples from otter trawls conducted at 40 and 60 ft were more erratic (Figure 10-6). Queenfish abundances decreased appreciably in all areas and depths during the December survey (Figure 10-4 through 10-6).

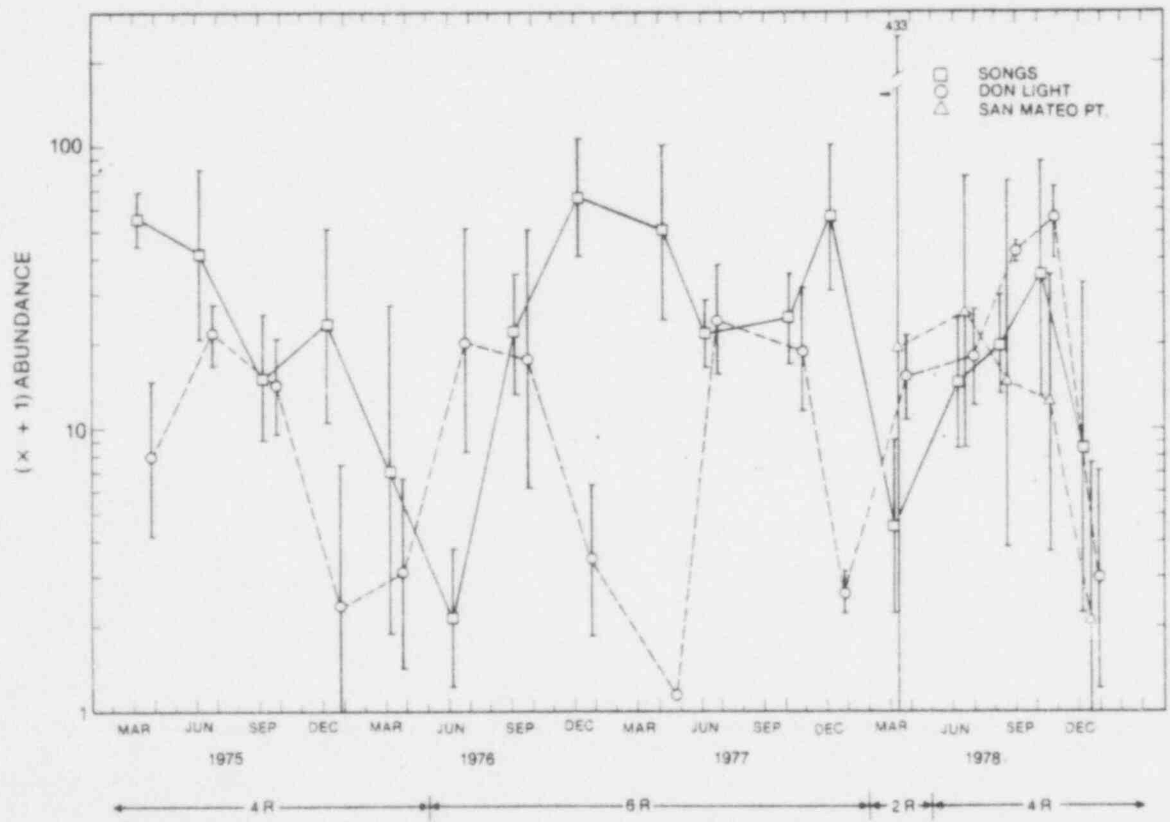

Figure 10-4. Geometric mean and 90% confidence limits of Seriphus politus captured at 30 ft in gill nets set at SONGS and Don Light during the period from 1975 to 1978 and San Mateo Point during 1978. The number of replicates (R) for all means are indicated below the abscissa.

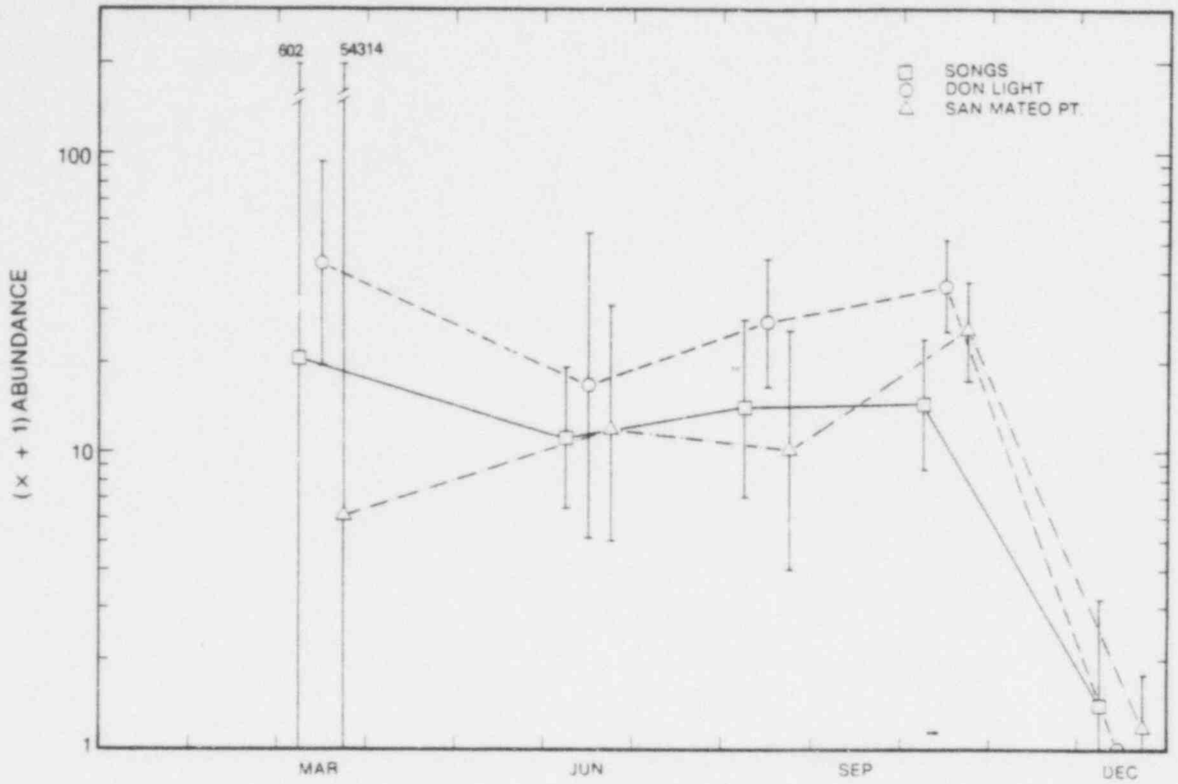

Figure 10-5. Geometric mean and 90% confidence limits of Seriphus politus captured at 45 ft in four replicate gill nets set at San Mateo Point, SONGS, and Don Light during 1978.

Seriphus was the most abundant species sampled in the San Onofre region during 1978, being most abundant in samples from otter trawls at 20 ft, and gill nets set at 30 ft (Figures 10-6 and 10-4) in all areas throughout the year. This species was least abundant offshore at 40 and 60-ft stations (Figures 10-5 and 10-6). Gill nets set adjacent to the SONGS Unit 1 discharge (Station 3) generally produced the highest catches for gill nets set on the 30-ft isobath throughout the year (Figure 10-7). Wide confidence limits about means of these gill net samples were due to the low number of replicates (2).

The long term periodicity of mean queenfish abundance reflected by samples from gill nets set at 30 ft in the SONGS and Don Light areas showed seasonal concordance between areas during 1978 only (Figure 10-4). From 1975 through 1977, seasonal catches varied discordantly between these two areas. From 1975 to 1977, queenfish catches were higher in the SONGS area during oceanic winter months of December to March, and lower at Don Light. However, in 1978 queenfish catches were lower in all areas during the winter.

Length Frequency. Gill nets collected similar modal size classes of Seriphus throughout the year (LCMR, 1979a, pages 246-277). These size classes were centered about the 135-140 mm, 175-180 mm, and 205-210 mm standard length (SL) modes in all areas at both 30 and 45 ft. The smaller size class (135-140 mm SL) was more prevalent from March through June. A shift in the number of larger Seriphus (175-180 mm SL) caught was evident in the August, October, and December surveys, although each size category was still represented by some individuals.

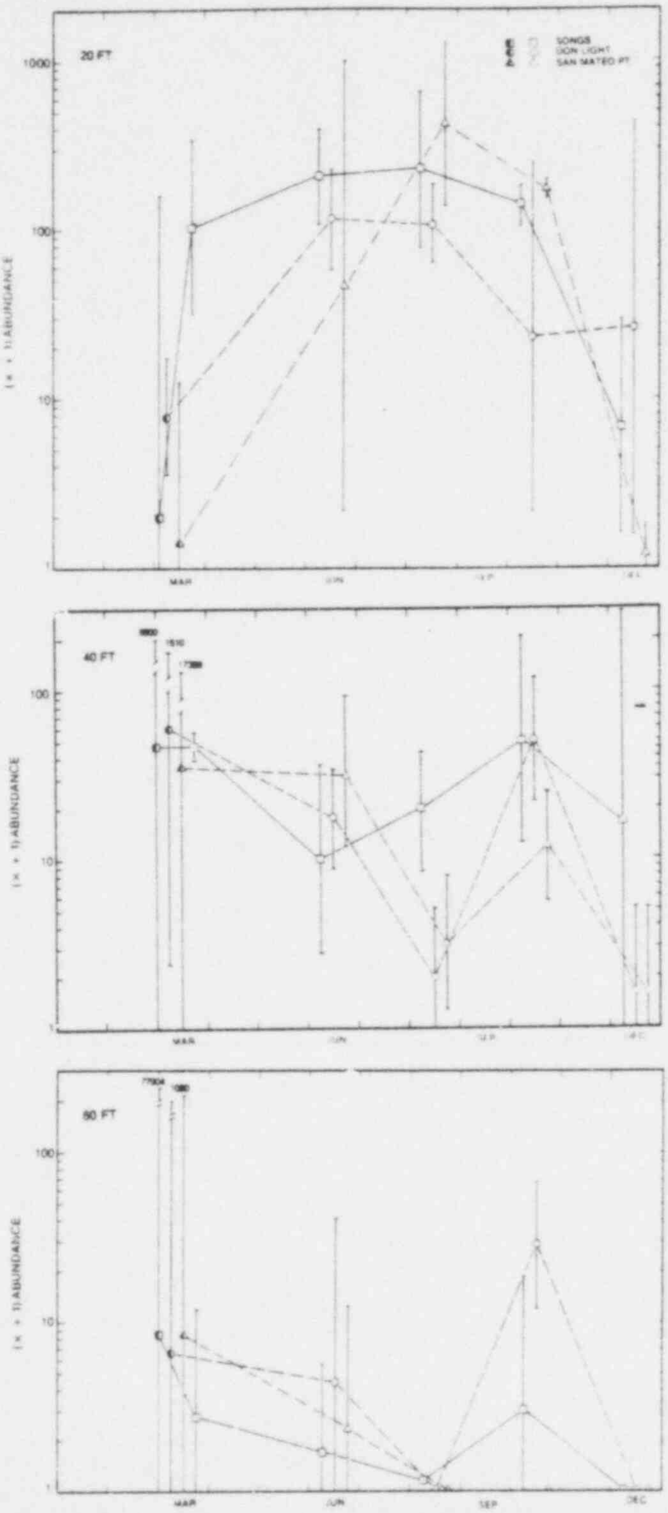

Figure 10-6. Geometric mean and 90% confidence limits of Seriphus politus caught at 20, 40, and 60 ft in daytime otter trawls conducted at San Mateo Point, SONGS and Don Light during 1978. Means from March preliminary trawls (half shaded) are based on two replicates, all other means are based on four replicates.

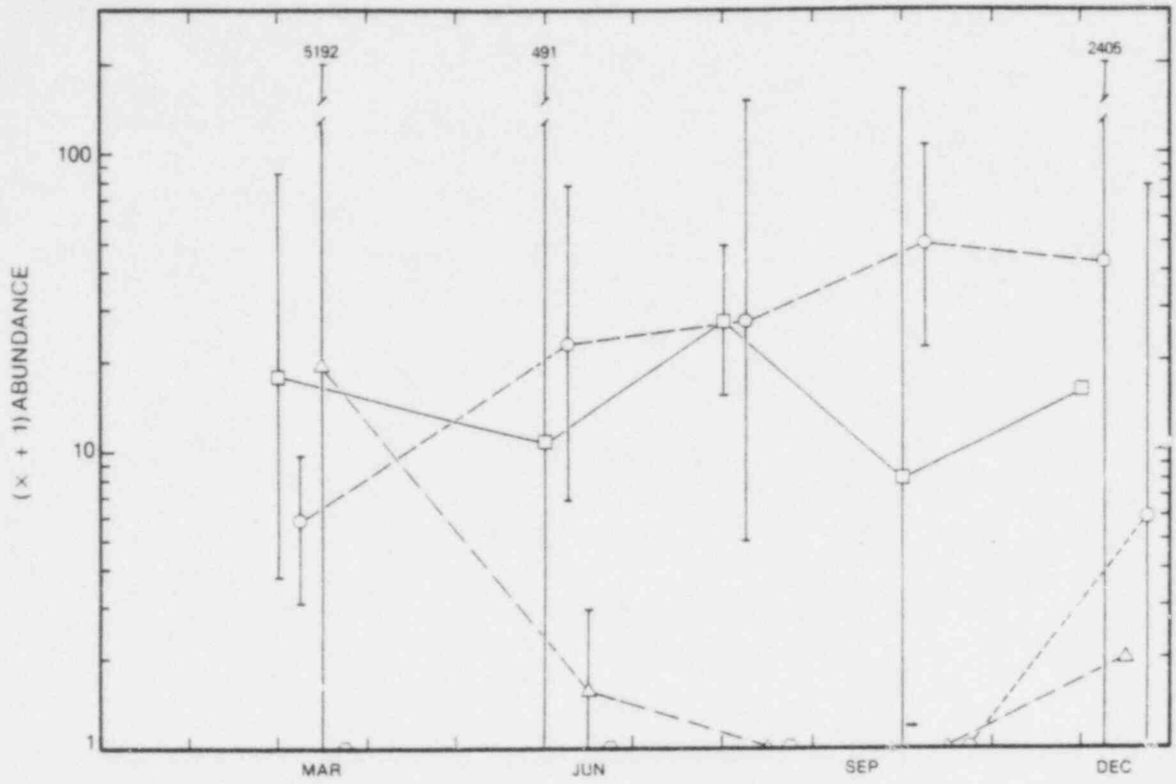

Figure 10-7. Geometric mean and 90% confidence limits for Seriphus politus (○), Genyonemus lineatus (□), Hyperprosopon argenteum (△) and Phanerodon furcatus (⬡) from the two replicate gill nets set adjacent to the SONGS Unit 1 discharge.

Seasonality of queenfish size class structure depicted by otter trawl catches coincided with published reproductive life history information for this species (Goldberg, 1976). The modal size distribution of queenfish at 20 and 40 ft in the SONGS area was 100-120 mm (SL) in March and June. Later in the year, during August and October, large numbers of small (20-80 mm SL) queenfish were captured at the 20-ft isobath. Small Seriphus (40-50 mm SL mode) were less abundant during December as a 60-70 mm SL mode was caught more frequently.

In general, slight shifts toward larger individuals were apparent in trawl collections made offshore SONGS at 40 and 60 ft compared to smaller individuals inshore (20 ft). March and October were the only surveys when juvenile queenfish appeared offshore in appreciable numbers. During other survey periods, the offshore population was mainly comprised of large Seriphus (120-200 mm SL).

The reference areas, Don Light and San Mateo Point, demonstrated nearly the same size class structural patterns as found at SONGS. One notable exception was the early collection (June) of very small (<40 mm SL) queenfish in the Don Light 20-ft area.

Sex Composition. Bar graphs in Figure 10-8 depict the sex ratios of queenfish according to sampling area, isobath, and gear-type for each survey. Sex ratios are displayed as a percentage of the total number of specimens sexed. Likewise, sex ratios are presented from impingement samples which were sampled within a time span similar to each of the offshore survey dates. Significant differences between males and females is indicated by a white cross within the bar representing the sex which is significantly more abundant (Figure 10-8).

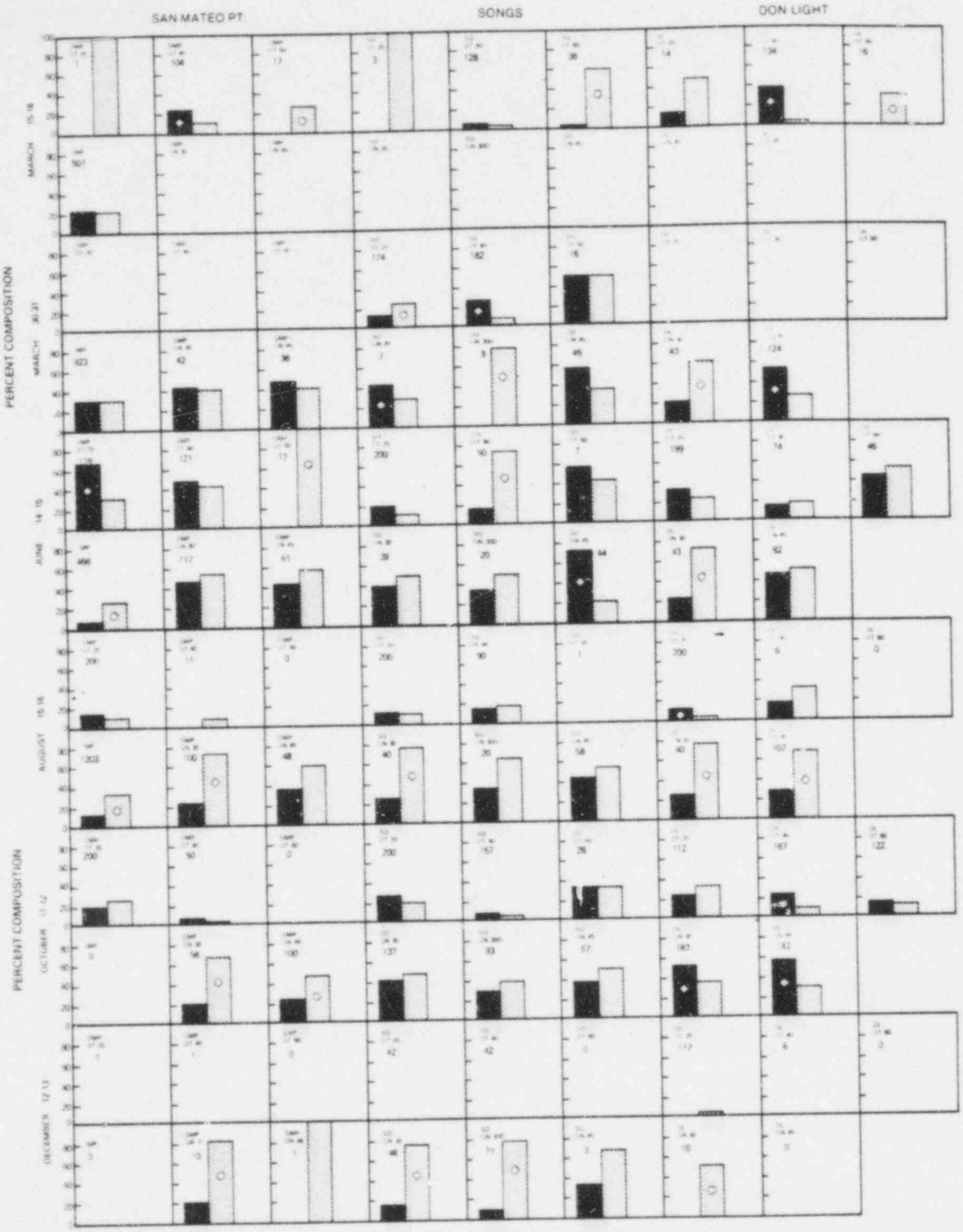

Figure 10-8. Sex ratio bar graphs of Seriphus politus based on otter trawl, gill net, and impingement collections during 1978. Area and depth per sample are indicated in light face type, while bold face type indicates the number of specimens sexed. The balance of collections totalling less than 100% are composed of indeterminant fish; blank graphs in which individuals were caught indicate 100% indeterminants. A dash (–) indicates an area not sampled. Crosses (✚) indicate a significantly greater number of either males (■) or females (□) based on chi square goodness of fit statistics ($p < 0.05$).

Based on Chi square goodness of fit analysis (Sokal and Rohlf, 1969), the sex composition of Seriphus at all isobaths demonstrated a large degree of variability (i.e., statistical heterogeneity) throughout 1978 in all areas. Sex composition based on annual catch of Seriphus indicated that significantly ($p < 0.05$) more females were captured in gill nets set at the 30-ft isobath in all areas. Gill nets set at 45 ft collected significantly ($p < 0.05$) more females only at San Mateo Point. No significant differences were detected in the annual catch of male and female queenfish collected by otter trawls from each area during 1978.

In general otter trawl collections for 1978, excluding the June samples at SONGS (20 ft) and Don Light (20 and 40 ft), were comprised of a high percentage of indeterminant individuals, a large portion of which were juveniles.

Genyonemus lineatus (White Croaker)

Abundance. Figures 10-7 and 10-9 through 10-11 depict the abundance patterns of Genyonemus lineatus in the San Onofre region reflected by gill net and otter trawl samples. In contrast to queenfish, gill net catches of white croaker at 45 ft showed abundance peaks during the March surveys in all areas. Like Seriphus, Genyonemus catches declined severely during December at all stations except for those gill nets set on the 30-ft isobath at San Onofre (Figure 10-9).

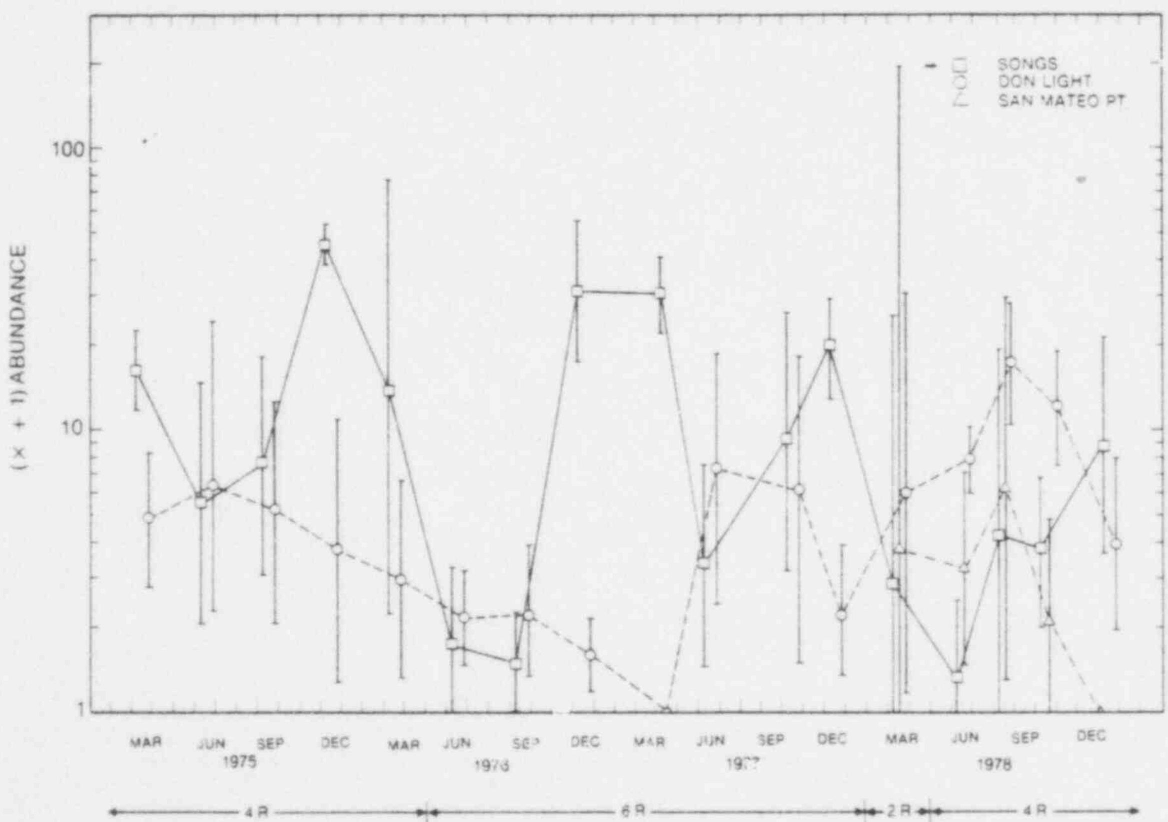

Figure 10-9. Geometric mean and 90% confidence limits of Genyonemus lineatus captured at 30 ft in gill nets set at SONGS and Don Light during the period from 1975 to 1978 and San Mateo Point during 1978. The number of replicates (R) for all means are indicated below the abscissa.

Data collected by either gear type reflected concordant seasonal patterns of mean abundance at each isobath in all areas. Between isobaths, however, discordant trends were obvious suggesting an onshore-offshore movement of white croaker.

Gill nets set in the Don Light area at 30 and 45 ft captured the greatest mean number of white croaker during 1978 (Figures 10-9 and 10-10). Seasonal mean abundance patterns were generally similar among all areas at 30 and 45 ft except at SONGS where the mean abundance pattern continued to increase through December. Gill nets set adjacent to the Unit 1 discharge generally caught the greatest mean numbers of Genyonemus compared to the other SONGS stations (Figure 10-7); however, they were not greater than mean abundances in the reference areas.

Otter trawls conducted at 20 ft in all areas reflected seasonal trends of mean abundance dissimilar to those observed at 40 and 60 ft (Figure 10-11). This dissimilarity was most evident during the period from June through October and suggested onshore-offshore movement of this species. Although isolated individuals were collected onshore at 40-ft San Onofre and Don Light stations, movements further offshore beyond 60 ft or upward in the water column, were indicated during December as the mean abundances generally declined to near zero in most areas.

Length Frequency. Gill nets set at 30 ft and 45 ft, consistently captured G. lineatus individuals in the 160-175 mm SL size mode throughout the year.

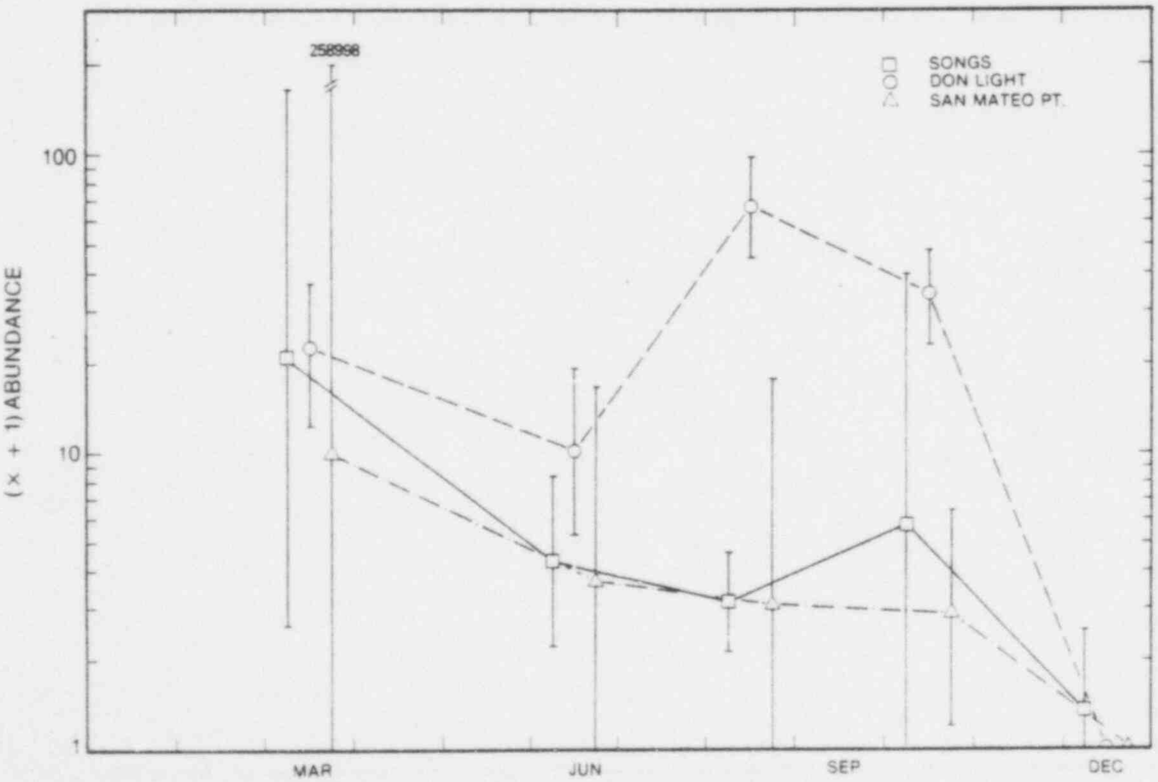

Figure 10-10. Geometric mean and 90% confidence limits of Genyonemus lineatus captured at 45 ft in four replicate gill nets set at San Mateo Point, SONGS, and Don Light during 1978.

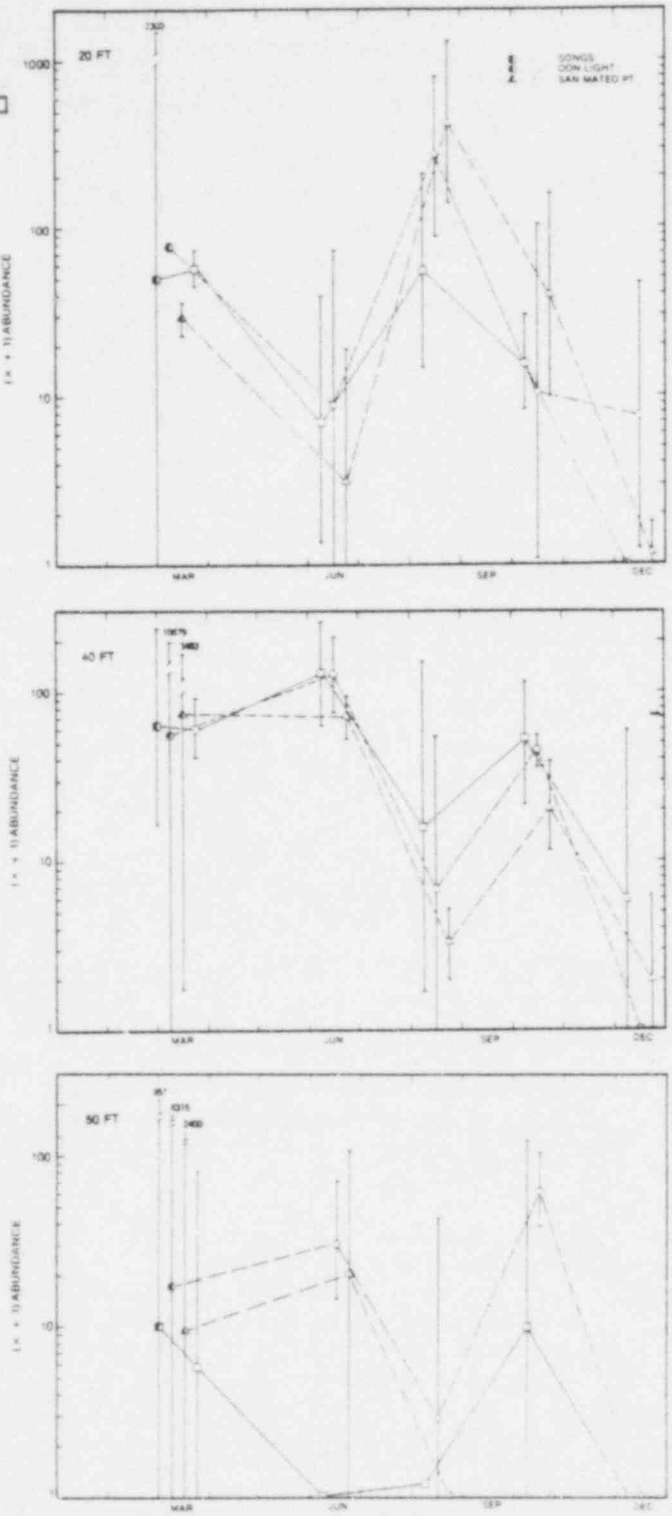

Figure 10-11. Geometric mean and 90% confidence limits of Genyonemus lineatus caught at 20, 40, and 60 ft in daytime otter trawls conducted at San Mateo Point, SONGS and Don Light during 1978. Means from March preliminary trawls (half shaded) are based on two replicates, all other means are based on four replicates.

Don Light collections at 45 ft demonstrated trimodal size distributions, 120-130 mm, 160-165 mm, 200-205 mm SL, during March and June. Genyonemus collected in gill nets set at 30 and 45 ft in the remaining areas were generally unimodal (160-175 mm SL). The August and October gill nets caught smaller (110- 135 mm SL modes) Genyonemus at San Mateo Point (30 ft) and at Don Light (30 and 45 ft). Gill nets set adjacent to the Unit 1 discharge captured these small white croaker only in October, while SONGS gill nets at 30 and 45 ft did not collect this juvenile size range. December SONGS gill nets captured Genyonemus in the 155-180 mm SL range at 30 ft.

Otter trawls conducted in March demonstrated a bimodal size grouping of Genyonemus (20-60 mm SL and 100-170 mm SL). Bimodal size groups were also caught in June, and were particularly evident in otter trawls taken at 40 ft in each area. In both the August and October trawl surveys, larger individuals were concentrated offshore in all areas. This occurrence was depicted best by Don Light otter trawl catches (LCMR, 1979a, pages 294-297 and 300-303). During October in the Don Light area, trawls collected distinctly different size modes at each isobath. Smaller individuals (20-60 mm SL) occurred at 20 ft; while at 40 ft, 70-130 mm SL individuals were caught, and 60-ft samples contained a 140-170 mm SL size mode.

In contrast to Seriphus, juvenile Genyonemus appeared earlier in 1978 during the March trawls made at 40 ft in the SONGS area. These small individuals persisted at 40 ft in SONGS otter trawl collections and in otter trawl collections within the reference areas, during both days of the June survey (LCMR, 1979a, pages 289-291). Inshore movement (20 ft) by small white croaker occurred in August, mainly in the San Onofre and Don Light areas (LCMR, 1979a, pages 294-297). The smallest juvenile white croaker were absent from trawl catches in all areas after August. The following two surveys (October and December) collected juveniles of increasing size. Trawl collections made offshore at 60 ft sampled larger individuals (120 mm and 160 mm SL) in all areas throughout the year.

Offshore trawl collection of adult Genyonemus were composed of bi- and trimodal size classes during March and June in all areas and at San Onofre (40 ft) during August. These classes were typically centered at either 40, 80, 120, or 160 mm SL. Later in the year (October), 80 and 120 mm SL modal length individuals were present at 40 ft, while collections made at 60 ft caught individuals whose modal lengths were centered around 160 mm SL and 190-200 mm SL. The entire December Genyonemus trawl catch was very sparse in comparison to all other surveys (LCMR, 1979a, pages 306-309).

Sex Composition. Sex ratios of white croaker, by area, isobath, and survey, are presented as bar graphs in Figure 10-12. Genyonemus collected in gill nets and otter trawls showed mixed patterns of sex composition. Overall, neither males nor females were significantly more abundant at any one depth. Otter trawls conducted at 60 ft demonstrated the only consistent patterns throughout 1978 with males significantly ($p < 0.05$) more numerous than females, based on annual totals for all areas. Males were also significantly more abundant in SONGS gill nets at 45 ft and in Don Light otter trawl samples at 40 ft. Females were significantly more abundant in gill net collections made adjacent to the SONGS Unit 1 discharge at 30 ft in the Don Light area, and in gill nets set at 45 ft at San Mateo Point. Significantly more females than males were also captured annually in SONGS otter trawl samples taken at 20 ft.

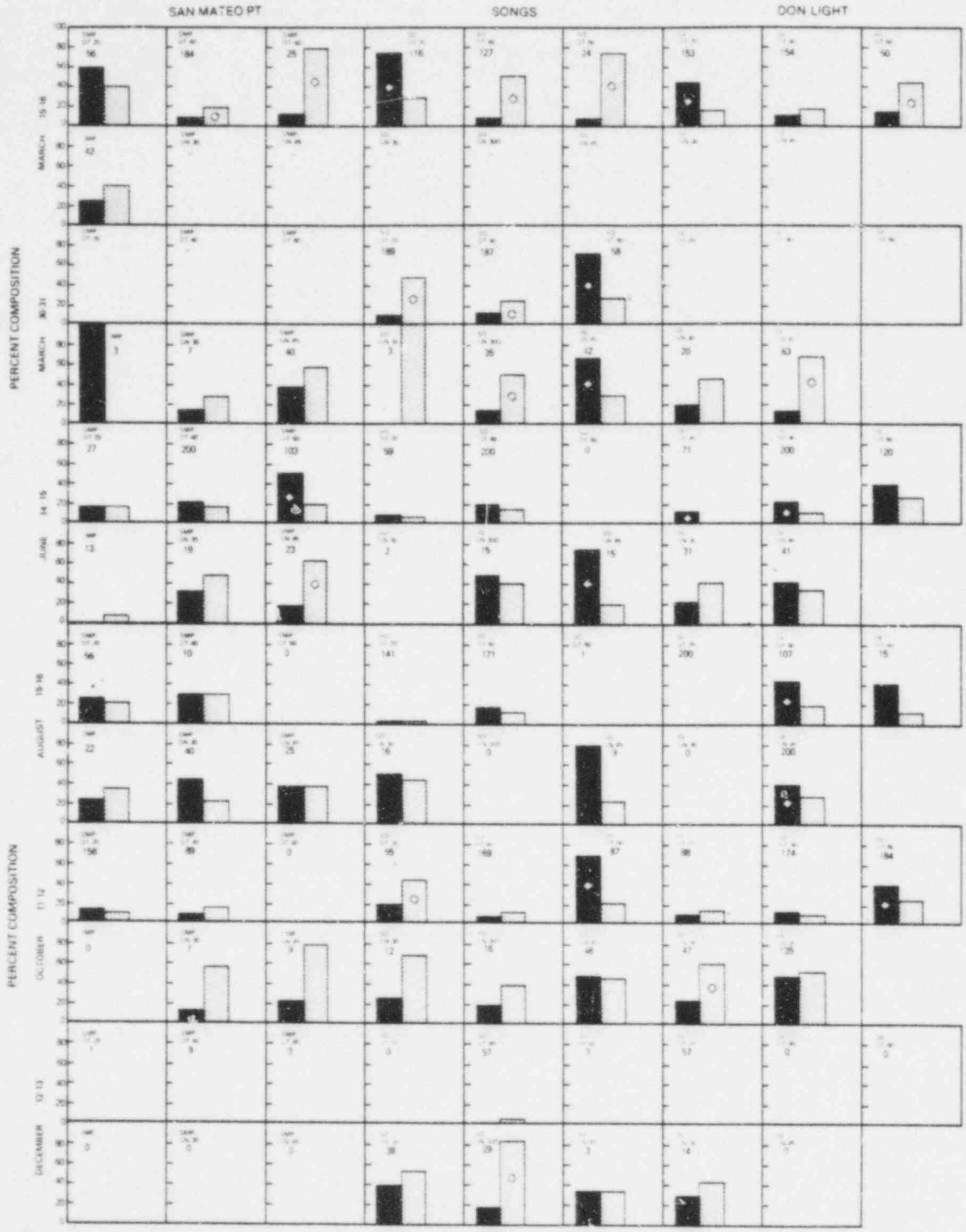

Figure 10-12. Sex ratio bar graphs of Genyonemus lineatus based on otter trawl, gill net, and impingement collections during 1978. Area and depth are indicated in light face type, while bold face type indicates the number of specimens sexed. The balance of collections totalling less than 100% are composed of indeterminant fish; blank graphs in which individuals were caught indicate 100% indeterminants. A dash (–) indicates an area not sampled. Crosses (✣) indicate a significantly greater number of either males (■) or females (□) based on chi square goodness of fit statistics ($p < 0.05$).

Like Seriphus, otter trawls collected a high percentage of immature individuals throughout 1978. The largest number of juvenile white croaker were taken at the 20 and 40-ft isobaths.

Hyperprosopon argenteum (Walleye Surfperch)

Abundances. The abundance of Hyperprosopon argenteum represented by gill net and otter trawl samples is presented in Figures 10-7 and 10-13 through 10-15. Walleye surfperch collected with both gear types were much less abundant offshore the San Onofre region than queenfish or white croaker. The consistently low abundances of Hyperprosopon in all otter trawls reveal limited information as to the seasonal movements over sand substrata (Figure 10-15).

Gill net catches of Hyperprosopon showed a dissimilar pattern between 30 and 45-ft depths. During the months of March and June, (Figures 10-13 and 10-14), all gill net sampling areas showed higher abundances of Hyperprosopon inshore. In August and October, Hyperprosopon increased in offshore collections made at 45 ft in all areas. In December a reduced catch occurred in all 45-ft gill nets, but the number of individuals increased substantially at the 30-ft SONGS stations. Gill nets set adjacent the Unit 1 discharge, however, did not reflect this December resurgence of Hyperprosopon (Figure 10-7).

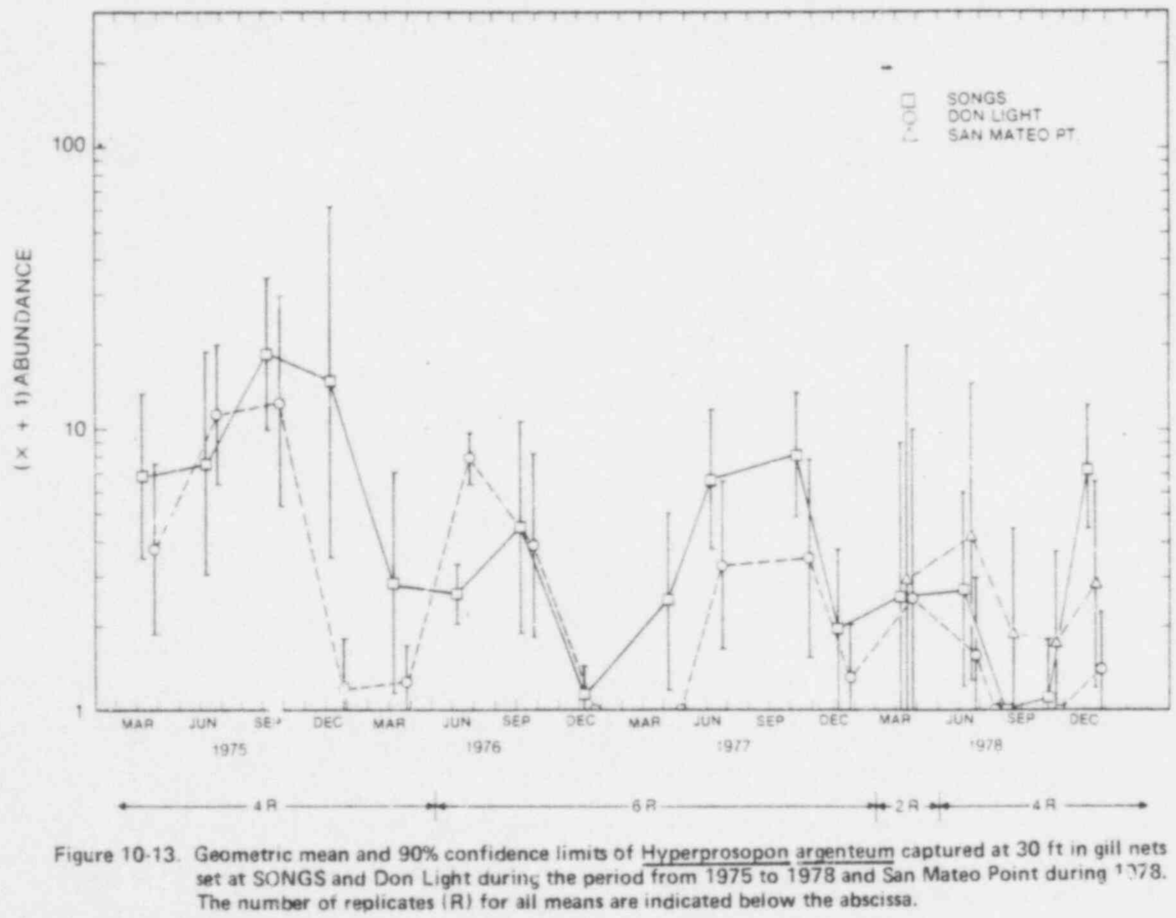

Figure 10-13. Geometric mean and 90% confidence limits of Hyperprosopon argenteum captured at 30 ft in gill nets set at SONGS and Don Light during the period from 1975 to 1978 and San Mateo Point during 1978. The number of replicates (R) for all means are indicated below the abscissa.

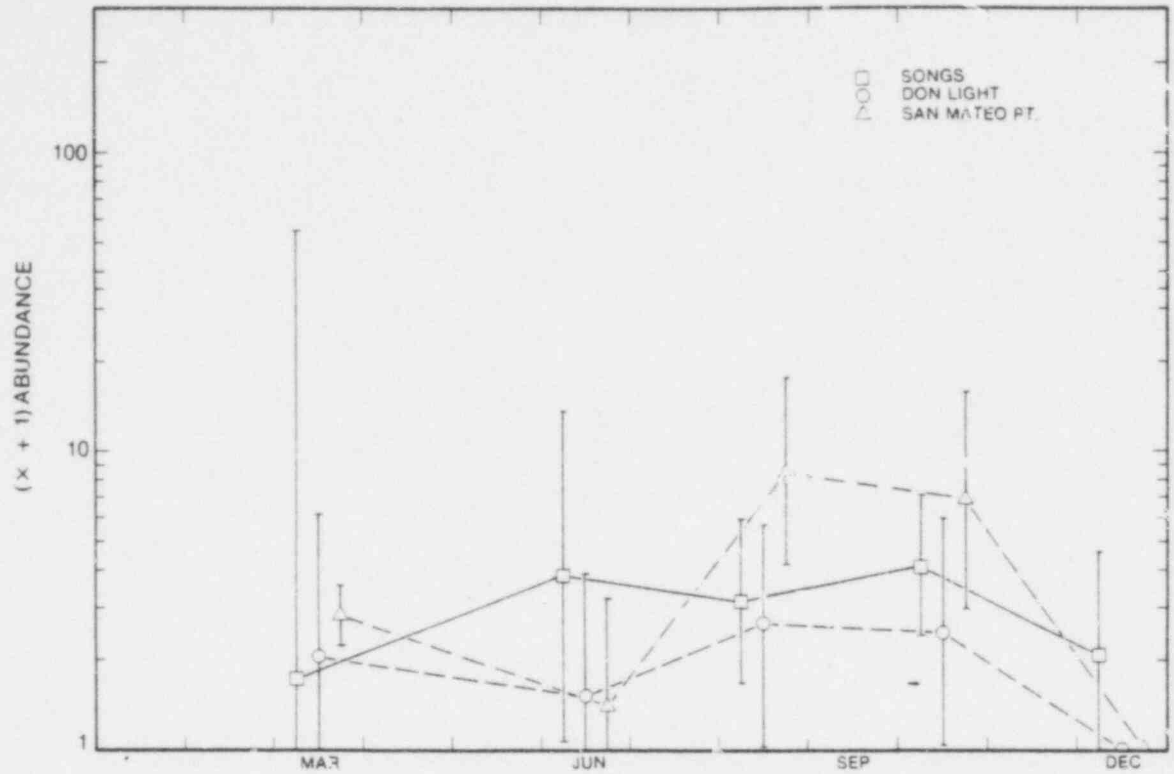

Figure 10-14. Geometric mean and 90% confidence limits of Hyperprosopon argenteum captured at 45 ft in four replicate gill nets set at San Mateo Point, SONGS, and Don Light during 1978.

The long term abundance pattern of Hyperprosopon collected in gill nets at 30 ft from 1975-1978 showed a unique pattern during 1978 (Figure 10-13). Historically (1975 through 1977), a general midyear peak of walleye surfperch occurred during June and October. During August and October 1978, Hyperprosopon mean abundance declined contradicting this general trend. Similar to Seriphus and Genyonemus, seasonal peaks in 1978 did not coincide with seasonal peaks in previous years; however, unlike the two sciaenids, the December catch of Hyperprosopon, at 30 ft, increased.

Length Frequency. The relatively low abundances of Hyperprosopon collected during each survey precluded a meaningful presentation of size structure by histograms. Length data for all surveys are presented in tabular form in LCMR (1979a, pages 310-484).

Gill nets set at 30 and 45 ft in all areas collected similarly sized individuals throughout 1978. Length classes of 80-100 mm, 110-125 mm, 140-155 mm SL were most common. Gill nets set at 30 ft in all areas caught an increased number of small Hyperprosopon (80-100 mm SL) during August and December.

Otter trawls generally collected individuals between 40 and 80 mm SL. During June, an influx of recently born (40-50 mm SL, Feder, Turner and Limbaugh, 1974; Eckmayer, 1975) walleye surfperch were apparent in 20 and 40-ft trawl collections made in all areas. Increased sizes of this newly recruited group of walleyes was observed in subsequent trawl collections.

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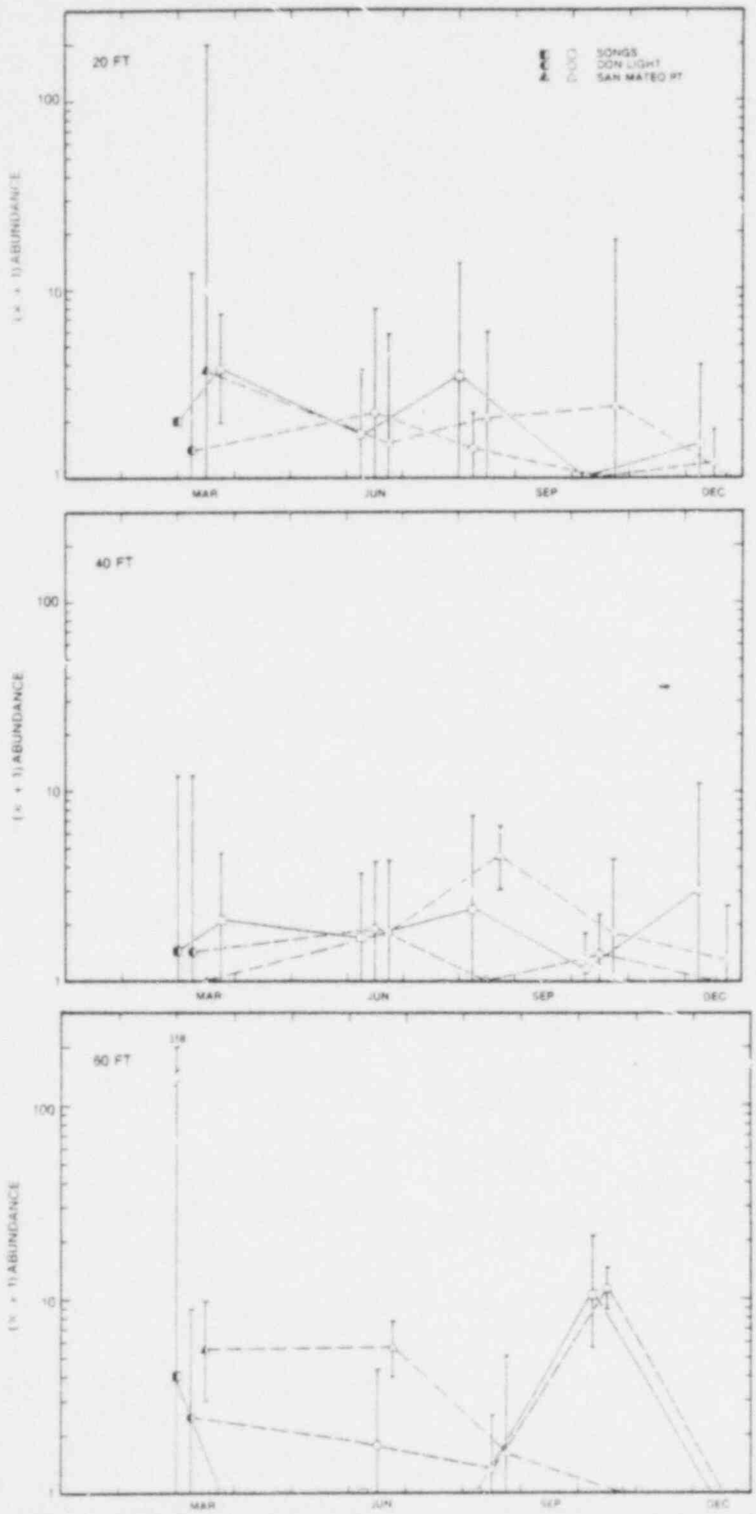

Figure 10-15. Geometric mean and 90% confidence limits of *Hyperprosopon argenteum* caught at 20, 40, and 60 ft in daytime otter trawls conducted at San Mateo Point, SONGS and Don Light during 1978. Means from March preliminary trawls (half shaded) are based on two replicates, all other means are based on four replicates.

Small Hyperprosopon were rarely collected in trawls conducted at 60 ft. Generally, walleye surfperch collected at the 60-ft isobath ranged in size from 100 to 150 mm SL. Hyperprosopon with lengths of 70-100 mm and 110-140 mm SL were captured offshore during December in trawls conducted at SONGS and Don Light.

Sex Composition. The distribution of male and female Hyperprosopon in the gill net and otter trawl collections conducted throughout the San Onofre region is depicted in Figure 10-16.

Chi-square analysis of Hyperprosopon sex ratios demonstrated no significant differences in the abundances of males and females during any survey (Figure 10-16). Male walleye surfperch were significantly more abundant than females on an annual basis in San Mateo gill net collections set at 45 ft and in otter trawls conducted off SONGS at 40 ft. Females were significantly more numerous only in otter trawls conducted offshore of San Mateo Point at the 60-ft isobath.

Phanerodon furcatus (White Surfperch)

Abundance. The abundances of Phanerodon furcatus collected in gill nets and otter trawls during 1978 are presented in Figure 10-7 and 10-17 through 10-19. Like Hyperprosopon, the mean catches of Phanerodon in gill nets and trawls were relatively low throughout the San Onofre region compared to the more abundant croakers.

The catch of white surfperch was small and seasonally variable in all areas in 1978. Gill net catches of Phanerodon at 30 ft steadily increased from March through December in all areas (Figure 10-17). Catches of Phanerodon in gill nets set at 45 ft increased from March to December at the SONGS area but varied at Don Light and San Mateo Point areas (Figure 10-18). Average catches of Phanerodon in otter trawls taken at 20, 40, and 60-ft depths were highly variable in all areas with the only apparent pattern being the maximum catch of Phanerodon in December at 20 and 40-ft depths in the SONGS area (Figure 10-19). White surfperch were seldom collected in gill nets set adjacent to the discharge, though an increase in catch occurred in December (Figure 10-7).

Phanerodon showed the most distinct seasonality of the numerically dominant San Onofre fish species. Figure 10-17 depicts the December to March peak in abundances for every year from 1975 through 1978. This increase was also noted in gill nets set near the discharge (Figure 10-7) and otter trawls conducted at 20 and 40 ft offshore SONGS in 1978 (Figure 10-19).

Length Frequency. Like Hyperprosopon, the relative low abundance of Phanerodon throughout 1978 precluded meaningful size structure presentation by histograms. As was the case with the other select species, gill nets captured more larger Phanerodon than did the otter trawls. Phanerodon size classes captured in gill nets were variable throughout the year, though the 80-100 mm, 120-135 mm, 150-165 mm, and 180-200 mm SL classes were the more common ones. White surfperch ranging from 45 to 105 mm SL were predominant in otter trawl collections in all areas. A large increase in small (35-55 mm SL) Phanerodon was observed during June in trawls conducted at 20 and 40 ft throughout the San Onofre region.

Sex Composition. The distribution of male and female Phanerodon in gill net and otter trawl collections conducted throughout the San Onofre area is depicted in Figure 10-20. Numerical dominance by males and females varied con-

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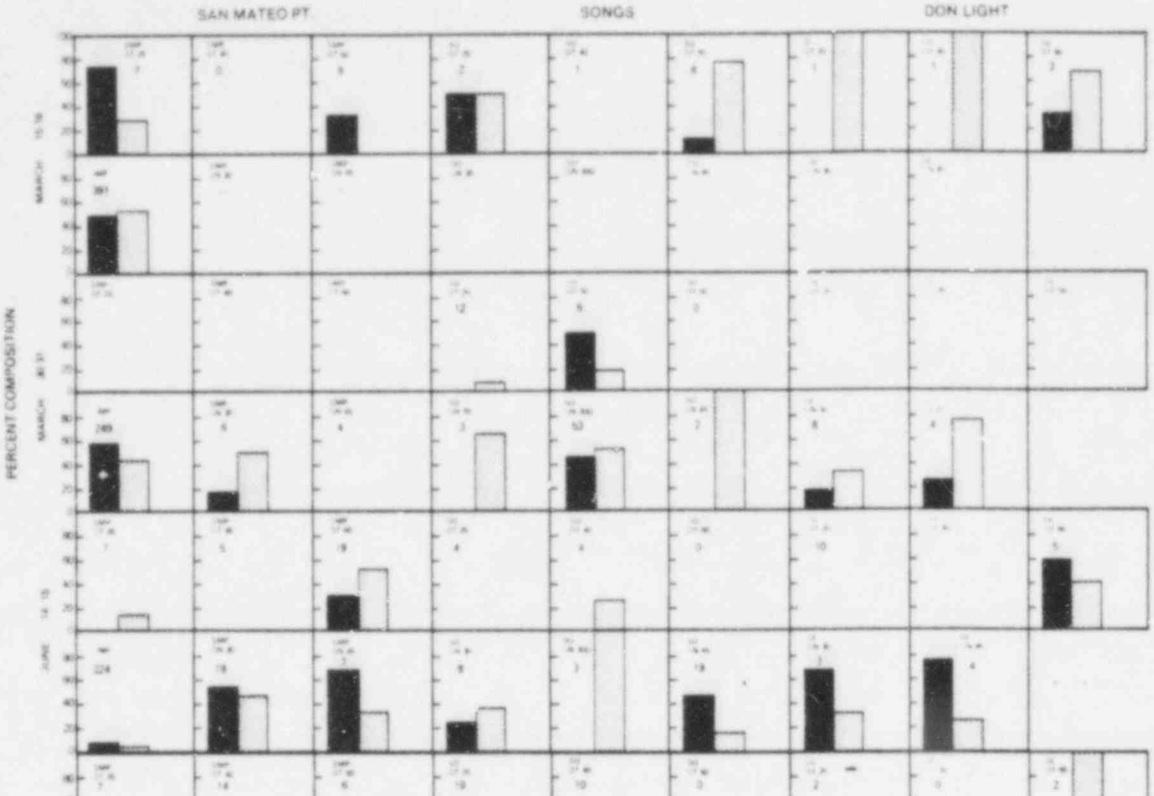

Figure 10-16. Sex ratio bar graphs of Hyperprosopon argenteum based on otter trawl, gill net, and impingement collections during 1978. Area and depth per sample are indicated in light face type, while bold face type indicates the number of specimens sexed. The balance of collections totalling less than 100% are composed of indeterminant fish; blank graphs in which individuals were caught indicate 100% indeterminants. A dash (–) indicates an area not sampled. Crosses (◌) indicate a significantly greater number of either males (■) or females (⁘) based on chi square goodness of fit statistics ($p < 0.05$).

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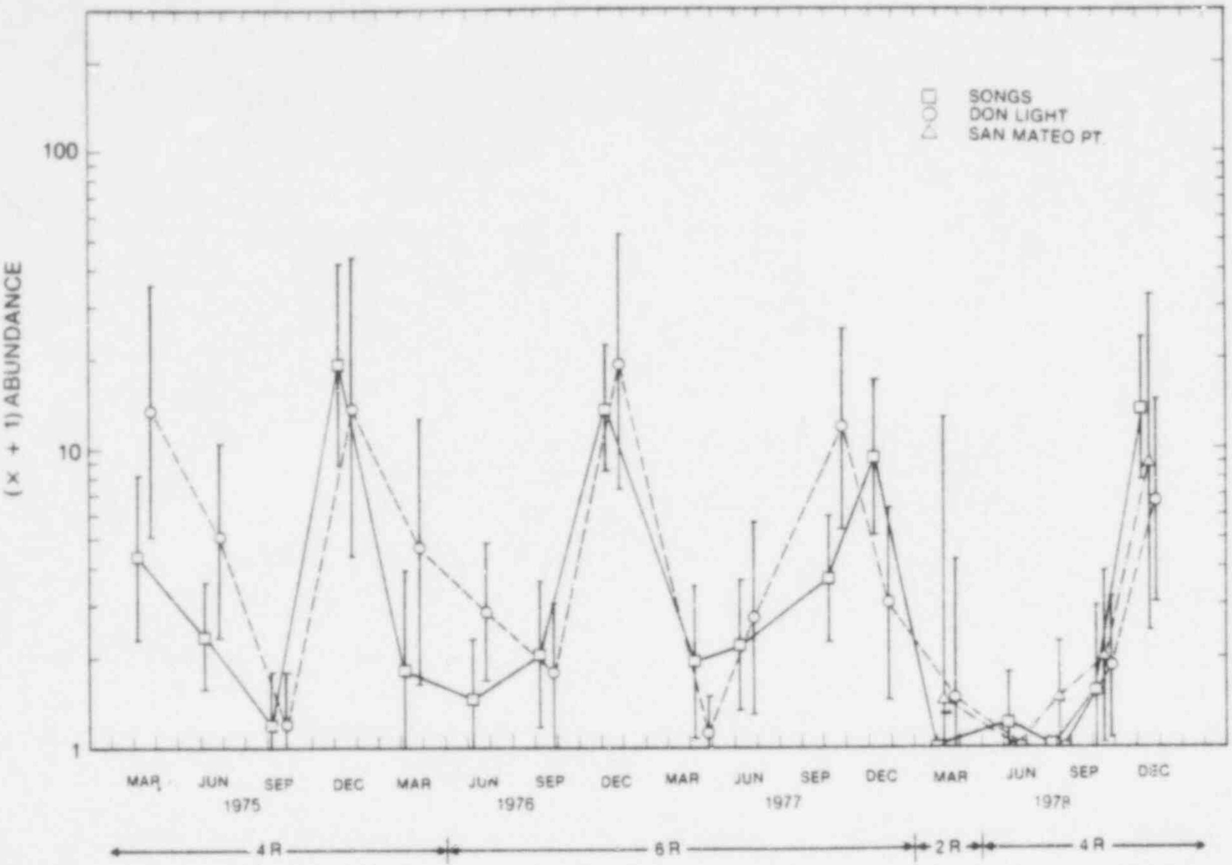

Figure 10-17. Geometric mean and 90% confidence limits of Phanerodon furcatus captured at 30 ft in gill nets set at SONGS and Don Light during the period from 1975 to 1978 and San Mateo Point during 1978. The number of replicates (R) for all means are indicated below the abscissa.

siderably with no apparent temporal or spatial trends. A high percentage of the white surfperch collected in otter trawls conducted at 20 and 40 ft in all areas were immature.

The sex composition of Phanerodon based on annual totals was not dominated by either sex in gill net collections. Otter trawls collected significantly ($p<0.05$) more females at San Mateo Point 20 and 40 ft, SONGS 40 ft, and Don Light 20 and 40 ft based upon pooled sex data for 1978.

Citharichthys stigmaeus (Speckled Sanddab). Catch data for Citharichthys stigmaeus collected in otter trawls is presented in Figure 10-21. This flatfish was more numerous offshore and most consistently captured at 40 ft in all areas. A seasonal trend in abundance was marked by low catches in March and June and relatively higher catches through the remaining months. December catches, notably at 40 and 60 ft in all areas, represented the period of greatest Citharichthys abundance (Figure 10-21). The Don Light area at all depths showed the most variable patterns in abundance.

Roncador stearnsii (Spotfin Croaker). Gill net catches of Roncador stearnsii were greatest during June (LCMR, 1979a, page 216) as has been observed in past years (LCMR, 1978c). Again, in 1978, this high catch of spotfin croaker

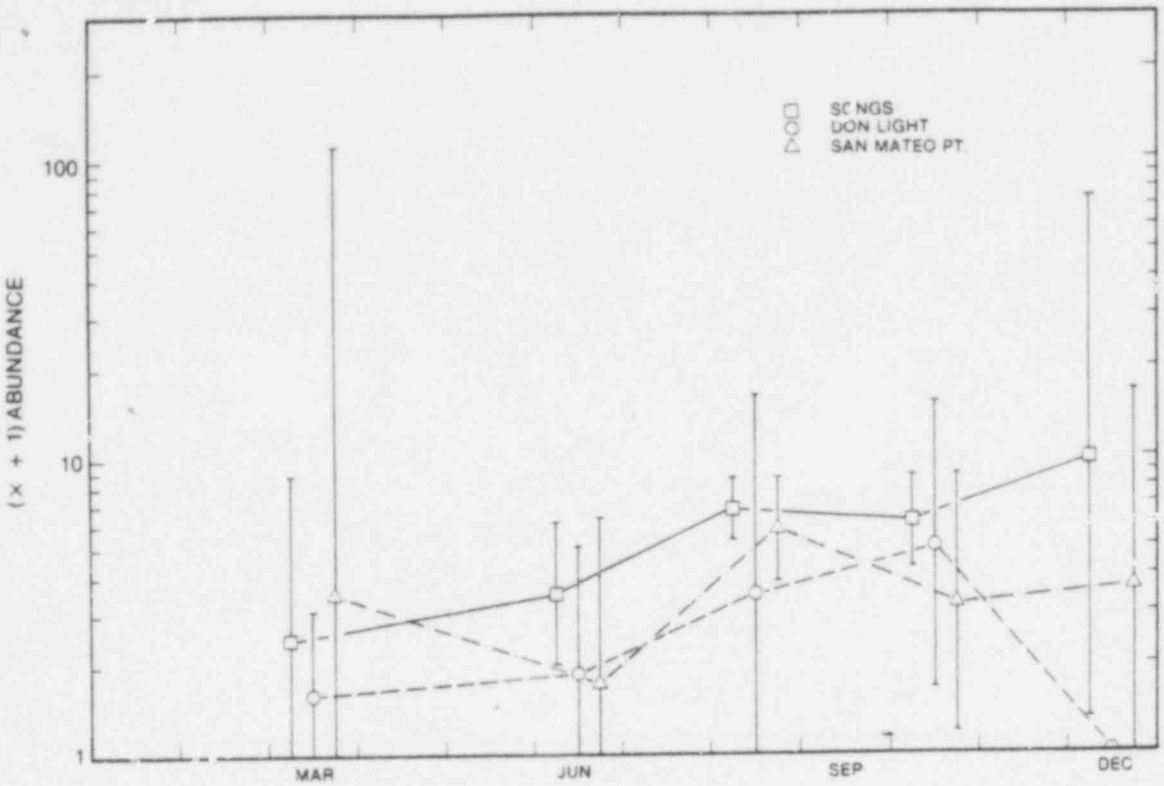

Figure 10-18. Geometric mean and 90% confidence limits of Phanerodon furcatus captured at 45 ft in four replicate gill nets set at San Mateo Point, SONGS, and Don Light during 1978.

was primarily restricted to the San Onofre gill nets at 30 ft, as few were collected in other areas or depths. The 30-31 March gill nets set adjacent to the Unit 1 discharge captured a relatively large number of spotfin croaker, while catches were relatively low in other SONGS and reference area collections (LCMR, 1979a, page 208). Male Roncador were collected in significantly ($p<0.05$) greater numbers than females during March and June (LCMR, 1979a, pages 487 and 491). Otter trawl catches indicate the sporadic presence of spotfin croaker throughout the entire year (LCMR, 1979a).

Physical Data

Temperature. Mean water temperatures measured within two meters of the bottom during the 1978 fish surveys at the 30-ft gill net stations were compared to the mean bottom temperatures from continuous records at oceanographic stations C2S, C22S, and F2S (BC, 1979) during the week prior to each 1978 fish survey (Figure 10-22). Continuous temperature data at oceanographic station C22S were not available for a majority of the week prior to the October survey. However, approximately 14 hours of temperature data for the day (October 10) prior to this survey indicated the mean bottom temperature at C22S during this time was 16.29°C (S.D. = 1.04). Mean continuous temperature measurements recorded in areas near (Station C2S is approximately 1300 m downcoast of the SONGS gill 30-ft net station, and Don Light stations are within 50 m of the C22S station) the gill net stations were similar to gill net survey temperature means.

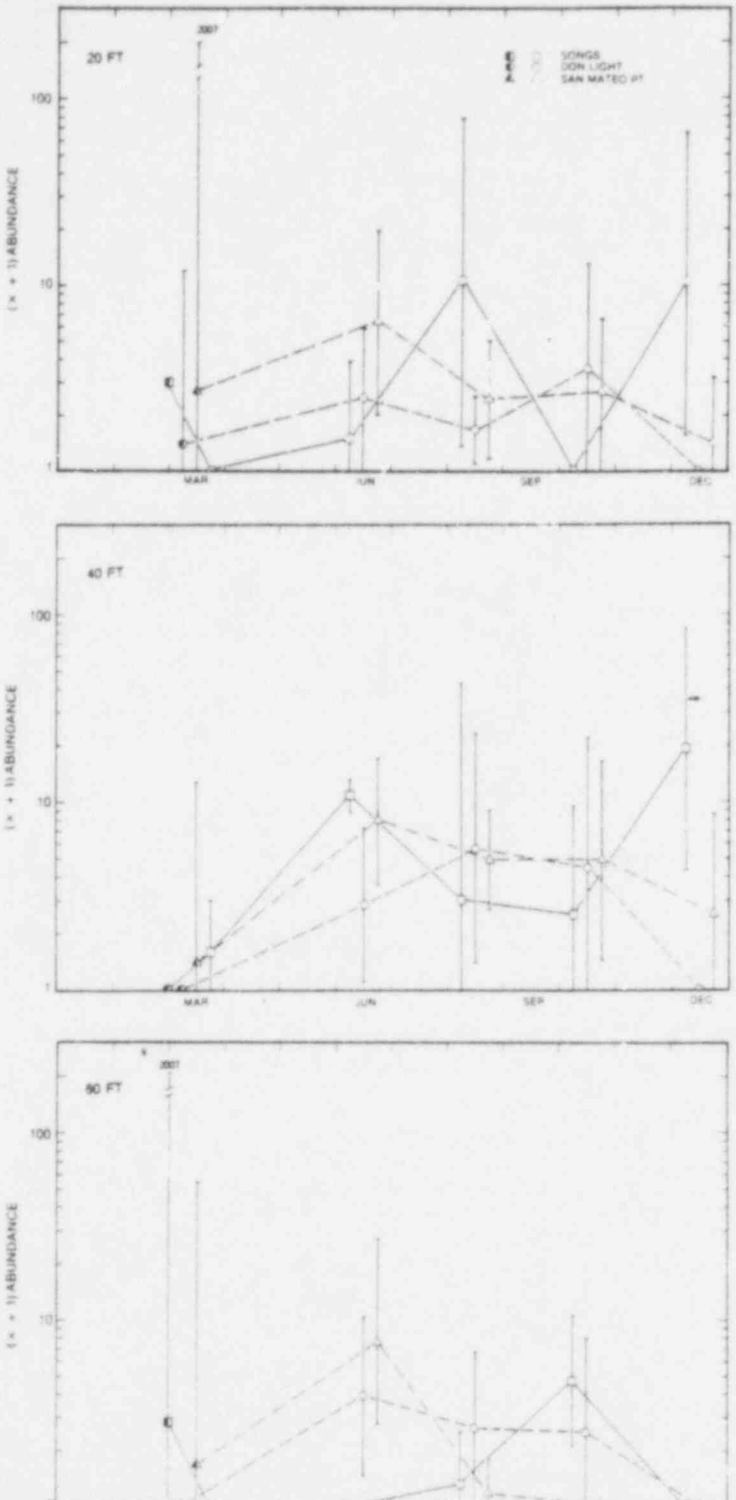

Figure 10-19. Geometric mean and 90% confidence limits of Phanerodon furcatus caught at 20, 40, and 60 ft in daytime otter trawls conducted at San Mateo Point, SONGS and Don Light during 1978. Means from March preliminary trawls (half shaded) are based on two replicates, all other means are based on four replicates.

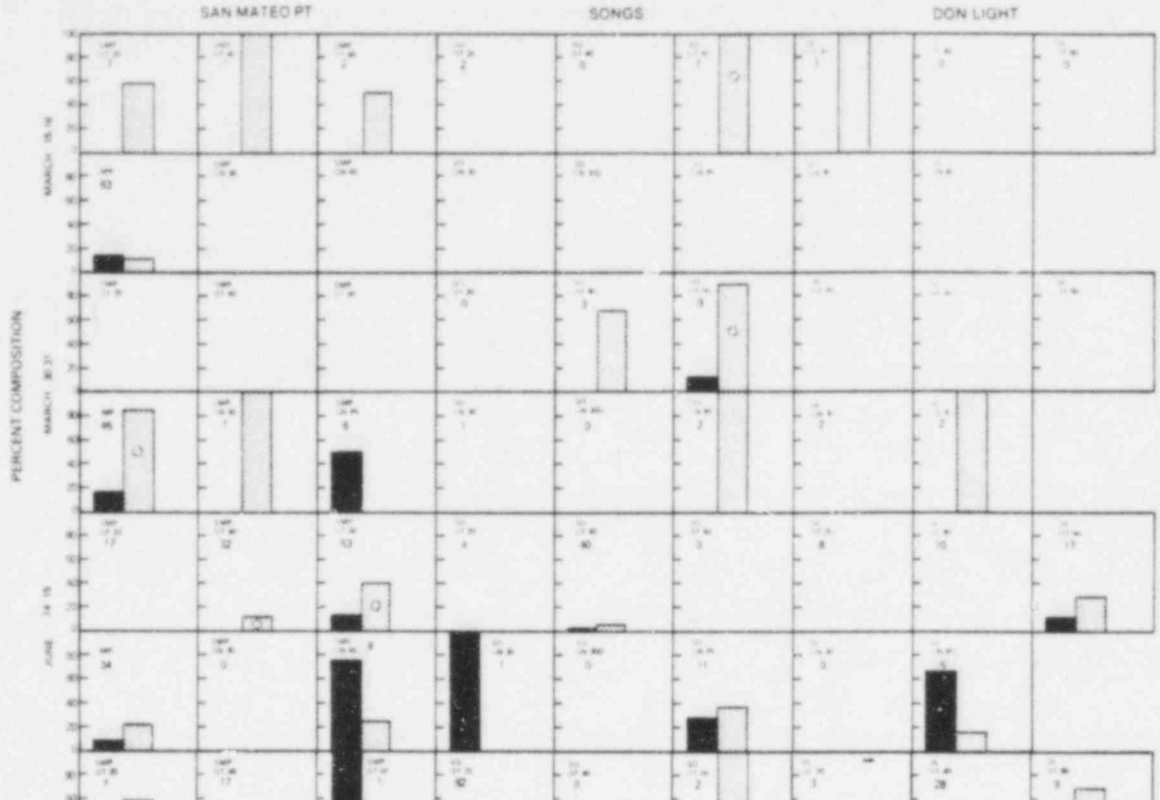

Figure 10-20. Sex ratio bar graphs of Phanerodon furcatus based on otter trawl, gill net, and impingement collections during 1978. Area and depth per sample are indicated in light face type, while bold face type indicates the number of specimens sexed. The balance of collections totalling less than 100% are composed of indeterminant fish; blank graphs in which individuals were caught indicate 100% indeterminants. A dash (—) indicates an area not sampled. Crosses (○) indicate a significantly greater number of either males (■) or females (⁚) based on chi square goodness of fit statistics ($p < 0.05$).

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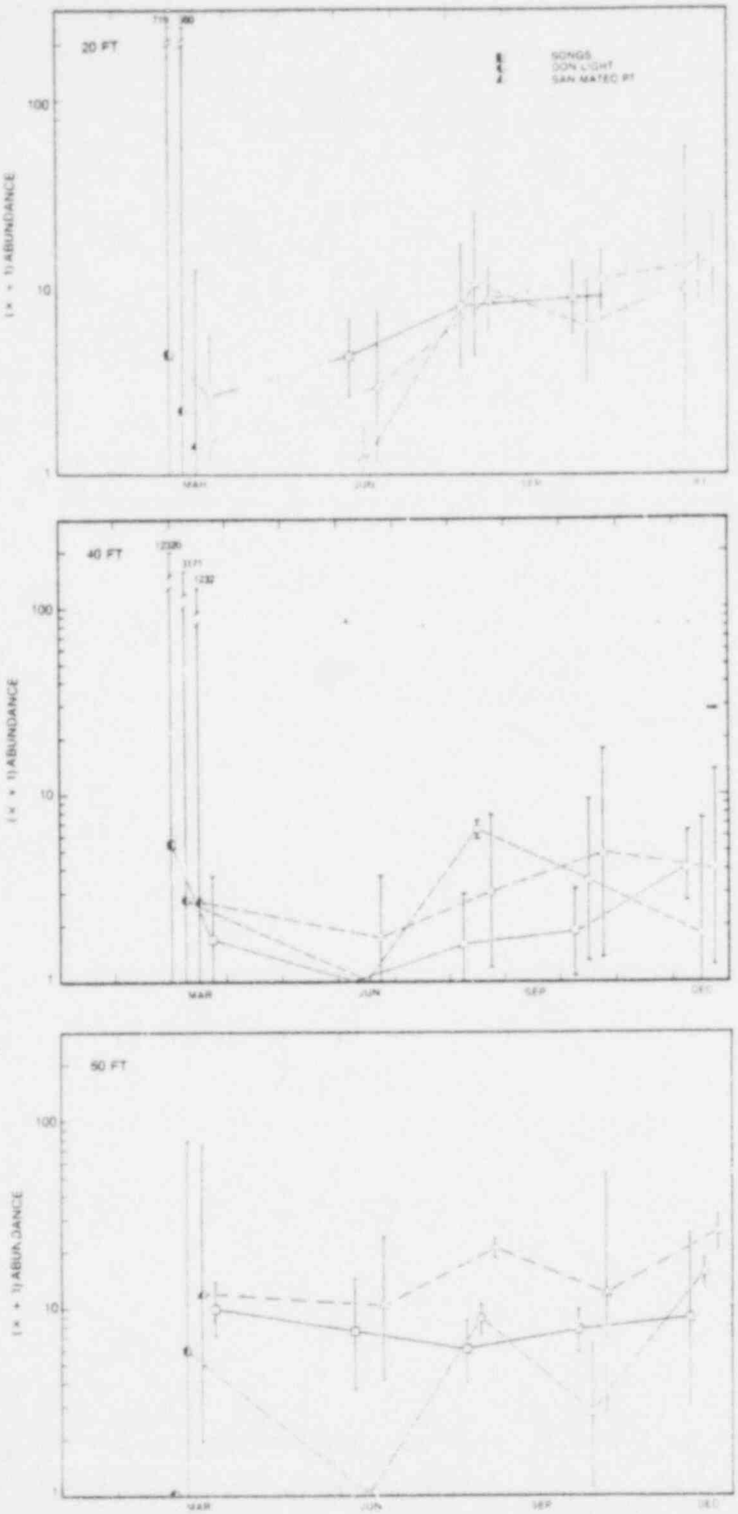


Figure 10-21. Geometric mean and 90% confidence limits of Citharichthys stigmaeus caught at 20, 40, and 60 ft in daytime otter trawls conducted at San Mateo Point, SONGS and Don Light during 1978. Means from March preliminary trawls (half shaded) are based on two replicates, all other means are based on four replicates.

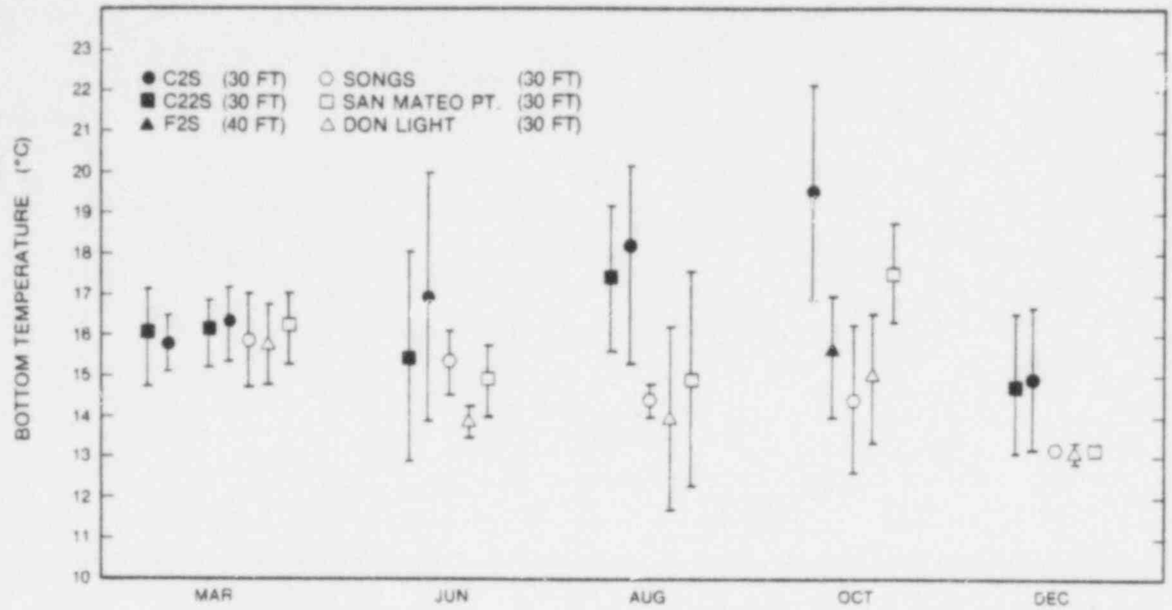


Figure 10-22. **Mean weekly bottom temperature (°C), ±2 standard deviations, based on continuous temperature records taken on seven days (at 1 h intervals) prior to 1978 gill net and otter trawl collections at oceanographic stations C2S, C22S, and F2S and mean bottom temperature recorded at 30-ft gill net stations on survey days.**

The annual thermal pattern, represented by monthly means, is depicted in Figure 10-23 (BC, 1979). Mean monthly temperatures increased from June through September while temperatures measured during each gill net survey demonstrated a fairly constant bottom temperature range throughout this period, except at San Mateo Point (Figure 10-22). Mean bottom temperatures based on continuous measurements (Figure 10-22) continued to be higher in the SONGS area while the generating station was offline in late September and October. Temperature readings taken during the December fish survey demonstrated a drop in temperature which was contrary to that recorded in past years (LCMR, 1978c). Temperature-depth profiles conducted at gill net stations during the year showed the development of thermoclines during the period from June through October, while an isothermal pattern was present in March and December surveys (LCMR, 1979a, pages 511-515).

Transmissivity. An overall decrease in turbidity with distance offshore was evident in the transmissivity readings (LCMR, 1979a, pages 511-515). Brown and Caldwell (1979) reported similar results. In several instances, however, bimodal transmissivity distributions, representing lenses of less turbid water sandwiched between higher turbidity layers, were observed.

IMPINGEMENT

The impingement section presents estimates of 1978 SONGS Unit 1 impingement for total fish and selected species catch. Comparisons of size (age) structure and sex ratios for queenfish and white croaker are made between impingement samples and offshore gill net and otter trawl samples.

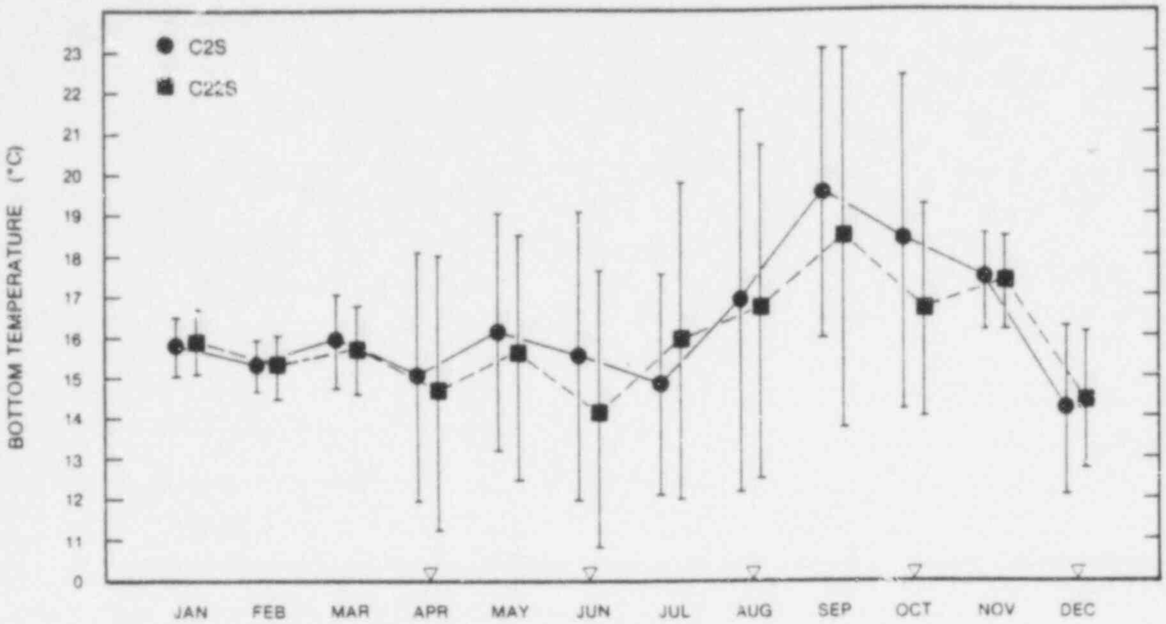


Figure 10-23. Monthly mean bottom temperature (°C) (BC, 1979) ±2 standard deviations. Fish Receiving Water survey dates indicated along abscissa by ▽. SONGS offline during October.

Annual Impingement Estimate

The estimate of 1978 fish impingement is based upon 81 normal flow impingement samples and seven heat treatment samples. Heat treatment samples consisted of an assessment of all fishes impinged during the heat treatment, while normal operation samples evaluated individuals impinged during a 24-h period of normal plant operation (i.e., both circulator pumps operating in normal configuration). A complete account of all species enumerated from the 81 normal operation samples and seven heat treatment samples is presented in LCMR (1979a). Mean monthly impingement catches for total fish and selected species by individuals and weight are presented in Table 10-4. Table 10-5 presents annual estimates of the number and weight of total fish and selected species using weighted monthly averages of catch (see Methods: data analysis section).

Mean monthly impingement of total fish ranged from a maximum of 4,764 individuals weighing a total of 270 lb in August to a minimum of 380 individuals weighing 16 lb in November (Table 10-4). No impingement samples were taken during October as the generating station was offline for refueling and maintenance operations. Impingement of individuals was highest for queenfish in April, for white croaker in August, for white surfperch in January, and for walleye surfperch in February. Highest impingement by weight also occurred during these months for all select species except queenfish, where maximum catch by weight occurred in February when approximately half as many individuals were impinged (Table 10-4) as were impinged in April.

An estimated 579,077 ± 87,651 (1 standard error of the mean) individuals weighing 40,264 ± 4,668 lb were impinged under normal operational conditions by SONGS Unit 1 in 1978. Individually, queenfish comprised 63% of the normal flow impingement by number, white croaker 13.1%, white surfperch 1.7%, and walleye surfperch 6.3%. Collectively, these species accounted for 84% of the total normal flow impingement by number.

Table 10-5. Annual estimate of number and weight of total fish and selected species impinged during normal operation and heat treatments by SONGS Unit 1 during 1978 based upon 81 samples and 302.3 operational days. Estimates for normal operation are mean catch ±1 standard error of the mean. Heat treatment values represent actual numbers and weights of fish impinged.

Taxa	Numbers of fish		Weight of fish (lb)	
	Normal Operation	Heat Treatments	Normal Operation	Heat Treatments
Queenfish	366,751 ± 42,546	5,769	15,852 ± 1,718	395
White Croaker	75,610 ± 38,606	438	5,365 ± 2,046	56
White Surfperch	10,085 ± 1,332	298	526 ± 103	44
Walleye Surfperch	36,293 ± 5,328	9,470	3,319 ± 642	980
Total Fish (all species)	579,077 ± 87,651	22,116	40,264 ± 4,668	3,557
Combined Total	601,193 ± 87,651		43,821 ± 4,668	

*Estimated catch of total fish and select species based upon weighted monthly mean catch.

Queenfish, by weight, accounted for 39% of the total estimated normal flow impingement, followed by white croaker (13.3%), walleye surfperch (8.2%), and white surfperch (1.3%).

A total of 22,116 individuals weighing 3,557 lb were impinged in heat treatment operations in 1978, with queenfish, walleye surfperch, white croaker, and white surfperch comprising 26%, 43%, 2%, and 1% of the total, respectively. On a weight basis walleye surfperch accounted for 28% of the heat treatment impingement, queenfish 11%, white croaker 2%, and white surfperch 1%. Collectively, 72% of the total heat treatment impingement by number and 42% by weight was attributed to these four species.

Combined totals for estimated normal flow and heat treatments equalled 601,193 ± 87,651 individuals weighing 43,821 ± 4,668 lb for a mean weight of 0.07 lbs/fish (Table 10-5). The method used to calculate total estimated impingement in previous years utilized weighted mean catch derived from two different types of circulating water systems operation (i.e., intermittent flow, no heat and continuous flow and heat). The estimated 1978 annual impingement utilizing this method results in a total of 605,625 individuals weighing a total of 43,830 lb or a mean weight of 0.08 lbs/fish.

Length Frequency Analysis

Analysis of size structure of Seriphus and Genyonemus from receiving water samples and impingement samples is presented as a method of assessing whether Unit 1 is selectively removing a length class or classes from offshore populations. Seriphus and Genyonemus were selected for study because they dominated gill net and otter trawl catches and because they have historically been a major component of the total annual impingement catch (LCMR, 1978c). Qualitative comparisons were made between length frequency histograms obtained from impingement, gill net, and otter trawl catches for the San Onofre area only. The assumption was made that fish populations occupying the SONGS area during the offshore surveys are likely to be the populations from which the impingement samples are drawn.

Figures 10-24 through 10-31 depict the size structure of both species for impingement and the catch for each gear type during March, June, August, and December 1978 surveys. The October survey is omitted because Unit 1 was offline for refueling and maintenance.

Queenfish impingement exhibited a bimodal size structure in March (85 and 130 mm SL) and August (85 and 120 mm SL) and a unimodal structure during June (100 mm SL) and December (75 mm SL) (Figures 10-24 through 10-27). Examination of gill net data indicated a bias toward the large mode with virtually no individuals less than 120 mm SL sampled. Otter trawl catches of queenfish, however, displayed size structure similar to that observed for the impingement catch.

Size structure of the white croaker population is somewhat ambiguous compared to queenfish. Impingement, over the short time periods examined, was virtually nonexistent in March and June (Figures 10-28 and 10-29) and was bi- and unimodal in August and December, respectively. Gill net catches of Genyonemus during these months were sparse with length frequencies skewed towards larger individuals (Figures 10-28 through 10-31). Length frequencies of white croaker captured in otter trawls vary from a polymodal distribution in March and June, to bimodality in August, followed by a unimodal distribution in December.

Sex Structure

Sex ratios of male and female Seriphus, Genyonemus, and Phanerodon furcatus taken in impingement, gill net, and otter trawl samples are presented in Figures 10-8, 10-12, 10-16 and 10-20. Again, impingement samples were grouped within each month so that they coincided, as closely as possible, with offshore fish survey dates. Sex ratios of fish in impingement samples are compared to those in receiving waters in the San Onofre study area.

Seasonal distribution of sex ratios of mature Seriphus impinged by Unit 1 reflected the seasonal changes of sex ratios in gill net and otter trawl catches in the receiving waters, but showed a greater female bias relative to gill net catches made at 45 ft. Sex ratios (percentages) for the March impingement catch were equally divided between males and females reflecting the trend observed in offshore samples. June and August impingement samples contained a significant number of females ($p<0.05$ in June, $p<0.05$ in August). SONGS Unit 1 was offline in October, precluding impingement sampling. For the three-day December period all queenfish impinged were sexually immature. Overall impingement of female queenfish during 1978 was significantly greater ($p<0.05$) than impingement of males.

In two of the three months tested (March and August), female Phanerodon furcatus significantly outnumbered their male counterparts in impingement samples ($p<0.05$ in March, $p<0.05$ in August). There was no significant difference between males and females in June, the plant was offline in October, and no Phanerodon were impinged during the three-day December sampling period. The disproportionate number of females caught in-plant in March was also observed in gill nets set at 45 ft and in otter trawls taken at 60 ft in the SONGS area. Collectively, impinged females of Phanerodon significantly outnumbered males ($p<0.05$) in 1978.

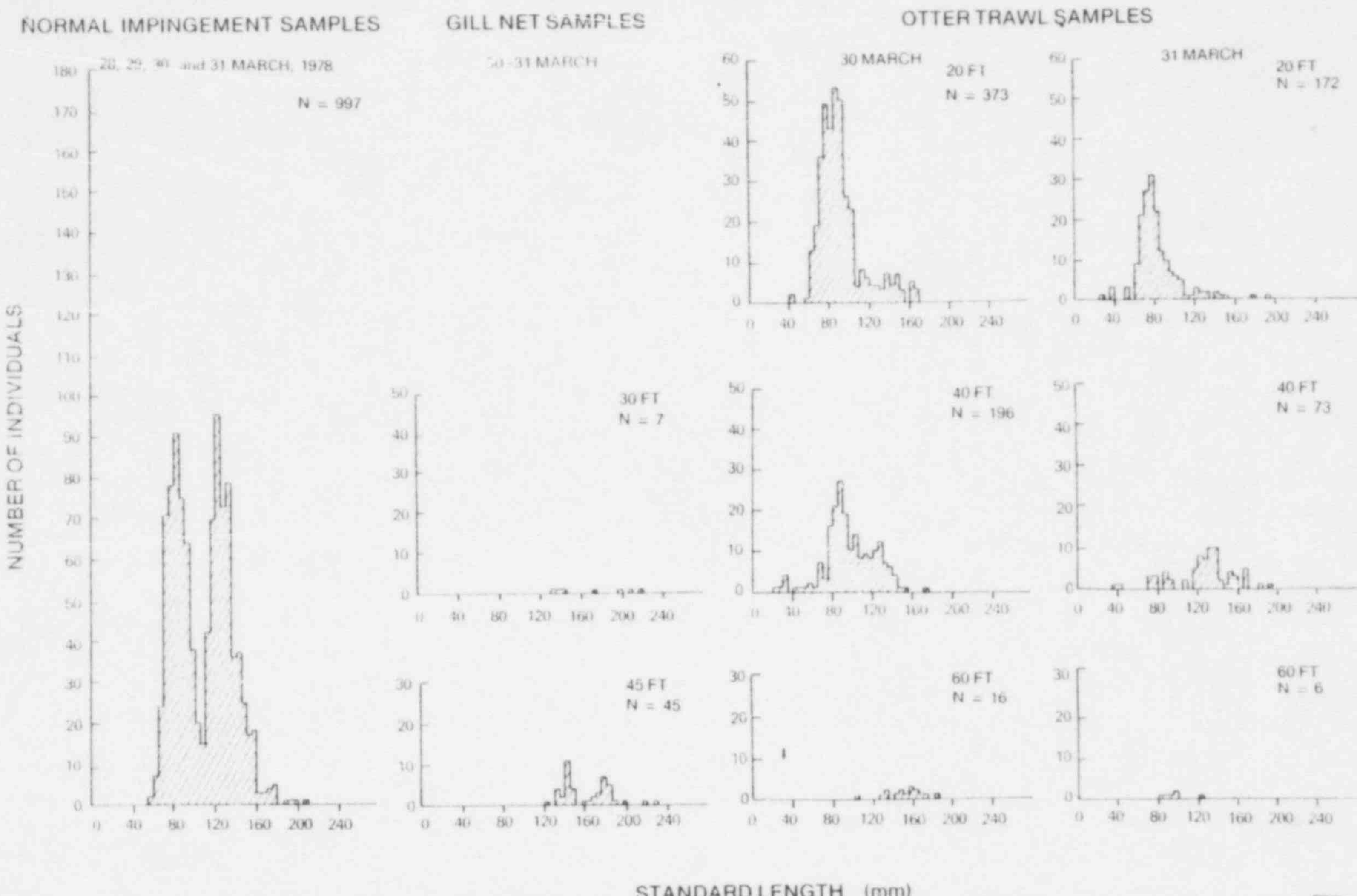


Figure 10-24. Length frequency histograms of Seriphus politus from normal impingement, and offshore gill net and otter trawl samples taken in March, 1978.

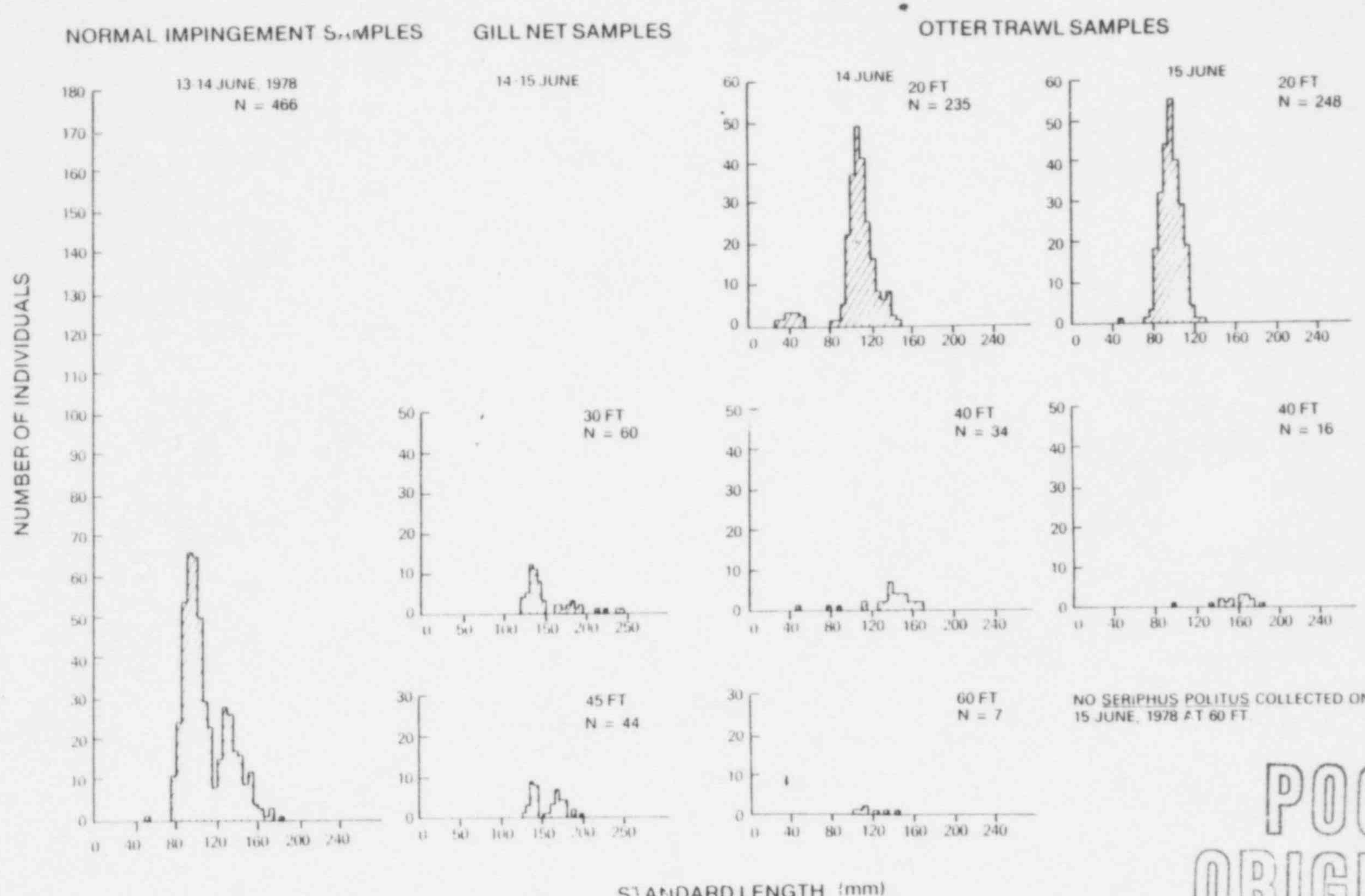


Figure 10-25. Length frequency histograms of Seriphus politus from normal impingement, and offshore gill net and otter trawl samples taken in June, 1978.

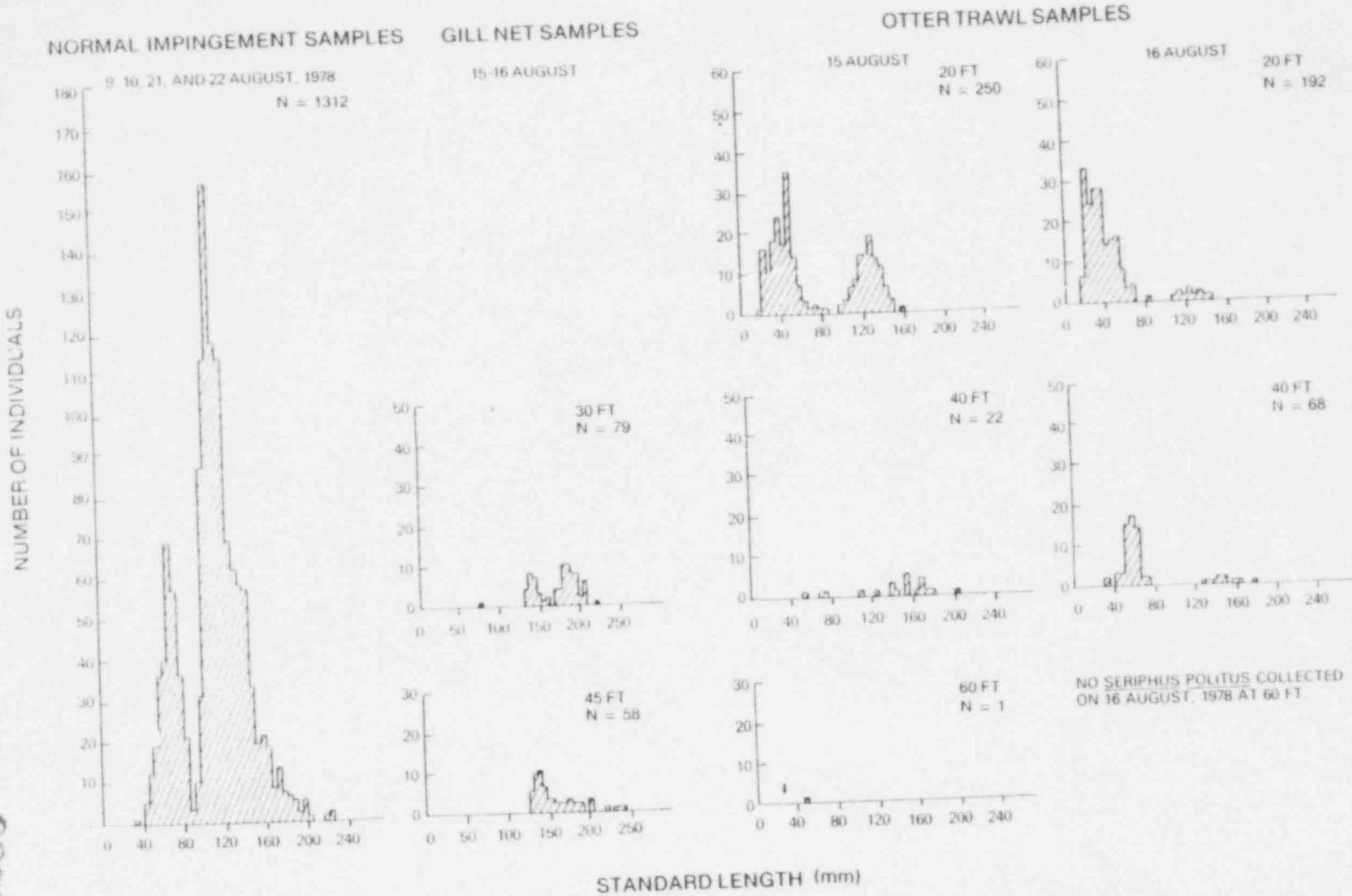


Figure 10-26. **Length frequency histograms of *Seriphus politus* from normal impingement, and offshore gill net and otter trawl samples taken in August, 1978.**

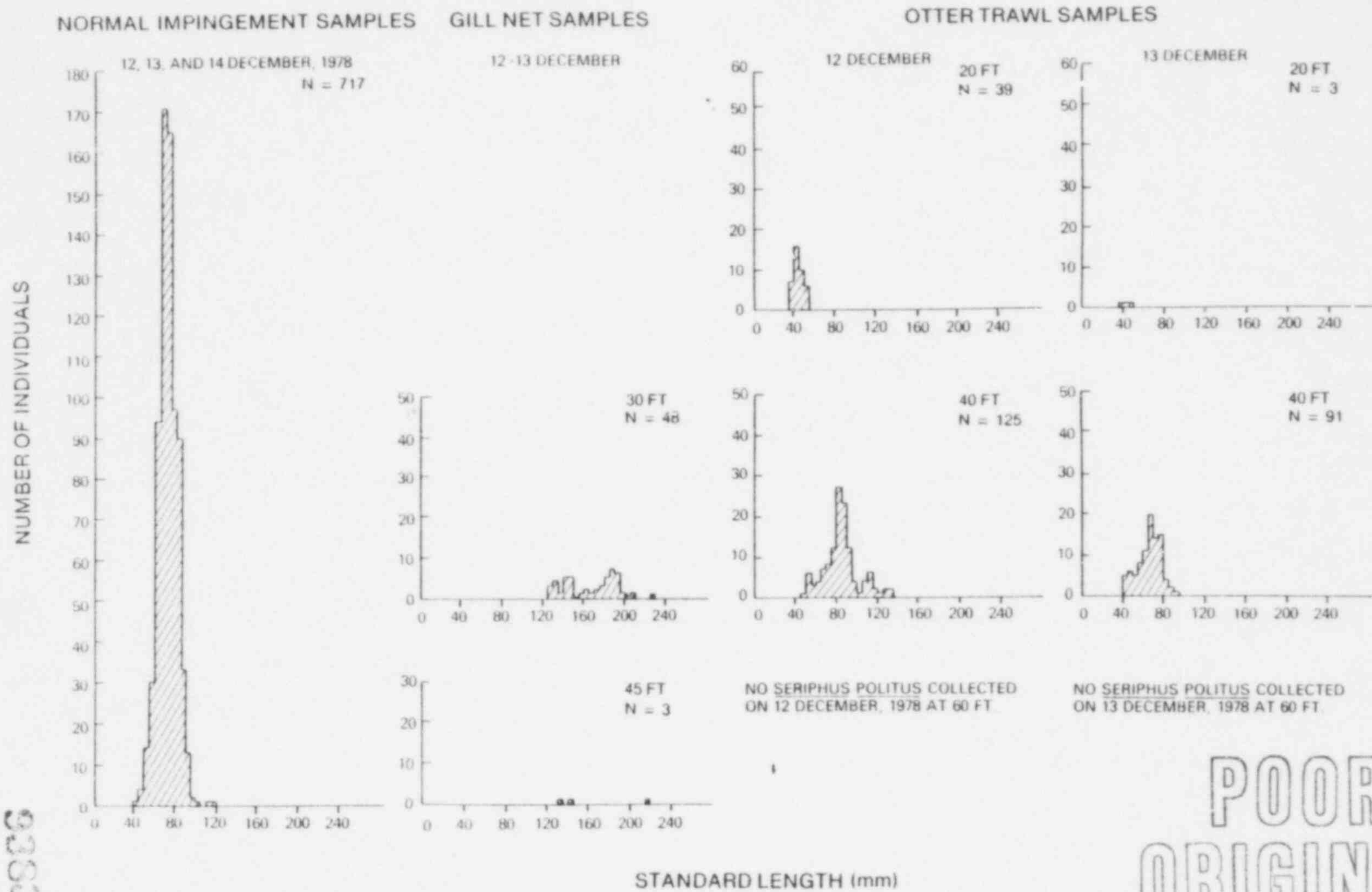


Figure 10-27. Length frequency histograms of *Seriphus politus* from normal impingement, and offshore gill net and otter trawl samples taken in December, 1978.

POOR ORIGINAL

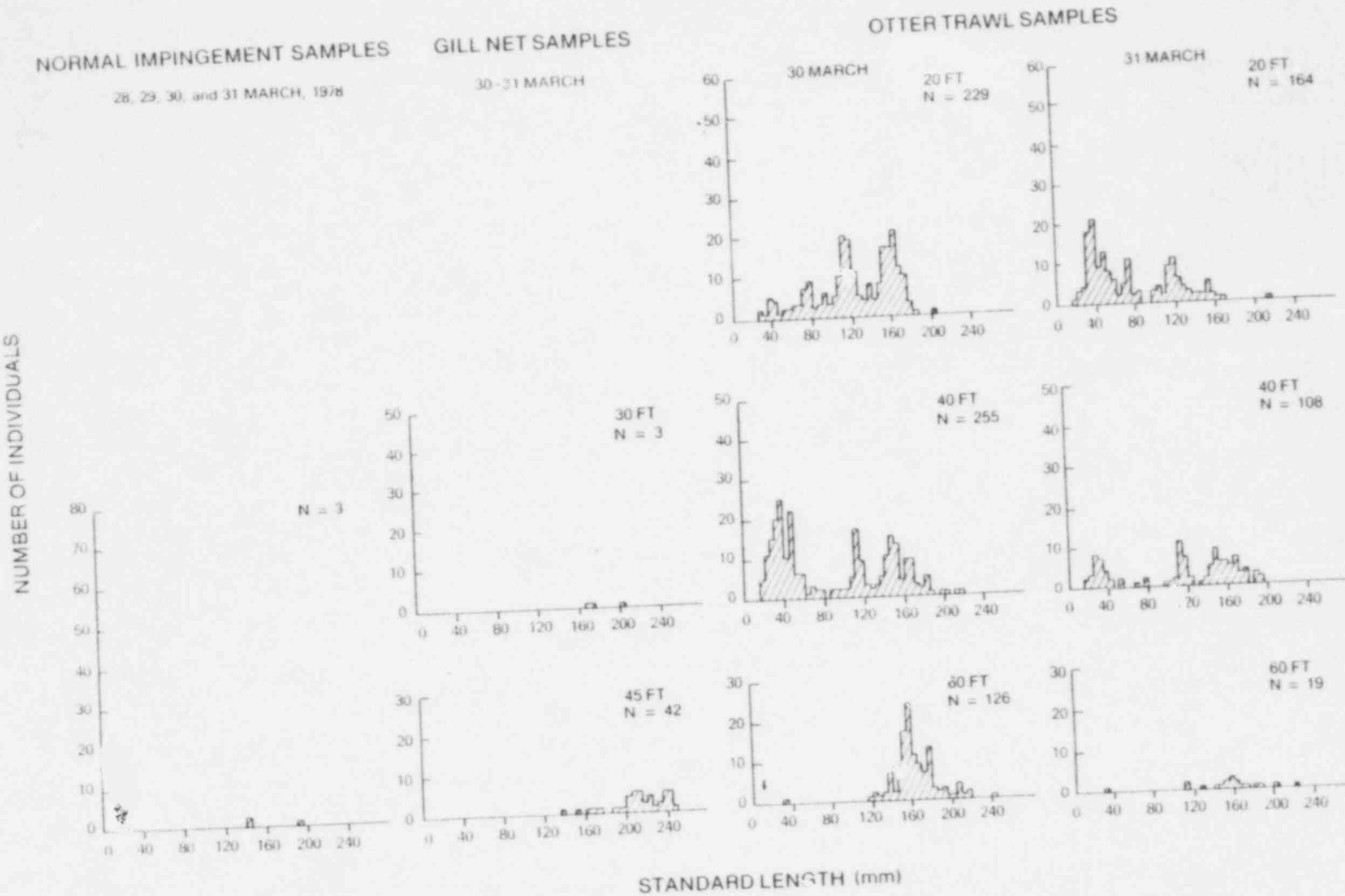
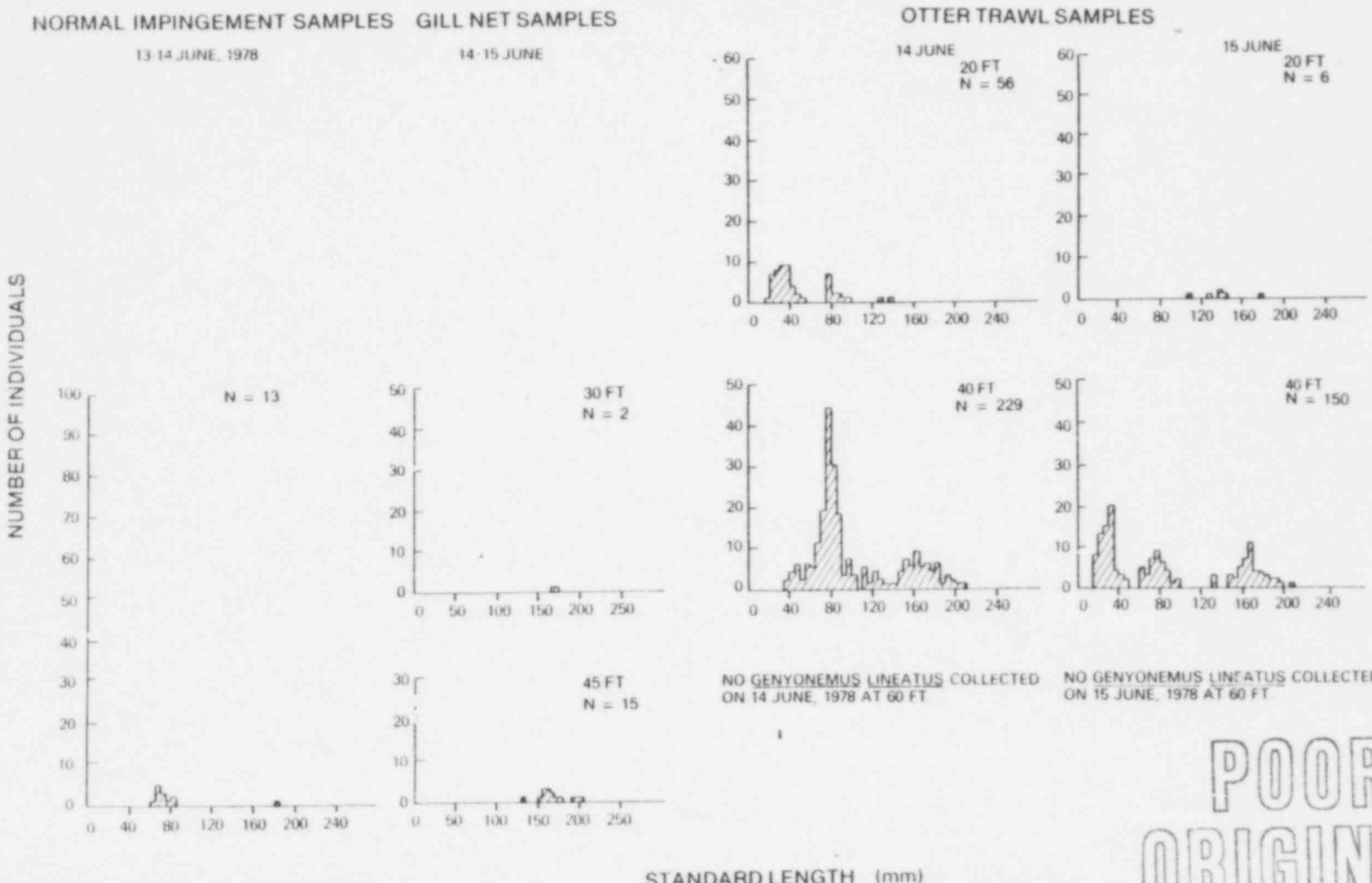


Figure 10-28. Length frequency histograms of Genyonemus lineatus from normal impingement, and offshore gill net and otter trawl samples taken in March, 1978.

POOR ORIGINAL



POOR ORIGINAL

Figure 10-29. Length frequency histograms of Genyonemus lineatus from normal impingement, and offshore gill net and otter trawl samples taken in June, 1978.

938324

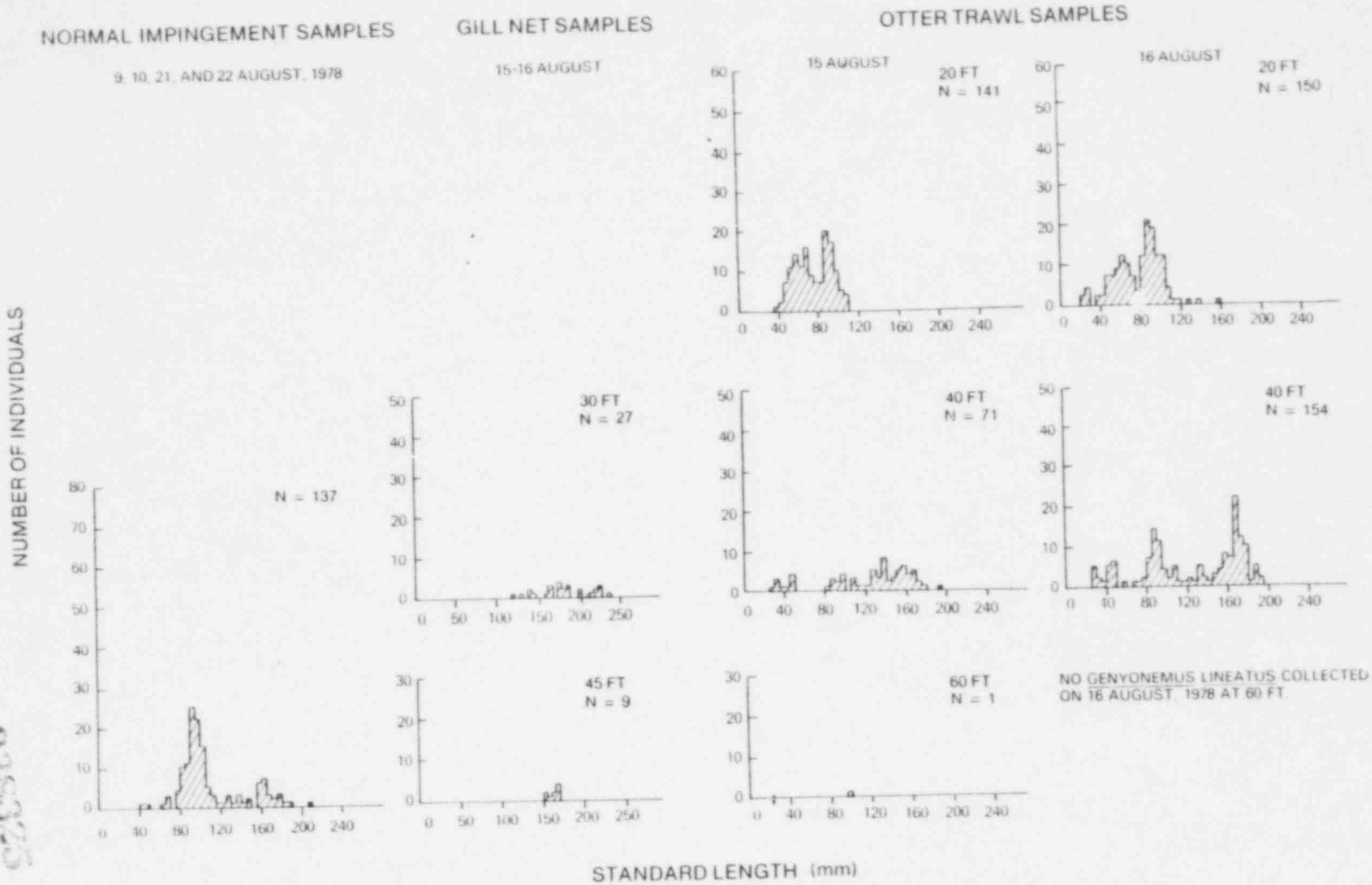
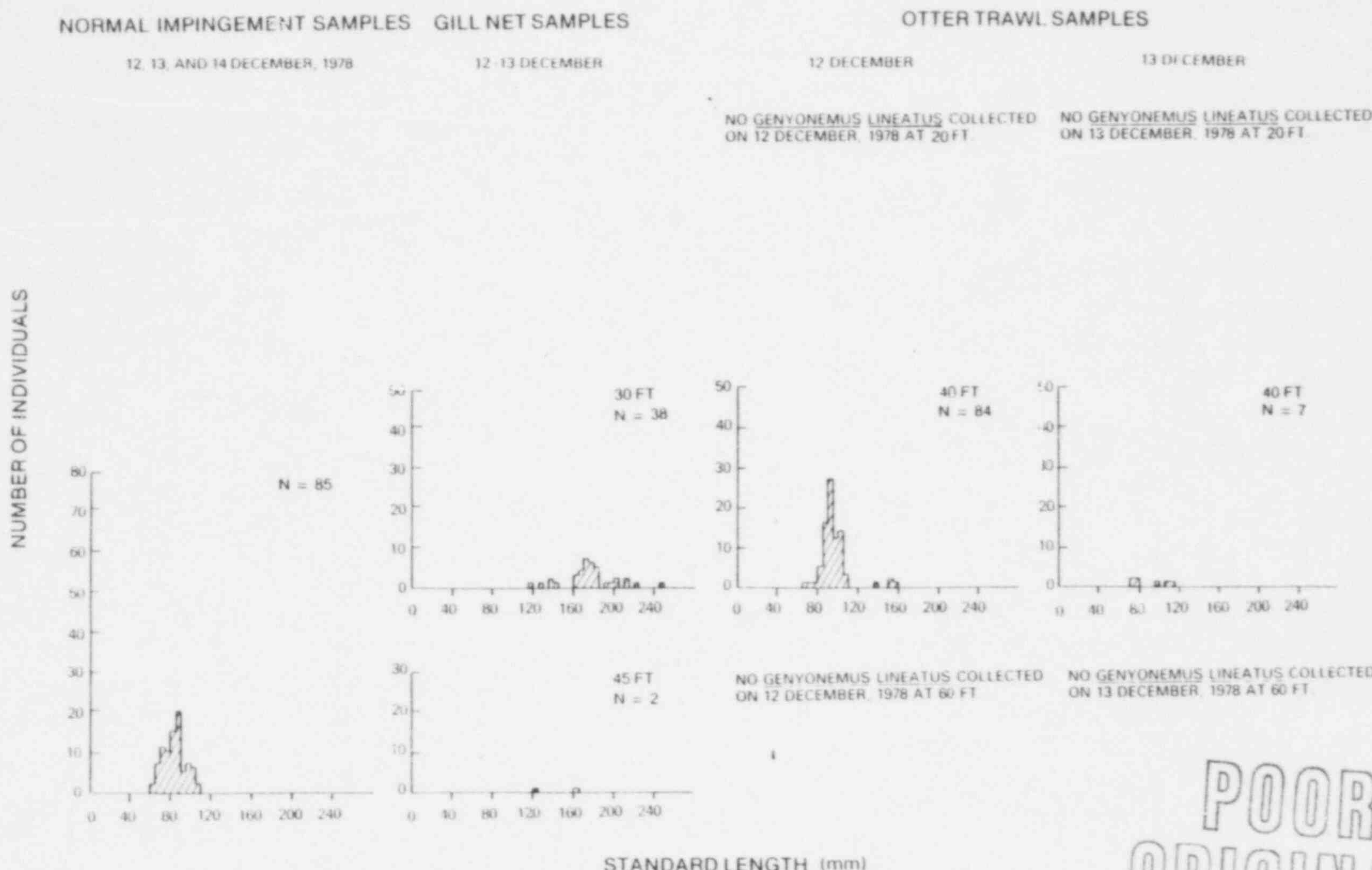


Figure 10-30. Length frequency histograms of Genyonemus lineatus from normal impingement, and offshore gill net and otter trawl samples taken in August, 1978.



POOR ORIGINAL

Figure 10-31. Length frequency histograms of Genyonemus lineatus from normal impingement, and offshore gill net and otter trawl samples taken in December, 1978.

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DISCUSSION

The fish studies currently being conducted offshore the San Onofre Nuclear Generating Station are designed to provide a baseline to determine possible effects of SONGS Units 2 and 3 when they become operational and to monitor the local fish community to detect biological alterations associated with the operation of Unit 1. Interpretation of the results is based upon the assumption that the combined fish program (i.e., using otter trawls and gill nets) is monitoring the general well-being of the local fish community. Even though sampling is biased (i.e., size, substrata, time of day) this assumption may be valid because the bias is systematic. Thus, relative differences in the parameters measured, are meaningful, and relative changes in a few abundant species are probably good indicators of community change.

Specific topics regarding the entire fish community and select species populations for the SONGS vicinity are addressed. References are made to past studies of fish in the area and to results of other fish studies in southern California to place the 1978 results in perspective with the marine environment offshore southern California.

RECEIVING WATERS

Community Analysis

Temporal (seasonal) and spatial (depth) variability in species composition-abundance data indicated that queenfish, white croaker, walleye surfperch, and northern anchovy were consistently caught in the greatest number in gill nets and/or otter trawls in all areas. Three of these species (queenfish, white croaker, walleye surfperch) have historically predominated in gill net catches offshore SONGS (LCMR, 1978c). Dominance of the neritic fish community by these four species is not unique to San Onofre. Otter trawl samples taken in the neritic zone at Mandalay Generating Station (MBC, 1978c) near Ventura, Huntington Beach (MBC, 1978a), and within the southern California Bight (Mearns, 1974) in general, display this dominance pattern by these species.

Absence of temporal patterns for species composition and abundance results from the persistent numerical superiority of Seriphus, Genyonemus, Hyperprosopon, and Engraulis coupled with the highly ephemeral catches of other species. This transiency arises, in part, because of a variety of onshore-offshore movement patterns which are difficult to sample using a Restricted Systematic Sampling Design (Venrick, 1978).

The recurrence of suites of species commonly associated with kelp habitat (Feder, Turner, and Limbaugh, 1975) in shallow (30 ft) and deep (45 ft) gill net samples at San Mateo Point and deep (45 ft) gill net samples in the SONGS area is also well documented along the southern California coast where the giant kelp, Macrocystis pyrifera, is present (Limbaugh, 1955; Quast, 1968c; Feder, Turner, and Limbaugh, 1974; Ebeling and Bray, 1976; and Love and Ebeling, 1978). The absence of these species at shallow SONGS gill net stations results from the absence of an extensive Macrocystis canopy at these stations and not from a Unit 1 operational effect.

Trawls showed that dominance of samples by a few species (relatively low J') was generally high in shallow (20 ft) and intermediate (40 ft) depths during March through August sampling periods. Dominance declined during October and December periods, first at San Mateo and SONGS, later at Don Light at these depths. Conversely, dominance of samples from the deeper station (60 ft) was generally low during the first three sampling periods, while increasing during

October and December periods with Don Light lagging as before. This implies that many species migrate seasonally at one growth stage or another: inshore during spring and summer and offshore during fall and winter.

This pattern was not so obvious for gill net samples, which were conducted at 30 ft and 45 ft over only cobble substratum. Unlike trawl samples, gill net samples showed low dominance during the March period at the shallower station, though higher at 45 ft. Like trawl samples, dominance of samples by a few species increased during June and August at all stations but SONGS, where dominance increased in October. Finally, in December, dominance was generally low areawide, except the deeper station at Don Light where dominance rose abruptly. This may reflect the general pattern of offshore migration of a few numerically dominant species (e.g., queenfish, white croaker) during fall and winter.

Comparisons between 1978 trawl data and past fish data from San Onofre cannot be made because 1978 was the first year in which otter trawl samples were taken throughout most of the year. Thus, it is not known whether the spatial and temporal patterns described above are typical or atypical of the San Onofre area. The seasonal nature of the dominance-diversity data (i.e., inshore movement in spring and summer and offshore movement in fall and winter) results, in part, from the recruitment of juvenile queenfish and white croaker (see discussion of these species in the following population analysis section) into shallow depths during the spring and summer, followed by their subsequent offshore movement in fall and winter.

Although several fish studies using otter trawls have been conducted in southern California in recent years (Mearns, 1974; Mearns and Word, 1975; Allen, 1975; Word, Mearns, and Allen, 1977; Farris, 1977, 1978; Fay, Vallee, and Brophy, 1978) most of these studies sampled demersal fish populations at depths exceeding those sampled at San Onofre; thus, it is difficult to evaluate seasonal patterns in diversity based upon these studies, because the fish communities sampled are different by virtue of the depth at which sampling occurred or because shallow water (<20 m) sampling occurred infrequently.

It appears that much of the variability in species composition, abundance, and diversity may be attributable to natural onshore-offshore migrations. Increased dominance by a few species (unevenness) probably resulted from onshore movement of juveniles to shallow depths where they can find small food particles and grow quickly with reduced predation. As they grow, they probably move offshore to feeding grounds where larger fish of all species abound. Although seasonal variability in catch appears less at the SONGS site, fish there generally do not show any marked and unexpected irregularities in these migratory patterns.

Population Analysis

Seriphus politus

The nearshore (<20 m) habitat, whether associated with the level sand bottom or cobble-boulder-kelp substrata, represents an area inhabited by queenfish populations during most of the year (Skogsberg, 1939; Limbaugh, 1955; Feder, Turner, Limbaugh, 1974; Maxwell, 1975). Depth and season are ecologically important factors in the life history of *Seriphus* in the SONGS vicinity. The inshore (<10 m) environment was inhabited by high numbers of young-of-the-year queenfish for approximately five months during summer and fall in 1978.

During the oceanic summer (May-October), queenfish were consistently abundant in the shallower isobaths (20, 30 ft) and inconsistently abundant in offshore depths (40, 45 ft). The deepest stations sampled (60 ft) were sporadically inhabited by queenfish, though emigration beyond the 60-ft isobath may occur during December. This seasonality corresponded well with environmental conditions measured in 1978 (BC, 1979). In 1978 the oceanic winter season was clearly confined to the months of January through April (BC, 1979). Beginning in May and part of June, the oceanic summer water temperatures, defined by thermoclines, began appearing and persisted through October. By December, complete water column mixing and low temperatures initiated the next oceanic winter season. The May through October warming trend differed from previous years in which higher water temperatures persisted through mid-December (BC, 1978). Water temperatures, including those near the bottom, in the San Onofre region during the summer months undergo radical fluctuations within short time spans. Fluctuations of 5 or 6°C were not uncommon within a 4 or 5 h period. It is likely that internal waves, along with changes in tidal height, were responsible for the great changes in temperature which, in turn, can influence temporal and spatial fish distribution and abundance patterns (North and Hubbs, 1978; Terry and Stephens, 1976).

In December, decreased abundance of queenfish and several other species, notably in otter trawl collections, appeared to be a direct reaction to the influx of colder water (10-12°C). Mass mortality was not observed, nor was there any evidence of mass movement upcoast or downcoast. The absence of estuaries in the immediate vicinity precludes movement into estuaries. Thus, it was likely that they left the nearshore sampling area for areas of deeper cold or colder water. A similar offshore migration was confirmed off Santa Barbara by deep trawls taken during winter and spring months (A. Ebeling, personal communication). Skogsberg (1939) found Seriphus in southern California to be abundant near shore from "late spring to the beginning of winter". In winter, he hypothesized that "they probably migrate into somewhat deeper waters where they become less available to sport fishermen". Offshore movement during fall and winter from an east coast estuary has also been documented for several sciaenids (Chao and Musick, 1977).

The winter offshore migration by Seriphus and other sciaenids appears to be well documented, but why they left the nearshore area for colder offshore areas is unknown. There was no evidence that predators move inshore with upwelled water. Perhaps food and refuge was depleted inshore where the effects of winter storms are most severe. As ectotherms, they may actually seek the coldest water during winter in order to lower their metabolism and thereby minimize energy requirements and food intake (A. Ebeling, personal communication). Another possibility is that they moved offshore to avoid the turbulence of the storms themselves.

Gill net catches in 1978 demonstrated an inshore trend in catch dissimilar to past years (1975-1977). The winter decrease in these past years occurred later in winter, as evidenced by catches in March of the following year. However, a December decline had been observed at Don Light during 1977 (Figure 10-4). Closer examination of 1975-1977 gill net results (Figure 10-4), revealed that the abundance of Seriphus in the SONGS and Don Light areas has been traditionally discordant. This obvious difference between the populations inhabiting the two areas, indicated that some biological or abiotic factors other than temperature alone have been affecting queenfish abundance patterns. Potential causes for these differences fall into four general categories: food, safety, reproduction, and comfort in, or tolerance to, physical conditions (temperature, light, salini-

ty, etc.), acting either over the long or short term (Bray and Ebeling, 1975; Ebeling and Bray, 1976; A. Ebeling, personal communication). Contrary to past differences in SONGS-Don Light gill net catches, the 1978 gill net catches were similar.

San Mateo Point queenfish catches at 30 ft, on the other hand, demonstrated a peak in mean abundance during June, with a consistent decline through December. Gill nets set at 45 ft throughout the San Onofre region displayed a pattern similar to catches for SONGS and Don Light at 30 ft. San Mateo Point abundances at 45 ft also paralleled the other stations common to this isobath, although the variability in catch increased through the course of the year.

Qualitatively comparing 1978 Seriphus length structure data with that collected in 1977 for the SONGS and Don Light 30-ft stations during June, October and December surveys indicated that Seriphus length structure has remained unchanged between 1977-1978, although the number of individuals within each length class has varied. No comparative length structure data are available for August or March, as 1977 gill net surveys were based upon a quarterly sampling frequency.

The most obvious feature of queenfish length structure sampled by otter trawls is the occurrence of a high percentage of juvenile fish in the 20-120 mm size range occurring at 20 ft in all areas during March, August, and October. The specimens ranging from 25-80 mm SL represent young-of-the-year which began appearing in March and remained in shallow water into October. By December, the young-of-the-year were absent from all depths. The individuals ranging in size from 100 to 150 mm SL are probably year class 1+ (D. Hunt, personal communication) or older individuals which are resident through the spawning season and eventually migrate from the study area in December. Since 1978 was the first year in which otter trawling was conducted at San Onofre throughout the year, there is no historical data base with which to compare the otter trawling results. However, recent otter trawling studies performed in neritic waters at Huntington Beach (MBC, 1978a) and Alamitos Bay (MBC, 1978b) indicate a similar pattern in Seriphus recruitment in August at Huntington Beach (MBC, 1978a) and in July at the more northerly Alamitos Bay site (MBC, 1978b). Thus, it appears that the queenfish recruitment phenomenon observed at the San Onofre study areas was observed over a broad nearshore area of southern California.

Gill net catches at 30 ft in all areas and during most surveys showed that female Seriphus were more abundant than males, while gill nets set offshore (45 ft) rarely captured greater numbers of females. This trend suggested that female queenfish occupied shallow waters for most of the year in greater numbers than the males. Since spawning in queenfish is known to occur more than once annually (Goldberg, 1976) females may occupy the inshore area as a refuge from larger predatory fish and/or because food availability may be greater and the competition for that food reduced, inshore.

High abundance of immature Seriphus collected in nearshore (20 and 40 ft) trawls during spring, summer, and fall suggested that this area was important in Seriphus recruitment because it affords an increased supply of food and is relatively free of predatory fish (A. Ebeling, personal communication) likely to prey on juvenile queenfish. The size bias of otter trawls toward juvenile fishes was evident at 20 ft, as this isobath was almost exclusively dominated during a large portion of the year by age 0+ (<125 mm, D. Hunt, personal communication) Seriphus.

Although direct evidence citing the use of nearshore depths as recruitment areas for queenfish is lacking, several studies of estuaries (Allen and Horn, 1975; Fritz, 1975; Haaker, 1975; Lane, 1975; and Odenweller, 1975) along the southern California coast have demonstrated the importance of shallow water areas in the early life stages of several neritic fish species. Evidence for open coastal shallow depths serving as recruitment areas has been demonstrated by Hardy (1971), Cushing (1975), and by Harden-Jones (1968) who found fixed spawning grounds and regular larval drift toward recruitment areas in temperate waters similar to those found along the California coastline.

Ichthyoplankton data obtained by Marine Biological Consultants (MBC) in the San Onofre area have shown larval Seriphus to be first collected regularly during June and July with peak catches in August and September (M. Sowby, personal communication). Seriphus yolk sac larvae have been found predominantly in the neuston layer, while older larval queenfish 3-6 mm in length were collected predominantly near the bottom (M. Sowby, personal communication). Apparently the long spawning period of Seriphus, from April through August (Skogsberg, 1939; Maxwell, 1975; Goldberg, 1976), perpetuated the abundance of juvenile individuals observed from June into October in shallow water.

The greatest numbers of queenfish, the majority of which were immature (0+ and 1+ age) were caught in an area encompassing the 20 and 40-ft isobaths from spring through fall. Newly recruited age 0+ Seriphus were rarely captured offshore at 60 ft. Larger juveniles (1+ age), however, were commonly collected at all depths year-round.

The presence of juvenile queenfish was observed at depths ranging from 20 to 40 ft throughout the San Onofre study area during a portion of the year, and at other southern California locations (MBC 1978a, b). The distribution of these juvenile fish encompasses the depth at which the SONGS 1, 2, and 3 intake structures are located (approximately 26 ft); and thus are potentially subject to entrainment in the SONGS cooling water system. Although seemingly large numbers of juvenile queenfish were impinged and killed by Unit 1 in 1978 (see subsequent impingement section), this probably had relatively little effect on adult population size, as females of this species are highly fecund and display the broadcast spawning mode of reproduction. This mode of reproduction is generally characterized by high levels of mortality in early stages of life, however the adult population can replace itself with the few recruits that survive, as a spawning pair produces thousands of larvae (Royce, 1972). Therefore, impinged juveniles have relatively little reproductive value in sustaining the population size (A. Ebeling, personal communication).

Genyonemus lineatus

White croakers displayed seasonal distribution patterns that appeared to result from ill-defined onshore and offshore movements. Catches of Genyonemus were greatest in March and August in both gill nets and otter trawls and also in June trawl collections throughout the San Onofre region. Lowest catches of Genyonemus occurred in the San Mateo Point and Don Light reference areas during December. The December decline in catch may be explained with the same arguments used in the Seriphus discussion.

March catches of Genyonemus indicated that this species was not restricted to a particular isobath, but rather, occurred uniformly over sand bottom on the 20 and 40-ft isobaths, and over cobble bottom at the 45-ft isobath. The June

catch of white croaker suggested that they preferred the sand bottom habitat near the 40-ft isobath. Movement inshore to at least the 20-ft isobath sand habitat occurred in August with high catches taken at the Don Light 45-ft cobble habitat. The Don Light 45-ft cobble substratum was still preferred in October, as it was at the SONGS 30-ft isobath. Additionally, in October, Genyonemus generally moved into deep water (40 ft) with many individuals located over the sand habitat further offshore in the Don Light area.

Substratum selection is likely to be a highly important factor affecting the distribution of this species, as its mouth is morphologically adapted for a bottom feeding existence (Skogsberg, 1939; Chao and Musick, 1977). Genyonemus stomach analyses indicate this species' preference for epibenthic and infaunal invertebrates (Skogsberg, 1939; Frey, 1971). The ill-defined movements observed in the Genyonemus population are likely to be associated with feeding resource abundance.

Genyonemus was consistently abundant throughout 1978 in gill net collections made adjacent to the Unit 1 discharge, and reached an annual peak in the other SONGS gill nets in December. While the circulating pumps were shut down during the October survey, gill nets adjacent to the discharge, as well as the SONGS non-discharge gill nets, demonstrated no differences in catch when compared with past years. Uniformity in annual thermal conditions, thermal buffering from cold shock (upwelling) and increased food availability from entrained-discharged food organisms (MRC, 1979) may account for the consistent abundance at the discharge and increased SONGS abundance in December.

The Don Light gill net collections made on the 30-ft isobath represented a substantial increase in annual Genyonemus abundance compared to past years. Catches of Genyonemus in this area, from 1975 to 1977, were a small fraction of the overall San Onofre regional gill net catch. They were numerically dominant throughout 1978, except in December (Figure 10-9). The December decline in catch agreed with previous gill net catches in the Don Light area.

Size structure of Genyonemus was characterized by a 160-175 mm SL modal length class throughout the year at all depths and areas. The quantity of white croaker caught in gill nets was sufficiently low throughout the year in all areas that seasonal trends in length classes susceptible to capture by gill nets were not apparent. Gill net samples of Genyonemus taken in 1977 at SONGS and Don Light areas indicate length frequency structure similar to that in 1978. Abundances within each modal class appear similar to those caught in 1978.

Otter trawl collections of Genyonemus suggested a variable size structure depending upon season. Otter trawl samples demonstrated the presence of juvenile white croaker in the 20-60 mm SL modal class during March and June with subsequent inshore movement of this length class in August and October. Again, as with queenfish, juvenile white croaker were absent by December. For most of the year (excepting December) there appeared to be a small resident population of 120-170 mm SL and 190-220 mm SL adult white croaker inhabiting 40 and 60-ft isobaths. Based upon the aforementioned movement of juveniles, it appeared that spawning and early development may occur at 40 ft with subsequent migration to shallower depths during the first few months following spawning. As with queenfish, the general whereabouts of white croaker during December are presently unknown, although it is believed that they move into deeper water with the onset of the oceanic winter (A. Ebeling, personal communication).

The recruitment of juvenile white croaker observed in the San Onofre region during March was documented simultaneously at El Segundo-Scattergood (LCMR, 1979b). The presence of newly recruited juvenile white croakers was also observed in July at Alamitos (MBC, 1978b) and in August at Huntington Beach (MBC, 1978a)

No seasonal trends in Genyonemus sex composition were discerned from either the gill netting or otter trawl samples taken in 1978. The significant abundance of males collected on an annual basis in trawls conducted at 60 ft represents an offshore concentration of this sex. An abundance of Genyonemus eggs, indicating recent spawning, has been collected near the 20-m (66-ft) isobath offshore San Onofre (MRC, 1979). A predominance of males in this area may reflect breeding behavior.

Genyonemus lineatus has been shown to begin spawning in October and continue intermittently into April and May (Skogsberg, 1939; Goldberg, 1976). This information corresponds well with March and June otter trawl catches in which large numbers of small white croaker in year class 0+ were caught at the 40-ft isobath in all three survey zones.

Results of icthyoplankton sampling conducted by MBC during 1978 show larval G. lineatus first occurring in relatively large numbers in November and continuing through May; peak abundances occurred in February and March (M. Sowby, personal communication).

The present results show that during March through October, most of these smaller fish had concentrated between 20 and 40 ft. The cyclic migration of young croaker out of shallow waters after a rapid period of growth follows a pattern similar to that observed for the juvenile (including post larval stages) life history in S. politus described previously. Cushing (1975) pointed out that such a periodic and predictable cycle in temperate waters would serve to maintain genetically distinct fish stocks through predictable current and temperature fluctuations. Nearshore waters serving as nursery areas would also be beneficial for larval fish according to Heincke's Law (Cushing, 1975), which declares that smaller fish may find security from predators in shallow depths.

Hyperprosopon argenteum

The seasonal abundance patterns of Hyperprosopon appear to be related to seasonal oceanic conditions. Gill net abundance patterns paralleled one another between 30 and 45 ft in all areas including nets set adjacent to the Unit 1 discharge. Walleye surfperch gill net catches were greatest at all areas and depths during the time of coldest bottom temperature in March, June, and December. During December, the observed concentration inshore was probably related to breeding aggregations, as Feder, Turner, and Limbaugh (1975) described the months of October through December as the peak breeding time in southern California.

Abundance patterns associated with otter trawl catches were not as obvious as that for gill nets. The low abundance of walleye surfperch in trawl collections precludes an analysis of seasonal trends of abundance. Breeding aggregations may be present in October at 60 ft in SONGS and Don Light, as evidenced by high catches during this month. Chi-square analysis demonstrated a lack of significant sex ratio differences for any particular survey, but small sample sizes probably hampered these tests.

Recruitment of young H. argenteum has been observed during April (Feder, Turner, and Limbaugh, 1975), which was substantiated by the 1978 otter trawl size class and sex composition results. These samples captured relatively low numbers of juveniles, but because of the advanced size of young at birth, and therefore, the improved chance for survival, low fecundity for this species is normal (Rechnitzer and Limbaugh, 1952). Age 0+ individuals appeared to move offshore in late August and September, because juvenile sized Hyperprosopon were absent in October collections. Whether this movement is indicative of the migration due to the onset of winter turbidity and food scarcity (Goldberg, 1978) is unknown.

Phanerodon furcatus

A seasonal abundance pattern for Phanerodon furcatus was evident but not coincident between the gill net and otter trawl samples. The abundance pattern from gill nets set at 30 ft indicated low catches of adults from March through August at all sampling areas and depths. A sharp increase in catch was observed during October and December. This pattern has been consistent during the period from 1975 through 1978.

The trawl results showed abundance patterns independent of the gill net results. For example, the SONGS area was different from Don Light and San Mateo Point areas in that Phanerodon were concentrated at the 40-ft isobath during June and December. Migration to 20 ft occurred in August and December in the SONGS area, while white surfperch were present at the 60-ft isobath only in October. During 15-16 March, Phanerodon was evenly distributed in all depths at the SONGS area; however, by 30-31 March fewer Phanerodon were present, and then only at 40 ft. This pattern was indicative of the high variability in all areas associated with the sand habitat.

The abundances of Phanerodon at Don Light and San Mateo Point tended to parallel each other. These two areas experienced low abundances of Phanerodon during March and December at 20 and 40 ft. During the remainder of the year consistent, though low, catches of Phanerodon were taken at both isobaths.

High inshore catches of Phanerodon during June were related to an increased abundance of juveniles, which corresponded with data obtained by Goldberg (1978), who showed that birth of white surfperch occurred from May to July in shallow waters. These young Phanerodon begin feeding immediately on particulate food, and continue to mature rapidly in the nearshore waters (Bray and Ebeling, 1975).

Results of subsequent otter trawls indicated that dispersal of juveniles apparently occurred within approximately two months of birth, as 20 and 40-ft depths contained larger sized juveniles in subsequent surveys. The mid-depth (30 and 40 ft) aggregations of Phanerodon in December are somewhat contrary to observed offshore migrations by more northern Phanerodon populations near Santa Barbara, California (A. Ebeling, personal communication). However, Goldberg (1978) stated that the breeding season for P. furcatus occurs during October through December, and just prior to offshore migrations of adults. This offshore movement may be in response to increased turbulence in the shallows, a decline in available food resources, or a need to seek colder waters where a reduced metabolism would lower energy requirements.

Sex ratios showed that even though Phanerodon furcatus did not appear in appreciable numbers during March, a predominance of females occurred. While larger numbers began to appear later in the year, the ratio of males to females was equal.

IMPINGEMENT

The 1978 annual estimate of total fish and selected species impinged by SONGS Unit 1 increased substantially compared to recent years (Table 10-6). Compared to annual impingement estimates for SONGS Unit 1 in 1975, 1976, and 1977, the 1978 annual impingement catch estimate was 2.0, 3.0, and 2.5 times greater, respectively, using a weighted mean catch based on two different operational phases of water circulation at SONGS (LCMR, 1978c). Furthermore, the average weight per fish impinged decreased from 0.12 lb/fish in 1976 to 0.07 lb/fish in 1978.

The overall increase in fish impinged and the concomitant decline in the average weight per fish impinged probably resulted from an influx of juvenile fish into the neritic waters off southern California (MBC 1978a, b) and unusually stormy weather conditions during 1978. Figures 10-24 through 10-26 show that queenfish size structure impinged by Unit 1 in 1978 was bimodal except in December (Figure 10-27); the 65 mm to 95 mm modal class representing juvenile queenfish was present throughout the year and, in many cases, comprised 50% or more of the queenfish impingement catch.

Goldberg (1976) reported that Seriphus smaller than 148 mm did not contain mature oocytes and thus were not thought to be part of the breeding population. Using 148 mm as the boundary between immature and mature Seriphus, the 1978 annual estimate of juvenile queenfish impingement under normal flow conditions was equal to 337,775 individuals or approximately 56.2% of the total impingement catch resulting from normal and heat treatment samples. Since queenfish made up approximately 63% of the total catch by number and 39% by weight, the increase in annual impingement catch and decrease in annual average weight per fish is partially the result of impingement of juvenile queenfish. Comparing 1978 queenfish impingement size data with 1977 data (LCMR, 1978c) indicated that queenfish recruitment, as measured by impingement samples, occurred infrequently and in low numbers in 1977.

Comparing the size structure and numbers of Genyonemus sampled with otter trawls with impingement samples suggested that, for the time period examined (two

Table 10-6. Estimated annual impingement values for four years of the ETS program.

Impingement	1975	1976	1977	1978
Total Number of Individuals	296,319	198,266	235,555	601,193**
Aggregate Weight (lb)	30,832	24,631	20,625	43,820
Days of Operation	317	270	283	302
Daily Mean Number of Individuals	935	734	832	1,897*
Daily Mean Weight (lb)	97	91	73	141*
Mean Weight (lb) Per Fish	0.104	0.124	0.086	0.073

* Unweighted means

**Based upon weighted monthly mean catches taken during an unusually stormy weather year.

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to three days/month), SONGS Unit 1 impinged few white croaker. This pattern was particularly evident during March and June. This trend suggested that juvenile white croaker (<143 mm SL, Goldberg, 1976) adopt a bottom oriented existence for shelter and feeding similar to that of the adults. Remaining near the bottom reduces the chance of being entrained by the inflow of Unit 1 cooling water, which is a problem faced by vertically migrating zooplanktivores such as queenfish.

Unusually high impingement catches of fish in 1978 may have resulted partially from abnormally severe weather conditions (Herald and Simpson, 1956). Rainfall totals, for example, were abnormally high in 1978. Rainfall at Oceanside, an area 13 miles downcoast of SONGS, totalled 22.6 inches in 1978; this was more precipitation than any year since 1940, when slightly less than 25 in of rainfall was recorded (Pryde, 1977). Using rainfall as an index of climatological conditions, it appeared that inclement weather may be partially responsible for high impingement catches, particluarly during the early part of 1978.

SONGS Unit 1 apparently impinged more female queenfish and white surfperch than males, as evidenced by the overall significance of chi-square tests. In the case of queenfish, this difference may simply result from the higher number of females present in receiving waters, as inferred from catches of female queenfish in gill nets set at the 30-ft isobath (see Population analysis: queenfish). Analysis of historical normal flow impingement data (Valentine, et al., 1977) and heat treatment data (LCMR, 1976d, 1978c, 1979a) for white surfperch indicated that significantly ($p<0.05$) more female white surfperch are impinged than males. Chi-square tests were used to test sex ratios for significant deviations from a 1:1 ratio; however, breeding aggregations of surfperch may not adhere to a 1:1 ratio of females to males. Evidence for unequal sex ratios in embiotocids was presented for the walleye surfperch by Rechnitzer and Limbaugh (1952) who observed small schools of four to ten females accompanied by a single male during breeding season. Additionally, a male did not invariably remain with a single female but wandered to another unaccompanied female. Thus, the postulated 1:1 sex ratio may not apply to embiotocids; therefore, the apparent selective impingement of Phanerodon may reflect the natural sex ratio.

SONGS UNIT 1 EFFECTS

Unit 1 effects are manifested primarily through the intake of cooling water. The impingement of an estimated 600,000 fish, a large percentage of which were juveniles, represents an unusually large catch compared to impingement in recent years. This phenomenon may affect certain species and not others. As stated previously, impingement of large numbers of juvenile queenfish will not be damaging to the parent population due to the high fecundity of queenfish females. Historical impingement data also indicates that queenfish have consistently exhibited the greatest impingement catch by number since impingement sampling began; if the last five years are representative of impingement catch since plant operation began, then it appears that SONGS Unit 1 impingement of queenfish is not adversely affecting the standing stock of this species.

The fish community does not appear to be adversely affected by the discharge of cooling water. There were no detectable effects of attraction to or avoidance of the thermal plume in the area, although the intake and discharge structures may attract fishes to the immediate area. Seasonal movement patterns of select species observed in reference areas were also observed in the SONGS area and appeared unaltered by SONGS Unit 1 operations.

SUMMARY

Integrated gill net and otter trawl sampling was conducted bimonthly during 1978 in March, June, August, October, and December at stations located on the 9-m (30-ft) and the 14-m (45-ft) isobaths. Fish collected were identified, enumerated, measured, sexed, and visually inspected for parasites and anomalies. A detailed analysis of the 1978 data compared with 1975, 1976, and 1977 results indicated the following.

1. Queenfish Seriphus politus, white croaker Genyonemus lineatus, walleye surfperch Hyperprosopon argenteum and northern anchovy Engraulis mordax were the numerically dominant species sampled by gill nets and otter trawls in 1978.

2. The distribution of the number of individuals among the species (Pielou's evenness coefficient, J') indicated numerical dominance by a few species from March through October followed by an even distribution (individuals apportioned equally among the species) in December. Numerical dominance from March through October is attributed to recruitment of juvenile queenfish and white croaker while movement offshore in December results in an even distribution of individuals among the species.

3. Analysis of abundances throughout the overall study area for Seriphus politus, Genyonemus lineatus, and Hyperprosopon argenteum caught in gill nets revealed seasonal increases in abundance from March through August followed by declining abundance from October through December. Phanerodon furcatus abundances are low March through August and high October through December. Increasing embiotocid abundances in December may be attributed to reproductive behavior, while declining sciaenid abundance may result from offshore movement in response to colder water temperatures.

4. Length frequency structure of Seriphus politus and Genyonemus lineatus is bimodal for most of the year. The high incidence of juvenile queenfish and white croaker from March through October in shallow depths (20 to 40 ft) suggests a period of high recruitment during 1978 and that nearshore depths represent areas for early growth and development for both sciaenids and embiotocids.

5. The recruitment of queenfish and white croaker observed at SONGS was also observed offshore of several other southern California coastal localities based upon other otter trawl studies conducted in 1978.

6. Analysis of sex composition revealed no seasonal trends for Genyonemus, Hyperprosopon or Phanerodon. Female Seriphus were predominant in gill net catches at 9 m throughout the San Onofre region. Otter trawl samples were dominated by juveniles of both sciaenid species throughout most of the year.

7. The estimated 1978 annual impingement for SONGS Unit 1 was 601,193 ± 84,820 individuals weighing an estimated 43,820.77 ± 4,668.37 pounds.

8. The estimated number of fish in 1978 was 2.0, 3.0, and 2.5 times greater than the 1975, 1976, and 1977 impingement catch, respectively. This increased impingement probably resulted from severe storm conditions coupled with recruitment of a large number of juvenile queenfish and white croaker into neritic waters of southern California. The total estimated weight of fish impinged in 1978 was 1.4 to 2.1 times greater than previous years (1975-1977).

9. The average weight per fish declined from 0.124 lb/fish in 1976 to 0.073 lb/fish in 1978, primarily due to higher percentages of juvenile fish impinged.

10. Sex composition of impinged Seriphus showed a seasonal pattern paralleling the dominance by females in gill net samples collected on the 9-m isobath.

11. Although a large percentage of juvenile queenfish were impinged in SONGS Unit 1 in 1978, it is anticipated that this impingement will not adversely affect queenfish standing stock due to the high fecundity of this species.

12. The fish community offshore does not appear to be adversely affected by the discharge of Unit 1 cooling water; the discharge and intake riser structures may attract certain species of fish.

13. It appears that much of the variability in species composition, abundance, and diversity may be attributable to natural onshore-offshore movements.

14. Although seasonal variability in catch appears less at the SONGS site, fish there generally do not show any marked and unexpected irregularities in these movement patterns.

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CHAPTER 11

KELP

The sea bottom in the vicinity of San Onofre is mixed sediment and includes sand, sand-cobble, cobble, and boulders. Most nearshore areas show evidence of periodic burial by to natural sand transport, which decreases the ability of long-term biotic community to become established. Offshore rock and cobble areas are apparently less exposed to periodic burial and are where the giant kelp, Macrocystis, forms kelp beds which support a relatively varied and abundant marine biota.

Monitoring of the San Onofre kelp bed and associated substrate during the construction of SONGS Units 2 and 3 was undertaken to determine if changes in the kelp canopy and substrate composition were related to construction activities or to naturally occurring events. In addition to the San Onofre kelp bed, two reference beds, San Mateo kelp and Barn kelp (Figure 11-1), were monitored to supply baseline data on environment conditions in kelp beds beyond the influences of construction activities.

GENERAL REVIEW OF HISTORICAL DATA

Kelp beds in the San Onofre region were initially investigated in 1910 to 1911 during a mapping survey of kelp beds of California and Baja California (Crandall, 1912). The San Onofre kelp beds were not investigated again until the 1950's when the Kelco Company (unpublished data) mapped them by aerial photography. Between 1911 and the 1950's major changes occurred in both the location of the kelp beds and areal extent of the canopies (Figure 11-2).

The San Onofre kelp bed region were not routinely monitored again until 1974 when Dr. Wheeler J. North of the California Institute of Technology (unpublished data) began annual aerial photographic mapping surveys of the canopies. The aerial mapping surveys were conducted monthly (weather permitting) beginning in December 1976. Since June 1974, the area of the kelp beds was mapped quarterly using an electronic positioning system (Lockheed Center For Marine Research 1974a; 1975a-e; 1976a,b,c,; MBC, 1978).

A period of kelp deterioration was first noted between 1957 and 1959 which culminated in the loss of all kelp canopy in the San Onofre region in 1963 (North, unpublished data). The deterioration occurred in many of the southern California kelp beds. Unusually warm sea temperatures from 1957 through 1959 were first cited as the reason for the loss of the beds, although recently it has been suggested that low nutrient concentrations (nitrate and phosphate), which are frequently associated with elevated sea surface temperatures (Jackson, 1977), may have been the causative factors. The second period of deterioration of the kelp canopy occurred again between June and September of 1976 and was noted throughout southern California for reasons that are unclear. Nutrient data for the San Onofre kelp beds, are lacking during this period, although data from other southern California coastal areas (Kelco Company, unpublished data; California Institute of Technology, unpublished data) indicate that nutrient concentrations (especially nitrogen) were substantially reduced during this period and may have been responsible for the deterioration of the San Onofre kelp beds in 1976. In the San Onofre region, deterioration was most noticeable at the San Mateo and San Onofre beds where approximately 89% and 81% of the canopy was lost in the two areas, respectively. Barn kelp bed experienced a smaller amount of deterioration (MBC, 1978).

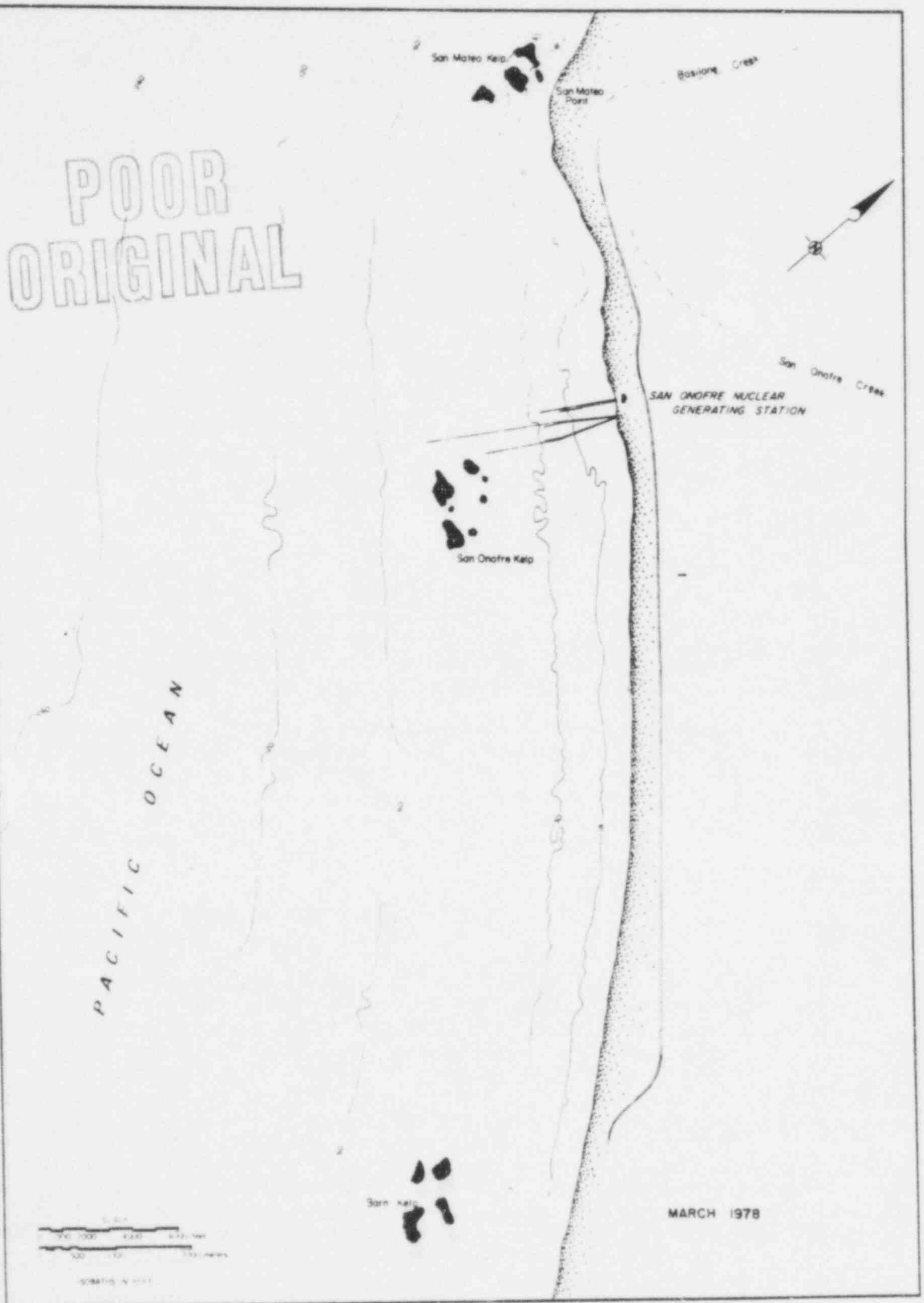


Figure 11-1. Study area of the kelp bed biology survey.

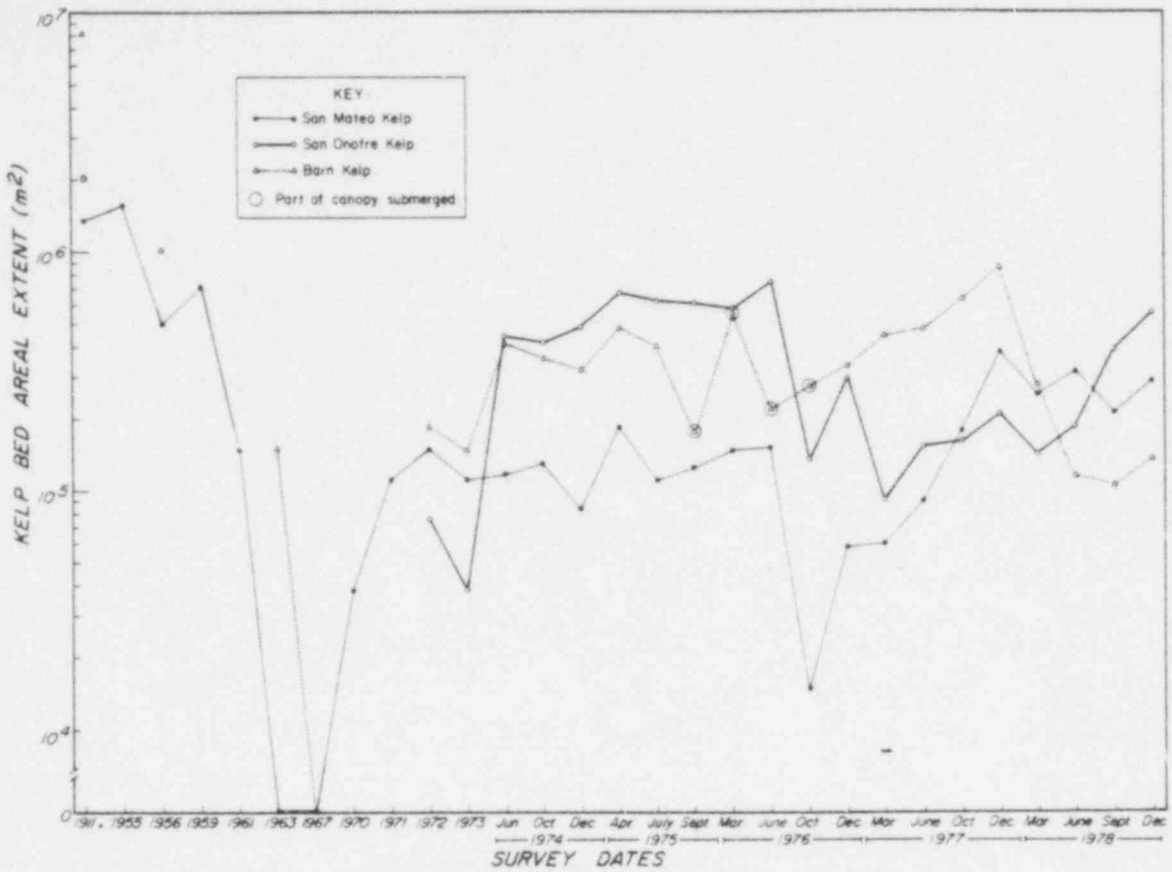


Figure 11-2. Estimated areal extent of the San Mateo, San Onofre, and Barn kelp canopy from 1911 through 1978.

By December 1977, the San Mateo and Barn kelp canopy bed appeared fully recovered, while the San Onofre kelp bed was still in the process of recovery (MBC, 1978).

MATERIAL AND METHODS

Studies of kelp beds in the San Onofre region were conducted from January 1978 through December 1978. Study tasks included: 1) quarterly mapping the areal extent of the kelp canopy and contiguous bottom topography using an electronic positioning system; 2) monthly mapping of the kelp beds by aerial infrared photography; 3) monthly determination of primary nutrient concentration (NO_2 $+NO_3$, NH_4, PO_4) of water in and adjacent to the kelp beds; 4) monthly determination of nitrogen content of kelp tissue; and 5) assessment of the general health of the kelp plants during April, September, and December.

AREAL EXTENT AND BOTTOM SUBSTRATE MAPPING

The areal extent of the existing kelp beds was mapped by Ecosystems Management Associates, Inc., using a Motorola Miniranger III. Information from the "Miniranger" was entered into an onboard computer which determined the vessel's position, and printed out the X-Y coordinates of each navigational fix, and a map showing the tract transversed by the vessel during the survey.

The areal extent of the individual kelp beds was determined from the maps developed during the field surveys, with a planimeter.

The associated bottom substrate was plotted using Klein Associates side scanning sonar with a two-channel recorder.

KELP RECONNAISSANCE

Qualitative assessments of the health of kelp plants (Macrocystis) in the established beds of the San Onofre region were made by diver-biologists during four quarterly surveys. Concurrently with these observations, a quantitative estimation of the success of kelp recruitment was conducted. Observations were made at single stations in each of the three kelp beds (Figure 11-3). In addition, observations were made along a 1,100 m transect (Transect B) in the San Onofre kelp bed.

NUTRIENTS

Monthly sampling and analysis of ammonia (NH_4), nitrogen (NO_3 + NO_2), and phosphate (PO_4) concentrations in, and adjacent to, the kelp beds was conducted in 1978. In addition, nutrient concentrations were determined monthly at a site approximately 4.3 km offshore of the San Onofre kelp bed. At the offshore site, nutrient concentrations were determined from samples collected at the surface and at 15 m, 30 m, 45 m. This site was occupied to evaluate the amount of natural upwelling occurring in the area and its effect on nutrient concentrations in the individual kelp beds.

Water samples for nutrient analysis were collected by Van Dorn Bottle. In the field, the water samples to be analyzed for nitrogen and phosphate concentrations were filtered through a Whatman GF/F glass fiber filter and frozen. Unfiltered samples for ammonia determination were frozen following recommendations of Solorzano (1969). In the laboratory, the samples were thawed and nutrient concentrations determined by spectrofluorometric techniques described by Strickland and Parsons (1968).

TISSUE ANALYSIS

Monthly analysis of the nitrogen content of kelp fronds from the San Mateo, San Onofre, and Barn kelp beds were conducted. Kelp fronds from an individual stipe were collected by biologist-divers in each of the three kelp beds. Every tenth frond on an individual stipe beginning with a sporophyll frond (reproductive

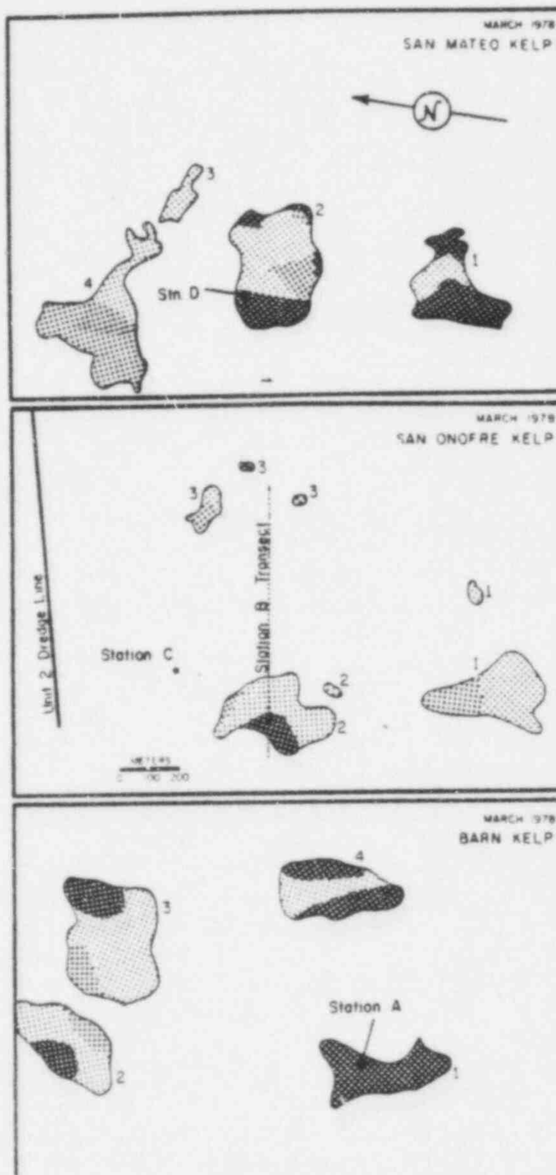


Figure 11-3. Location of stations and transect occupied for assessment of general health of kelp plants within San Mateo, San Onofre, and Barn kelp beds from January 1978 through December 1978.

portion of kelp plant located near the base of the plant) was detached and returned to the laboratory where all encrusting organisms were removed and the fronds dried. The nitrogen content (NO_3 + NO_2) of each frond was then determined by Kjeldahl nitrogen analysis described in Standard Methods (Rand et al., 1976).

RESULTS

AREAL EXTENT OF KELP CANOPIES

The estimated areal extent of the existing kelp beds was determined using an electronic positioning device, which permits accurate mapping of the borders of the existing canopy, but provides no information on the density of the canopy, Aerial infrared photographs were taken monthly (weather permitting) to provide canopy density data and document changes in the kelp canopy size and configuration which may have occured between the quarterly mapping surveys.

San Mateo Kelp Bed

Seven distinct kelp canopies were recorded in the San Mateo bed during 1978 of which three (Area 1, 2, and 4) were present during each of the four quarterly surveys (Table 11-1; Figure 11-4). Area 1, the downcoast section of the canopy, decreased in areal extent during each succeeding survey. The center section of the kelp canopy (Area 2) encompassed the largest area during three of the four surveys with values ranging from 59,236 m^2, in September, to 233,876 m^2 in December. Area 4, the area of the canopy upcoast section, fluctuated between each survey (Figure 11-4).

The overall area of the San Mateo kelp canopy, fluctuated between each survey. The maximum area was recorded in June and the minimum expanse in September.

Bottom substrate mapping conducted concurrently with the canopy mapping indicated that the kelp as a whole was associated with substrate compored of 30 to 60% cobble but that the major section of San Mateo kelp (Area 2) was always associated with 60 to 100% cobble substrate (Figure 11-4), The surveys also indicated that the substrate composition in, and around, the San Mateo kelp bed constantly changes. Major increases were noted between surveys in the are of the 60 to 100% cobble substrate which are the most suitable substrate for the

Table 11-1. Estimated kelp canopy extent (m2) at the San Mateo, San Onofre, and Barn kelp beds.

Survey Date	Canopy Areas 1	2	3	4	5	6	7	Total Area
				San Mateo				
Mar 1978	54,039	94,803	10,547	81,090	1	1	1	240,389
Jun 1978	26,487	195,116	-	59,997	19,161	-	-	300,761
Sep 1978	24,421	59,236	-[a]	123,294	-	9,956	-	216,907
Dec 1978	3,694	233,876	-	40,952	-	-[b]	1,816	281,779
				San Onofre				
Mar 1978	61,741	62,305	11,397	-	-	-	-	135,443
Jun 1978	59,550	101,315	21,415	-	-	-	-	182,280
Sep 1978	318,848	25,172[c]	-	48,779	-	-	-	372,799
Dec 1978	133,814	130,557	102,192	157,483	102,192	-	-	567,565
				Barn				
Mar 1978	50,971	58,673	105,072	59,361	-	-	-	274,072
Jun 1978	52,586	35,191	15,191	-	-	-	-	102,968
Sep 1978	104,321	-	2,630	-	-	-	-	106,951
Dec 1978	32,123	-	-	-	101,941	-	-	134,064

[a] Areas 3 and 4 merged during this survey.

[b] This area not mapped during the survey.

[c] Portion of Area 2 merged with Area 1 during this survey.

settlement of Macrocystis spores and the development of juvenile kelp plants. The areal extent of Area 2 of the kelp canopy corresponded to similar changes in the 60 to 100% cobble area (Figure 11-4).

San Onofre Kelp Bed

The area of the San Onore kelp bed increased between each survey with values ranging from 135,443 m^2 in March to 567,565 m^2 in December (Table 11-1). In March, the San Onofre kelp bed was composed primarily of two offshore canopies (Areas 1 and 2) with minor canopy fragments occurring inshore (Area 3). By June, the three areas had expanded by approximately 25% (11-5). Between the June and September surveys, Area 1 and part of Area 2 merged to form a 1,250 m long offshore canopy, while Area 3 disappeared. A new area of kelp canopy of approximately 48,779 m^2 was observed inshore and downcoast of the construction site during the September survey (Figure 11-5).

Between September and December the kelp canopy increased approximately 65%. Areas 1 and 2 divided again into two separate canopies. Area 3 reappeared and was approximately 5 times larger than it was in June. Kelp in Area 4 was also greatly expanded and was approximately 3.5 times larger that it was in September. By December, Areas 1, 2, 3, and 4 had expanded to encompass the outer margin of area previously prior to the period of deterioration in 1976. Within the area, a new section of canopy (Area 5) was observed for the first time in December (Figure 11-5).

Substrate data indicated the canopy was located in areas composed primarily of sand, or 10 to 60% cobble. Between the March and June surveys, a major portion of the sand cover in the area of the San Onofre kelp bed disappeared leaving a substrate of exposed cobble and boulders. Most of the kelp plants providing the canopy during the June study were located in substrate types of 30% to 100% cobble and boulders (Figure 11-5).

Sand inundated the San Onofre kelp bed again in September although the sand cover was not as extensive as that recorded in March. Kelp that formed the offshore canopy (Areas 1 and 2) was located on a substrate composed primarily of sand or 60 to 100% cobble and boulders while Area 4 was located in an area whose substrate was subdivided into sand, 10 to 30% cobble, and 30 to 60% cobble (Figure 11-5).

The sand cover diminished slightly between September and December, leaving the majority of the substrate in the study area composed of 60 to 100% cobble and boulders. With the exception of Area 2 of the canopy, kelp plants providing the canopy were located in an area of 60 to 100% cobble and boulders. Kelp plants under the Area 2 canopy were located on a substrate composed of both 30 to 60% and 60 to 100% cobble and boulders (Figure 11-5).

Barn Kelp Bed

The areal extent of the Barn kelp decreased from March (274,072 m^2) to June (102,968 m^2) and then increased slightly during the remaining two surveys (Table 11-1). The canopy configuration was similar to that mapped in 1976 (LCMR, 1976b) with four major areas present (Figure 11-6). The June survey revealed that the inshore, downcoast section of the canopy (Area 4) had disappeared and that the remaining three areas of the canopy, especially Areas 2 and 3, had undergone major deterioration.

By the September survey, Area 1 had undergone a substantial recovery with its area exceeding 104,000 m^2, a value larger than the entire canopy in June. Though Area 1 increased, Area 2 of the kelp canopy disappeared, and Area 3 was reduced to approximately 2,600 m^2 (Figure 11-6).

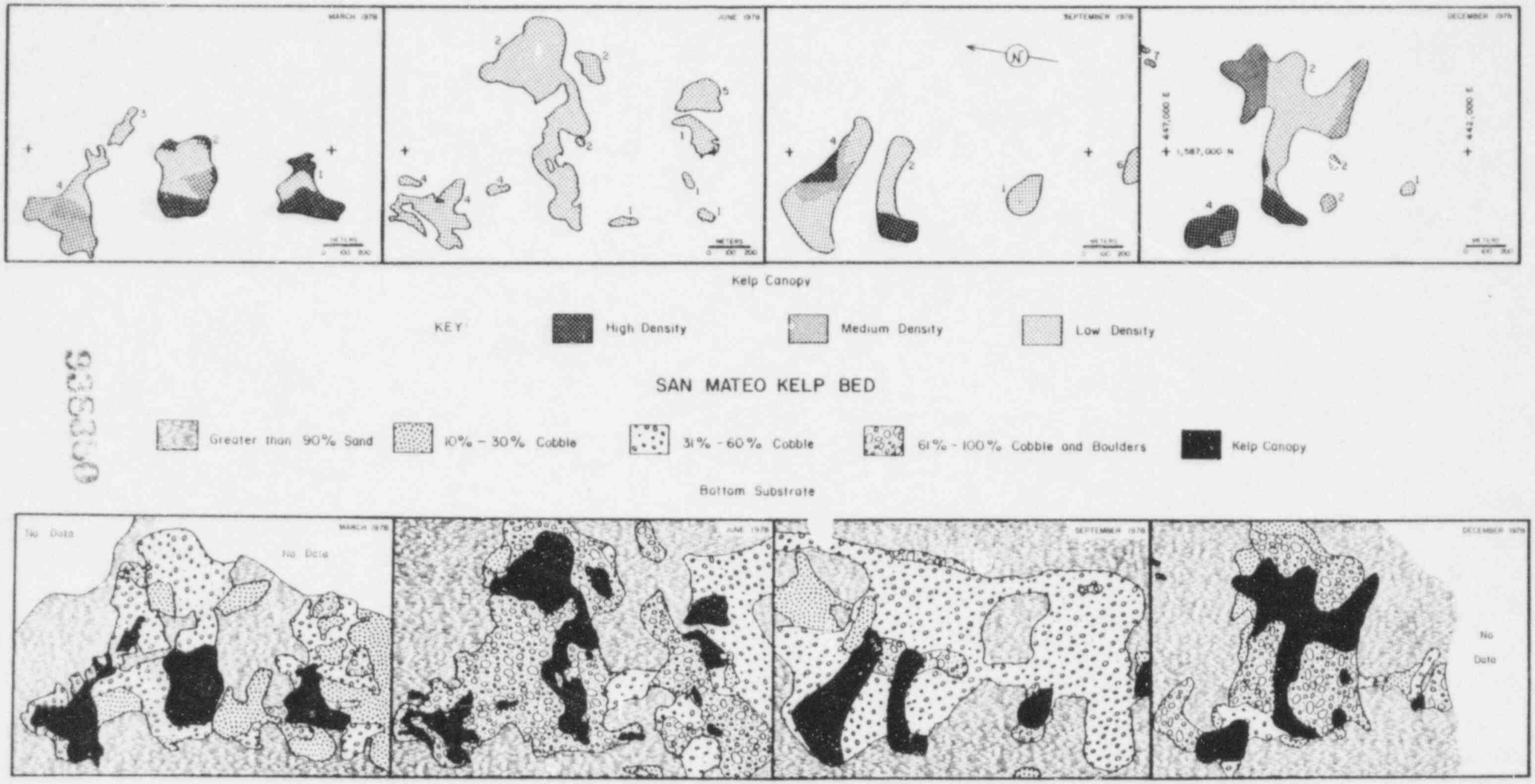


Figure 11-4. Kelp canopy configuration, relative canopy density, and substrate composition of the San Mateo kelp bed from March 1978 through December 1978 (data supplied by Ecosystem Management Associates, Inc.).

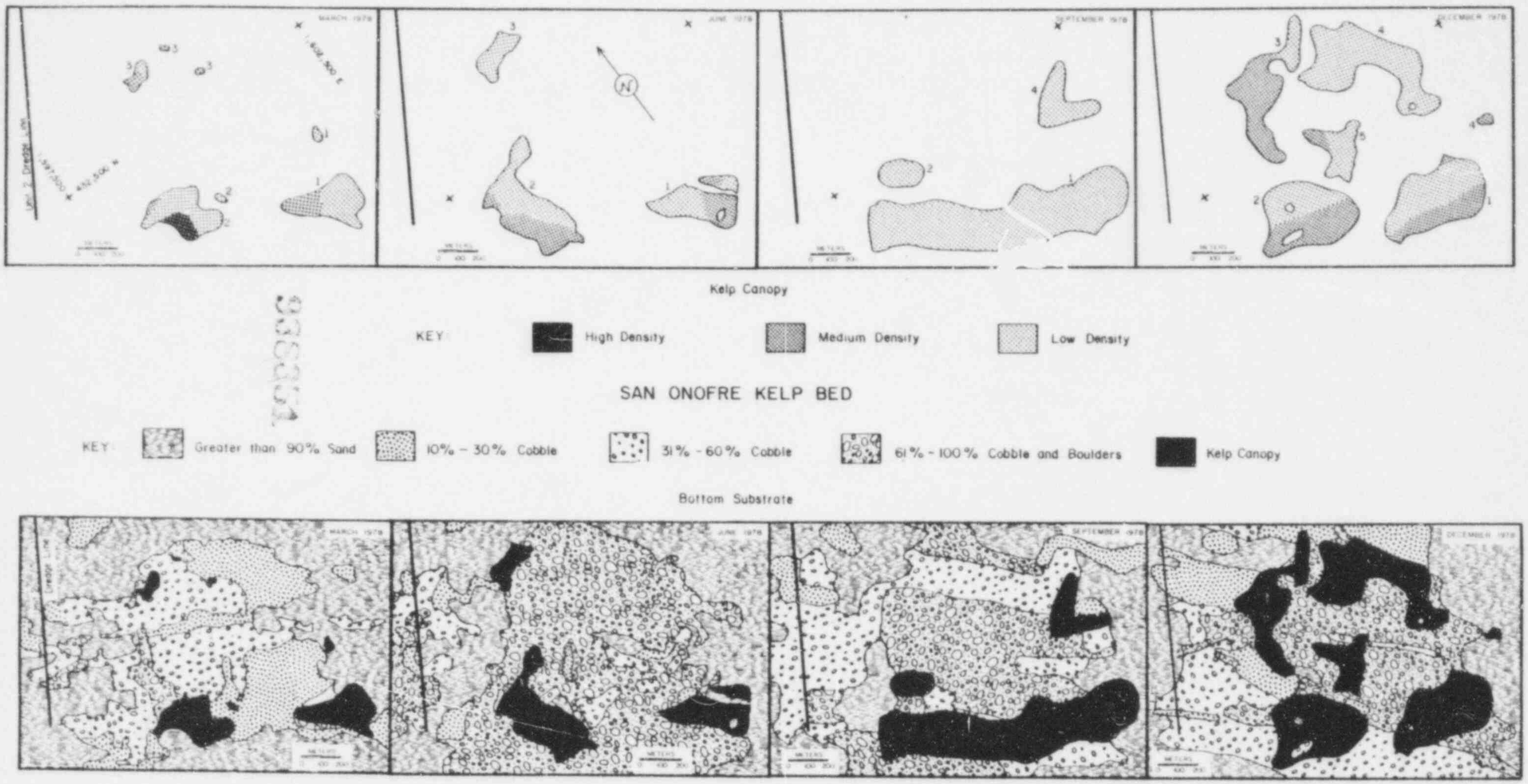


Figure 11-5. Kelp canopy configuration, relative canopy density, and substrate composition of the San Onofre kelp bed from March 1978 through December 1978 (data supplied by Ecosystem Management Associates, Inc.).

Over 75% of the kelp canopy recorded in December was in areas where canopy had not previously occurred in 1978 although these areas had supported kelp prior to 1978. Only Area 1 continued to support a canopy through the preceeding three surveys, however this canopy was considerably reduced in area (Figure 11-6).

Substrate data indicated that during March a majority of the kelp plants forming the surface canopy were located on substrate composed of 30 to 60% cobble. However canopy Areas 2 and 3 appeared to extend into a segment of the bottom consisting of more than 90% sand (Figure 11-6). Data from the June survey indicated that encroachment of sand into the study area had resulted in a considerable reduction of suitable substrate of more than 30% cobble. During June, the remaining kelp canopy was located in areas of a mixture of substrate types. These areas were characterized by of 10 to 30% cobble (generally exceeding 50% of the available substrate) and approximately equal areas of 30 to 60% cobble, and 60 to 100% cobble and boulders (Figure 11-6).

Between the June and September surveys, encroachment of sand continued into the area that previously supported the inshore portion of Barn kelp. Sand covered the cobble substrate that once supported the Area 2 kelp canopy as well as the cobble area offshore of the Area 1 kelp canopy. Conversely, sand receeded under the Area 1 canopy resulting in a substrate composed of a 60 to 100% cobble and boulder (Figure 11-6).

Data from the December survey indicated that between September and December sand cover began to diminish in inshore and upcoast areas that once supported canopies 2, 3, and 4. In addition, the cobble substrate adjacent to the Area 1 canopy was expanding in all directions (Figure 11-6).

GENERAL HEALTH OF KELP PLANTS

The general health of kelp plants in the San Mateo kelp, San Onofre kelp, and Barn kelp beds was assessed during April, September, and December. A single station was occupied during each survey at the three kelp beds. Additional observations were made along a 1,100 m transect through the existing San Onofre bed (Figure 11-3).

April Survey

Prior to the April survey two major storms (see Table 9-10) occurred in southern California. The first storm began on February 10, the second storm on 1 March 1978. Aerial surveys indicated that the February storm had no detectible effect on kelp canopies. However, aerial photographs taken after the March storm indicated major canopy losses.

Kelp plants in the San Mateo kelp bed appeared to be in fair to good condition, especially in the midwater region. Tattered fronds were present in the canopy and sporophyll clusters were often sparse and tattered. Nearly all canopy blades bore light deposits of sediment and some appeared to be deteriorating. Healthy new growth was abundant from the holdfast to approximately midwater.

Kelp at the San Onofre bed station (Figure 11-3) appeared to have been the most severely affected by the storms. Many of the longer fronds were tattered from the surface to depths of 10-12 m. The basal 3 m of all plants, however, were in good condition and new growth was developing.

Overall the Barn kelp bed appeared to be the most severely affected of the three kelp beds. Much of the epibenthic algal turf, typical of the area, had disappeared. Laminaria and Pterygophora, large brown alga, often abundant in the area, were absent. Macrocystis plants were affected as well, but most of the

kelp plants were in fair to good condition. Nearly all canopy blades bore light depostis of sediments and some appeared to be deteriorating.

Evidence of sediment shift was an additional manifestation of the storms. The most obvious change was observed near the offshore end of the San Onofre bed Transect B (Figure 11-3), where a sediment deposit approximately 400 m long and 45 cm deep covered most of the transect previously. The area was composed of large rock. Because of limited visibility, the width of this sediment deposit and its effect on the general area could not be determined.

September Survey

By September, the kelp beds of the San Onofre region were showing signs of recovery. The Macrocystis plants inhabiting the San Mateo kelp appeared to be the healthiest of those observed in September, although senescent fronds were still present in midwater sections. Most adult plants terminated 2 to 3 m below the surface. Juvenile Macrocystis, of all sizes, were abundant throughout the area while traces of sediment were still present in the cobble areas, sediment cover was the lowest of any of the areas examined in September.

At San Onofre stations, juvenile and adult Macrocystis were scattered throughout the area. Holdfasts and midwater sections of the adult plants appeared in good condition. Light concentrations of silt persisted on the rocky substrate. Old holdfasts, encountered along Transect B were associated with heavy concentrations of the sea urchin Strongylocentrotus franciscanus.

Observations at the Barn kelp station indicated juvenile Macrocystis plants, ranging from approximately 15 cm to 3 m, were common. The base and midwater sections of adult plants appeared healthy though senescent fronds were also present and apical sections of adult plants still exhibited the effects of prior deterioration.

Sediment was still present on much of the rocky substrate inhibiting recolonization by invertebrates in some areas of the Barn kelp. Other areas of rocky substrate supported moderate new growth of invertebrates, especially bryozoans and turf algae. Large areas of decayed Macrocystis holdfasts were present in the area.

December Survey

By December, Macrocystis plants in the San Mateo kelp bed exhibited little or no effects of the storm damage. Juvenile macrocystis plants were abundant in the entire area. Sediment cover of the cobble areas increased slightly over that observed in September, though generally the sediment cover was still less than in the San Onofre and Barn kelp beds.

At the inshore edge of Transect B, in the San Onofre kelp bed (Figure 11-3), adult Macrocystis were sparse although in good health. Juvenile plants ranged from approximately 10 to 100/m^2. Approximately 300 m offshore of the origin of Transect B, the substrate was dominated by sea urchins, mainly S. franciscanus. At the offshore terminus of Transect B (Figure 11-3) juvenile plants reached densities of approximately 1 to 5/m^2. Some of the juveniles appeared distressed, while others were in excellent health. All adult plants appeared to be in good condition.

Between the September and December surveys, the Barn kelp bed station again had become partially covered with sand (approximately 50% of rock substrate). The Macrocystis growth consisted mainly of tufts of fronds on extensive old holdfast remains. Adult plants in the area supported sparse sporophyll clusters. Approxi-

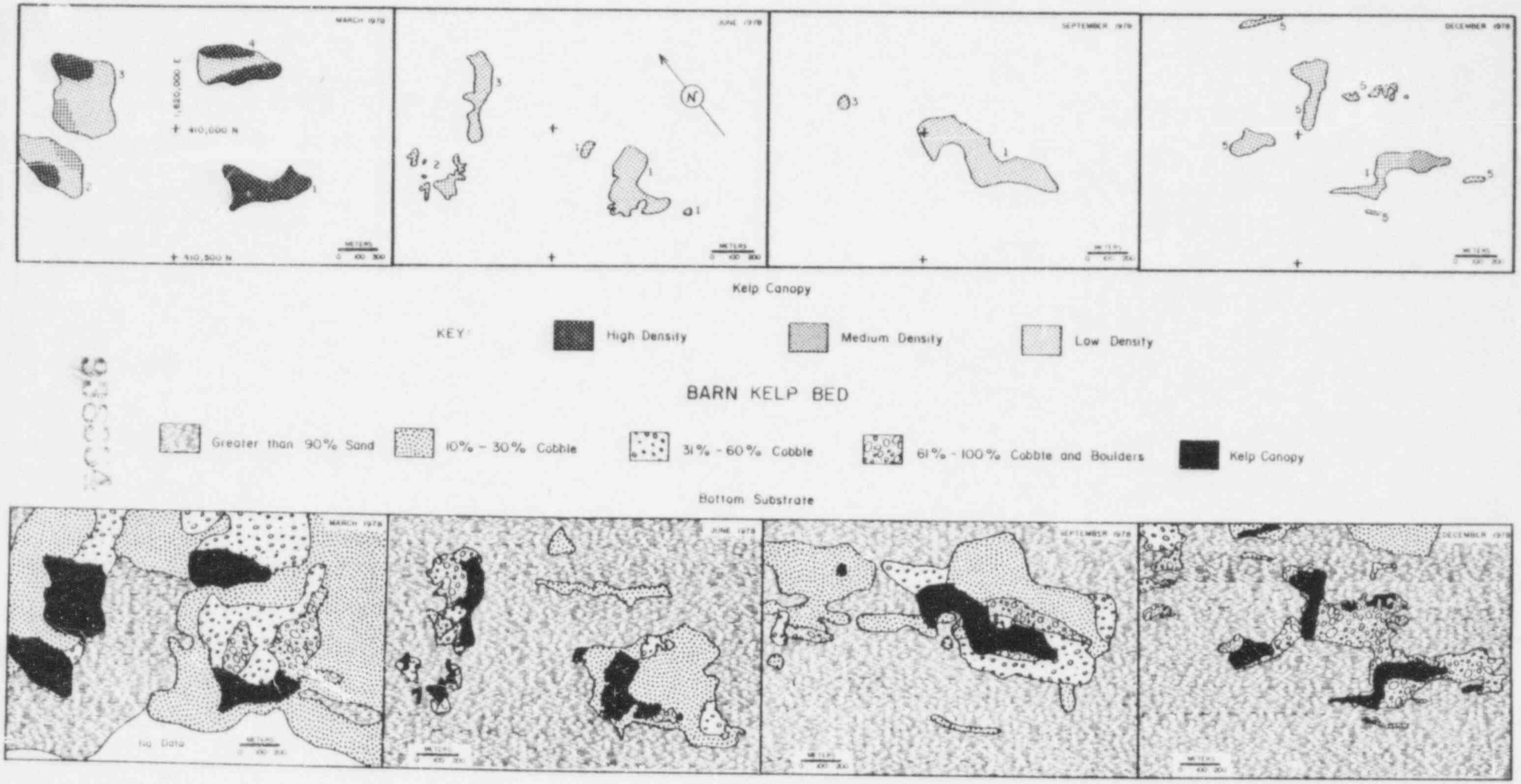


Figure 11-6. Kelp canopy configuration, relative canopy density, and substrate composition of the Barn kelp bed from March 1978 through December 1978 (data supplied by Ecosystem Management Associates, Inc.).

mately 20% of the fronds were senescent while the remaining fronds appeared healthy. Light sedimentation was still present on some of the kelp blades.

WATER COLUMN NUTRIENT ANALYSIS

Surface and bottom water concentrations of nitrogen (NO_2+NO_3), amonia (NH_4) and phosphate (PO_4) were determined monthly at stations inside and outside of the San Mateo, San Onofre, and Barn kelp beds. In addition, a station approximately 4.3 km offshore of the San Onofre kelp bed was occupied monthly. At the offshore station, water samples were collected from the surface and at depths of 15, 30, and 40 m for analysis.

The offshore station was occupied to monitor upwelling offshore of San Onofre. Nutrient concentrations from inside and outside of the individual kelp beds were averaged because of differences between the two areas were generally small or absent. In addition, ammonia concentrations, with few exceptions, were less than 0.10 µg/ℓ; thus, the following discussion of nitrogen concentrations is based on total available nitrogen (NO_2+NO_3+NH_4) and not the two individual forms (NO_2+NO_3; and NH_4). All raw nutrient data are presented in the San Onofre Construction Monitoring Data Report for 1978 (MBC, 1979).

Total Nitrogen Concentrations

Nitrogen concentrations in the San Mateo kelp bed increased slightly in March and then decreased in April. Major increases in nitrogen were recorded in May and June correspondinn to the onset of upwelling in the offshore waters (Figure 11-7). Nitrogen concentrations began to decrease in July and by August concentrations reached levels similar to those recorded prior to upwelling. Only minor fluctuations in nitrogen concentrations were recorded from August through December (Figure 11-7).

Nitrogen concentrations at the San Onofre kelp bed were similar to those in the San Mateo bed from January through May. Concentrations decreased slightly in June, peaked again in July, and then declined sharply in August. A major increase was again recorded in October after which concentrations decreased to low levels for the remainder of the year (Figure 11-7).

Nitrogen levels increased substantially in the Barn kelp bed during February, May, and July with a minor increase occurring in October. With the exception of the major concentrations increase in February, the nitrogen nutrient regime generally followed that observed at the San Onofre kelp bed (Figure 11-7).

High nitrogen concentrations at the offshore station indicated that some upwelling occurred from April through approximately October. However, its effect on the nutrient regimes above a depth of 30 m appears to have varied considerably. Nitrogen concentrations at the 15 m depth reflected upwelling only in June and July. Upwelling had little or no effect on the surface water nitrogen regime at the offshore station (Figure 11-7).

Phosphate Concentrations

Surface water phosphate concentrations of the San Mateo kelp bed fluctuated between 0.24µg-at/ℓ and 0.5 µg-at/ℓ throughout the year with peak concentrations occurring in April, August, and December. Bottom water concentrations increased from February through July and then decreased in November. A major increase in phosphate was again recorded in December (Figure 11-8).

The seasonal distribution of phosphate concentrations at the San Onfre kelp bed followed those of nitrogen with increases occuring in May, July, and October in bottom waters. Surface water concentration varied slightly during the year (Figure 11-8).

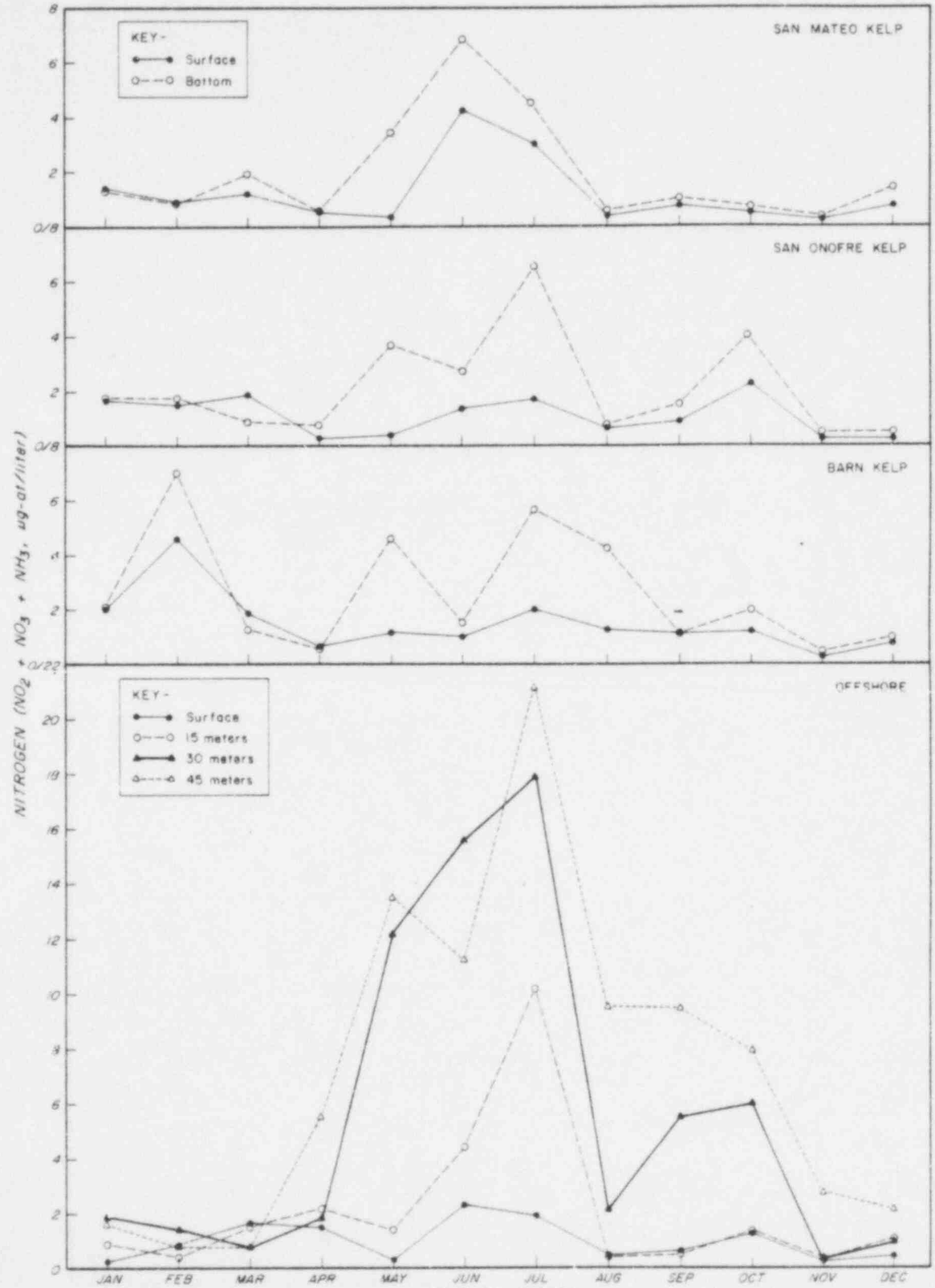


Figure 11-7. Average monthly concentrations of total nitrogen (NO_2 + NO_3 + NH_4) in the surface and bottom waters at the San Mateo, San Onofre, and Barn kelp beds at the surface, 15 m, 30 m, and 40 m depths at the offshore station from January 1978 through December 1978.

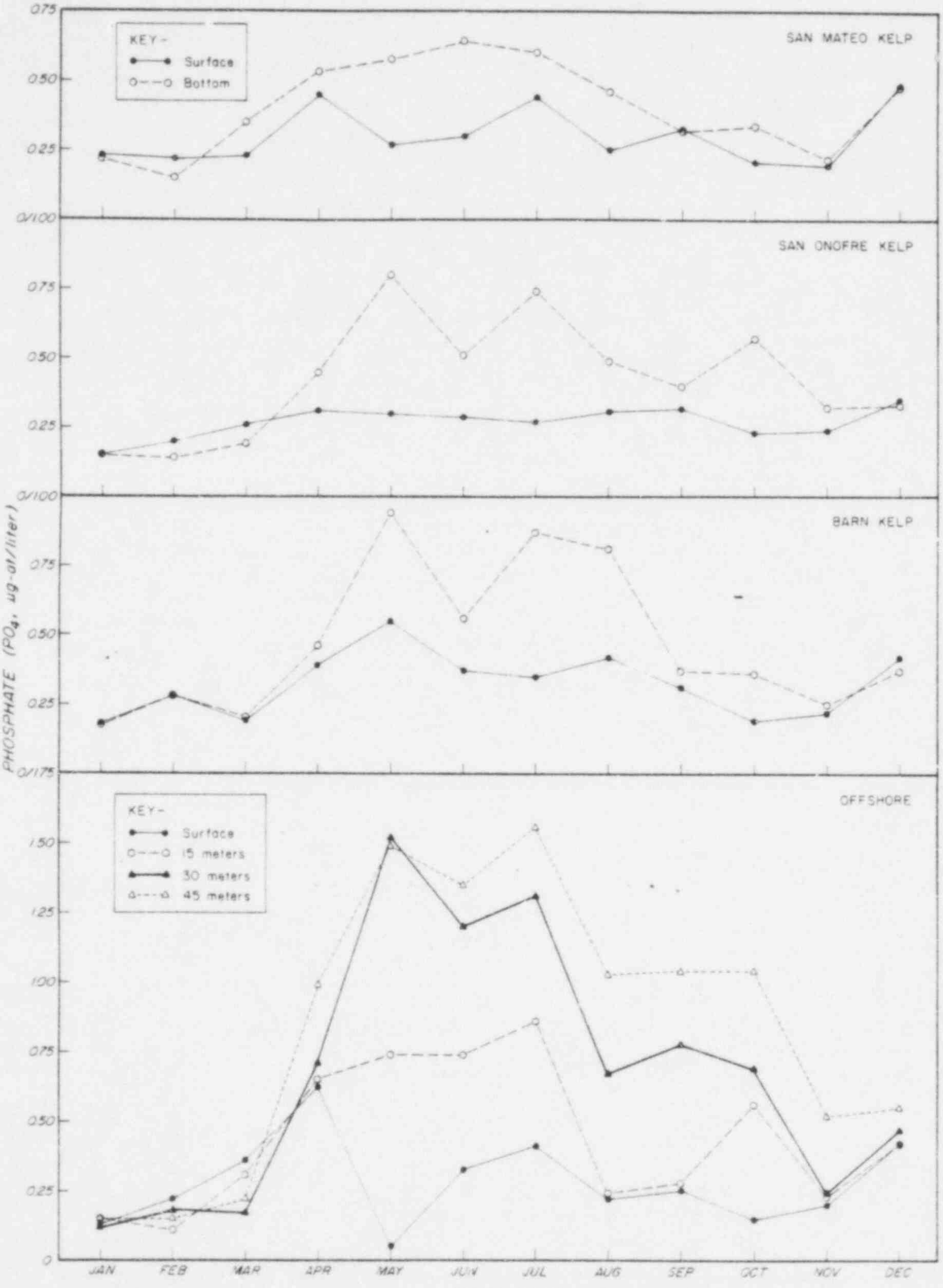


Figure 11-8. Average monthly phosphate concentrations (PO_4) in surface and bottom waters of the San Mateo, San Onofre and Barn kelp beds and at the surface, 15 m, 30 m, and 40 m depths at the offshore station from January 1978 through December 1978

Bottom water phosphate concentrations in the Barn kelp bed increased from March through May, decreased in June, and then peaked again during July and August. Surface concentration peaked in May and then generally decreased through October. A minor increase in surface phosphate concentrations was recorded in December (Figure 11-8).

Phosphate concentrations at the offshore station reflected upwelling from April through October. The effect was most pronounced at depths of 30 and 40 m. At 15 m, elevated phosphate concentrations were present from April through July and in October. Phosphate in the surface waters peaked during April with secondary increases recorded in July and December (Figure 11-8).

NITROGEN CONTENT OF KELP TISSUES

Nitrogen content of kelp blades varies according to availability of inorganic nitrogen compounds (primarily ammonium nitrate) in the surrounding waters. Blade tissue analysis provides an integrated concept of nutrient conditions in the water for several weeks prior to sample collection. Values of 1.0 to 1.2% of the dry weight of kelp tissue as nitrogen probably represent healthy mature tissues that lack nutrient reserves (W. J. North, personal communication). Except during periods of stormwater runoff, vertical nitrate gradients are characteristic of the water column, with concentrations tending to increase with depth. Macrocystis accumulates nitrogen compounds at rates that are directly proportional to concentrations in the surrounding water (except that saturation begins as concentrations rise much above 5 µg-at/ℓ). Consequently, vertical concentration gradients of compounds such as nitrate results in differential accumulation rates in various parts of the plant. Accumulation will be highest in the lower portions of plants when upwelling raises nitrate levels in bottom waters of a kelp bed. Differentials in accumulation yield corresponding differences in N-contents of the tissues. Thus, highest N-contents are usually in kelp tissues closest to the bottom during upwelling peaks.

Kelp tissue nitrogen concentrations (expressed as percent dry weight of kelp tissue) are reported as averages for surface, midwater, and bottom water samples. Surface water samples were kelp leaves occurring in the waters from 0 to 1 m in deep. Midwater samples were kelp tissues occurring in waters ±1 m of the midpoint between the surface and bottom, while bottom samples were those kelp leaves occurring within 1 m of the bottom.

Kelp tissue results reported blow includes data collected from May 1977 through December 1978. The 1977 data were not available at the time of the 1978 report (MBC, 1978) preparation and thus, are presented below.

San Mateo Kelp Bed

Nitrogen concentrations of the kelp tissue were above 1% from May through July 1977. In August, values dropped below 1% in midwater, and by September values were 0.9% or lower at all three depths. Concentrations again increased above 1% in kelp leaves collected from mid and bottom waters in October. From November 1977 through Janyary, nitrogen concentrations at all depths ranged from 0.5 to 0.9%. Values increased above 1% In February and except at the surface in April, remained above this level through May. From June through December 1978, surface and midwater nitrogen concentrations of the kelp tissue fluctuated widely without an apparent pattern while bottom water concentrations remained above the 1% level (Figure 11-9).

San Onofre Kelp Bed

The average percentage of kelp tissue as nitrogen per dry weight remained above 1% from May through October 1977 except for a surface tissue value in May

(0.9%) and a midwater value in Octover (0.7%). From November 1977 through December 1978, nitrogen levels generaly fluctuated between 0.6% and 1.5% at the surface and midwater depths. Only during May did the kelp tissue at these depths appear to have any substantial nitrogen reserve. Nitrogen levels in the bottom water tissue also fluctuated widely, especially from July through December 1978. Although major changes in bottom kelp tissue nitrogen levels were noted, values less than the 1% level were only present in November 1977 through January 1978, August and October (Figure 11-9).

Barn Kelp Bed

Tissue nitrogen levels at surface and midwater depths exceeded 1% from May through Octover 1977 except at the surface during September. In November and December 1977 values ranged from 0.69 to 0.89%. From January through March 1978 nitrogen levels approached or exceeded 1%. Tissue nitrogen levels for the remainder of 1978 exceeded 1% only twice in the surface canopy and three times at mid depth. Nitrogen concentrations in kelp from bottom waters generally followed the trend observed in the surface and midwaters from May 1977 through February 1978. From February through December 1978, concentrations decreased below 1% only during August (Figure 11-9).

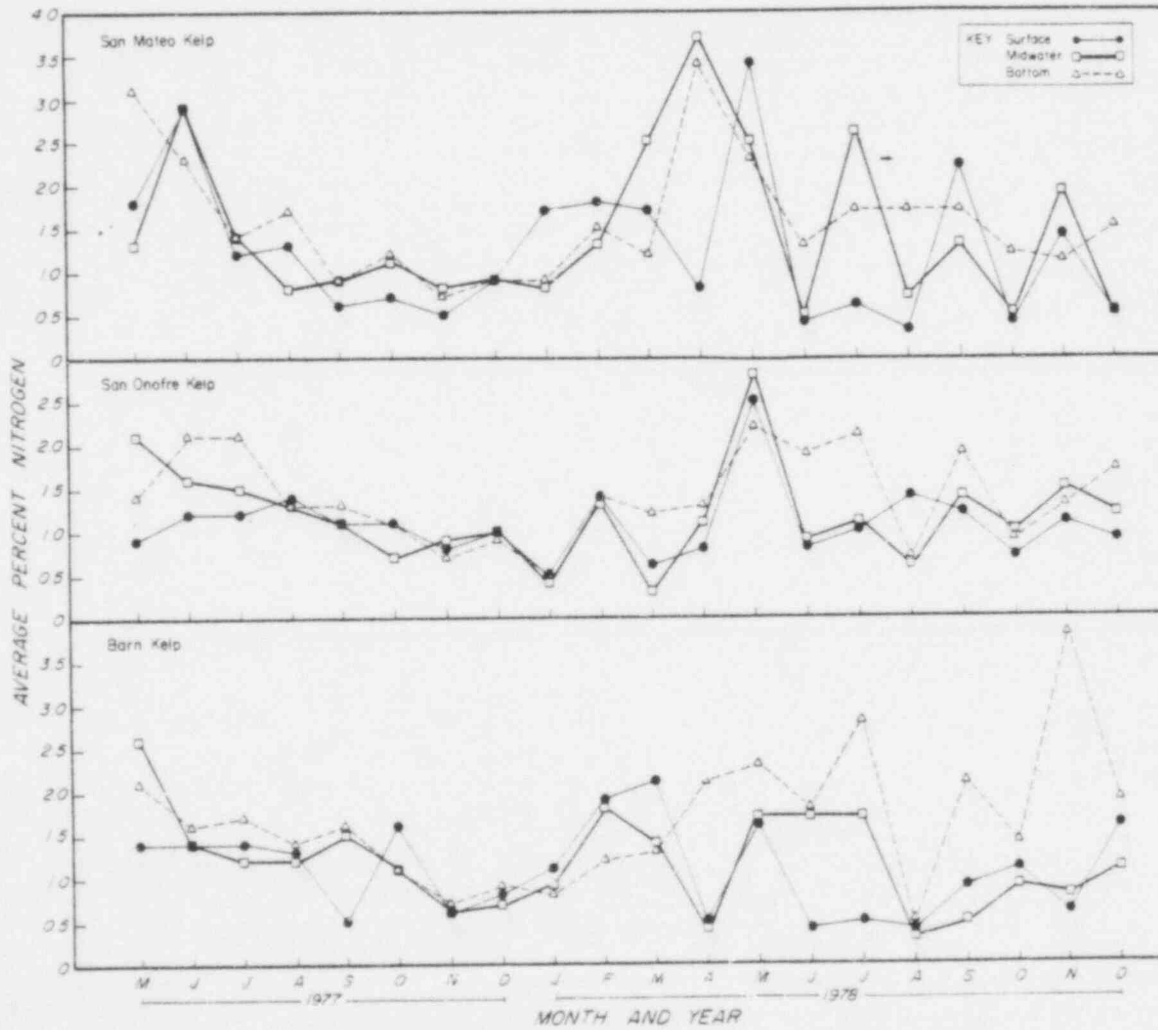


Figure 11-9. Average nitrogen concentrations expressed as a percentage of dry weight of the surface, midwater, and bottom water kelp leaves occuring in the San Mateo, San Onofre, and Barn kelp beds from May 1977 through December 1978.

DISCUSSION

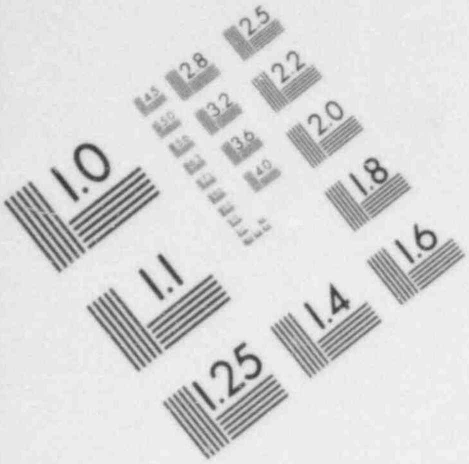
The development, maintenance, and growth of kelp beds may be severely hindered by several factors including grazing by herbivores, storms, reduction of bottom irradiance, loss of suitable substrate, and lack of nutrients (especially nitrogen). The present study was designed to monitor the San Onofre kelp bed during the dredging phase of SONGS Units 2 and 3 construction in order to document any change in area or configuration of the kelp bed that may be attributed to construction related sedimentation or turbidity. In addition, the San Mateo and Barn kelp beds were monitored to provide control or baseline information on kelp beds beyond the influence of SONGS construction activities.

To date, no evidence suggests that either construction related turbidity or sedimentation has had a detrimental effect on the development, maintenance, or growth of the San Onofre kelp bed, although dredge related effects may have been masked by apparently detrimental natural events.These included a suspected reduction of upwelling in 1976, which led to the deterioration of kelp beds of the San Onofre region in late 1976 and early 1977 (MBC, 1978), and the major storms of February and March 1978.

A major period of stormwater runoff was associated with these storms. After the runoff had subsided kelp leaves, especially in the San Mateo and Barn beds, were covered by fine sediments. Furthermore, the leaves were in various stages of deterioration. The accumulation of fine sediments on kelp leaves and subsequent tissue deterioration was also noted after the major storms of 1969 (W. J. North, personal communication) suggesting a relationship between terrestrial runoff and canopy deterioration. Deterioration may be related to exposure of kelp tissue to high levels of heavy metals or other toxicants bound to the fine sediment. According to W. J. North (personal communication) the tissue deterioration observed in the field resembled manifestations he noted in the laboratory following exposures of juvenile *Macrocystis* to growth-inhibiting concentrations of toxic metals such as zinc and copper.

No evidence suggested that dredge related sedimentation affected kelp plants of the San Onofre kelp bed. Changes in the sediment cover of the bottom in, and adjacent to, the San Onofre kelp bed, as well as the San Mateo and Ba[illegible] kelp beds appeared to be a naturally occurring event. Quarterly substrate mapping surveys at the three kelp beds indicated major changes in sand cover occurred between survey periods, especially at the San Onofre and Barn kelp beds. These were related to oceanographic conditions in the area and not to dredging operations. Sediment movement may have had a detrimental effect on the beds, especially at the Barn kelp bed, where the canopy showed virtually no sign of recovery from the deterioration that occurred between December 1977 and June 1978. Burial of suitable substrate by sediment and the scouring associated with sediment movement both are detrimental to the success of *Macrocystis* spore settlement and spore and juvenile survival (North 1970; Devinny and Volse, 1978). Heavy sedimentation noted during the April survey together with periodic burial and removal of sediment at the Barn kelp bed may in part explain the apparent inability of the Barn kelp canopy to recover from its decline in 1978.

Dredging activities off SONGS were in progress during the last 18 months of study. During this time, turbidity plumes generated from dredging operations and natural occurring events inundated at least part of the San Onofre kelp bed (Brown and Caldwell, 1979). Decreased light levels in the water column associated with increased water turbidity were reported as limiting the growth of juvenile *Macrocystis* plants (Clendenning, 1964; Rosenthal et al., 1974). Although turbidity plumes have encroached into the San Onofre kelp bed, no evidence indicates that the plumes adversely affected the growth of the kelp bed. Mapping investigations indicated that the area of the San Onofre kelp bed generally



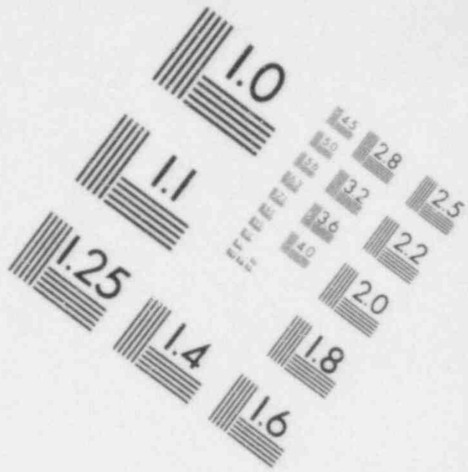
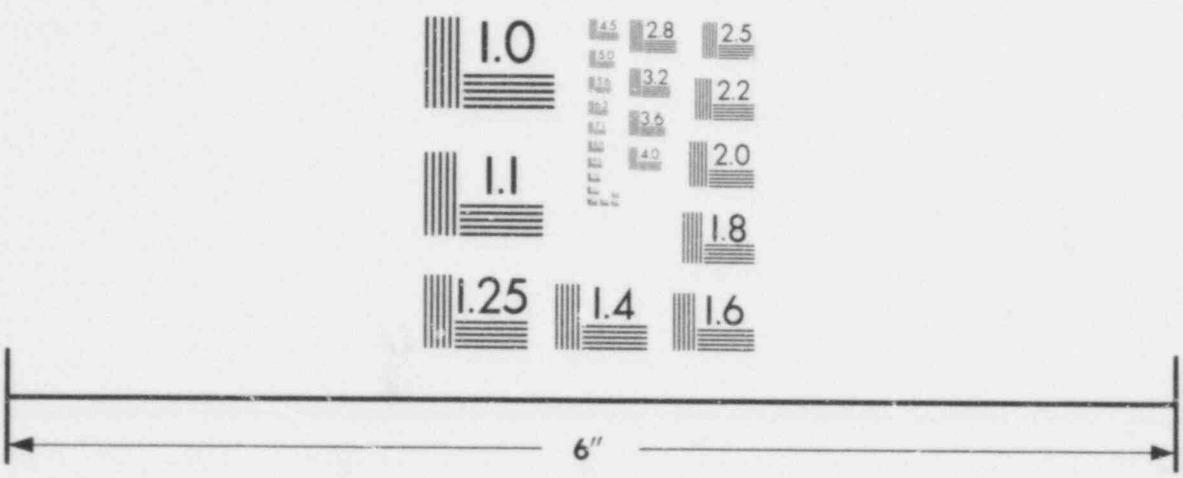
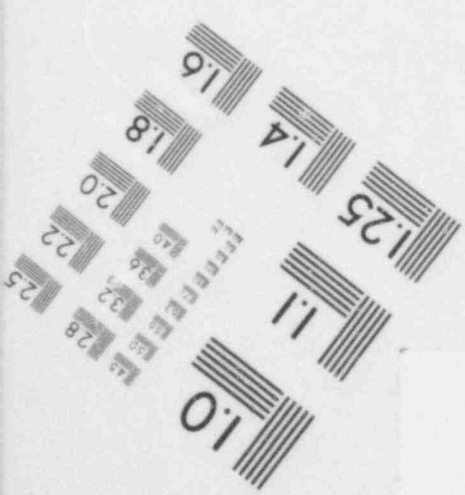
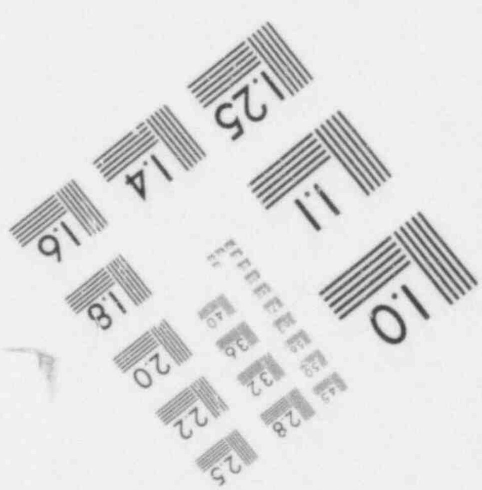


IMAGE EVALUATION TEST TARGET (MT-3)







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increased since dredging activities were initiated. Thus it appears that construction induced turbidity had no detectible effect on the maintenance and growth of the San Onofre kelp bed.

SUMMARY

Studies of the kelp beds in the San Onofre region were conducted from January 1978 through December 1978. The investigations included: 1) mapping the areal extent of the kelp canopy and associated substrate of the San Mateo, San Onofre, and Barn kelp beds; 2) determination of the general health of the kelp plants within the three kelp beds; 3) nutrient analysis of the waters adjacent to the three kelp beds; and 4) determination of nitrogen concentrations of kelp leaves from the three kelp beds.

1. Since dredging operations were initiated June 1977 off SONGS, available data suggest that dredge related turbidity or sedimentation has had no detectable effect on maintenance or growth of the San Onofre kelp bed. Data collected in the general area suggest that changes in the area and configuration of the San Onofre kelp bed, as well as the San Mateo and Barn kelp beds, was a response to natural environmental conditions (e.g. storm damage, terrestrial runoff, available nutrients).

2. The major storms that passed through the study area during February and March 1978, and possibly toxicants in associated terrestrial runoff, appear to have had a detrimental affect on the San Mateo and Barn kelp beds. In comparison, no short term effect was observed at the San Onofre kelp bed.

3. Since the initiation of the present monitoring program in December 1976, the area of the San Onofre kelp bed has generally increased, while areas of the San Mateo and Barn kelp bed canopies experienced major declines. The data suggest that environmental factors effecting the growth of kelp plants, (e.g. nutrient regimes, storm related damage, terrestrial runoff and sediment movement) were not equal at the three kelp beds during the course of the investigation.

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Appendix A. Temperature

[redacted]

Appendix A-1. Mean and range of surface, mid-depth (4 m), and bottom temperature for the SONGS 1 operational and SONGS 2 and 3 preoperational study areas by survey (°C).

	Depth	Item	January	March	May	July	September	November	Year
Operational Stations	Surface	Min/Sta[a]	15.5/B6S	16.2/A1N	16.0/DS2	19.2/D0	20.3/E4N	17.4/D6N	15.5/B6S
		Max/Sta	20.0/X0	23.1/X0	20.1/X0	24.5/X0	23.9/X0	19.0/B0	24.5/X0
		Mean	16.4	16.9	16.8	19.9	20.9	17.9	18.1
		Std Dev	0.93	1.07	0.87	0.78	0.72	0.47	2.03
	Mid-Depth	Min/Sta	15.5/B6S	15.9/B2N	16.0/D2S	18.8/D0	20.3/D0	17.2/C14N	15.5/B6S
		Max/Sta	17.0/C0	22.3/X0	18.9/X0	21.9/X0	21.5/X0	17.8/B1N	22.3/X0
		Mean	16.1	16.6	16.7	19.4	20.6	17.5	17.8
		Std Dev	0.40	0.98	0.66	0.50	0.30	0.15	1.39
	Bottom	Min/Sta	15.6/A4S	15.7/D0	12.9/Barn Kelp	13.3/E2N	19.4/E2N	16.9/C14N	12.9/Barn Kelp
		Max/Sta	17.9/A0	17.3/A0	17.8/A1N	20.4/A2N	21.1/A0	18.7/A1N	21.1/A0
		Mean	16.0	16.0	16.1	16.6	20.2	17.4	17.0
		Std Dev	0.33	0.26	0.86	1.84	0.34	0.29	2.12
Preoperational[b] Stations	Surface	Min/Sta	-	-	15.9/F6N	19.0/M8N	20.3/H2N	17.4/J8N	15.9/F6N
		Max/Sta	-	-	16.6/F24S	20.2/F14S	20.7/F2S	17.8/F6S	20.7/F2S
		Mean	-	-	16.2	19.7	20.5	17.5	18.5
		Std Dev	-	-	0.17	0.28	0.12	0.13	0.37
	Mid-Depth	Min/Sta	-	-	16.0/J4N	18.8/M8N	20.3/H0	17.3/J8N	16.0/J4N
		Max/Sta	-	-	16.6/F24S	20.0/F26S	20.6/M2N	17.6/F2S	20.6/M2N
		Mean	-	-	16.2	19.4	20.5	17.5	18.4
		Std Dev	-	-	0.15	0.27	0.09	0.08	0.33
	Bottom	Min/Sta	-	-	10.9/M8N	10.8/M8N	14.0/M8N	16.2/M8S	10.8/M8N
		Max/Sta	-	-	15.5/F14S	15.0/F14S	19.7/F26S	17.5/F6S	19.7/F26S
		Mean	-	-	13.3	12.5	18.0	17.0	15.2
		Std Dev	-	-	1.16	1.25	1.66	0.43	2.42

[a] Minimum or maximum temperature and the station at which they occurred; station presented is the station closest to the discharge which had the minimum or maximum for the survey.

[b] SONGS 2 and 3 preoperational surveys began in May 1978.

833004

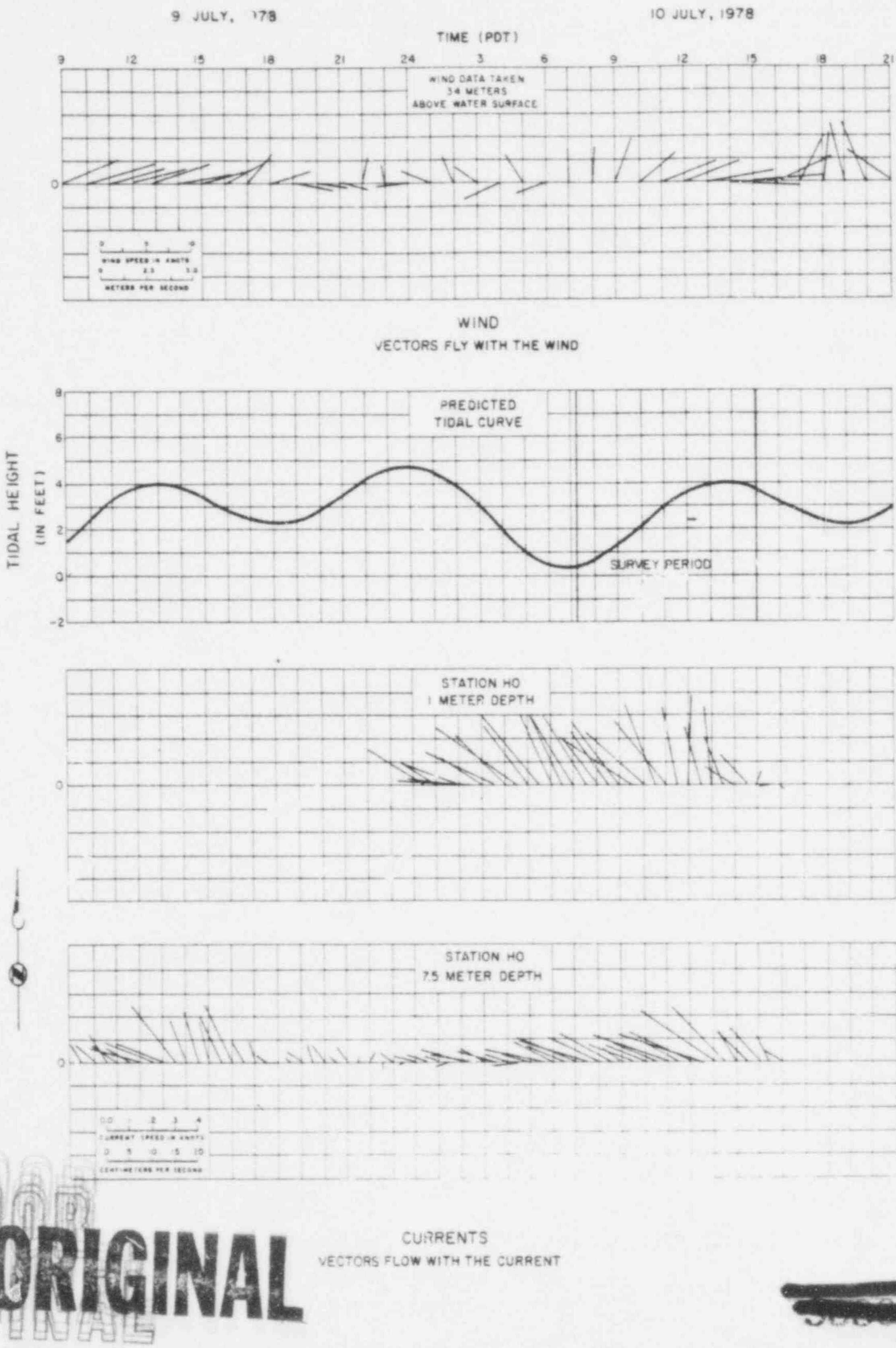
POOR ORIGINAL [redacted]

Appendix A-2. Yearly mean and ranges of surface, mid-depth (4 m), and bottom temperatures at each station (°C).

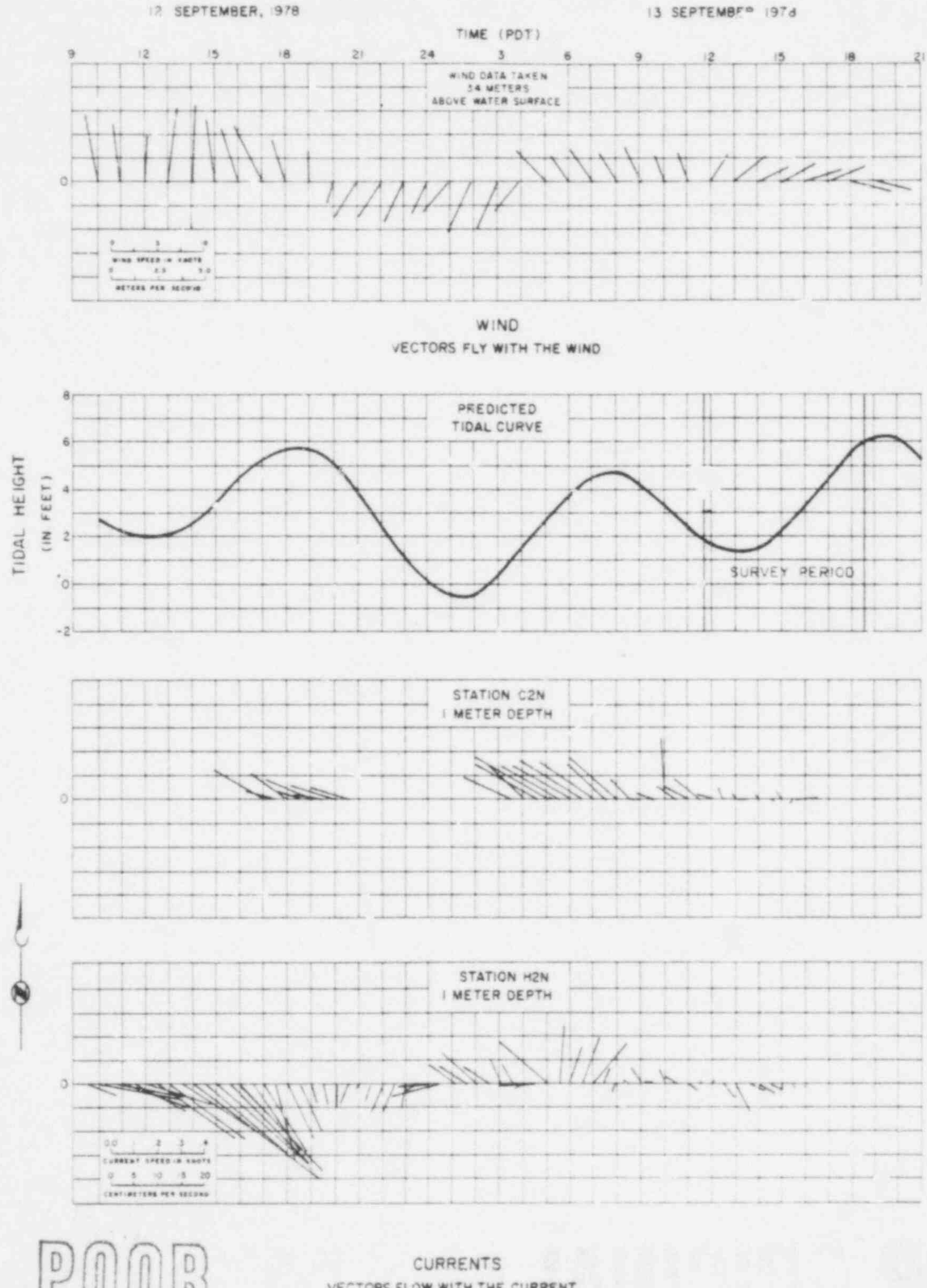
VERY POOR ORIGINAL

333005

Appendix 4-3. Predicted tidal curve and wind and current vectors measured before and during the 10 July survey.

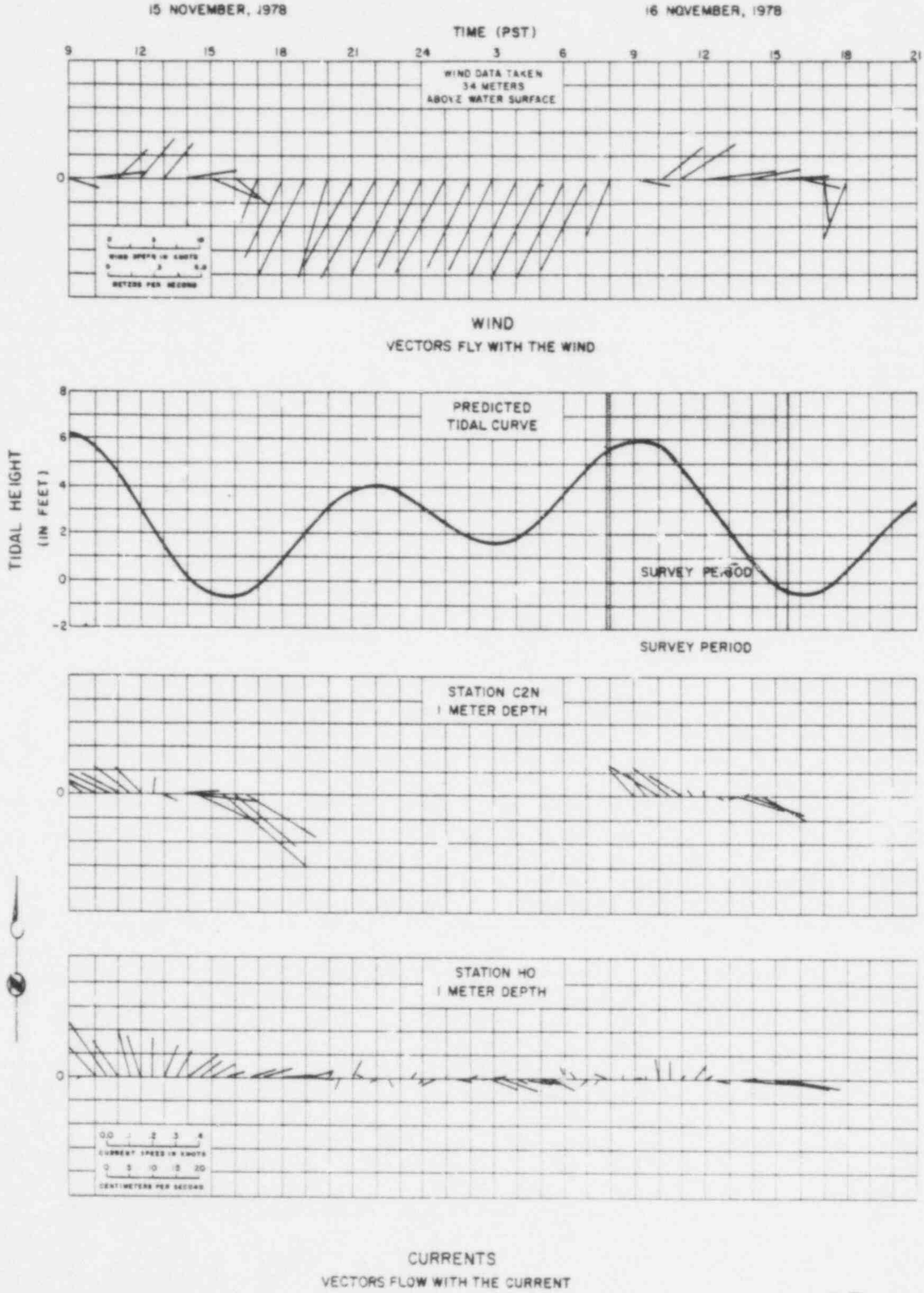


Appendix A-4. Predicted tidal curve and wind and current vectors measured before and during the 13 September 1978 survey.



933007

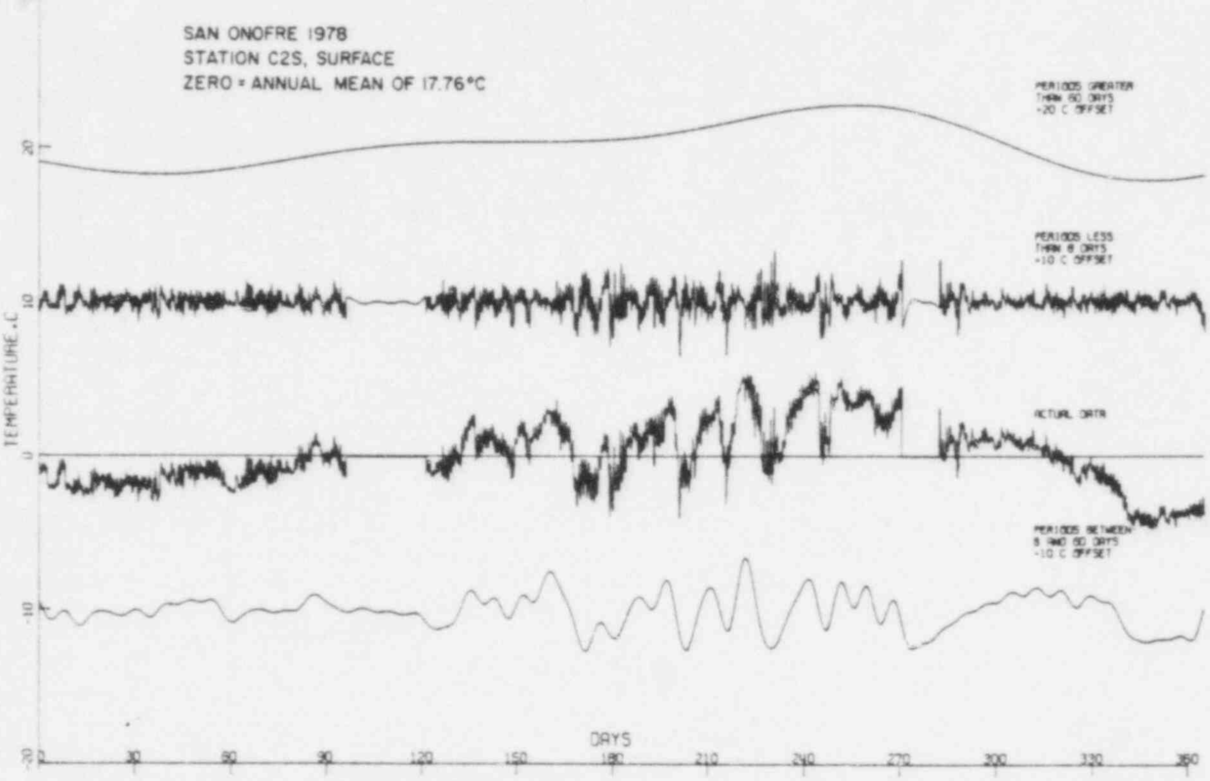
Appendix A-5. Predicted tidal curve and wind and current vectors measured before and during the 16 November 1978 survey.



POOR ORIGINAL

933008

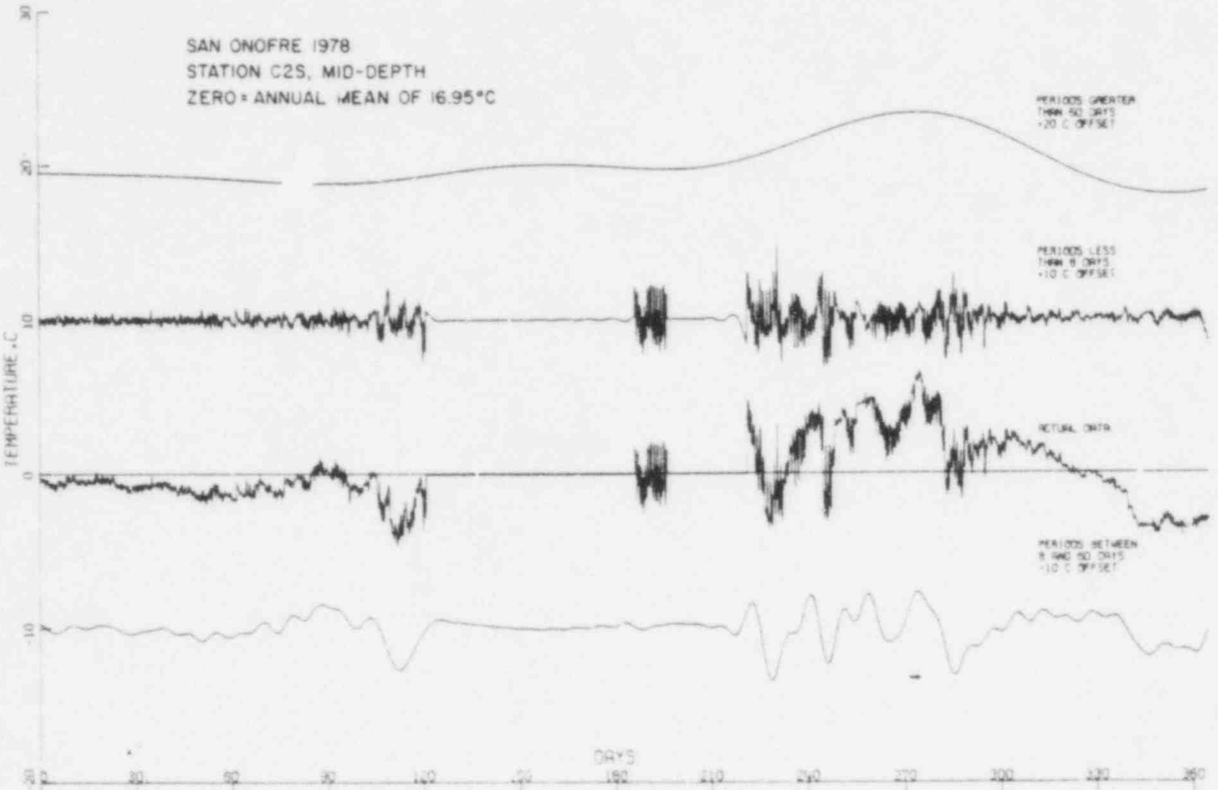
Appendix A-6. Frequency components of surface temperature variations at station C2S during 1978.



POOR ORIGINAL

933069

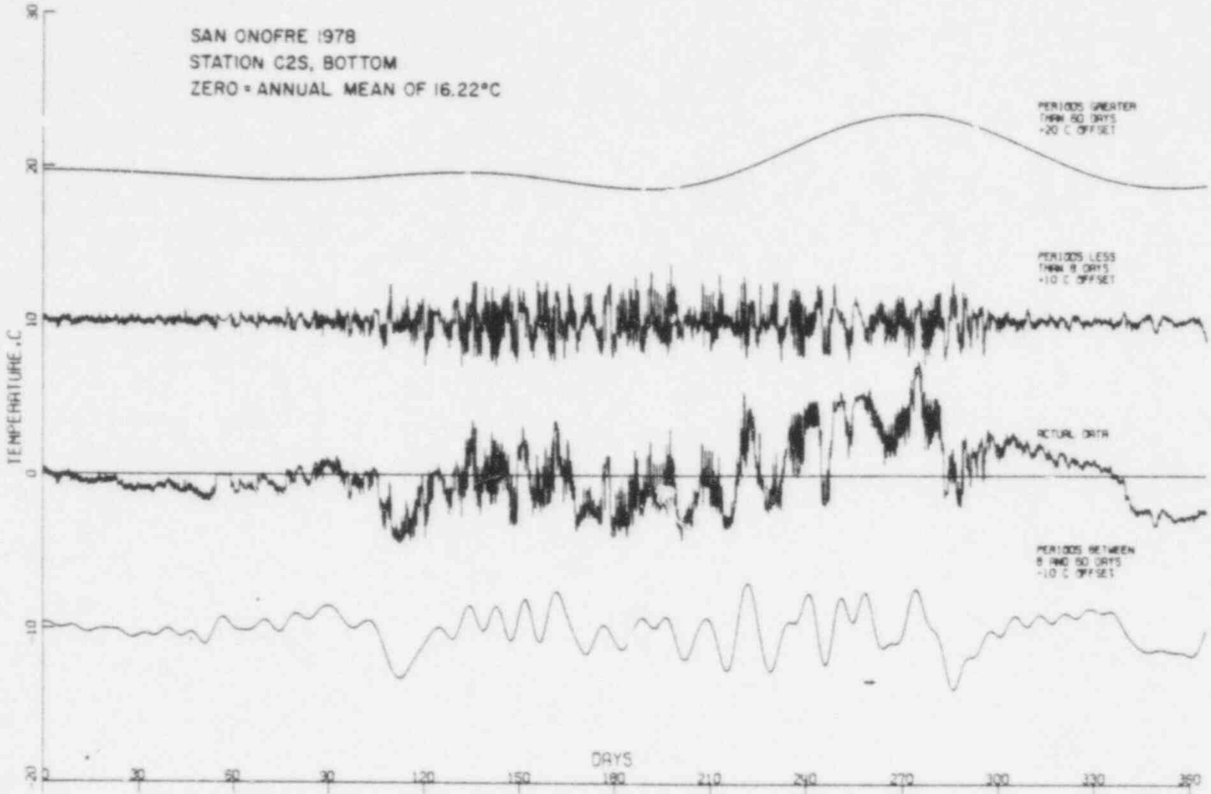
Appendix A-7. Frequency components of mid-depth temperature variations at station C2S during 1978.



POOR ORIGINAL

933010

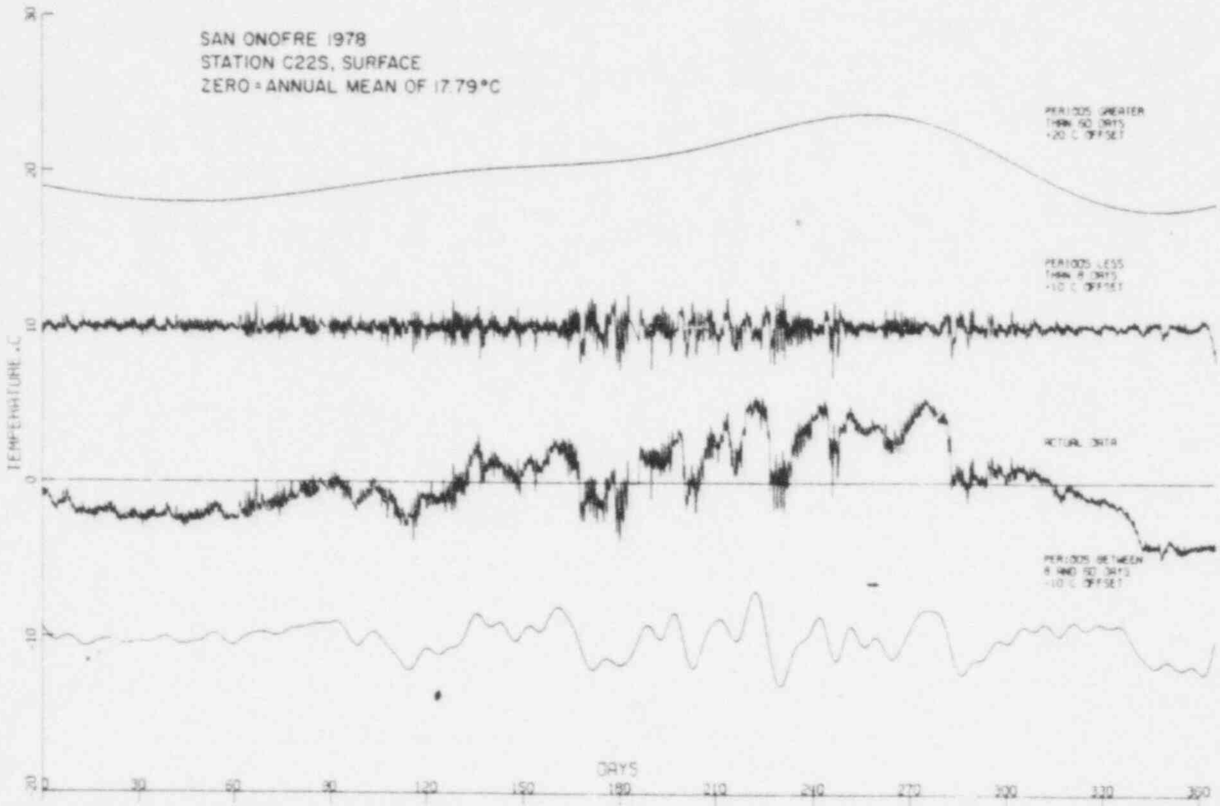
Appendix A-8. Frequency components of bottom temperature variations at station C2S during 1978.



POOR ORIGINAL

333011

Appendix A-9. Frequency components of surface temperature variations at station C22S during 1978.

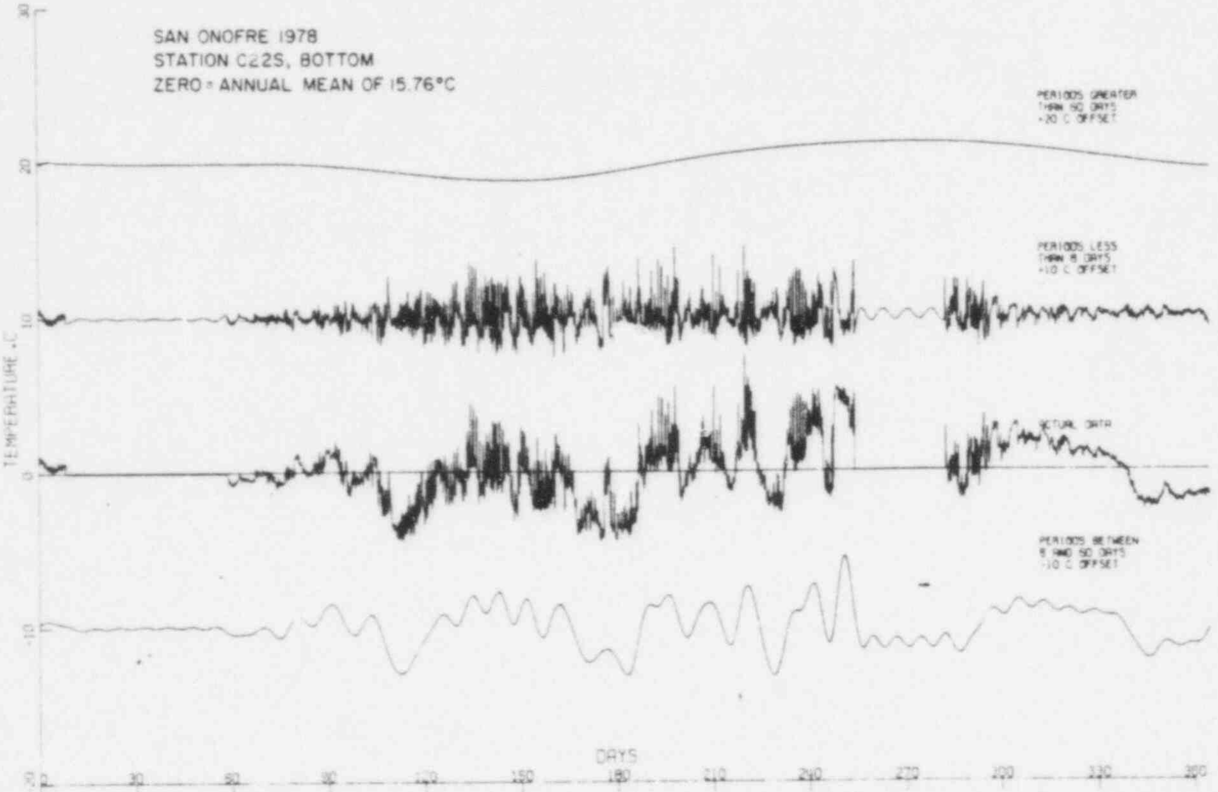


930012

POOR ORIGINAL

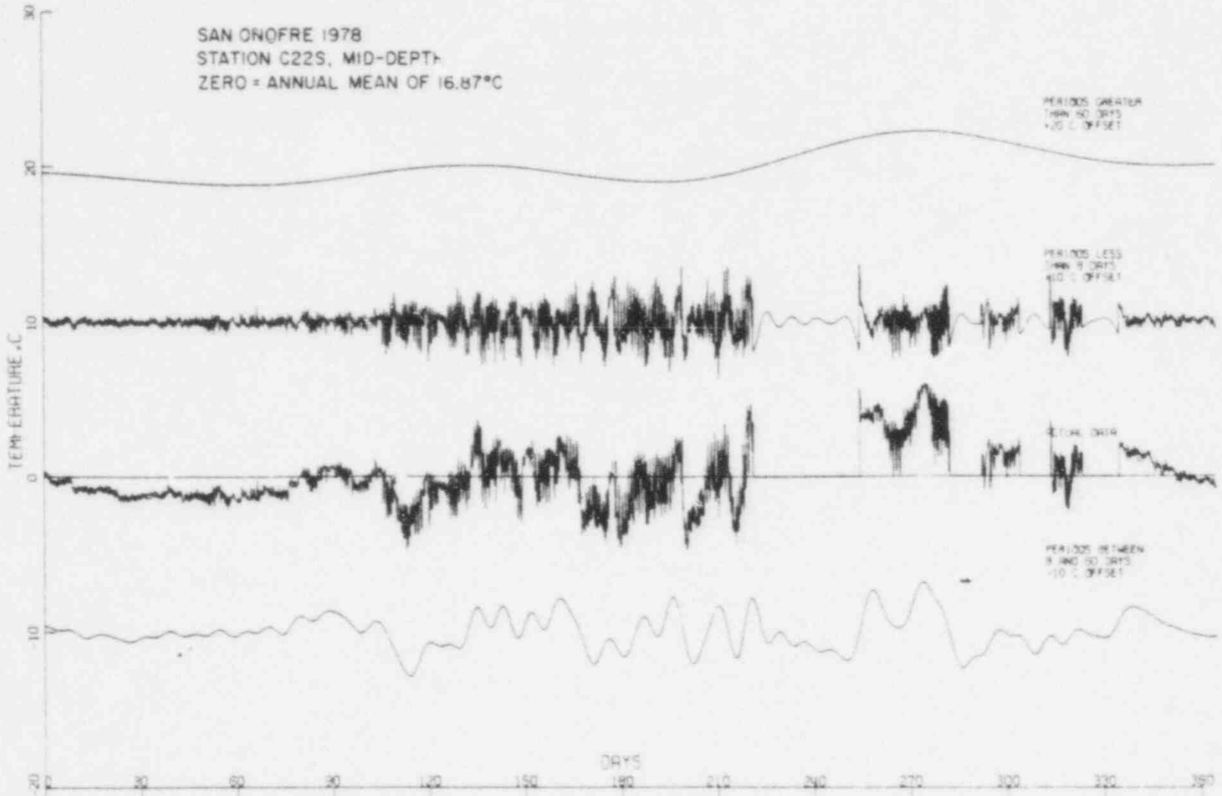
[redacted]

Appendix A-10. Frequency components of mid-depth temperature variations at station C22S during 1978.



933013

Appendix A-11. Frequency components of bottom temperature variations at station C22S during 1978.



830014

Appendix B. Turbidity

Appendix B-1. Mean and range of surface, mid-depth (4 m), and near-bottom (1 m above bottom) light transmittance during 1978 bimonthly surveys (percent/m).

	Depth	Item	January	March	May	July	September	November	Year
Operational Stations	Surface	Min/Sta[a]	0/X0[b]	0/X0[b]	0/X0	3/X0	1/B0[b]	29/A8S	0/X0[b]
		Max/Sta	3/F6N	11/F14N	53/E2S	66/E2N	69/C20N	69/C26N	69/C20N[b]
		Mean	0	1	17	48	25	53	23
		Std Dev	0.6	2.4	16.7	16.1	22.4	7.5	24.7
	Mid-Depth	Min/Sta	0/X0[b]	0/X0[b]	0/X0[b]	0/A1N[b]	0/B0[b]	11/B0	0/X0
		Max/Sta	2/F0	7/E0	53/E2S	60/E2N	67/C20N	66/E4N	67/C20N
		Mean	0	2.3	16	31	16	50	18
		Std Dev	0.8	0.8	17.5	15.1	17.8	12.5	21.3
	Near-Bottom	Min/Sta	0/X0[b]	0/X0[b]	0/X0[b]	0/X0[b]	0/X0[b]	3/B1N	0/X0[b]
		Max/Sta	0/X0[b]	0/X0[b]	1	11/A2N	16/D2N	63/E2S	63/E2S
		Mean	0	0	0/X0[d]	1	0	36	6
		Std Dev	0.1	0.0	3.3	1.8	2.5	18.0	15.3
Preoperational Stations[c]	Surface	Min/Sta	-	-	46/F20N	44/F6S	30/H2N[b]	55/F26A	30/H2N[b]
		Max/Sta	-	-	78/M8S	76/M0[b]	70/M8N	87/M8N	87/M8N
		Mean	-	-	61	67	55	70	64
		Std Dev	-	-	7.5	6.7	11.5	7.1	10.1
	Mid-Depth	Min/Sta	-	-	44/F20N	10/F6N	28/J4N	50/F26S	28/J4N
		Max/Sta	-	-	77/M8S	75/M0[b]	77/J8S	86/M2N	86/M2N[b]
		Mean	-	-	61	56	53	68	60
		Std Dev	-	-	7.8	18.1	15.0	8.4	14.2
	Near-Bottom	Min/Sta	-	-	0/F0[b]	0/F2S[b]	0/F0[b]	28/F14N	0/F0[b]
		Max/Sta	-	-	1/H0[b]	60/M0[b]	0/X0[b]	73/M2N	73/M2N
		Mean	-	-	0	22	0	60	21
		Std Dev	-	-	0.5	22.1	0.0	9.7	27.5

[a] Minimum or maximum percent light transmittance and station.
[b] Minimum or maximum observed at several stations; reading closest to discharge presented.
[c] SONGS 2 and 3 preoperational survey began in May 1978.

330016

Appendix B-2. Mean and range of surface and mid-depth (4 m) suspended solids concentrations during bimonthly surveys (mg/l).

Depth	Item	July	September	November	Year
Operational Stations					
Surface	Min/Sta[a]	0.4/C2S	1.0/C8S[b]	0.2/D0[b]	0.2/D0[b]
	Max/Sta	120/A2N	45/A2S	6.8/C2N	120/A2N
	Mean	12.4	9.5	1.5	7.8
	Std Dev	23.89	12.35	1.39	16.04
Mid-Depth	Min/Sta	0.4/M0	0.2/X0[b]	0.2/D0[b]	0.2/X0[b]
	Max/Sta	110/A2N	42/A2S	3.2/C8N	110/A2N
	Mean	13.7	10.2	1.5	8.2
	Std Dev	21.09	10.27	0.95	14.23
Preoperational Stations					
Surface	Min/Sta	1.2/M0	0.8/J8S	0.2/F6N[b]	0.2/D0[b]
	Max/Sta	14/F6N	8.0/F0	2.4/M8N	[illegible]/F6N
	Mean	[illegible]	3.5	0.7	2.8
	Std Dev	3.87	3.43	0.73	3.32
Mid-Depth	Min/Sta	0.4/M0	0.2/H0[b]	0.2/F0[b]	0.2/F0[b]
	Max/Sta	9.4/F6N	2.2/F22S	2.2/F22S	9.4/F6N
	Mean	2.5	1.2	0.9	1.9
	Std Dev	[illegible]	0.68	0.77	2.20

[a] Minimum or maxiumum concentration and station.

[b] Minimum or maximum observed at several stations; reading closest to discharge presented.

Appendix B-3. Mean and range of Secchi disc depths of visibility during 1978 bimonthly surveys (m).

Item	Jan	Mar	May	Jul	Sep	Nov	Year
Operational Stations							
Min/Sta[a]	0.0/ X0[b]	0.5/ 0X0[b]	1.0/ X0[b]	2.0/ X0	1.0/ A0	2.5/ A1N	0.0/ X0[b]
Max/Sta	2.0/ F6N	2.0/ E4N[b]	8.0/ E2N	9.0/ E2N	10.0/ C20N	11.0/ E2N	11.0/ E2N
Mean	1.0	0.9	3.4	6.1	3.9	7.3	3.6
Std Dev	1.52	0.48	2.24	1.59	2.22	2.06	2.96
Preoperational Stations[c]							
Min/Sta	-	-	7.0/ F20N	6.0/ F6N	5.0/ H0[b]	7.0/ F26S	5.0/ F26S
Max/Sta	-	-	11.0/ J8N	12.0/ J0[b]	11.0/ M8S	18.0/ M2S	18.0/ M8S
Mean	-	-	9.1	10.0	7.4	13.8	10.2
Std Dev	-	-	1.23	2.08	1.75	3.34	3.22

[a] Minimum or maximum Secchi disc value and station.

[b] Minimum or maximum observed at several stations; reading closest to discharge presented.

[c] SONGS 2 and 3 preoperational survey began in May 1978

933018

Appendix C. Sediment Monitoring

9330119

Appendix C-1. Correspondence factor analysis of Subtidal grain size variables, factor loadings, with percentage of total variance explained.

Grain Size	Factor I	II	III	IV
March 1978				
Medium Gravel	0.23	-0.13	-0.09	0.08
Fine Gravel	0.06	-0.03	-0.02	0.01
Granule	0.11	-0.02	-0.08	-0.03
Very Coarse Sand	0.15	-0.05	-0.06	0.02
Coarse Sand	0.35	-0.18	-0.14	-0.02
Medium Sand	0.69	-0.30	-0.24	-0.55
Fine Sand	0.38	0.50	0.69	0.08
Very Fine Sand	-0.23	0.41	-0.49	-0.16
Coarse Silt	-0.68	-0.64	0.40	-0.23
Medium Silt	-0.09	-0.17	-0.08	0.38
Fine Silt	-0.07	-0.066	-0.04	0.60
Very Fine Silt	-0.04	-0.020	-0.08	0.46
Coarse Clay	0.004	-0.002	-0.07	0.37
Mean Grain Size	-0.04	-0.002	0.003	0.06
Sorting	0.03	-0.004	-0.002	0.18
Skewness	0.01	-0.01	0.001	0.12
Kurtosis	0.013	-0.01	-0.02	0.03
Mean Grain Size	-0.04			
% of Variability explained	42.0	31.9	14.5	8.4

Grain Size	Factor I	II	III	IV
June 1978				
Very Coarse Sand	[illegible]	-0.01	-	-0.08
Coarse Gravel	-	-	-	-
Medium Gravel	0.09	<0.01	0.05	0.43
Fine Gravel	-	-	-	-
Granule	0.11	0.03	-0.216	
Very Coarse Sand	0.23	0.04	0.0003	0.161
Coarse Sand	0.46	0.04	0.21	0.63
Medium Sand	0.70	0.08	-0.48	-0.22
Fine Sand	0.29	-0.22	0.72	-0.48
Very Fine Sand	-0.27	-0.50	0.22	0.16
Coarse Silt	-0.24	0.75	0.07	-0.020
Medium Silt	-0.05	0.13	<0.01	<0.01
Fine Silt	-0.03	0.03	0.05	0.02
Very Fine Silt	-0.02	0.03	0.11	-0.02
Coarse Clay	-0.01	0.01	0.14	-0.06
Mean Grain Size	-0.04	0.02	-0.01	-0.01
Sorting	0.02	0.01	0.03	-0.01
Sorting	0.02	0.01	0.03	-0.10
Kurtosis	-0.01	0.02	0	0.01
% of Variability Explained	62	31	3	2

Grain Size	Factor I	II	III	IV
September 1978				
Granule	0.03	-0.07	0.03	<0.01
Very Coarse Sand	0.01	-0.05	-0.02	0.07
Coarse Sand	0.02	-0.10	<0.01	-0.19
Medium Sand	0.10	-0.49	0.22	0.69
Fine Sand	-0.35	-0.41	0.612	0.47
Very Fine Sand	-0.50	0.32	-0.30	0.18
Coarse Silt	0.72	-0.17	0.16	0.19
Medium Silt	0.24	-0.27	0.09	0.30
Fine Silt	0.20	0.58	0.68	-0.28
Very Fine Silt	-	-	-	-
Mean Grain Size	0.02	0.01	0.03	0.02
Sorting	-0.02	-0.05	0.04	-0.05
Skewness	-0.01	0.08	<0.01	0.12
Kurtosis	0.01	0.02	-0.07	-0.05
% of Variability Explained	58.2	20.8	12.1	5.5

Grain Size	Factor I	II	III	IV
November 1978				
Very Coarse Gravel	0.06	-0.04	0.25	-0.30
Granule	0.03	0.04	-0.04	0.03
Very Coarse Sand	0.03	0.21	0.02	0.03
Coarse Sand	0.10	0.37	0.11	0.05
Medium Sand	0.18	0.77	0.20	0.16
Fine Sand	-0.39	0.26	-0.72	-0.34
Very Fine Sand	-0.49	-0.19	0.39	0.18
Coarse Silt	0.69	-0.22	-0.06	0.54
Medium Silt	0.17	-0.05	<0.01	-0.38
Fine Silt	0.10	0.01	-0.06	0.02
Very Fine Silt	0.13	-0.09	-0.23	0.03
Coarse Clay	0.07	-0.05	-0.29	0.54
Mean Grain Size	0.02	-0.03	0.01	-0.02
Sorting	0.03	0.04	-0.04	0.03
Skewness	0.03	0.01	-0.08	-0.01
Kurtosis	0.07	-0.08	-0.23	0.20
% of Variability Explained	47.9	37.3	6.4	4.2

POOR ORIGINAL

933020

Appendix C-2. Subtidal textural characteristics of sediment facies.

	Composite Mean Grain Size	Composite Sorting	Composite Skewness	Size Populations: Coarse Sand	Size Populations: Fine Sand	Size Populations: Silt
March						
Facies A						
A-1	3.58	0.90	0.24	0.4	72.3	24.9
B-1	3.52	0.50	0.32	0.2	84.5	15.1
C-1	3.44	0.52	0.23	0.6	89.7	7.2
D-1	3.33	0.70	-0.30	6.3	83.3	10.0
E-1	3.28	0.55	0.01	3.0	87.8	9.4
F-1	2.84	0.60	0.14	5.7	88.7	5.5
C-2	3.26	1.00	-0.16	13.4	74.9	11.1
D-2	3.28	0.93	-0.50	14.5	63.9	13.5
B-2	3.63	0.43	-0.06	0.7	82.9	15.8
x̄	3.35	0.68	-0.01	5.0	80.9	12.5
Facies B						
A-2	5.14	2.44	0.72	0.2	41.5	46.0
A-3	3.98	0.48	0.19	0.1	55.0	42.4
F-2	3.77	0.38	-0.12	1.2	69.1	29.9
E-2	3.63	0.63	-0.35	6.2	69.1	24.8
x̄	4.13	0.98	0.11	1.9	58.7	35.8
Facies C						
B-3	4.24	0.71	0.27	0.1	36.4	62.1
C-3	4.19	0.53	0.04	0.3	32.4	63.1
D-3	3.57	1.20	-0.54	16.2	30.3	51.6
F-3	4.22	0.68	0.32	0.1	[illegible]	67.8
x̄	4.06	0.78	0.02	4.2	31.8	61.2
Facies D						
E-3	2.29	1.59	0.31	..3	22.6	19.1
September						
Facies A						
A-1	3.25	0.48	-0.10	0.8	93.2	6.1
B-1	3.17	0.59	-0.20	5.5	90.1	4.5
C-1	3.42	0.45	-0.06	2.3	88.6	9.0
D-1	3.20	0.49	0.00	1.9	93.5	4.7
E-1	3.41	0.53	0.09	3.0	89.1	4.7
F-1	3.43	0.37	0.05	0.3	93.6	5.2
x̄	3.31	0.48	-0.04	2.3	91.4	5.7
Facies B						
A-2	3.64	0.63	-0.39	5.4	73.4	21.1
B-2	3.67	0.62	-0.08	3.5	75.0	20.9
C-2	3.60	0.59	-0.36	4.6	72.1	22.9
D-2	3.81	0.56	-0.06	2.4	61.2	34.5
E-2	3.87	0.41	-0.29	2.0	55.5	42.2
x̄	3.72	0.56	-0.24	3.6	67.4	28.3
Facies C						
F-2	3.89	0.66	-0.39	8.7	46.9	44.3
C-3	3.93	0.59	-0.36	3.6	42.1	53.6
B-3	4.29	0.68	0.32	0.2	33.8	61.4
F-3	4.15	0.38	0.02	0.6	27.9	71.3
A-3	4.24	0.64	0.28	0.2	36.5	70.9
x̄	4.10	0.59	-0.03	2.66	37.4	60.3
Facies D						
D-3	3.41	1.11	-0.64	16.2	31.8	48.3
E-3	3.65	1.06	-0.61	11.7	24.5	63.7
x̄	3.53	1.08	-0.62	14.0	28.2	56.0
June						
Facies A						
A-1	3.59	0.41	-0.08	0.7	83.4	15.8
C-1	3.54	0.48	-0.22	2.8	84.7	11.9
E-1	3.34	0.44	0.04	1.4	90.8	7.7
F-1	3.43	0.39	-0.20	1.4	92.9	5.2
B-2	3.69	0.36	-0.16	0.9	79.4	19.9
C-2	3.61	0.47	-0.33	3.3	82.5	13.0
x̄	3.53	0.42	-0.16	1.8	85.6	12.3
Facies B						
A-2	3.92	0.48	0.08	1.4	56.8	41.5
A-3	3.97	0.32	-0.16	0.2	49.8	50.0
D-1	3.64	0.62	-0.13	2.1	67.9	28.0
D-2	3.63	0.63	-0.43	7.8	65.9	25.7
E-2	3.47	1.00	-0.58	13.7	44.0	42.0
F-2	3.88	0.36	-0.14	2.4	57.3	39.9
x̄	3.75	0.57	-0.23	4.6	57.0	37.9
Facies C						
B-3	4.17	0.46	0.20	0.1	32.2	67.8
C-3	4.11	0.52	-0.12	2.8	28.9	67.7
D-3	4.22	0.39	-0.02	1.0	20.6	77.6
F-3	4.18	0.35	0.07	1.0	23.5	75.5
x̄	4.17	0.43	0.03	1.2	26.3	72.2
Facies D						
B-1	1.71	1.04	-0.11	63.1	35.1	1.8
E-3	2.32	1.44	0.35	56.9	21.8	20.7
x̄	2.02	1.24	0.23	60.0	28.5	11.3
November						
Facies A						
A-1	3.22	0.60	0.16	1.0	92.2	4.1
B-1	3.29	0.49	-0.08	2.1	92.0	5.1
C-1	3.25	0.59	-0.20	5.4	88.2	6.5
D-1	3.25	0.66	-0.07	5.4	88.3	2.8
E-1	3.41	0.40	0.02	0.9	91.6	7.0
F-1	3.43	0.38	0.04	0.5	93.1	5.8
x̄	3.31	0.52	-0.02	2.6	90.9	5.2
Facies B						
A-2	3.74	0.51	-0.12	3.6	66.2	29.8
B-2	3.66	0.62	-0.14	3.8	73.3	23.7
C-2	3.59	0.67	-0.24	6.3	73.9	17.9
D-2	3.72	0.66	-0.19	3.9	63.3	30.7
E-2	3.82	0.85	-0.04	4.0	55.1	37.5
F-2	3.89	0.38	-0.18	3.3	54.9	41.4
x̄	3.74	0.62	-0.15	4.2	64.5	30.2
Facies C						
A-3	4.17	0.88	0.43	0.0	42.5	53.3
B-3	4.35	0.81	0.37	0.5	26.3	70.9
C-3	4.06	0.97	0.26	1.1	30.9	64.2
D-3	3.97	0.67	-0.33	4.8	37.1	56.6
F-3	4.19	0.55	0.10	1.2	30.9	66.7
x̄	4.15	0.78	0.17	1.5	33.5	62.3
Facies D						
E-3	2.62	1.55	0.26	45.6	19.1	35.2

Appendix D. Plankton

ZOOPLANKTON DRY WEIGHT BIOMASS(MG/CUBIC METER)
FOR THE PLANKTON SURVEY DURING JULY 1978

DATE OF SURVEY	STATION NUMBER	UPPER STRATUM* REP 1	UPPER STRATUM* REP 2	LOWER STRATUM* REP 1	LOWER STRATUM* REP 2
7/14/78					
	1	8.78	3Ø9.82	3.87	8.65
	2	4.Ø2	6.52	6.4Ø	6.26
	3	21.9Ø	1Ø.Ø6	7.Ø4	4.89
	4	4.51	8.1Ø	1.51	3.6Ø
	5	17.68	13.84	6.28	15.18
	6	7.28	6.21	6.75	3.17
	7	14.63	8.18	16.27	9.34
	8	Ø.ØØ	Ø.ØØ	Ø.ØØ	Ø.ØØ
	9	4.55	2.96	5.77	3.71
	1Ø	2Ø.89	19.61	11.43	9.24
	11	72.93	33.69	14.43	15.73
	12	11.67	7.92	9.56	21.7Ø
	13	8.96	8.58	3.91	11.5Ø
	14	26.59	29.96	16.5Ø	17.74
	15	26.33	28.55	22.42	2Ø.26
	16	24.42	33.ØØ	4.54	1Ø.86
	17	22.48	2Ø.59	6.22	26.12
7/19/78					
	1	57.Ø9	5.73	1Ø.61	15.24
	4	9.33	4.85	21.64	169.94
	6	8.73	4.45	4.79	16.Ø7
	7	7.93	6.23	5.21	8.Ø7
	8	Ø.ØØ	Ø.ØØ	Ø.ØØ	Ø.ØØ
	9	1Ø.54	8.72	14.28	12.78
	1Ø	7.Ø5	7.96	57.11	25.91
	11	4.33	179.7Ø	48.22	Ø.ØØ
	12	5.53	2.98	8.99	6.Ø1
	13	8.17	7.21	8.45	8.7Ø
	14	37.Ø5	37.83	24.92	42.63
	15	27.47	4Ø.58	48.24	26.62
	16	26.43	19.69	57.Ø7	47.36
	17	27.35	19.81	34.36	36.14
7/2Ø/78					
	1	5.55	3.76	12.26	11.Ø4
	4	3.Ø9	8.13	5.63	7.27
	6	7.Ø7	11.64	7.5Ø	9.7Ø
	7	1Ø.67	5.ØØ	12.87	17.49
	8	Ø.ØØ	Ø.ØØ	Ø.ØØ	Ø.ØØ
	9	24.96	24.9Ø	4Ø.78	41.5Ø
	1Ø	14.58	12.2Ø	36.6Ø	33.27
	11	6.81	7.67	81.37	63.4Ø
	12	5.85	4.71	17.51	22.58
	13	11.99	11.32	11.66	9.39
	14	22.51	28.49	33.76	36.76
	15	26.36	17.57	29.93	31.91
	16	28.72	23.ØØ	31.66	23.37
	17	15.68	24.36	19.82	22.71

* UPPER STRATUM = O-5 M AND Ø-8 M; LOWER STRATUM = 5 M - BOTTOM AND 8 M - BOTTOM AT STATION 1-8 AND 9-17 RESPECTIVELY.

ZOOPLANKTON DRY WEIGHT BIOMASS(MG/CUBIC METER)
FOR THE PLANKTON SURVEY DURING SEPTEMBER 1978

DATE OF SURVEY	STATION NUMBER	UPPER STRATUM* REP 1	UPPER STRATUM* REP 2	LOWER STRATUM* REP 1	LOWER STRATUM* REP 2
9/ 8/78					
	1	182.00	76.80	511.64	12.28
	2	16.60	21.76	59.54	24.36
	3	16.29	16.61	96.55	13.94
	4	42.71	39.15	64.91	*1089.
	5	51.64	202.24	143.69	266.59
	6	40.12	48.24	9.39	3.92
	7	25.82	16.50	7.27	6.77
	8	12.58	13.17	5.75	8.70
	9	5.86	25.38	18.02	146.32
	10	34.28	37.62	60.10	12.88
	11	30.15	26.84	200.40	176.01
	12	30.49	27.34	10.20	7.83
	13	60.16	51.91	10.93	9.84
	14	52.52	57.51	21.44	27.45
	15	22.21	26.58	23.62	23.02
	16	28.02	33.70	29.75	30.51
	17	34.57	41.16	15.19	28.74
9/ 9/78					
	1	27.50	27.76	83.09	10.75
	4	63.06	48.96	16.85	17.15
	6	17.80	19.26	757.39	116.91
	7	46.85	39.15	31.22	9.34
	8	11.19	10.05	10.38	10.19
	9	17.64	16.07	9.64	17.31
	10	33.08	87.53	713.05	[illegible]
	11	25.82	28.05	48.78	128.90
	12	20.45	12.09	71.52	409.24
	13	14.92	12.97	19.04	312.22
	14	31.87	44.84	36.47	29.47
	15	18.68	40.62	38.57	58.83
	16	37.77	39.22	46.91	73.52
	17	57.78	57.25	29.93	31.89
9/10/78					
	1	[illegible]	14.63	91.88	532.85
	4	94.70	26.55	340.36	163.27
	6	30.18	34.30	68.85	426.24
	7	22.61	11.75	14.85	19.52
	8	35.12	13.89	32.94	16.15
	9	44.11	47.12	22.33	30.21
	10	18.63	17.83	18.89	13.71
	11	30.30	52.02	*1394.	*2622.
	12	33.50	18.01	51.21	67.07
	13	36.31	41.56	257.22	332.89
	14	33.49	24.65	31.85	36.52
	15	25.26	39.45	37.78	35.71
	16	43.10	40.17	27.38	20.64
	17	33.33	39.11	29.93	35.88

* UPPER STRATUM - 0-5 M AND 0-8 M; LOWER STRATUM - 5 M - BOTTOM AND 8 M - BOTTOM AT STATION 1-8 AND 9-17 RESPECTIVELY.

POOR ORIGINAL

ZOOPLANKTON DRY WEIGHT BIOMASS(MG/CUBIC METER)
FOR THE PLANKTON SURVEY DURING NOVEMBER 1978

DATE OF SURVEY	STATION NUMBER	UPPER STRATUM* REP 1	UPPER STRATUM* REP 2	LOWER STRATUM* REP 1	LOWER STRATUM* REP 2
11/16/78					
	1	26.28	6.52	31.08	6.83
	2	10.91	11.43	11.99	18.96
	3	18.06	11.89	19.27	12.01
	4	8.36	7.45	16.26	11.52
	5	9.33	10.18	14.06	12.26
	6	12.85	12.79	16.01	13.31
	7	13.25	14.15	47.70	25.24
	8	537.96	40.89	30.42	29.09
	9	38.24	24.37	28.76	21.68
	10	7.49	22.13	26.24	14.64
	11	9.16	9.58	76.33	74.64
	12	7.44	8.30	24.70	30.73
	13	9.37	18.52	21.90	18.02
	14	97.77	14.79	17.04	12.02
	15	26.56	21.27	10.20	11.86
	16	14.03	6.31	9.40	6.90
	17	11.01	9.96	6.73	13.40
11/17/78					
	1	46.18	10.55	47.58	42.55
	4	25.15	16.55	25.30	23.41
	6	12.38	11.66	19.82	14.51
	7	8.96	10.37	14.82	17.26
	8	31.85	19.88	15.47	15.70
	9	25.06	39.34	40.31	28.65
	10	26.41	25.57	37.78	33.78
	11	8.47	23.57	14.87	32.21
	12	3.84	3.12	12.49	13.30
	13	8.48	80.61	900.91	96.55
	14	13.14	28.64	5.17	10.85
	15	16.05	14.44	9.05	8.57
	16	10.08	21.93	8.26	[illegible]
	17	14.49	70.39	11.97	12.4[illegible]
11/18/78					
	1	20.90	24.27	23.11	23.39
	4	20.67	18.60	33.1[illegible]	21.76
	6	16.65	28.18	30.61	23.01
	7	17.21	11.70	17.32	18.29
	8	34.00	34.91	26.59	21.34
	9	18.94	18.38	23.91	23.89
	10	17.41	12.33	25.82	31.62
	11	27.37	36.62	36.67	30.66
	12	14.41	19.73	46.55	138.88
	13	14.96	17.40	26.77	73.52
	14	13.46	16.61	9.28	9.51
	15	13.00	15.31	11.17	14.07
	16	13.77	14.96	9.64	10.53
	17	20.00	16.71	19.96	12.43

* UPPER STRATUM - 0-5 M AND 0-8 M; LOWER STRATUM - 5 M - BOTTOM AND 8 M - BOTTOM AT STATION 1-8 AND 9-17 RESPECTIVELY.

Appendix E. Intertidal Cobble

Appendix E. Summary of data collected at three fixed 0.25-m^2 quadrats at the five intertidal stations during the 1977 intertidal surveys. Data indicate percent sand in each quadrat and percent coverage of the two most abundant taxa in each quadrat during each survey.

Survey Date	Category	Station 1, Quadrat 1	Station 1, Quadrat 2	Station 1, Quadrat 3	Station 2, Quadrat 1	Station 2, Quadrat 2	Station 2, Quadrat 3	Station 3, Quadrat 1	Station 3, Quadrat 2	Station 3, Quadrat 3	Station 4, Quadrat 1	Station 4, Quadrat 2	Station 4, Quadrat 3	Station 5, Quadrat 1	Station 5, Quadrat 2	Station 5, Quadrat 3
February 15	Sand	20	6	60	27	95	95	12	8	17	15	40	60	20	15	20
	Zonaria farlowii			20	10	7	34		7	16	36	34				
	Turf - *Parvosilvosa*	22	12					12		5			30	8	10	2
	Jania spp. (*tenella*)	14	18	14												
	Corallina/*Haliptylon*				10		1				20	16	11	50	42	60
	Sargassum spp.					11		20	7							
	(footnotes)					(1)			(2)			(3)				
June 3	Sand	15	12	70	15	10	8	20	36	30	50	35	25	15	7	30
	Zonaria farlowii	8		14	11	17	44	12	15	19	20	32				
	Dictyota/*Pachydictyon*		5			9	11				12					
	Turf - *Parvosilvosa*					9		15	19	7			27	6		
	Corallina/*Haliptylon*	5	10	20	13						12	15	14	72	23	52
	Endocladia muricata															8
	(footnotes)					(4)			(5)							
October 13	Sand	5	15	15	20	22	30	30	50	25	100	20	15	100	60	100
	Zonaria farlowii		10	15	12	8	20	15	20	25		20	25			
	Jania spp. (*tenella*)	40	40	30												
	Corallina/*Haliptylon*											5	5		30	
	Sargassum spp.				15	10	10	20	25	10						
	Phyllospadix spp.	10														
	Ralfsia														3	
	(footnotes)								(6)			(7)			(8)	
December 9	Sand	4	20	12	8	96	100	60	53	0	48	26	16	80	36	54
	Zonaria farlowii		8			1		9	10	13	16	22	6			
	Jania spp. (*tenella*)			35												
	Corallina/*Haliptylon*	13		15	7						30	18		8	12	36
	Turf - *Parvosilvosa*					1							20		16	9
	Sargassum spp.				8		1	12	75	35						
	Phyllospadix spp.	8	18											4		
	Patiria miniata					1										
	(footnote)								(9)							

( ) Footnotes appear on the following page.

Appendix E (continued)

Footnotes of 1977 Intertidal Cobble Surveys

(1) 9 people in area, 2 clamming holes nearby.

(2) Q3 about 1/3 dug up, 4 clamming holes nearby, inshore 3 m of Zone 4 sanded in, 5 people in area, Zone 3 sanded in.

(3) Q1 has rock overturned, Q3 still dug to bedrock and thin sand layer over it.

(4) 2 clamming holes in Zone 4 near fixed quadrats.

(5) 5 clamming holes in Zone 4 near fixed quadrats, 5 m of inshore Zone 3 sanded in, offshore 2 m of Zone 4 sanded in.

(6) Shoreward stakes sanding in.

(7) Q1 not located (under sand).

(8) Q1 not located (under sand), Zone 4 sanding in.

(9) 17 clammers in area.

Appendix F. Benthic Infaunal

Appendix F-1. Number of benthic infaunal species by feeding type.

Station	Filter Feeders	Carnivores	Omnivores	Surface Deposit Feeders	Sub-surface Deposit Feeders	Total Deposit Feeders
			March			
A1	7	5	0	13	0	13
A2	4	8	2	13	4	17
A3	7	8	3	21	4	25
B1	3	6	1	8	1	9
B2	5	8	1	16	5	21
B3	7	17	5	24	8	32
C1	8	6	0	16	0	16
C2	8	9	4	12	8	20
C3	8	7	2	25	6	31
D1	1	0	0	4	1	5
D2	5	6	1	9	2	11
D3	9	6	4	22	11	33
E1	7	5	2	15	4	19
E2	6	6	3	18	5	23
E3	4	6	2	15	6	21
F1	3	4	1	9	1	10
F2	4	12	4	19	8	27
F3	5	7	3	22	5	27
Mean	5.61	7.00	2.11	15.61	4.39	20.00
			June			
A1	6	2	1	13	5	18
A2	14	11	4	18	7	25
A3	11	12	1	24	6	30
B1	6	4	0	14	2	16
B2	11	6	1	13	6	19
B3	14	12	4	25	7	32
C1	6	4	2	13	4	17
C2	12	6	4	14	8	22
C3	13	8	5	22	10	32
D1	7	5	0	12	2	14
D2	15	4	4	29	6	35
D3	11	10	4	27	8	35
E1	8	3	1	14	4	18
E2	8	12	5	13	8	21
E3	13	6	4	32	7	39
F1	4	6	3	13	5	18
F2	11	8	1	28	7	35
F3	13	14	6	22	11	33
Mean	10.17	7.39	2.78	19.22	6.28	24.61
			September			
A1	2	4	3	8	2	10
A2	8	9	4	14	13	27
A3	16	15	5	28	8	36
B1	8	2	1	10	3	13
B2	9	9	8	17	8	25
B3	14	17	3	28	8	36
C1	8	3	2	11	4	15
C2	13	11	5	21	8	29
C3	10	10	6	25	8	33
D1	4	5	3	9	2	11
D2	13	12	6	18	8	26
D3	13	10	9	15	10	25
E1	6	5	3	11	2	13
E2	16	9	7	23	9	32
E3	12	9	4	26	12	38
F1	6	8	3	11	4	15
F2	11	16	4	14	9	23
F3	14	14	3	22	9	31
Mean	10.16	9.33	4.39	17.28	7.06	24.33
			November			
A1	6	3	2	14	0	14
A2	13	13	2	19	9	28
A3	15	15	2	24	12	36
B1	4	7	2	11	3	14
B2	10	9	3	19	9	28
B3	21	24	6	26	14	40
C1	8	9	3	15	4	19
C2	14	12	5	24	10	[illegible]
C3	19	11	3	19	9	28
D1	4	5	3	15	3	18
D2	13	8	6	15	11	26
D3	12	8	5	28	12	40
E1	8	3	4	13	2	15
E2	14	11	4	24	8	32
E3	15	8	6	31	9	40
F1	6	4	2	11	2	13
F2	11	16	7	16	8	24
F3	17	15	4	25	13	38
Mean	11.67	10.05	3.83	19.39	7.67	27.05

GLOSSARY

Accretion — Natural accretion is the buildup of sediment solely by the action of forces of nature; on a beach by deposition of waterborne or airborne material. Artificial accretion is a similar buildup of sediment due to an act of man.

Adsorption — The adhesion in a thin layer of molecules to the surface of solid bodies or to a gas/liquid phase boundary with which they are in contact.

Ambient Transmittance — The light transmittance in waters beyond the influence of SONGS Unit 1 and within the survey area.

Assimilation — The incorporation into protoplasm.

Attenuation — The reduction in light intensity caused by the absorption and scattering of light energy in air or water.

Backwash — The seaward return of water following the uprush of the waves.

Barnacle — A marine crustacean permanently attached to rocks or other solid substrate as an adult, with feathery appendages for food gathering, and enclosed in a calcareous conical shell.

Beach — The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of the beach - unless otherwise specified - is mean lower low water line.

Beach Face — The section of the beach normally exposed to the action of the wave uprush. The foreshore of a beach.

Beach Profile Area — The area occupied by the intersections of the ground surface with a horizontal plane at MLLW and vertical plane. The vertical plane extends to the elevation of the reference marker at individual transects.

Benthos — Organisms living in or on the sea bottom.

Berm — A nearly horizontal part of the beach formed by the deposit of material by waves.

Glossary

Bray-Curtis Dissimilarity — A measure of dissimilarity between two sample entities (species or stations).

$$D = \frac{\sum_{j=1}^{S} \left| x_{1_j} - x_{2_j} \right|}{\sum_{j=1}^{S} \left(x_{1_j} - x_{2_j} \right)}$$

where x_{1_j} = number of individuals of species j at site 1
x_{2_j} = number of individuals of species j at site 2
S = total number of species found at sites 1 and 2

Bubble — Turbulent surface waters above the Unit 1 cooling system discharge.

Carnivore — Consumer of living animal material.

Celsius Temperature — Temperatures based on a scale in which water freezes at 0° and boils at 100° (at standard atmospheric pressure). Related to Farenheit temperature by °C = 5/9 (°F-32) and (9/5 x °C) + 32.

Chi2 — Chi-square is a method of comparing observations to expected results to determine whether the observation deviates statistically from theoretical expectation.

Chlorophyll a — An important photosynthetic pigment occurring in phytoplankton. The quantity of chlorophyll a in seawater is measured by fluorescence according to the following equation.

$$\text{Chlorophyll } \underline{a}\ (mg/m^3) = \frac{\dfrac{Fo/Fa_{max}}{(Fo/Fa_{max})-1}\ (k_x)(Fo-Fa)}{\text{liters filtered}}$$

where Fo = fluorescence before acidification
Fa = fluorescence after acidification
Fo/Fa_{max} = maximum acid factor which can be expected in the absence of phaeo-pigment
k_x - calibration constant for a specific sensitivity scale

Cirripedia — Subclass of crustacea: barnacles.

Coastal Currents — Major oceanic boundary currents and associated residual currents.

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Coefficient of Variation — An expression of the amount of variation, the standard deviation, expressed as a fraction of the mean.

For a population: $C = \sigma/\mu$ sample estimate: $C = s/\bar{X}$

where:

σ = Population standard deviation

μ = Population mean

$\underline{s}$ = Sample standard deviation

$\bar{X}$ = Sample mean

Community — A spatially and functionally related assemblage of animal, plant, bacterial, and fungal populations. The populations vary with respect to composition but each assemblage demonstrates a distinct structure. Abiotic and biologic environmental variables control composition and distribution of the community. The organisms form a living system that interacts with complimentary linked processes.

Constancy — A qualitative term employed to describe the repeated occurrence pattern of an organism or organism group.

Contageous Distribution — A quantitative description of the spatial dispersion patterns of an organism or organism group when the sample variance is greater than the sample mean.

Contemporary Terrigéneous Sediments — Mineral and rock particles washed from areas that have been eroded during approximately the last 7,000 year . These sediments were deposited under present hydrodynamic conditions.

Convergence — In refraction phenomena, the decreasing of the distance between orthogonals in the direction of wave travel. Denotes an area of increasing wave height and energy concentration.

Copeoda — Order of small crustaceans (generally 0.6 to 4.0 mm) which represents the major group of zooplankton found in waters overlaying continental shelves.

Correlation Coefficient — The Pearson Product Moment (r) may be used to test the hypothesis that there exists a linear relationship between two independent variables, X and Y. The statistic is computed by the following formula:

$$r = \frac{\Sigma XY - \Sigma X \Sigma Y/N}{\sqrt{[\Sigma X^2 - (\Sigma X)^2/N]\,[\Sigma Y^2 - (\Sigma Y)^2/N]}}$$

Crustacean — Any animal of a large class (Crustacea) characterized by having a chitinous or calcareous and chitinous exoskeleton and jointed appendages (as lobsters, shrimp, crabs, and barnacles).

Glossary

Dendrogram — A tree-like graphic representation of a similarity analysis in which each classified entity is represented by a branch. The point of origin of each branch on the "tree" indicates the entity cluster to which it belongs and the relative similarity of the entity to others in the cluster.

Density — Mass per unit volume. Governed in seawater by temperature, salinity, and pressure. May also refer to number of individuals per unit area or volume.

Depth Control — Pertains to detrital sediments in which the distribution is controlled by present hydrodynamic conditions.

Dichotomy — The point at which two branches of a dendrogram unite.

Diel — Daily, occurring within a 24 hr period, such as diel vertical migration in which organisms migrate toward the surface and back to depth within one day.

Diurnal — Daily, especially referring to actions which are completed within approximately 24 hrs and which recur every 24 hrs (i.e. daily vertical migrations or plankton, fish, and tidal cycles).

May also refer to occurrences during the daytime, as contrasted to nocturnal.

Diversity — A measure of the number of species present relative to the total population of organisms.

Dominant — Highly important in a community: importance may be based on abundance, biomass, productivity, or functional role.

Downcoast — A direction generalization which references specific positions while moving on a compass heading of 120 degrees.

Elevated Temperature Field — The total surface area enclosed within a particular isotherm (in this report, 1°F and 4°F isotherms) used as comparison criteria for thermal dispersion data.

Entrainment — Intake of water column organisms into a cooling system. May also describe the drawing in and transporting of sediments through the momentum of discharged waters.

Epifauna — Animals living on the substratum.

Errant — Free living, motile (Polychaeta: Errantiate).

Eurythermal — Able to tolerate a wide range of temperatures.

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Family — Term used in classification, signifying a group of related genera.

Fidelity — A qualitative term employed to describe the restricted (site specific) distribution pattern of an organism or organism group.

Flexible Sorting — A clustering strategy used in the building of dendrograms to reduce "chaining" and allocate as many entities as possible to groups.

Foreshore — The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

Frequency Domain Filter — A breakdown of a complete curve with many superimposed frequencies into component curves of specific frequencies.

Genus — A category of biological names ranking between the family and species names and designating a group of closely related organisms.

Grab Sample — A sediment sample collected typically by a remote sampling device lowered from a boat (as a clamshell dredge, Petersen grab, Shipek grab).

Grab Sampler — An instrument possessing jaws that seizes a portion of the bottom sediments for retrieval and study (e.g. Shipek grab).

Gradient — A linear change in the magnitude of a parameter with distance.

Grand Mean — Also, overall mean; the mean of several means. Used to indicate overall trends of several independent sets of data.

Grazer — Synonym for herbivore.

An animal which generally feeds upon attached, living primary producers.

Heat Treatment — The control of marine fouling organisms by means of recirculation of a portion of the condenser discharge in order to increase the water temperature within the cooling water system. Heat treatment of the intake conduit results in reversed flow through intake and discharge conduits and the expulsion of fouling organisms and debris.

Glossary

Heip's Evenness A mathematical expression of the evenness of apportionment of individuals among species within a given community.

$$E = \frac{e^H - 1}{S - 1}$$

where:
- e = base of natural logs
- H = Shannon Wiener Diversity Index
- S = total number of species in sample

Herbivore Consumer of living plant material.

Holocene In the geologic time scale it represents recent time or approximately the last 18,000 years.

Holoplankton Organisms with an entire life cycle spent within the plankton.

Infauna Those animals living at or below the water-substrate interface in bottom sediments.

Intertidal Relating to or being part of the zone bounded by high and low tide waters.

Inverse Classification A numerical technique which measures similarity of organisms in terms of their distribution among sampling entities.

Isopleth A line on a map connecting points of equal value.

Isotherm A line connecting points of equal temperature.

Knot A unit of speed equal to one nautical mile per hour (approximately 51 centimeters per second).

Kurtosis (KG) A measure of the ratio of the sorting in the extremes of the distribution compared with the sorting in the central part.

$$K_G = \frac{\phi_{95} - \phi_5}{2.44\,(\phi_{75} - \phi_{25})}$$

Langley A unit of solar radiation equivalent to one gram calorie per square centimeter of irradiated surface.

Light Transmittance The ratio of the transmitted light energy to the received light energy. Light transmittance (T) is a function of the attenuation coefficient of the medium (σ) and the distance over which the light is transmitted (r), $T = e^{-\sigma r}$.

Limpet A marine mollusk (Gastropoda) with a low, conical single-whorl shell that browses on algae and adheres tightly to the substrate when disturbed.

Longshore Parallel to the shoreline.

Low Tide Terrace A horizontal or nearly horizontal topographical feature interrupting a steeper slope that occurs near mean lower low water (MLLW).

Mean A mathematical average, such that given numerical values of Y_1, Y_2, Y_3, ..., Y_N, the "mean" of these values is defined by the following equation:

$$\bar{X} = \frac{\sum_{i=1}^{i=N} Y_i}{N}$$

Mean Diameter (Mz) The average size in the central 68% of the particle size distribution.

$$M_z = \frac{\phi_{16}+\phi_{50}+\phi_{84}}{3}$$

Median Grain Diameter (Md) The grain diameter corresponding to the 50th percentile of the cumulative curve. Half the diameters (by weight) of the distribution are larger and half are smaller than the median diameter.

Mean Lower Low Water The average height of the lower low waters over a 19 year period.

Meroplankton Organisms which spend only a portion of their life cycle in the plankton either as adults or larval forms.

Mixed Layer The upper layer of the ocean in which wind induced wave action mixes the water to the depth of the principal pycnocline.

Mollusc Any animal of a large phylum (Mollusca) of organisms characterized by a soft unsegmented body which is usually enclosed in a calcareous shell (as snails or clams).

Natural Temperature The temperature of the receiving water at locations, depth, and times which represent conditions unaffected by any artificially induced elevated temperature.

Nekton Free-swimming animals (as fish and marine mammals).

.nal Classification	A numerical classification technique which measures similarity of sampling entities in terms of their biota.
Null Hypothesis	In statistics, the null hypothesis is the assumed relationship which is to be tested. In comparing data sets, the null hypothesis states that no difference exists between the sets. If the sets prove to have statistically significant differences, the null hypothesis is assumed to be incorrect, and a true difference or relationship probably exists.
Nursery Area	Distinct habitat isobath or range of depths utilized nearly exclusively by juveniles and newly recruited organisms.
Omnivore	Any animal which is capable of feeding on both plant or animal material.
Opportunistic	In the trophic sense a strategy of eating what is most easily available with little or no selectivity.
Opportunist Species	A species whose life history allows it to rapidly expand its population during periods of favorable environmental conditions, and to persist in very low densities during unfavorable periods.
Oscillatory Tidal Current	The alternating horizontal movement of water associated with the rise and fall of the tide.
Oscillatory Wave	A wave in which each individual particle oscillates about a point with little or no permanent change in mean position. The term is commonly applied to progressive oscillatory waves in which only the form advances, the individual particles moving in closed or nearly closed orbits.
Parameter	Any of a set of physical properties whose values determine the characteristics or behavior of something.
Perturbation	A disturbance of either abiotic or biotic origin which modifies a stable state; often resulting in community changes.
pH	The negative logarithm of the hydrogen ion concentration of a solution which provides a measure of acidity or alkalinity.
Phaeo-pigments	Biological inactive pigment. Degradation product of photosynthetic pigment, chlorophyll a.

$$\text{Phaeo-pigments } (mg/m^3) = \frac{\frac{Fo/Fa_{max}}{(Fo/Fa_{max})^{-1}} (k_x) \left[Fo/Fa_{max} (Fa) - Fo \right]}{\text{liters filtered}}$$

where Fo = fluorescence before acidification

Fa = fluorescence after acidification

Fo/Fa_{max} = maximum acid factor which can be expected in the absence of phaeo-pigment

k_x = calibration constant for a specific sensitivity scale

Photosynthesis — The process by which plants use carbon dioxide and water, in the presence of light to form carbohydrates and oxygen.

Phylogenetic — Based on natural evolutionary relationships.

Phytoplankton — Portion of the plankton represented entirely by plants, containing chlorophyll and capable of photosynthesis.

Pielou's Evenness — A mathematical expression of the evenness of apportionment of individuals among species within a given community:

$$J' = \frac{H'}{\log S}$$

given: H' = the Shannon-Wiener Index

S = number of species within the community

Plankton — Those animals depending on water movement for transportation, floating or drifting passively in water.

Polychaete — Any animal of the large class of annelid worms (Polychaeta) characterized by having paired segmental appendages.

Precipitation — The separation from a solution or suspension by physical or chemical change.

Predator — Those species which actively prey upon other organisms.

Primary Consumers — Animals which graze on plant material; herbivores.

Primary Producers — Green plants which, by photosynthesis, transform solar energy into chemical energy. These plants are the basic link in a food chain or web.

Quadrat — Generally a rectangular frame enclosing a sampling plot for ecological or population studies.

Raptorial — Predatory behavior type always involving active prey capture, usually involving search for and/or chase of prey, and generally implying a degree of prey selectivity.

Relict Sediments — Mineral and rock particles washed from areas that have been eroded before the end of the last holocene

	transgression. These sediments were deposited under hydrodynamic conditions that existed when sea level was up to 130 m below its present level.
Regular Distribution	A quantitative description of the spatial dispersion patterns of an organism or organism group when the sample variance is less than the sample mean.
Rip Tide	A strong narrow surface current flowing outward from a shore that results from the return flow of waves and wind-driven water.
Salinity	Total amount of dissolved salts in seawater usually expressed as parts per thousand (ppt or o/oo).
Scavenger	Those species which are opportunistic in feeding habits, feeding upon animals and plants, living or dead.
Secchi Disc	A white disc of standard size (30 cm diameter) used in the measurement of water clarity in the water column by observing the depth at which the disc disappears from sight.
Sedentary	(Sedentate) permanently attached or located.
Sediment	Particulate organic and inorganic matter which accumulates in a loose, unconsolidated form.
Sessile	Permanently attached to the substatum.
Settleable Solids	The residue which settles out of a sample of seawater contained in an Imhoff cone, after a predetermined amount of time.
Shannon-Wiener Species Diversity Index	A measure of diversity in a single sample set of species.

$$H' = -\sum_{j=1}^{S} \frac{n_j}{N} \log \frac{n_j}{N}$$

where n_j = number of individuals in the j^{th} species

S = total number of species

N = number of individuals

Sigma-t	A convenient form of expressing density defined by (density - 1) x 10^3.
Skewness (SKI)	A measure of the direction and extent of departure of the mean from the median (in a normal or symmetrical curve they coincide). In symmetrical curves, SK_I = 0.00 with limits of -1.00 and+1.00. Negative values indicate the particle distribution is skewed

toward the larger particle diameters, while positive values indicate the distribution is skewed toward the smaller particle diameters.

$$SK_I = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

Solar Irradiance — The incident flux of solar energy striking a unit area.

Sorting Coefficient (σ_I) — Sorting measures the spread or assortment of grain sizes. Folk-Ward sorting approximates the statistical standard deviation if the distributions are nearly Gaussian (normally distributed).

$$\sigma_I = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

Source Control — Pertaining to relict sediments of which distribution was controlled by past hydrodynamic conditions.

Species — A category of biological names ranking immediately below the genus name and designating related organisms potentially capable of interbreeding.

Specific Gravity — The ratio of the density of a substance to the density of another substance.

Species Turnover — A measure of percentage change in the species composition of a community between two successive sampling periods.

$$\Delta sp = 100\left(\frac{e + r}{A}\right)$$

where:

e = extinction (species lost between t_1 and t_2)

r = Recruitment (species gained between t_1 and t_2)

A = Number of species present at t_1

Stability — (of biological communities) The ability of a system to maintain itself after small external perturbations.

Standard Deviation — A measure of the dispersion of sample variates about the mean measured by the square root of the sample variance.

Standard Error — The standard deviation of a distribution of means.

Stratification — The vertical division of distinct horizontal layers.

Glossary

Surge	1) The name applied to wave motion with a period intermediate between that of ordinary wind waves and that of the tide (1/2° to 60 min), 2) in fluid flow, long, interval variations in velocity and pressure, not necessarily periodic, often transient in nature.
Suspended Solids	Solid matter found entrained in, but not dissolved in, the water column.
Suspension Feeder	Any animal which is able to filter out food particles from the surrounding water medium.
Swash	The rush of water up onto the beach face following the breaking of a wave.
Taxon	Name or coded identifier of a taxonomic group at any heirarchical level (pl. taxa).
Taxonomic Group	Any grouping of related units in the classification of plants and animals.
Thermal Plume	A mass of water measureably warmer than surrounding waters which is produced by cooling water discharge.
Thermocline	Within the water column a layer in which there occurs a steep gradient of temperature with depth ($<0.1°C/m$).
Tidal Current	The alternating horizontal movement of water associated with the rise and fall of the tide.
Transect	An imaginary or real line established across an area for the purpose of sampling.
Transgression	The landward shift of the boundary between marine and non-marine deposition caused by worldwide rise in sea level and/or subsidence (lowering) of the land mass.
Transit Time	Time for water to traverse the cooling system.
Transmissivity	A measure of the ability of light to pass thorugh a water parcel, usually measured as percent transmittance per unit length.
Trawl	A large conical net usually attached to two down-planing boards and dragged along the sea bottom to gather fish or other marine life.
"t" Test	A special case of ANOVA which enables the comparison of two sample means based on the distribution of the "t" statistic (a sample) mean divided by its variance.
Trophic Level	Functional level in a food chain or web.

Turbidity	Decreased water clarity caused by the presence of suspended and/or dissolved materials.
Upcoast	A direction generalization which references specific positions while moving on a compass heading of 300 degrees.
Variance	A measure of dispersion around the mean of a distribution.
Velocity Cap	A deflection plate which causes a horizontal flow of water into the cooling system intake.
Vertical Control	The establishment of an elevation in reference to a given datum such as MLLW, bench mark, or reference mark.
Wave Energy	Total wave energy per unit surface area, defined by the equation:

$$E = \rho g \langle \sigma^2 \rangle$$

where:

ρ = fluid density

g = gravitation acceleration

$\langle \sigma^2 \rangle$ = total variance of the sea surface

Wave energy is customarily reported as a function of $\langle \sigma^2 \rangle$ only.

Wind Drift	Wind induced surface currents.
Zooplankton	Portion of the plankton composed entirely of animals.