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SAN ONOFRE NUCLEAR GENERATING STATION

Volume V

Biological and Oceanographic Data Analyses

ENVIRONMENTAL TECHNICAL SPECIFICATIONS
Unit 1

CONSTRUCTION MONITORING PROGRAM
Units 2 and 3

PREOPERATIONAL MONITORING PROGRAM
Units 2 and 3

SPECIAL STUDY: Ichthyoplankton

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EXECUTIVE SUMMARY

This report presents analyses and discussions of oceanographic and marine biological studies conducted during 1979 in the vicinity of San Onofre Nuclear Generating Station (SONGS), which is located on the coast of southern California between the cities of San Clemente and Oceanside. Physical, chemical, and biological data were analyzed to: 1) assess the effects of the operation of SONGS Unit 1; 2) determine the effects of the construction of Units 2 and 3; and 3) provide a baseline for future assessment 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 (ETS) for Unit 1 and Preoperational Monitoring Program (PMP) and special ichthyoplankton study, as well as the California Regional Water Quality Control Board, San Diego Region - NPDES Permit receiving water and sediment Monitoring for Units 1, 2 and 3 and Construction Monitoring Program (CMP) for Units 2 and 3.

Oceanographic studies examining nearshore water temperatures, turbidity, nutrients and water quality as well as local sedimentology were performed to assess natural and operational induced variability.

Thermal changes induced by Unit 1 were determined to be insignificant compared to natural temporal and spatial variations in waters of the San Onofre region. The magnitude of thermal discharge variability was the same as spatial variations in natural temperatures.

Turbidity at San Onofre varied with season and were greatest in winter and least in fall. Storm water runoff from San Onofre and San Mateo Creeks and wave action which resuspended bottom sediment had the greatest effect on local turbidity. The influence of the Unit 1 discharge on turbidity was perceptible but extremely localized, and lower in degree than the natural turbidity of the nearshore area.

Construction and dredging activities for Units 2 and 3 had limited effect on water clarity. Dredging effects were short term and spatially limited. The effects rapidly disappeared when activities ended.

Measurements of dissolved oxygen, hydrogen ion concentration and heavy metals showed the Unit 1 discharge to be in regulatory compliance. Between 1975 and 1979 iron midwater concentrations increased while copper mid-water concentrations in 1979 were the highest since 1975. These levels were distributed over a large area, and attributed to general concentrations rather than specific effluent influence. Bottom sediment heavy metal concentrations showed no accumulations over the five year study period.

The study of physical and chemical properties of intertidal and subtidal sediments as well as subtidal sedimentation rates, sea floor elevations, and beach morphology revealed that fluctuations in the distribution of sediment properties were natural except for those caused by impounding sand upcoast of the construction pad for Units 2 and 3. No permanent changes were induced in the sediments of the intertidal and subtidal environments by construction or dredging activities.

As observed in previous years, oceanographic processes were responsible for seasonal variability in plankton distribution and abundance. Localized differences were observed in zooplankton upcoast of San Mateo Point but were attributed to population patchiness. A gradient of decreasing plankton abundance proceeding offshore was observed. Effects of Unit 1 on plankton populations were not apparent since fluctuations fell within natural variability.

Impacts on sandy intertidal biota were observed and attributed to the proximity of construction support structures. Community diversity was depressed immediately upcoast of the laydown pad, and enhanced within 500 m downcoast of the pad. Normal cycles of beach accretion and erosion and sediment transport have been modified by the presence of the pad. Numbers of individuals throughout the area have declined since 1977, and the decline has been greater near the laydown pad. The intertidal area and its community should return to its pre-construction status after pad removal.

Rocky intertidal community changes were largely attributed to physical changes in the habitat resulting from natural processes. Seasonal patterns of sand accretion/erosion, cobble instability and freshwater runoff were primarily responsible for community variability. Other factors including local disruption of habitat by clamming activities probably contributed to a lesser extent. The community examined near the laydown pad was buried by sand accretion resulting from construction. However, this situation is expected to reverse once the pad is removed. No operational effects of Unit 1 were detected.

Benthic infaunal community studies revealed that distribution patterns of dominant species were not significantly modified by SONGS construction activities. Community composition and abundance were influenced by environmental factors. These factors were altered by both natural causes and SONGS. Differences in species diversity, number of individuals, and biomass were detected in areas immediately upcoast and downcoast of Units 2 and 3 offshore construction areas and Unit 1 discharge. Benthic infaunal effects resulted from inhibition of longshore sediment transport caused by construction activities and operation of Unit 1. After construction related structures are removed, a natural infaunal community will be reestablished.

Depth, substrate stability, and light were responsible for variations in the inshore, offshore and kelp bed cobble benthic communities in the vicinity of SONGS. Natural oceanographic events such as storms had a more pronounced effect on community stability than construction or plant operation.

Diverse assemblages of fishes occurred offshore of SONGS. The dominant species included the queenfish, white surfperch, walleye surfperch and northern anchovy. Fish populations exhibited variations in seasonal abundance corresponding to reproductive, oceanographic and meteorological events. Queenfish, anchovy, and white croaker were the most abundant larval fishes both offshore San Onofre and entrained annually at Unit 1 as characterized in an ichthyoplankton investigation. Cooling water discharge from Unit 1 had no apparent effect on the distribution or abundance of the fish community.

Queenfish numerically dominated normal Unit 1 impingement while heat treatment catches were dominated by walleye surfperch. Length structure of impinged fish resembled that of fish caught offshore; however, more females than males were impinged. Peak catches of the walleye surfperch coincided with inshore movement of gravid females and offshore movement of juveniles. No effects of construction activities were detected.

Variations in the kelp around San Onofre between 1910 and 1979 have been attributed to variations in oceanographic and meterological conditions. Turbidity, temperature, nutrients, light and biotic grazing pressures control kelp recruitment and growth success. As demonstrated from kelp mapping, construction activities increased turbidity in the upcoast sections of the San Onofre kelp bed without areal decline in extent of the kelp. Major canopy deterioration was associated with midwinter storms. Successful kelp recruitment was observed in the upcoast section of the San Onofre kelp bed in September and December of 1978 and 1979.

It is concluded from these studies that only localized effects were caused by construction and cooling water system operation; however, these effects were small when compared to the effects of natural environmental variations.

Station operation has localized effects and provides no impediment to maintenance of the coastal biota. This is based on the following observations and assumptions that: 1) the benthic infauna exhibit patterns of high species diversity across environmental gradients, and this variation will be within the range of natural change along the coast; 2) fishes readily adapt to habitat modifications; 3) trophic relationships may be altered by station operation, but new food webs form and maintain energy flow; 4) the resources lost by entrainment and impingement are minimal compared to the available resource; and 5) kelp distribution and production may be modified, but within the range of natural variability observed along the coastal zone.

TECHNICAL SUMMARY

TEMPERATURE

Temperature monitoring was performed as part of the San Onofre Nuclear Generating Station Environmental Technical Specifications (ETS), Construction Monitoring Program (CMP), and Preoperational Monitoring Program (PMP) programs.

Natural surface temperature and the amount of vertical stratification of temperature generally followed the annual insolation pattern. Several shorter duration (one to thirty days) cooling and warming trends were observed within the annual cycle, and resulted in temperature fluctuations as large as the seasonal range (6°C).

The frequency of variations in natural tempera[illegible] covered the entire range of the frequency spectrum, from seasonal fluctuations to fluctuations within a few hours. The larger natural variations were at frequencies with periods corresponding to 75, 37, 30, 20, 11, and 1 days. Fluctuations of various frequencies combined to result in 10° changes in natural temperature within 30 days. Short term fluctuations in natural temperature (periods of a day to a week), were relatively small during the winter, on the order of 1.0°C and often quite large during the summer, resulting in 4 to 5°C variations. Tidal currents were responsible for diurnal and semidiurnal fluctuations in temperature.

Continuous temperature measurements revealed that temperature conditions at San Onofre were persistent for periods of a few days to two weeks. The integrated study approach of bimonthly surveys and continuous temperature measurements provided detailed spatial and temporal information on the distribution of temperature.

Continuous temperature measurements at two locations 1000 and 2000 m offshore revealed that surface temperature usually decreased with distance offshore during the first half of 1979, and then increased with distance offshore during the second half of the year. During bimonthly surveys of 1979 the difference in natural surface temperature with distance offshore ranged from 0.5 to 2.0°C, differences in monthly mean surface temperature between these two locations ranged from 0.1 to 1.3°C.

Results of continuous temperature measurements reveal that simultaneous temperature measurement at two locations can be significantly different depending on the amount of separation between locations. Daily, weekly, and monthly mean temperatures between continuous temperature sampling locations were often significantly different. Therefore, temperature measurements from far removed control locations do not accurately represent ambient conditions for the area of the generating station.

Although absolute temperature between locations are not always similar, the fluctuations in temperature between continuous sampling locations were often similar. Fluctuations in temperature that had periodicities of 0.5, 1, 2, 4, 12, and 20 days were coherent between continuous temperature sampling locations. Low frequency (long duration) fluctuations were usually more coherent than higher frequencies, with the exception of tidal frequencies. Longshore coherency in continuous temperature records was usually greater than offshore coherency.

The circulating cooling water system for SONGS 1 produced a surface thermal plume approximately three meters thick. Temperatures within this plume ranged from 0.5 to 2.2°C above natural temperature. The surface extent of the 1°F (0.5°C) elevated temperature field was contained within 1000 acres of less, 80 percent of the time. The 4°F (2.2°C) elevated temperature field was contained within 15 acres or less, 80 percent of the time and was not observed 30 percent of the time.

Middepth temperature from 610 m south of the SONGS 1 intake was used to estimate cooling water recirculation. Recirculation was sufficient to increase intake temperature by 1.0°C or more, 45 percent of the time. During periods of recirculation, the increase in intake temperature was usually between 1 and 2°C. Therefore, approximately one half of the time, 10 to 20 percent of previously discharge water is recirculated back through the generating station.

The thermal effect of SONGS 1 was comparable to the natural temporal and spatial variation in water temperature in the SONGS study area. The variability caused by the thermal discharge was of the same magnitude (0.5 to 2.0°C) as spatial variations in natural temperature observed during bimonthly surveys. Thus, the thermal impact of SONGS 1 is considered negligible.

TURBIDITY

Turbidity was monitored as part of the San Onofre Nuclear Generating Station Environmental Technical Specifications (ETS), Construction Monitoring Program (CMP), and Preoperational Monitoring Program (PMP) programs.

Turbidity conditions varied significantly with waves and the amount of rainfall in 1979. The greatest effect on the amount of turbidity in the study area was storm water runoff from San Onofre and San Mateo Creeks and large waves which resuspended bottom sediment. Bimonthly survey measurements document spatial variability of turbidity throughout the study area, but were not frequent enough to document all the changes in the amount of turbidity with time, primarily due to the variability of wave and swell height.

Natural turbidity generally decreased with distance from shore and vertical distance above the bottom.

Intense vertical stratification of natural turbidity in the nearshore area occurs approximately one half the time. The circulating seawater system of SONGS 1 redistributed a surface turbid plume only during periods of intense natural vertical stratificiation of turbidity.

The influence of SONGS 1 on the distribution of turbidity was significantly smaller than the natural variability of turbidity with space and time in the nearshore coastal environment and therefore the impact of SONGS 1 on turbidity was negligible.

Dredging activities for offshore construction of SONGS 2 and 3 circulating seawater system, resulted in turbidity plumes of limited extent. The duration of these turbidity plumes was short due to the sporadic nature of dredging activities.

WATER QUALITY

Water Quality at San Onofre was monitored as part of the Environmental Technical Specifications (ETS), Construction Monitoring Program (CMP), and Preoperational Monitoring Program (PMP) programs.

The operation of SONGS 1 did not depress dissolved oxygen (DO) by more than 10%, nor did it alter hydrogen ion concentration (pH) by more than 0.2 pH units, and thus was in compliance with regulatory requirements in DO and pH.

An increase in receiving water iron concentration has been observed throughout the SONGS 1 study area, including the control station from 1975 to 1979. These changes are attributed to natural variability in concentration and not to the operation of SONGS 1.

During the past five years, there has been no consistent measurable increase in receiving water nor in ocean bottom sediment heavy metal concentrations due to SONGS 1 operation. It is therefore anticipated that heavy metal sampling for SONGS 1 will be discontiunued in accordance with ETS.

Nutrient concentrations at the kelp beds varied between surveys of 1979 but mean concentrations showed no significant differences between kelp beds.

SEDIMENT

The purpose of the sedimentology study was to determine the effects of SONGS Units 2 and 3 construction and dredging operations upon the intertidal and subtidal sedimentary environments and to provide physical/chemical data to correlate with infaunal surveys.

Intertidal beach profile measurements showed that erosion and accretion were minimal at the extreme upcoast and downcoast transects. Just upcoast of the construction pad accretion was maximal and the beach was the widest. Downcoast of the pad the beach exhibited maximum variation due to erosion and accretion.

Intertidal sediments occurred in five sediment facies all of which were typical of the southern California beach environment. The areal distribution of sediment facies varied with time indicating seasonal changes in the wave climate and downcoast beach drift. Variation in sediment statistics was lowest at the transect just upcoast of the construction pad; indicating that sediment impoundment occurred upcoast of the pad.

Subtidal sedimentation rates were lowest and least variable at off-shore (15 m) stations. The sedimentation rate indicated that most of the changes in sea floor elevation were caused by lateral, tractive motion of sediments rather than by vertical suspension and deposition, suggesting that dredge spoil deposition was minimal compared to other sources of sedimentation. No seasonal trends in sedimentation or correlation with high (>5 ft) waves were evident.

Subtidal sediments occurred in four facies: a shallow water, fine sand facies; a sand-silt facies, a deep water, coarse silt facies; and a coarse, polymodal relict facies. The facies were distributed according to depth (except for the relict facies) and varied little in position during the years 1978 and 1979. These facies are produced by natural processes; therefore, slight seasonal shifts of the facies normal to shore were interpreted as a response to summer/winter changes in the wave intensity. The seaward shift of coarse sediments offshore from the construction pad was probably caused by the seaward deflection of littoral drift by the construction pad.

The contemporaneous subtidal sediments varied in organic carbon content; however, no consistent areal or temporal patterns were evident. The carbonate carbon content of the contemporaneous sediments varied from 0 to 0.14% with only a slight tendency toward higher values at the deepest stations.

Relict sediments tended to have higher carbonate carbon content and, occasionally a higher content of organic carbon.

Sand was impounded in the intertidal zone upcoast of the construction pad. Downcoast, the stability of the beach has been reduced. Anomalous sediments, thougnt to be a result of dredge spoil dumping, were removed within one quarter, indicating that recovery from such perturbations occurs within three months. No permanent changes in the intertidal sediments were seen.

PLANKTON

Bimonthly plankton surveys were conducted to collect operational data for Unit 1 and preoperational data for Units 2 and 3.

Chlorophyll *a* concentrations were lowest in March and highest in September. Peak chlorophyll *a* concentrations in July and September did not occur in previous years; however, they could not be related to any other physical or biological event during that period. No consistent pattern of upcoast-downcoast variability was found for chlorophyll *a*. Phaeopigment concentration exhibited spatial and temporal distribution similar to that observed for 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. Phytopigment flourescence ratios indicated that phytoplankton stocks in the study area were in a healthy state during all surveys.

Mean total zooplankton abundance was lowest in January and highest in March. Typically, zooplankton were more abundant at the 10 and 15 m stations than at the 30 m stations. However, in July the opposite pattern was observed. Total zooplankton abundance at the upcoast reference transect tended to be either higher or lower than at other transects, otherwise, no consistent upcoast-downcoast pattern of total abundance was observed. Zooplankton dry weight biomass was lowest in January and highest in March, paralleling the pattern of total abundance. No consistent upcoast-downcoast pattern of biomass was detected.

Zooplankton species composition and rank order of abundance for select taxa was similar to that observed during 1975-1978. Any deviations from this pattern during 1979 were attributed to the inclusion of stations located farther offshore for the preoperational objective.

Significantly higher values of chlorophyll *a*, phaeopigments, total zooplankton abundance, and zooplankton biomass were observed for the lower depth stratum.

Periodic climatic patterns which affect local oceanographic phenomena, such as upwelling and intrusion of offshore surface water, appear related to distribution patterns of plankton observed from 1975 to 1979. No patterns of distribution or abundance (concentration) could be related to the operation of SONGS Unit 1. The natural variability of the offshore planktonic community near SONGS obscured any effects of Unit 1 operation.

SANDY INTERTIDAL

The effects of construction activities on the infaunal community occupying intertidal sands near SONGS in 1979 was studied. The results were similar to that observed in previous years. Although distinguishable from sandy infaunal communities at other exposed sites in the southern California Bight, the SONGS community was very similar in structure and species composition. Weighted multiple discriminant analysis of intertidal data indicated that beach slope and substrate grain size characteristics were the abiotic variables most closely associated with biotic distributional patterns. Slope and grain size characteristics of the sites immediately upcoast of the laydown pad were affected by the interruption of long-shore sediment transport. The unnaturally wide beach near the laydown pad has stabilized, and has ceased growing. Sites within 500 m downcoast of the pad were unstable in 1979, with marked accretion and/or erosion between surveys. The fauna at these sites remained rich, but density declined at a higher rate in the construction affected areas. Intertidal infaunal community changes were related to the presence of the laydown pad and changes in sediment transport associated with its presence. The mechanism through which the fauna are affected is unclear. The area will remain biotically and abiotically disturbed until the pad is removed, but should return to its pre-construction status with no long-term residual effects following pad removal.

INTERTIDAL COBBLE

Distributional characteristics of intertidal organisms and substrate were surveyed to detect changes related to operation of Unit 1 and construction of Units 2 and 3. Sampling was not conducted during the third quarter of because there were not acceptable low tides (lower than -0.1 m MLLW).

The most abundant taxa observed in 1979 were those that had previously been reported. Biotic variability in 1979 was attributed to seasonal changes in recruitment, mortality, and long-term population fluctuations.

Sand inundation and public recreational activities were the only observed factors altering the intertidal cobble community. Clamming activity at all stations was lower in 1979 than in previous years. Photographs of the fixed intertidal quadrats at all stations revealed that new cobble habitat was made available for the settlement of organisms during the winter and summer. Bare substrate was probably caused by wave induced cobble movement, fresh water runoff, sedimentation, and sand abrasion.

Construction of SONGS Units 2 and 3 caused temporary changes in the cobble communities at Station 3, due to accumulation of sand by the construction laydown pad.

No operational effects of SONGS Unit 1 on intertidal cobble biota were detected with this study. Detectable biotic changes that occurred were caused by sand inundation, resulting from winter-summer beach processes and winter storms.

SEDIMENT INFAUNA HABITAT

The benthic infaunal community in the vicinity of SONGS was investigated as part of the construction monitoring program for Units 2 and 3 and the operation of Unit 1. Benthos at stations upcoast and immediately adjacent to the Units 2 and 3 dredgeline construction site, and the operational Unit 1, displayed elevated numbers of species, individuals, and biomass in all trophic categories compared to reference areas. These patterns apparently resulted from accretion of sediments and elevated sediment organics related to construction and operation activities, respectively. Fewer infaunal species and individuals with lower overall biomass in all trophic categories occurred at stations downcoast and immediately adjacent to the dredgeline construction activities. These patterns apparently resulted from the interruption of natural longshore sediment transport processes by construction impediments.

Community distribution patterns of the dominant species were not influenced by construction activities. Dominant patterns included: increasing number of species with depth, species that were characterized by high abundance within specific depth regimes, and ubiquitous species groups. Community distribution patterns were controlled by depth, sediment composition, water clarity, sedimentation, and organic carbon content of the sediments. These features were influenced by natural processes, construction activities and generating station operation. It was not possible to separate natural and construction related effects; however, construction related impacts should not persist following the cessation of construction and removal of structural impediments to longshore sediment transport.

. .TIDAL COBBLE

Macroorganisms occupying subtidal cobble substrates were investigated as part of the Environmental Technical Specifications (ETS) program related to operation of SONGS Unit 1, the Construction Monitoring Program (CMP) and Preoperational Monitoring Programs (PMP) realted to SONGS Units 2 and 3. No biological data was collected at inshore stations completely covered with sand during the February 1979 survey.

An evaluation of quantitative data collected between 1975 and 1979 suggested the four principal factors responsible for the structure of benthic cobble communities in the vicinity of SONGS were: depth, substrate stability, light intensity, and biological interactions.

Comparison of substrate composition at the inshore cobble stations indicated sand accretion due to unusually adverse meteorological and/or oceanographic conditions had occurred rapidly during short periods of time (e.g. three months). Sand erosion, resulting in exposure of the original cobble habitats, was projected to take two years or longer.

The structure of the offshore kelp forest cobble communities was primarily a function of substrate composition and stability. The high abundance of crustose coralline algae at stations in the vicinity of the San Onofre Kelp (SOK) forest suggested that sand scouring had occurred. Additionally, the instability of the cobble substrate probably resulted in the mortality of juvenile Macrocystis plants in this area.

Foraging by the sea urchin Lytechinus was also advanced to explain low Macrocystis recruitment and development of foliose red algae in certain areas of the SOK forest. Abundance patterns of crustose coralline algae and Parvosilvosa at offshore cobble stations in the vicinity of the SOK forest appeared to be caused by both physical and biological perturbations. Sand scour, turbidity, shading, predation, and cobble abrasion were suggested as factors which influenced these patterns.

The San Mateo Kelp canopy grew over sampling stations between February and July 1979, and provided a natural experiment to evaluate the effect of shading on hard bottom communities. The most obvious effect was the significant reduction in abundance of the algal assemblage Parvosilvosa and the foliose red alga Rhodymenia. All offshore cobble stations in the SOK area had significantly higher mean percent algal cover than sessile invertebrate cover. In contrast, stations located in the San Mateo Kelp and near Barn Kelp had significantly higher mean sessile invertebrate cover.

No physical, chemical or ecological effects associated with the operation of Unit 1 or the construction of Units 2 and 3 were discernible at the inshore cobble stations, the kelp stations, or the offshore cobble stations during 1979.

ICHTHYOPLANKTON

An ichthyoplankton investigation was conducted near the San Onofre Nuclear Generating Station from August 1978 through July 1979 as a special activity of the preoperational monitoring program for Units 2 and 3. Samples of entrained ichthyoplankton were pumped from the Unit 1 intake riser via a 3 m standpipe. Intake samples were collected once each month during a 24 hr period. Concurrent nearshore ichthyoplankton samples were collected from the neuston by Manta net, the water column by Bongo net, and the epibenthos by Auriga net.

Twenty-five taxa comprised 99.9% of the intake collections, with the dominant species being Engraulis mordax, northern anchovy (52.9%), Genyonemus lineatus, white croaker (14.1%), and Seriphus politus, queenfish (5.8%). Size-selective entrainment was established for each target species. The maximum size class was 9 to 21 mm for northern anchovy, 0 to 9 mm for queenfish and white croaker. Estimates indicated that Unit 1 annually entrained about 900 million larvae.

A comparison of intake and nearshore ichthyoplankton samples indicated that water entrained by the Unit 1 intake is biologically representative of the midwater, with occasional strong influences from the epibenthos.

ADULT FISH FIELD STUDY

A diverse community of demersal fishes was studied in the community offshore SONGS using gill net and otter trawl. Temporal and spatial variability were related to foraging movements and reproductive activities including spawning and juvenile recruitment.

Within the community, the queenfish, Seriphus politus; white croaker, Genyonemus lineatus; walleye surfperch, Hyperprosopon argenteum; white surfperch, Phanerodon furcatus; and northern anchovy, Engraulis mordax were the numerically dominant species. The relative abundance of these species were seasonally predictable as evidenced by gill net catches from 1975 to 1979 and from otter trawl catches from 1978 to 1979. The numbers of individuals of Seriphus, Genyonemus, Hyperprosopon, and Phanerodon caught were generally greatest from April through October and least in December through March. Increased catches during April through October resulted from recruitment of Seriphus, Genyonemus, Hyperprosopon, and Phanerodon young-of-the-year, and the presence of reproductively active adults. Reduced catches of these species from December through March resulted from offshore and/or vertical migrations initiated or mediated by oceanic and/or meteorological distrubances such as storms.

The fish community did not appear to be adversely affected by the discharge of Unit 1 cooling water; although the reproductive condition (based on gonosomatic indices) of Seriphus and Genyonemus caught near the discharge was significantly different than that observed for other areas.

ADULT FISH IN PLANT

SONGS Unit 1 impinged an estimated 565,934±56,937 fish weighing an estimated 22,728.2±2,412.52 kg (50,107.04 lb) under normal operating conditions in 1979 and 18,713 individuals weighing 1,274 kg (2,809 lbs) under heat treatment conditions.

Queenfish (Seriphus politus) numerically dominated the normal flow impingement catches while walleye surfperch (Hyperprosopon argenteum) numerically dominated heat treatment catches. The length structure of impinged Seriphus was similar to the length structure of Seriphus caught offshore during all surveys. Analysis of sex composition of Seriphus revealed that more females were impinged at Unit 1 than were caught offshore.

Peak impingement catches of walleye surfperch occurred during the period of the year when gravid females were moving inshore and when young-of-the-yea, were moving offshore.

SPORT FISHERIES STATISTICS

Unpublished sport fishing data for the block surrounding SONGS (Block 756) was obtained from the California Department of Fish and Game. Data included monthly landings by species, number of angler hours, and southern California catch statistics.

Between 1975 and 1978, the sport catches of rockfish, barred sand bass, kelp bass, Pacific mackerel, Pacific bonito, California barracuda were 29.3, 52.3, 27.0, 29.6, 42.6, and 53.4 percent, respectively, for Block 756. This acccounted for 1.0, 16.5, 3.8, 3.9, 8.8, and 9.0% of the total landings for these species in southern California.

Catch per unit effort (CPUE) for the block in the vicinity of SONGS was significantly greater in 1978 than between 1973-1977. The CPUE FOR Block 756, however, was significantly lower than for other blocks. This was due to differences in fishing effort.

KELP

Studies of the kelp beds in the vicinity of San Onofre region were conducted from January 1979 through February 1980. Results of these investigations indicate that turbidity and sedimentation rates were elevated in the upcoast section of the kelp bed by construction dredging activities. No measureable change in kelp canopy accompanied the dredging activities; however, the affect of dredge-related turbidity and sedimentation on potential bed development and expansion is not known. Major canopy deterioration was associated with midwinter storms. Successful recruitment of Macrocystis was observed in the upcoast section of the SOK from September to December in 1978 and 1979.

CHAPTER 1

INTRODUCTION

This report presents analyses and interpretations of the data collected during oceanographic and marine biological studies conducted in 1979 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, III, and IV of the SONGS 1979 Annual Operating Report. These studies meet the requirements of the Federal Nuclear Regulatory Commission (NRC) and the State of California Regional Water Quality Control Board, San Diego Region (CRWQCB).

The analyses and discussions in this report integrate the physical, chemical, and biological data collected during 1979 in order to provide a basis for characterizing the marine environment in the vicinity of SONGS, and for evaluating the effects of SONGS operation and construction activities on the marine environment.

PURPOSE OF STUDIES

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

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 CRWQCB until 1975. In 1975, the Unit 1 Environmental Technical Specification (ETS) program was implemented in compliance with NRC requirements and this program has continued to the present. In 1976, in accordance with the Federal Water Pollution Control Act, the CRWQCB issued National Pollutant Discharge Elimination System (NPDES) permits for SONGS Units 1, 2, and 3 which included marine monitoring programs to replace previous MEM requirements. The existing NPDES monitoring program is essentially identical to the ETS program.

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 until December 1976. The emphasis then shifted when dredging began for the emplacement of the offshore portions of Units 2 and 3 cooling systems began. Studies focused on the offshore construction activities as set forth in the CRWQCB Order No. 71-6, Technical Change No. 2. These studies are referred to as the Construction Monitoring Program (CMP).

In 1978, a Preoperational Monitoring Program (PMP) was initiated in compliance with requirements of the Nuclear Regulatory Commission. The PMP along with other programs mentioned above, will provide a baseline of oceanographic and marine biological data prior to the operation of Units 2 and 3. The Preoperational 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 was started in June 1978 and is scheduled to end in June 1980, with 24 months of oceanographic and biological studies. A total of 18 months of preoperational data are reported in this volume.

DYNAMICS OF THE ECOSYSTEM

To determine the effects of SONGS operation on the local marine environment, it is necessary to understand both the natural system and the potential ways SONGS may impose environmental change. The oceanographic forces driving the biological community are large in both number and effect. Many natural, cyclic phenomena including seasonal changes in the current, water temperature, and nutrient regimes impose significant biological change. Events such as storms, whether local or distant, may impact the biotic and abiotic components of the ecosystem. Changes occurring in bottom topography as a result of sand and sediment transport may be reponsible for extensive habitat modification, thereby resulting in concomitant biotic redistribution.

The San Onofre Nuclear Generating Station Unit 1 adds natural changes in the physical environment, including currents, turbidity, temperature, and the substrate. Local populations may respond to these changes by altering their behavior and/or abundance. This may eventually lead to changes in community structure and the trophic structure. However, in context with the many variables which naturally assail biological resources, the generating station might not necessarily cause any significant changes.

It is concluded from these studies that only localized effects were caused by construction and cooling water system operation; however, these effects were small when compared to the effects of natural environmental variations.

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 Non-radiological Surveillance, and Section 4 Special Surveillance and Study Activities

- Nuclear Regulatory Commission - San Onofre Nuclear Generating Station, Units 2 and 3, Preoperational 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

Table 1-1. Data collection schedule for 1979.

	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	11		14		16		11		5		7[b] 27[c]	
Aerial Infrared Radiometry	X	X			11		14		a	1	11		5		7,27	
Surface Temperature Mapping	X	X			11		14		16	1	11		5		7	
Shoreline Temperature	X	X			11		14		16	1	11		5		7,27	
Continuous Temperature Maintenance	X			X	10,26	8	13	11,26	11,15	1	3,5, 20	1,8	4,14	2	2,13	6
Turbidity Vertical Profiles	X	X		X	11		14		16		11		5		7,27	
Secchi Disc Visibility	X	X			11		14		16		11		5		7,27	
Suspended and Settleable Solids					11		14		16		11		5		7	
Aerial Photographs of Turbidity	X				11		14		a	1	11		5		7,27	
Currents					10,11		13,14		15,16		10,11		4,5		6,7	
Heavy Metals	X	X		X	10		13		15	1[d]	12		4		9,29	
Dissolved Oxygen	X	X		X	11		14		16		11		5		7,27	
Hydrogen Ion Concentration	X	X		X	11		14		16		11		5		7,27	
Continuous Light and Temperature												7,31	9,10, 13,25	9,25	8,20	5,18
Biological Surveys																
Plankton	X	X		X	17-19		14-16		16-18		10-12		5-7		6-9	
Intertidal																
Sand			X			21,22			16,17			6,7				4,5
Cobble	X			X		26-27				13-14						3-19
Subtidal																
Sand			X			12,13 19,22			21,22			28,29 30			28,29	
Cobble	X	X	-	X		6-12		12-26			17	16		18	5	
Kelp Bed Macrobiota			X			6-12		12-26			17	16		18	5	
Fish																
Receiving Waters	X	X		X		15-16		17-18		27-28		26-27		16-17		12-13
Impingement																
Normal Operation	X	X							Twice	weekly						
Heat Treatments	X	X				15		22		24		5[e]	29		18	
Kelp Bed Mapping			X					13		6			20			20
Nutrient Analysis			X		26	15	15	17	16	20	11	20	11	12	16	28
Special Study: Ichthyoplankton*				X												

* Monthly, August 1977 to July 1979
[a] Equipment malfunction, flights rescheduled for 1 June
[b] Generating station offline, survey rescheduled for 27 November
[c] Unit 1 stations only
[d] Station 04N resampled
[e] Unattended

- o 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

- o Nuclear Regulatory Commision - Special ichthyoplankton study.

Table 1-1 shows the data collection schedule for 1979 and indicates the regulatory agency requirements fulfilled by each sampling task.

DESCRIPTION OF THE STUDY AREA

The San Onofre Nuclear Generating Station is located along the California coastline at 33° 22.5'N and 117° 32.5'W between the cities of San Clemente and Oceanside (Figure 1-1). The study area extends approximately 6.4 km (4 mi)

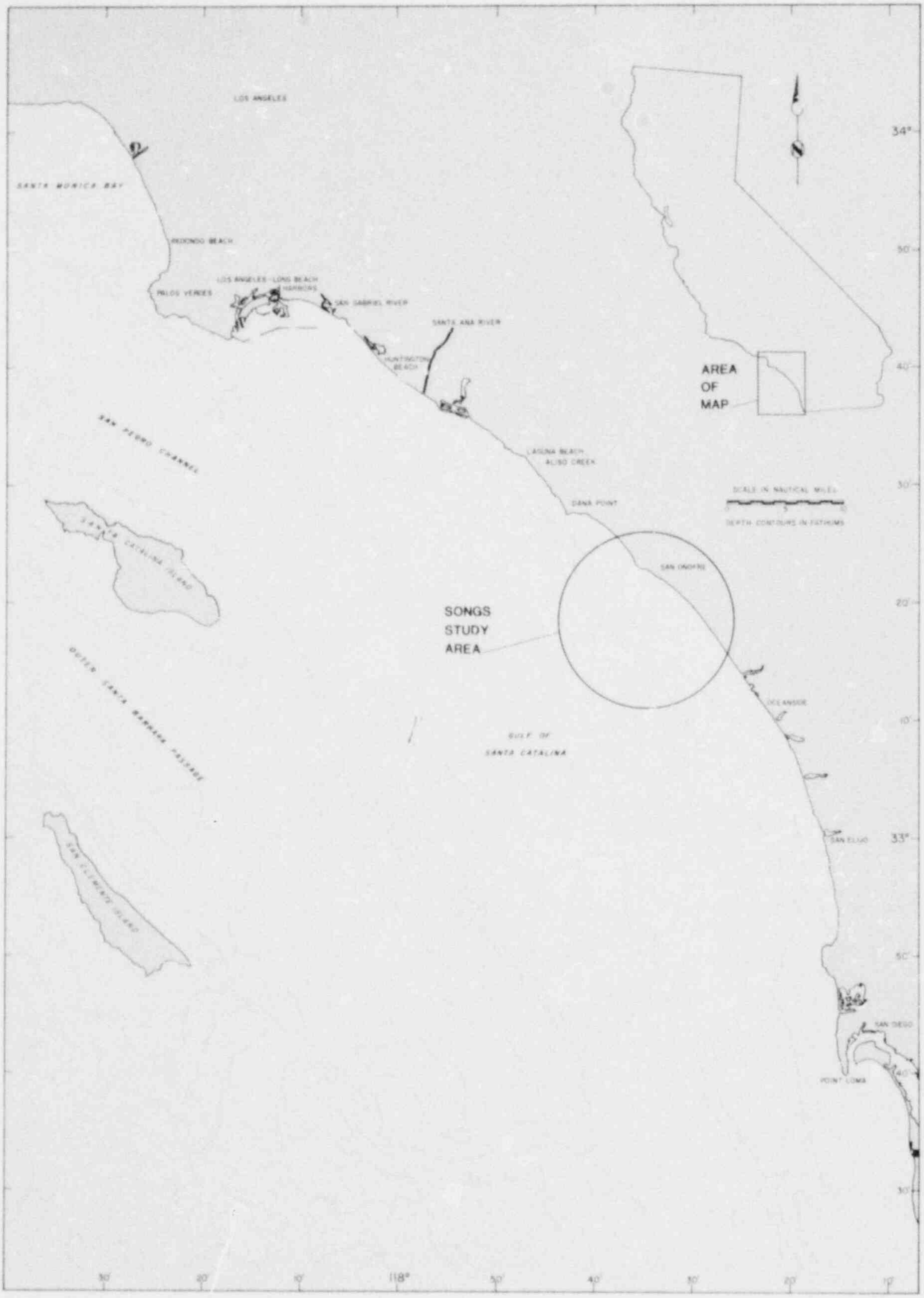

Figure I-1. Study area location.

upcoast (NW), 11.5 km (7 mi) downcoast (SE), and 3.3 km (2 mi) offshore from the generating station. 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. Electrical output of Unit 1 is 456 MW.

A once-through cooling system is used to cool the steam condensers. As illustrated in Figure 1-2 and shown in Table 1-2, seawater is drawn from a point 907.4 m (2977 ft) offshore, located in approximately 8.2 m (27 ft) of water. The offshore intake structure is fitted with a velocity cap which is designed to reduce the entrapment of marine organisms and draws water horizontally from a depth of 4 to 5 m. After passage through the intake conduit and the condensers, the cooling water travels through a discharge conduit which terminates in a vertical discharge structure located 750.4 m (2,462 ft) offshore in approximately 7.6 m (25 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 19°F across the condensers at a flow rate of 1,325 m^3/min (350,620 gpm).

The Unit 1 screenwell contains 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 1180 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 across the condensers of 19.1°F. As seen in Figure 1-2, the intakes will be located 970.2 m (3,183 ft) offshore in 9.8 m (32 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 1,786.1 m (5,860 ft) to 2,510.9 m (8,238 ft) offshore and range in depth from 11.9 m (39 ft) to 14.9 m (49 ft). The Unit 3 discharge diffuser will extend from 1,024.4 m (3,361 ft) to 1,889.8 m (6,200 ft) offshore and range in depth from 9.8 m (32 ft) to 11.6 m (38 ft).

SCOPE AND ORGANIZATION OF THE REPORT

Volumes I, II, III, and IV of the San Onofre, 1979 Annual Operating report were data reports containing the detailed results of the 1979 sampling. Volume I presented the physical-chemical oceanographic data from the Unit 1 ETS program, Units 2 and 3 Preoperational Monitoring Program (PMP), and NPDES monitoring. Volume II presented the biological data for intertidal infaunal, subtidal infaunal, kelp, and ichthyoplankton to meet requirements of Construction Monitoring Program, Preoperational Monitoring Program and special study of the PMP. Volume III contained biological data for plankton, hard benthos, rocky inter-

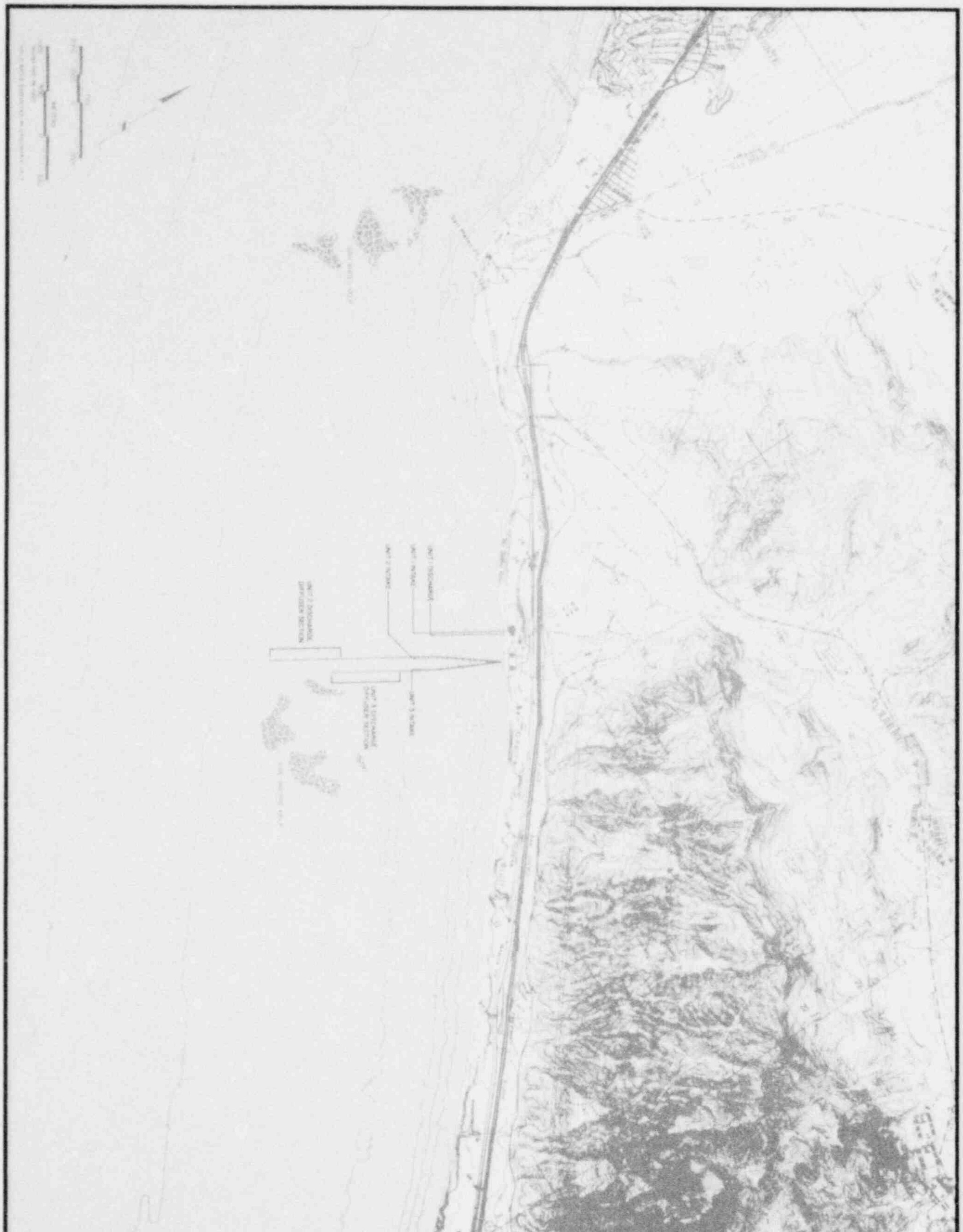

Figure I-2. Location of intake and discharge conduits for SONGS 1, 2, and 3.

Table 1-2. Circulating cooling water system characteristics at San Onofre Nuclear Generating Station.

	Unit 1	Units 2 and 3
Intake - Distance from Shoreline*	907.4 m (2977 ft)	970.2 m (3183 ft)
Flow Rate (gpm)	350,620	830,000 ea
Entrance Velocity	0.7 mps (2.2 fps)	0.5 mps (1.7 fps)
Bottom Material	Sand	Sand
Bottom Profile	Mild slope	Mild slope
Cap Dimensions	9.1 x 10.7 m (30 x 35 ft)	14.9 m (49 ft dia)
Cap Depth Below MLLW	3.5 m (11.5 ft)	3.7 m (12.25 ft)
Cap Height Above Bottom	4.7 m (15.5 ft)	5.4 m (17.8 ft)
Cap Overhang From Riser	1.3 m (4.3 ft)	2.2 m (7.3 ft)
Opening Height	1.2 m (4 ft)	2.1 m (7 ft)
Rip-rap Profile	Low relief	Mounded, low relief
Pipes - Offshore Diameter and Velocity	3.7 m/2.1 mps (12 ft/6.9 fps)	5.5 m/2.2 mps (18 ft/7.3 fps)
Length, Intake/Discharge	910.1/750.4 m (2986/2462 ft)	970.2/2510.9 m (3170/8238 ft 1889.8 m (6200 ft) (Unit 3)
Pump to Condenser Velocity	2.1 mps (6.3 fps)	2.1 mps (7.0 fps)
Condenser to Screenwell	2.0 mps (6.7 fps)	2.1 mps (7.0 fps)
Time - Intake to Screenwell	7.2 min.	7.9 min.
Screenwell to Pump	1.0 min.	1.5 min.
Pump to Condenser	0.3 min.	0.6 min.
Condenser to Outfall	6.4 min.	18.5, 13.3 min.
Screenwell Quiet Areas	No	Yes
Flow Pattern	Straight and turbulent	Angled and uniform
Screen Approach Velocity	0.5 mps (1.7 fps)	0.6 mps (2.0 fps)
Velocity Through Screen	1.2 mps (3.8 fps)	1.0 mps (3.0 fps)
Screen Number/Type	2-Trav.	7-Trav. each unit
Screen Mesh Opening	5/8 inches	3/8 inches
Trash Bar Opening	2.54 cm (1 in)	2.54 cm (1 in)
Pumps - Number and Type	2-Vert.	4-Vert. each
Submergence-margin	1.4 m (4.6 ft)	0.3 m (1 ft)
ΔT-degrees	19°F	19.1°F
Baseload or Peaking	Base	Base
Capacity Factor - 1979	87.9	Under Construction
Availability - % of Time in 1979	90.2	Under Construction
Theoretical Yearly Flow (gals)	18.43×10^{10}	43.6×10^{10} (ea)
Actual - 1979 Yearly Flow (gals) (approx.)	16.59×10^{10}	0 (under construction)

* Assuming a 45.7 m (150 ft) beach in front of the Units 2 & 3 seawall (the distance from the seawall to MHHW = 15.2 m ± 15.2 m (50 ft ± 50 ft) distance from seawall to MLLW = 61 m ± 30.5 m (200 ft ± 100 ft)

tidal for ETS Unit 1; NPDES; CMP Units 2 and 3; and PMP Units 2 and 3. The last data report, Volume IV, was concerned with the offshore fishery, impingement, and fishery statistics to fulfill ETS Unit 1, NPDES, and PMP Units 2 and 3 requirements.
P Units 2 and 3 requirements.

This report, Volume V, includes the results of analyses of these data and a discussion of how the results relate to the objectives of the studies. The chapters address oceanographic/biological elements of the ecosystem. Each chapter contains an introduction which outlines the scope of the work and pertinent background information. A brief description of the methods is followed by the results and discussion relative to the study objectives.

GENERATING STATION ACTIVITIES IN 1979

San Onofre Nuclear Generating Station, Unit 1 operational characteristics for 1979 are presented in Figure 1-3.

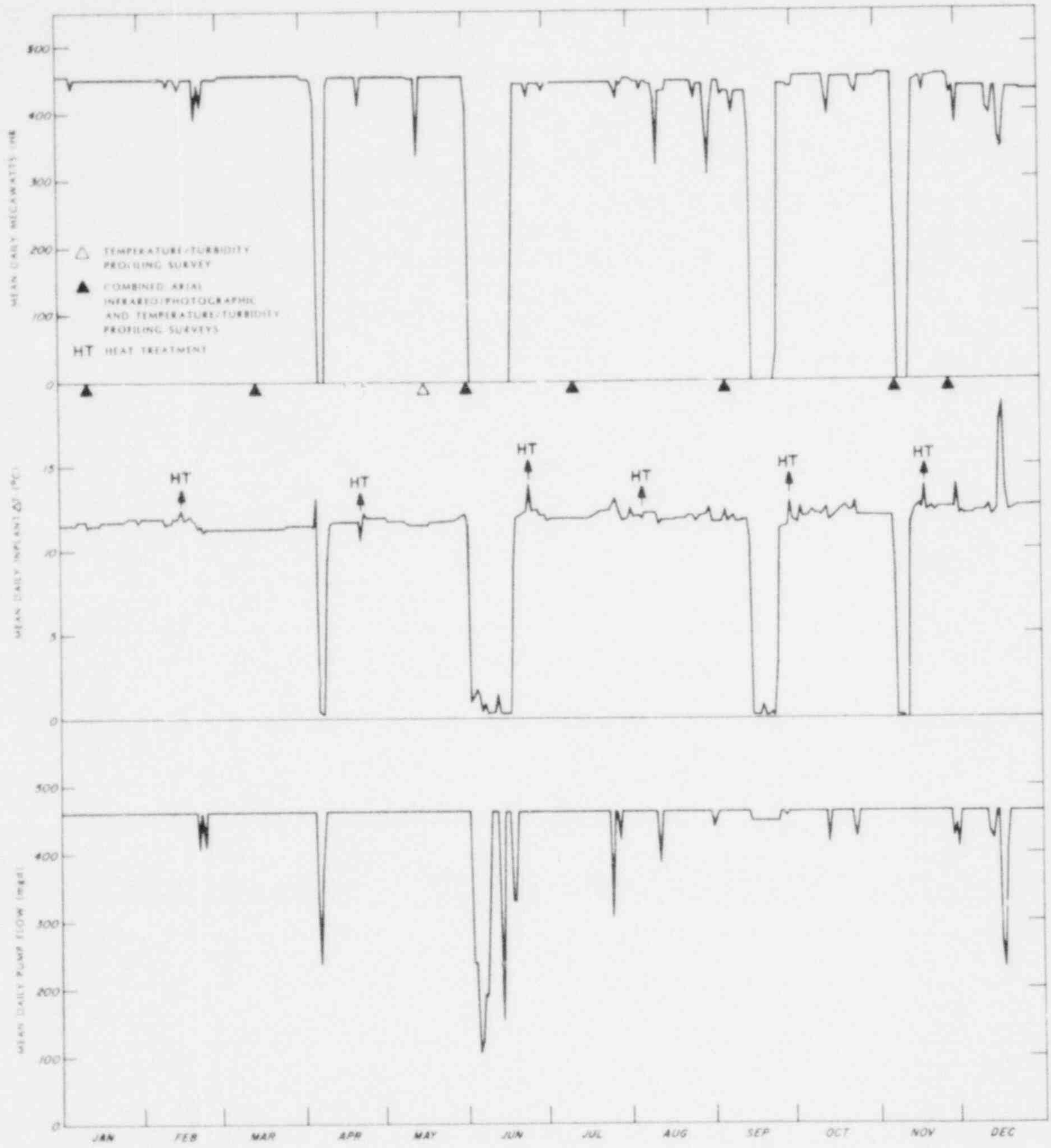

Figure 1-3. San Onofre Nuclear Generating Station Unit 1 operating characteristics during 1979.

CHAPTER 2

OCEANOGRAPHY

INTRODUCTION

This chapter presents the results, analysis, and interpretation of physical, chemical, and geological oceanographic measurements for San Onofre environmental studies. Major areas investigated were temperature, turbidity, dissolved oxygen, pH, selected heavy metals, beach and bottom sediment characteristics, beach slope, and deposition rates of suspended material. Wave, nearshore current, nutrient, light intensity, air temperature, wind speed and direction, and precipitation were obtained to aid in the definition of oceanographic conditions at San Onofre and the determination of effects of SONGS on the marine environment. Results of these temperature, turbidity, water quality, and sedimentology studies are presented in the following section.

CHAPTER 2A

TEMPERATURE

Temperature is the physical oceanographic parameter most directly affected by coastal generating stations which use ocean water for once-through cooling of steam condensers. The San Onofre Nuclear Generating Station Unit 1 (SONGS 1) utilizes 460 million gallons per day (mgd) (1209 m^3/min) of ocean water for cooling of steam condensers. As ocean water passes through the steam condensers of the circulating seawater system of SONGS 1, its temperature is increased by approximately 12°C. When SONGS 2 and 3 commence operation, each unit will utilize 1195 mgd (3137 m^3/min) of ocean water, and the temperature increase will be approximately 11°C. This combined flow of 2850 mgd of warmed seawater represents 19.3 x 10^9 BTU's of waste heat introduced to the ocean each hour.

Since the most ostensible effect of SONGS on the marine environment is the discharge of large volumes of heated water, temperature measurements are the most appropriate way to show the area of influence of SONGS. Temperature is also a good indicator of natural phenomena in the marine environment. Temperature can be used to identify oceanographic processes such as upwelling, storms, major currents, internal waves, and general characteristics of water masses.

Temperature monitoring at San Onofre began in 1963, five and one half years before full operation of SONGS 1. Between 1963 and 1975, temperature was measured as a portion of the Marine Environmental Monitoring (MEM) program required by the California Regional Water Quality Board, San Diego Region (CRWQCB). From 1975 to present, temperature measurements were obtained as a portion of the SONGS 1 Environmental Technical Specifications (ETS) program required by Nuclear Regulatory Commission (NRC). In 1976, the CRWQCB issued permits for SONGS 1, 2, and 3 under the National Pollutant Discharge Elimination System (NPDES) which included a temperature monitoring program similar to the ETS temperature program. Temperature measurements were initiated in 1978 as a portion of the Preoperational Monitoring Program (PMP) required by the NRC to determine natural baseline conditions for SONGS 2 and 3. Temperature measurements have been obtained in conjunction with the Construction Monitoring Program (CMP) for SONGS 2 and 3 which began in 1974.

Temperature was extensively measured throughout the seventy square kilometer SONGS study area as part of the physical and biological monitoring programs. The objectives of temperature studies were to: 1) document large spatial and temporal changes in temperature throughout the study area, 2) establish preoperational baseline conditions before operation of SONGS 2 and 3, 3) determine the horizontal and vertical extent of the thermal plume from SONGS 1, 4) determine the area of influence of SONGS 1, 5) estimate the extent to which heated water from SONGS 1 is recirculated back into the intake of the circulating water system, and 6) provide temperature data for the analysis and interpretation of biological findings.

METHODS

An integrated study approach to monitoring was used to fulfill objectives of temperature studies. This integrated study approach consisted of intensive bimonthly field surveys to determine spatial variations in temperature, continuous temperature monitoring at a few locations to determine temporal variations in temperature, and discrete temperature measurements in conjunction with biological sampling.

A detailed, nearly-instantaneous picture of temperature conditions throughout the study area was obtained from bimonthly survey measurements. Vertical temperature profile measurements at 74 stations (Figures 2A-1 and 2A-2) documented spatial differences in temperature, vertically and horizontally, throughout the study area. Aerial infrared radiometer measurements and surface temperature mapping by survey vessel were used to determine horizontal extent and location of the surface thermal field from SONGS 1. Aerial infrared measurements also documented spatial variation of surface temperature in the area of SONGS 2 and 3 diffusers. Shoreline temperature measurements were used to determine shoreward extent of the thermal field.

Surface, middepth, and bottom temperature was continuously recorded by ENDECO Type 109 temperature sensors at three stations to determine temporal variations in temperature due to natural conditions and SONGS 1. Surface, middepth, and bottom temperature was continuously measured at one location 2000 feet (610 m) downcoast of SONGS 1 discharge (Station C2S) to document natural and plant induced changes in temperature with time. A SONGS 1 continuous temperature control station (Station C22S), located beyond the influence of SONGS 1, documented natural temporal fluctuations of temperature. Continuous temperature measurements in the vicinity of SONGS 2 and 3 diffusers (Station F2S) also documented natural variations prior to operation of SONGS 2 and 3. Continuous temperature measurements at hard bottom benthic stations for SONGS 2 and 3 began in September 1979.

In-plant intake and discharge temperature data were continuously recorded by SCE within the upper three feet of the intake and discharge conduits. Intake and discharge temperature data were used to estimate the extent to which heated water is recirculated back into the intake of the circulating water system and determine the increase in discharge temperature as a result of recirculation.

Each technique of the integrated study of temperature has its advantages and disadvantages. Field survey measurements are the only practical method of defining in detail spatial variations (vertically and horizontally) throughout the study area, and the location and extent of the thermal plume from SONGS 1. Continuous temperature monitoring at selected sites is the best method of determining the overall temperature environment at San Onofre. These measurements are used to identify large scale natural oceanographic phenomena, determine the representativeness of survey measurements to natural conditions, document temporal variations in temperature, and estimate the frequency and amount of recirculation through the cooling water system of previously discharged waters.

By taking an integrated study approach, the most advantageous techniques may be utilized to fulfill specific objectives of the study.

A detailed description of instrumentation and methods used for temperature measurements was presented in Volume 1, Oceanographic Data Report (SCE 1980a).

RESULTS

Results of receiving water temperature monitoring are separated into three sections: 1) bimonthly surveys, 2) continuous temperature, and 3) intake, discharge, and ambient temperature comparison.

BIMONTHLY SURVEYS

Bimonthly surveys were conducted on 11 January, 14 March, 16 May, 11 July, 5 September, and 7 November 1979. An additional survey of SONGS 1 stations was conducted on 27 November 1979. Data collected during these surveys were presented in tabular and graphical form in Volume 1, Oceanographic Data Report (SCE 1980a). Results of bimonthly survey measurements are presented in tabular and graphical form in Appendix I.

Vertical profiles of temperature were taken at the 74 stations shown on Figure 2A-2. The temperature distribution at the surface, four meters of depth, and bottom determined from these profiles are shown as temperature contours on Figures I-1 through I-21 of Appendix I.

Surface temperatures were affected by the SONGS 1 thermal discharge, as illustrated in the surface contours. Other predominant features of the surface isotherms were variations in natural temperature with distance offshore, and among SONGS 2 and 3 sampling stations. The variation in natural surface temperature with distance offshore ranged from 0.4°C during the January survey to 2.0°C during the July survey, with offshore waters generally being cooler than inshore waters. Surface temperatures at offshore locations for SONGS 2 and 3 varied from 0.4°C during the January survey to 1.8°C during the July survey.

Temperatures at four meters of depth were not affected by the thermal discharge from SONGS 1, with the exception of a few stations within 600 m of the discharge. Natural offshore variations in temperature at four meters of depth ranged from 0.4°C during the January survey to 2.0°C during the May and September surveys. Natural variations in temperature for SONGS 2 and 3 stations at four meters of depth also ranged from 0.4°C during the January survey to 2.0°C during the September survey.

Bottom temperatures were not affected by the SONGS 1 thermal discharge except at shallow nearshore stations (depth less than 4 m) inshore of the discharge. Bottom temperature showed the largest variations with distance offshore and among SONGS 2 and 3 stations, due to increasing depth of the bottom with distance offshore and natural stratification of temperature with depth. Bottom temperature usually decreased with distance offshore (increased depth). The variation in natural bottom temperatures at SONGS 1 stations ranged from 0.7°C during the January survey to 8.5°C during the September survey. The variation in natural bottom temperatures at SONGS 2 and 3 stations was similar, ranging from 0.4°C during the January survey to 7.0°C during the July survey.

A comparison of the mean, standard deviation, and range of surface, four meters of depth, and bottom temperatures is presented by survey in Table I-1. Similar information is presented by station in Table I-2.

The vertical temperature structure of waters offshore of SONGS is illustrated in isometric vertical cross-sections (Figures I-22 through I-28). These figures illustrate that the depth of the thermal field seldom exceeded three meters of depth, and became shallower with distance from the discharge.

Results of aerial infrared radiometer measurements are shown on Figures I-29 through I-43. The 1° and 4°F elevated temperature fields exhibited large variations in their size, shape, and location. The approximate surface area of the 1°F (0.6°C) elevated temperature field ranged from 1 acre on 5 September to 1500

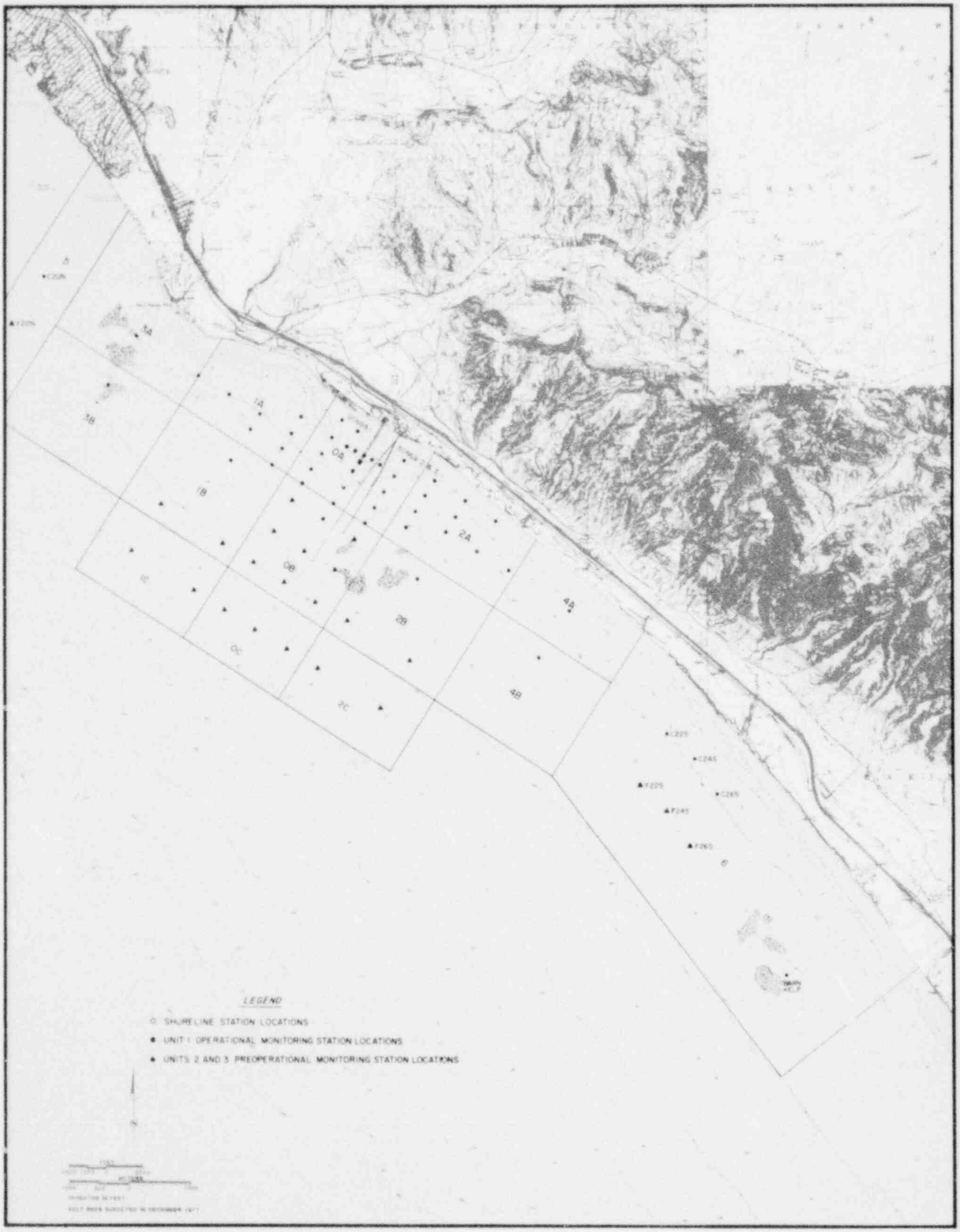

Figure 2A-1. Environmental surveillance zones and physical and chemical station locations.

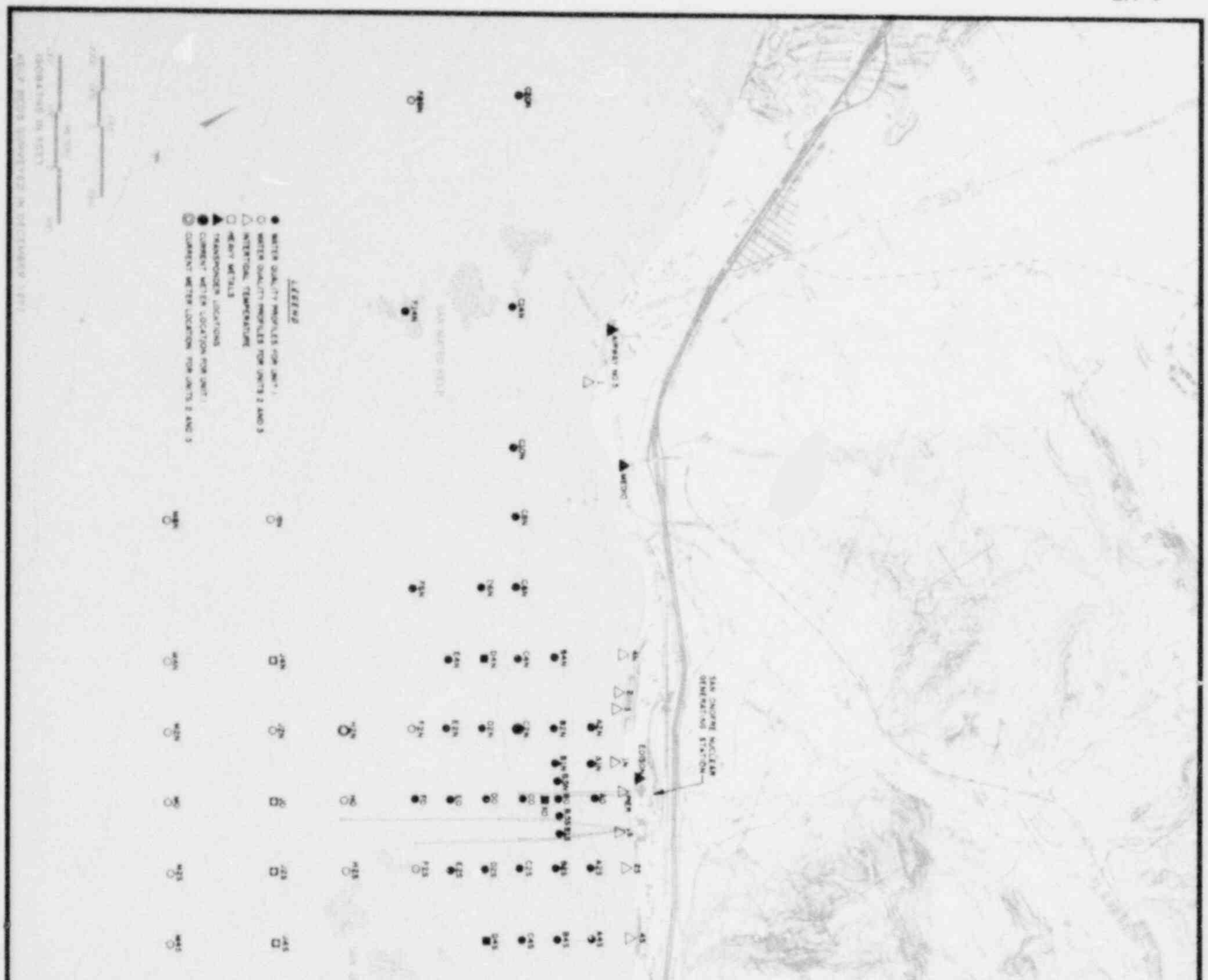

Figure 2A-2. Location and identification of oceanographic sampling stations.

acres on 11 July. The 4°F (2.2°C) elevated temperature field had a maximum surface area of 30 acres on 14 March, and was not observed during the 5 September and 7 November aerial flights.

The maximum extent of the 1°F elevated temperature field away from the discharge was approximately 3800 m during the 14 March survey, and the maximum extent of the 4°F elevated temperature field was 600 m during the same survey. The 1°F elevated temperature was observed in contact with the shoreline during 11 of the 15 infrared radiometer flights. The 4°F elevated temperature field was never observed in contact with the shoreline.

The variation in natural surface temperature with distance offshore and in the SONGS 2 and 3 discharge area ranged from 0.3 to 1.6°C during infrared radiometer flights.

Results of survey vessel mapping of surface temperature during bimonthly surveys are shown on Figures I-44 through I-51. The size, shape, and extent of the surface thermal field were similar to that determined from infrared radiometer flights.

CONTINUOUS TEMPERATURE

Continuous temperature data at the surface, middepth, and bottom of Stations C2S and C22S and at the surface, two middepth locations (4.5 and 9 m of depth), and bottom of Station F2S were presented graphically in Volume 1, Oceanographic Data Report (SCE 1980a). Monthly mean temperatures and standard deviations at Stations C22S, C2S, and F2S are presented in Table I-3. The percent of time that temperatures at these stations differed from one another by more than 1.0°C is shown in Table I-4.

A Student's t-test comparison of monthly mean temperatures reveals that surface, mid-depth (4.5 m), and bottom (9 m) temperature were significantly different between stations for each month of 1979. An F-distribution comparison of variances between locations revealed that variances in temperature were significantly different during most months. No apparent pattern was observed in the comparison of monthly mean temperatures, with the following exceptions: 1) monthly mean surface temperatures at Station C2S were usually warmer than at Station F2S for the first six months of the year, and monthly mean surface temperatures at Station F2S were warmer than at Station C2S for the next five months, and 2) monthly mean surface and bottom temperatures at Station C2S were usually warmer than at Station C22S.

Observed fluctuations in ocean temperature are composed of several cyclic components of various amplitudes and frequencies. Power spectral density estimates are shown for each continuous temperature monitoring location on Figures I-52 through I-61. These figures present the relative importance, based on duration and amplitude, of temperature fluctuations in the temperature record. Since this type of analysis includes the duration of the temperature fluctuation as well as its amplitude, low frequency (long duration) changes with small amplitudes can have greater power spectral density than high frequncy (short duration) changes with large amplitudes (Jenkins and Watts 1968).

Meaningful power spectral estimates for low frequencies depend on the length of the continuous temperature record. Estimates with periods greater than one-third of the record length are of marginal value. Power spectral estimates were determined for the four-year data base of 1976 through 1979 at the surface and bottom of Station C2S, located 610 m downcoast of SONGS 1 intake, to obtain better estimates of the lower frequency fluctuations in temperature. The power spectral density estimates for the four-year data base at the surface and bottom of Station C2S are presented on Figures I-62 and I-63.

The relative importance of the amplitude of temperature fluctuations is illustrated in filter band plots shown on Figures I-64 through I-73 for each continuous temperature location. These figures present the fluctuations of temperature within frequency bands which correspond to the following periods: less than or equal to eight days, between 8 and 60 days, and greater than or equal to 60 days. The actual temperature record is also shown on these figures.

Fluctuations with periods greater than 60 days represent seasonal cycles in continuous temperature records. Fluctuations with periods between 8 and 60 days represent fluctuations usually due to large-scale meteorological and oceanographic conditions, and fluctuations with periods less than eight days usually represent changes caused by local processes in the San Onofre area (Koh and List 1974). The amplitude of short term fluctuations is often greater than the amplitude of seasonal fluctuations.

Filter plots of the four-year data base of surface and bottom temperatures at Station C2S are presented on Figures I-74 and I-75. These figures illustrate only the temperature fluctuations which had periods of 8 to 60 days, or greater than 60 days during the four-year period of 1976 through 1979. The actual temperature record is also shown in these figures.

Bimonthly filter plots better illustrate the magnitude of higher frequency temperature fluctuations. Bimonthly filter plots at the surface, middepth, and bottom of Station C2S, the surface of Station C22S, and the bottom of Station F2S are shown in Figures I-76 through I-85 for winter (January-February) and summer (July-August) conditions. These figures illustrate the fluctuations in temperature with periods less than or equal to 10 hours, between 10 and 30 hours, and greater than 30 hours. The actual temperature record and the predicted tide height are also shown on these figures.

Results of autocorrelation of surface, middepth, and bottom temperature at Station C2S, and bottom temperature at Station F2S are shown on Figures I-86 through I-93 for winter (January-February) and summer (July-August) conditions. These figures show how persistent temperature measurements at one location are with time (Bendat and Piersol 1971). Results of an autocorrelation of the amount of thermal stratification at Station C2S (surface minus bottom temperature) are presented on Figures I-94 and I-95 for winter (January-February) and summer (July-August) conditions, respectively.

A coherency function was calculated to determine how well fluctuations in surface, middepth, and bottom temperatures at Station C2S matched similar fluctuations at Station C22S and Station F2S. The coherency function is calculated as:

$$Hxy^2(f) = Gxy^2(f) / Gx(f)\ Gy(f)$$

where: $Hxy^2(f)$ is the coherency function between two records x and y, $Gxy^2(f)$ is the cross-spectral density function of records x and y, $Gx(f)$ is the power-spectral density function of the x record, and $Gy(f)$ is the power-spectral density function of the y record.

The coherency function has a value between 0 and 1 and relates how well two records vary together with frequency (Bendat and Piersol 1971). The coherency functions between the surface, middepth, and bottoms of Stations C22S and C2S, and between Stations C2S and F2S are presented in Figures I-96 through I-102.

INTAKE, DISCHARGE, AND AMBIENT TEMPERATURE COMPARISON

Intake, discharge, and ambient temperatures were measured hourly during 1979. Monthly plots of intake, discharge, and ambient temperatures are shown in Figures I-103 through I-114. The ambient temperature used for these figures is the surface temperature at Control Station C22S, as set forth in ETS for SONGS 1.

Monthly means and standard deviations of intake, discharge, and surface ambient temperatures are presented in Table I-5. Seasonal and monthly variations were similar for intake and ambient temperatures. Intake temperatures were warmer than surface ambient temperatures from January through April and during November and December. Intake temperatures were cooler than surface ambient temperatures from May through October. These cooler intake temperatures were primarily the result of natural temperature stratification during the spring and summer months.

The percent of time that intake and ambient temperatures differed by more than 1.0°C is also presented in Table I-5. Intake temperature was warmer than ambient temperature by 1.0°C or more 28 percent of the time. Ambient temperature was warmer than intake temperature by 1.0°C or more 17 percent of the time. Intake and ambient temperatures were within 1.0°C of each other 55 percent of the time.

Discharge temperatures exhibited greater monthly variations than intake temperatures due to fluctuations in generating station operation. Short-term fluctuations in generating station operation occurred during periods of normal operation. These operational fluctuations are shown as spikes in discharge temperature records on Figures I-103 through I-114. The larger spikes in discharge temperature were usually due to heat treatment of the cooling water conduit.

DISCUSSION

The most direct effect of coastal generating stations which use ocean water for once-through cooling of steam condensers is on temperature of receiving waters. Temperature was extensively measured throughout the San Onofre area to determine natural temperature conditions and the effect of SONGS 1 operation on the distribution of temperature.

TEMPORAL TRENDS

The annual temperature cycle at San Onofre for 1979 was typical of average conditions, as illustrated by the comparison of monthly mean surface temperature at the downcoast control station to the fourteen year mean of surface temperature at San Clemente Pier (Conway 1980; Robinson 1978) shown in the lower graph of Figure 2A-3. Monthly mean temperatures at the downcoast control station were within 1°C of the monthly mean temperatures for the previous fourteen year period (1965 through 1978) at San Clemente Pier, located 17 km upcoast of the control station. Natural temperature followed a cyclic heat balance consistent with the seasonal variation in the amount of insolation. Natural temperature was coolest during the winter months, when insolation was at a minimum, and increased during the spring and summer months as insolation increased. Natural temperature steadily decreased after its peak in August.

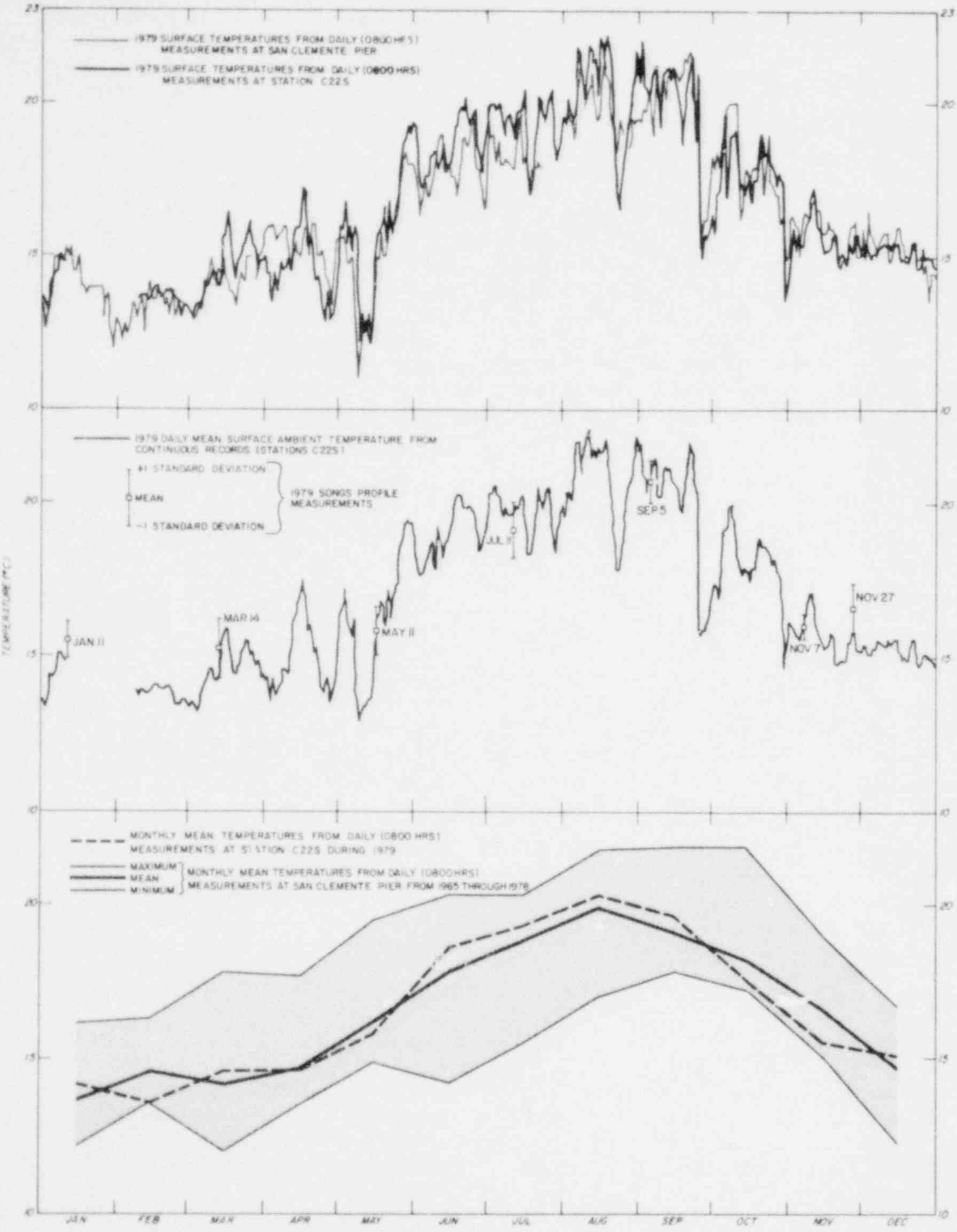

Figure 2A-3. Surface temperature conditions near San Onofre.

The seasonal fluctuations in natural surface temperature during 1979 followed the seasonal insolation pattern more closely than the three previous years, as illustrated in filter plots for natural surface temperature from 1976 through 1979 (Figure I-74).

Within this seasonal cycle, several shorter duration natural cooling and warming trends were observed. These cooling and warming trends, with periods of a few days to a month, generally had the greatest effect on natural temperature during the summer months, as shown in Figure I-74, and caused temperatures to vary as much as the seasonal range (approximately 6°C) within five days. The seasonal trends and shorter term trends combined to result in a 10°C range in natural temperature during 1979.

The shorter duration warming and cooling trends in natural temperature were observed throughout the study area, as shown by the comparison of daily temperature records at the downcoast control station and San Clemente Pier (upper portion of Figure 2A-3). Natural fluctuations within the seasonal cycle were similar at these two locations, but temperature differences of 2 to 3°C were often observed between locations.

The representativeness of bimonthly surveys is illustrated on the central graph of Figure 2A-3. The daily mean natural surface temperature at downcoast control stations (C22S) was within one standard deviation from the mean for surface temperatures at SONGS 1 sampling stations, with the exception of the 11 January and 27 November surveys. The mean and standard deviation at SONGS 1 sampling stations includes stations influenced by the discharge. Bimonthly surveys during 1979 were fairly representative of the seasonal cycle in temperatures, but were not always representative of short duration warming and cooling trends.

The period of time for which bimonthly surveys were representative of temperature conditions at San Onofre varied with time of the year. Results of autocorrelation analyses of continuous temperature records for two month periods reveal that discrete surface temperature measurements were representative of surface temperature conditi for periods ranging from approximately 3 to 6 days. Middepth temperature measurements (4.5 m) were representative for longer periods, ranging from 3 to 14 days. Bottom temperatures were representative of conditions from 3 to 15 days, with longer periods of representativeness during the first half of the year (January to June).

Patterns in vertical stratification of temperature followed the seasonal insolation pattern. During winter months, temperatures throughout the water column were relatively isothermal. Increased insolation during spring and summer increased surface temperatures and resulted in formation of a thermocline. The intensity of this thermocline generally increased from spring through summer and decreased in fall. Autoc relation analysis shows that the intensity of the thermocline was persistent for periods of 3 to 7 days.

TEMPORAL VARIATIONS

Temporal variations in natural temperature covered the range of the frequency spectrum, from seasonal ends to fluctuations within a few hours. Spectral analysis of continuous temperature records shows that significant cyclic fluctuations in temperature occurred at frequencies corresponding to periods of approximately 75 days, 37 days, 30 days, 20 days, 10 days, and 25 hours during 1979. The power spectrum of the four year data base at Station C2S surface and bottom illustrate that the fluctuations with periods of approximately 60 days, 37 days, 30 days, 20 days, 10 days, and 25 hours are present throughout the four-year data base.

The power spectral density estimates indicate the relative importance of temperature fluctuations with respect to the duration and amount of temperature variation. For evaluating the impact of a thermal discharge, the magnitudes of natural temperature fluctuations are more important than the duration of their effect. The magnitude of temperature variations with time is illustrated in filtered annual temperature records. The magnitude of temperature variations with periods of greater than 60 days was approximately 6°C at the surface and middepth, and approximately 4°C at the bottom (9 m of water). The magnitude of temperature variations with periods of 8 to 30 days was approximately 6°C at the surface, middepth, and bottom.

Short-term fluctuations, with periods of less than eight days, significantly affected surface, mid-depth, and bottom temperature records at continuous temperature stations for SONGS 1, 2, and 3. The magnitude of these short term temperature variations at the surface, mid-depth, and bottom varied with season. During winter months (December through February), the magnitude of fluctuations was small, on the order of 1°C. During the summer months the magnitude of fluctuations was significantly greater; 2 to 3°C at the surface, 3 to 4°C at mid-depth, and 4 to 5°C at the bottom.

The relative importance, magnitude, seasonality, and tidal correlation of these short term fluctuations are better illustrated in the bimonthly filter plots. These plots illustrate the correlation of tidal and temperature fluctuations. The often large, short duration fluctuations in temperature are due to tidal currents which can bring water masses of different temperature to a sampling location within a few hours.

SPATIAL TRENDS

Spatial trends in the distribution of natural temperature were observed during bimonthly oceanographic surveys. Ocean temperatures at the surface and four meters of depth generally decreased with distance offshore during bimonthly surveys, with the exception of the 7 November survey, when natural temperature increased with distance offshore. Differences in natural temperature with distance offshore ranged from 0.4 to 2.0°C. Bottom temperatures naturally decreased with distance offshore due to increasing bottom depth and natural temperature stratification with depth.

Differences in temperature from profile measurements were due to spatial trends as well as time differences between measurements. Nevertheless, results of nearly instantaneous infrared measurements revealed changes of similar magnitude in natural temperature at the surface with distance offshore and in the SONGS 2 and 3 study area.

Continuous temperature measurements illustrated several spatial trends. Nine out of 12 monthly mean surface temperatures at the station 610 m downcoast of SONGS 1 intake (Station C2S) were warmer than at the downcoast control station (Station C22S) due to the influence of the thermal field. Monthly mean bottom temperatures at Station C2S were slightly warmer than at Station C22S. Monthly mean surface temperatures at Station C2S were warmer than those at Station F2S (910 m offshore of Station C2S) from January through June, and December. Even though surface temperatures at Station C2S are periodically influenced by the thermal plume from SONGS 1, monthly mean temperatures at Station C2S were cooler than at Station F2S from July through November 1979.

SPATIAL VARIATIONS

Significant spatial variations were observed in natural temperature. Spatial variations of natural temperature in the SONGS 1 and SONGS 2 and 3 study areas ranged from 0.4 to 2.0°C during bimonthly surveys.

Figure 2A-4. Composite 1° F elevated temperature fields from aerial infrared measurements during 1979.

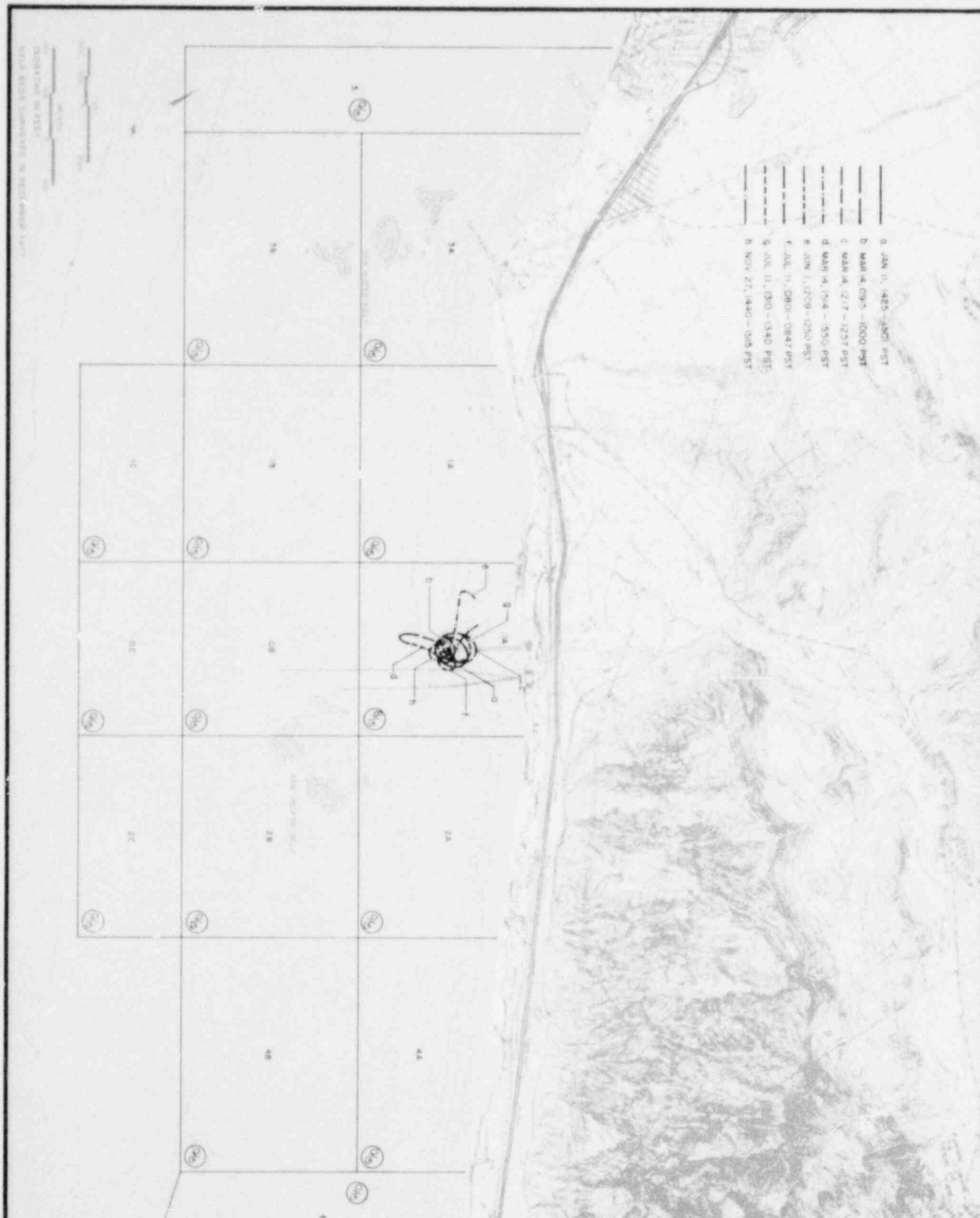

Figure 2A-5. Composite 4° F elevated temperature fields from aerial infrared measurements during 1979.

Temperature profile measurements revealed significant alongshore variations in natural temperature. These variations were of similar magnitude to those observed in the onshore-offshore direction, but there was no consistent pattern in longshore distributions. The variation in natural temperatures at the surface and four meters of depth in the SONGS 2 and 3 preoperational study area ranged from 0.4 to 1.8°C during bimonthly surveys.

Significant differences were also observed between continuous monitoring locations. Daily, weekly, and monthly mean temperatures were often significantly different between locations. Due to the large natural spatial variability of temperature, it is futile to compare simultaneous temperature measurements from two locations separated by a kilometer or more and expect them to be the same.

Although simultaneous temperature measurements at two locations were often different, the fluctuations in temperature with time at two locations were often similar. Results of coherency analysis reveal that low frequency fluctuations in surface temperatures at Stations C2S, F2S, and C22S were usually more coherent than higher frequency fluctuations, although several discrete high frequency fluctuations had high coherency. High coherency was observed for temperature fluctuations of approximately 0.5, 1, 3, 13, and 21 days.

The coherency of surface temperature fluctuations was higher between Stations C2S and C22S than between Stations C2S and F2S, especially at lower frequencies. Stations C2S and C22S are both in nine meters of water and are separated by 6,100 m alongshore. Station F2S is in 15 m of water and is 900 m offshore of Station C2S. These coherency functions illustrate that surface temperature fluctuations are more coherent in the longshore direction than in the offshore direction even though the longshore separation was approximately seven times that of the offshore separation.

Coherency of middepth temperature fluctuations was generally higher between Station C2S and F2S than between Stations C2S and C22S. Coherency of middepth temperature in the longshore direction was usually greatest at higher frequencies and relatively small in lower frequencies. This pattern may be due in part to gaps in the continuous temperature record at Station C22S mid-depth. Low frequency fluctuations of middepth (4.5 m) temperatures were usually more coherent than high frequency fluctuations between Stations C2S and F2S.

Coherency of bottom temperature fluctuations was generally greater for lower frequencies, although high coherency occurred for frequencies with corresponding periods between one and two days. Coherency of bottom temperature fluctuations were generally greater in the longshore direction, especially in temperature fluctuations with periods between 2 and 10 days.

THERMAL INFLUENCE OF SONGS 1

The area of thermal influence of SONGS 1 is illustrated by the composites of the areal extent of the 1 and 4°F elevated temperature fields shown on Figures 2A-4 and 2A-5. The circled fraction located in the corner of each environmental surveillance zone indicates the number of times during the fifteen infrared flights of 1979 that the elevated temperature field was observed in any portion of that surveillance zone.

The surface extent of the 1 and 4°F elevated temperature fields exhibited large variations during 1979, as shown on Figures 2A-4 and 2A-5, and presented in Table 2A-1. Significant differences in the size of the 1 and 4°F elevated temperature fields were also observed between infrared flights of the same survey, especially during the 11 January, 11 July, and 27 November surveys.

Table 2A-1. Characteristics of the 1° F and 4° F elevated temperature fields, 1979.

Date	Time PST	Tidal Height (m)	Wind Speed (kn)	Wind Dir (°T)	Air Temp (C)	Plantload MW	Plantload ΔT (°C)	Natural Surface Temp (°C)	Area of Thermal Field (Acres) 4°F	Area of Thermal Field (Acres) 1°F	Thermal Field Horizontal Extent (m)[a] 4°F UC	4°F DC	4°F IS	4°F OS	1°F UC	1°F DC	1°F IS	1°F OS
Jan 11	1023-1101	1.1	2.7	237	13.7	430	11.4	15.2±0.1	< 1	380	90[b]	-	-	-	1300	500	750[c]	650
	1425-1501	-0.2	5.3	277	14.7	431	11.4	16.0±0.2	20	660	150	200	100	150	800	1700	750[c]	650
Mar 14	0915-1000	1.6	9.7	173	14.6	431	11.[illegible]	14.7±0.1	6	700	150	40	90	100	3100	950	750[c]	1000
	1217-1257	0.9	5.5	216	15.3	432	11.2	14.9±0.2	20	720	200	150	300	90	2100	2200	700	500
	1514-1550	0.1	5.2	263	15.2	433	11.2	15.5±0.3	30	1500	600	100	350	60	3800	3600	750[c]	750
June 1	1209-1250	0.8	9.4	258	18.0	425	12.0	18.6±0.1	10	320	150	150	-	500	350	1000	750[c]	700
Jul 11	0801-0847	0.6	11.8	155	18.7	430	11.7	18.3±0.1	9	100	20	150	20	200	550	300	200	450
	1114-1150	1.5	8.2	193	19.3	427	11.8	18.6±0.3	d	450		d			2200	30	600	750
	1310-1340	1.1	5.4	208	19.4	426	11.8	19.2±0.1	15	1100	200	90	150	100	1900	3100	750[c]	700
Sep 5	0957-1035	1.5	6.0	199	20.6	421	11.9	20.2±0.1	d	20		d			350	-	300	50
	1303-1339	0.4	5.2	219	21.2	421	11.8	21.2±0.1	d	< 1		d				d		
Nov 7	0757-0841	1.1	9.2	144	15.7	432	12.0	16.1±0.3	d	400		d			2200	350	750[c]	550
	1300-1346	1.4	10.5	154	16.4	0[e]	0.3[e]	16.4±0.3	d	210					350-2600[f]	-	150-750[f]	-
Nov 27	1150-1233	0.8	7.5	280	16.7	433	12.6	17.1±0.1	< 1	20		g			200	150	200	[illegible]
	1440-1515	1.3	8.4	306	16.7	432	12.6	16.6±0.3	11	610	150	80	-	250	500	1650	750	630

[a] Extent along sea surface of 4°F and 1°F temperature contours as measured from discharge (Station X0): UC = upcoast; DC = downcoast, IS = inshore, OS = offshore.

[b] One measurement equal to 4°F elevated temperature field taken 90 m upcoast of discharge.

[c] Thermal field came in contact with shoreline.

[d] No elevated temperature field was present.

[e] Unscheduled plant outage at 1245 hr.

[f] Distances where elevated temperature field started and ended.

[g] One measurement equal to 4°F elevated temperature field taken at discharge.

These large variations in the extent of the thermal field were not due to changes in SONGS 1 operation. Plant load was near capacity (430 megawatts net) and the inplant increase in temperature of circulating seawater was between 11 and 12°C for all infrared flights of 1979 with the exception of the second flight on 7 November, during which an unscheduled plant outage occurred.

The surface area enclosed by the 1°F elevated temperature field ranged from less than 1 acre to 1,500 acres, and averaged 490 acres. The surface area enclosed by the 4°F elevated temperature field ranged from less than 1 acre to 30 acres, and averaged approximately 12 acres.

The maximum extents of the 1°F elevated temperature field were 3800 m upcoast, 3600 m downcoast, 1000 m offshore, and 750 m onshore during 1979. The average extents of the 1°F elevated temperature field were 1500 m upcoast, 1030 m downcoast, 500 m offshore and 580 m onshore. The maximum extents of the 4°F elevated temperature field were 600 m upcoast, 200 m downcoast, 500 m offshore, and 350 m onshore. The average extents of the 4°F elevated temperature field were 110 m upcoast, 65 m downcoast, 100 m offshore, and 70 m onshore.

The frequency of occurrence of the surface area enclosed by the 1 and 4°F elevated temperature contours is shown in Figure 2A-6. The data used to prepare this figure includes all areas measured during infrared flights from 1969 through 1979 when the generating station was at, or near, full load. Eighty percent of the time, the 1°F elevated temperature field was contained within 1000 acres or less and the 4°F elevated temperature field was contained within 15 acres or less. Fifty percent of the time, the 1°F elevated temperature field was contained within 600 acres or less and the 4°F elevated temperature fields within 5 acres or less. The 4°F elevated temperature field was not present thirty percent of the time.

The large range in the surface area of the 1 and 4°F elevated temperature fields is due to natural conditions, since these measurements were taken during periods of full plant operation. Natural conditions have caused the surface area of the 1°F elevated temperature field to range from less than 1 acre to approximately 3500 acres over the past ten years, and the 4°F elevated temperature field ranged in size from less than 1 acre to 220 acres.

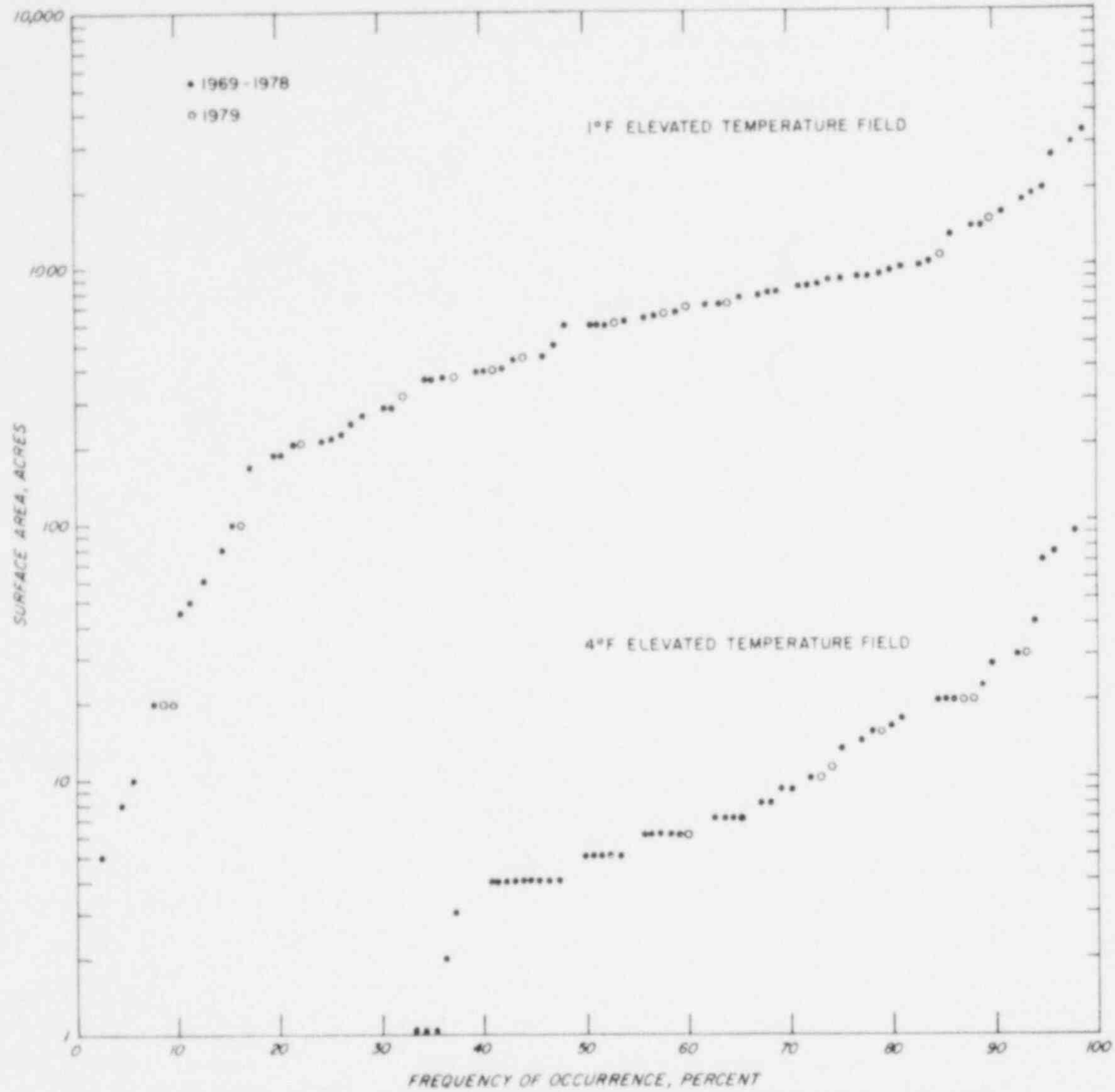

Figure 2A-6. Frequency of occurrence of the surface area enclosed by the 1° F and 4° F elevated temperature fields, 1969 through 1979.

Natural conditions which affect the size of the thermal field include natural temperature stratification, currents, rate of mixing in receiving waters, tide height, and winds (IAEA 1974). A correlation analysis of the size and extents of the 1 and 4°F elevated temperature fields during the last 4 years with natural phenomena is presented in Table 2A-2. Results of this analysis reveal that the variation in natural temperature stratification had the most significant effect on the surface area of the 1 and 4°F elevated temperature fields. Winds, currents, and the rate of heat dissipation (indicated by the difference between air temperature and natural surface temperature) also significantly affected the surface area of the 1°F elevated temperature field.

Areal extent of the thermal field was typically less during periods of natural temperature stratification with depth. When temperature stratification occurs, the bottom and middepth waters withdrawn by the intake were cooler than surface waters. As the cooling water flow is discharged vertically, it entrains cooler bottom and middepth waters. The withdrawal and entrainment of cooler middepth and bottom waters by the circulating water system results in a cooler temperature directly over the discharge than would be observed if there was not thermal stratification. Thus, the amount of thermal stratification significantly

Table 2A-2. Correlation analysis of size and extent of the 1° F and 4° F elevated temperature fields, 1976 through 1979.

	1°F			4°F		
	Upcoast Extent	Downcoast Extent	Surface Area	Upcoast Extent	Downcoast Extent	Surface Area
Temperature Stratification	-0.162	-0.290	-0.462**	-0.326	-0.243	-0.384*
Current Speed	-0.233	0.331	-0.429	-0.044	-0.347	-0.253
Tide Height	-0.74	-0.159	-0.026	-0.090	-0.227	-0.167
Air-water Temperature	-0.078	-0.152	-0.362*	-0.105	-0.101	-0.092
Longshore Wind	-0.184	0.187	0.340*	0.089	0.050	0.047
On-offshore Wind	0.196	0.305	0.084	0.361	0.361	0.349*

** $p < 0.01$
* $p < 0.05$

affects the difference between natural surface temperature and surface temperature of the thermal plume and therefore the surface area of the thermal field.

The magnitude of the effect of natural temperature stratification on the size of the elevated temperature field is shown by comparison of the thermal fields during the 14 March and 5 September surveys. There was no vertical stratification of temperature with depth during the 14 March survey, and surface areas of the 1 and 4°F elevated temperature fields were large. The water column was thermally stratified during the 5 September survey with natural temperature decreasing with depth from 21 to 17°C in 9 m of water. The extent of the 1°F elevated temperature field was confined to the immediate vicinity of the discharge during the first aerial infrared flight of 5 September, and 1°F elevated temperatures were not observed during the second flight. No 4°F elevated temperatures were observed during either of the infrared flights on 5 September 1979. The extent and area of the 1°F elevated temperature field was generally small during periods of higher velocity currents, and during periods of high atmospheric heat dissipation when there are large differences between air temperature and temperature of the 1°F elevated temperature field.

The vertical extent of the surface thermal plume from SONGS 1 was limited to three to four meters of depth. The elevated temperature fields did not come in contact with the bottom except at shallow stations inshore of the discharge and at the shoreline.

IMPACT OF SONGS 1 ON TEMPERATURE

Thermal impact of SONGS 1 was small when compared to natural temporal and spatial temperature variation in the San Onofre study area.

The circulating cooling water system for SONGS 1 resulted in a surface thermal plume approximately three meters thick, in which temperatures were increased from 0.5 to 2.2°C above natural temperature. The thermal influence of SONGS 1 was decreased by natural conditions such as vertical stratification, currents, and heat transfer to the atmosphere.

The natural spatial variability of surface temperature in the SONGS study area resulted in surface temperature differences of from 0.5 to 2.0°C during bimonthly surveys. Natural temporal variations resulted in temperature changes of 0.5 to 3.0°C in several hours.

Since the magnitude of thermal influence by the generating station was similar to natural spatial and temporal temperature variations, the impact of SONGS 1 on receiving water temperature is considered negligible.

RECIRCULATION

Intake, discharge, and ocean ambient temperatures were compared to estimate the extent to which SONGS 1 heated water is recirculated into the intake of the circulating water system and to determine the increase in discharge temperature compared to ocean ambient temperature due to recirculation. ETS requirements for SONGS 1 established ocean ambient temperature as "the surface temperature in the upper two feet of the water column as measured by a continuous temperature monitoring station in Zone 6 ... located not less than 22,000 feet from the cooling water discharge port and a distance offshore equivalent to a 30 foot depth of water."

Surface temperature at continuous temperature Station C22S satisfies the ETS requirements for ocean ambient temperature, but does not always reflect ambient temperature conditions at the depth of the SONGS 1 intake (5 m). Natural temperature stratification results in surface temperatures which are warmer than middepth temperatures.

The percent of time that intake and surface ambient temperature differed by more than 1.0°C from 1976 through 1979 is presented on Figure 2A-7. Over the four-year period, intake temperature exceeded surface ambient temperature by 1.0°C or more 24 percent of the time and surface ambient temperature exceeded intake temperature by 1.0°C or more 19 percent of the time.

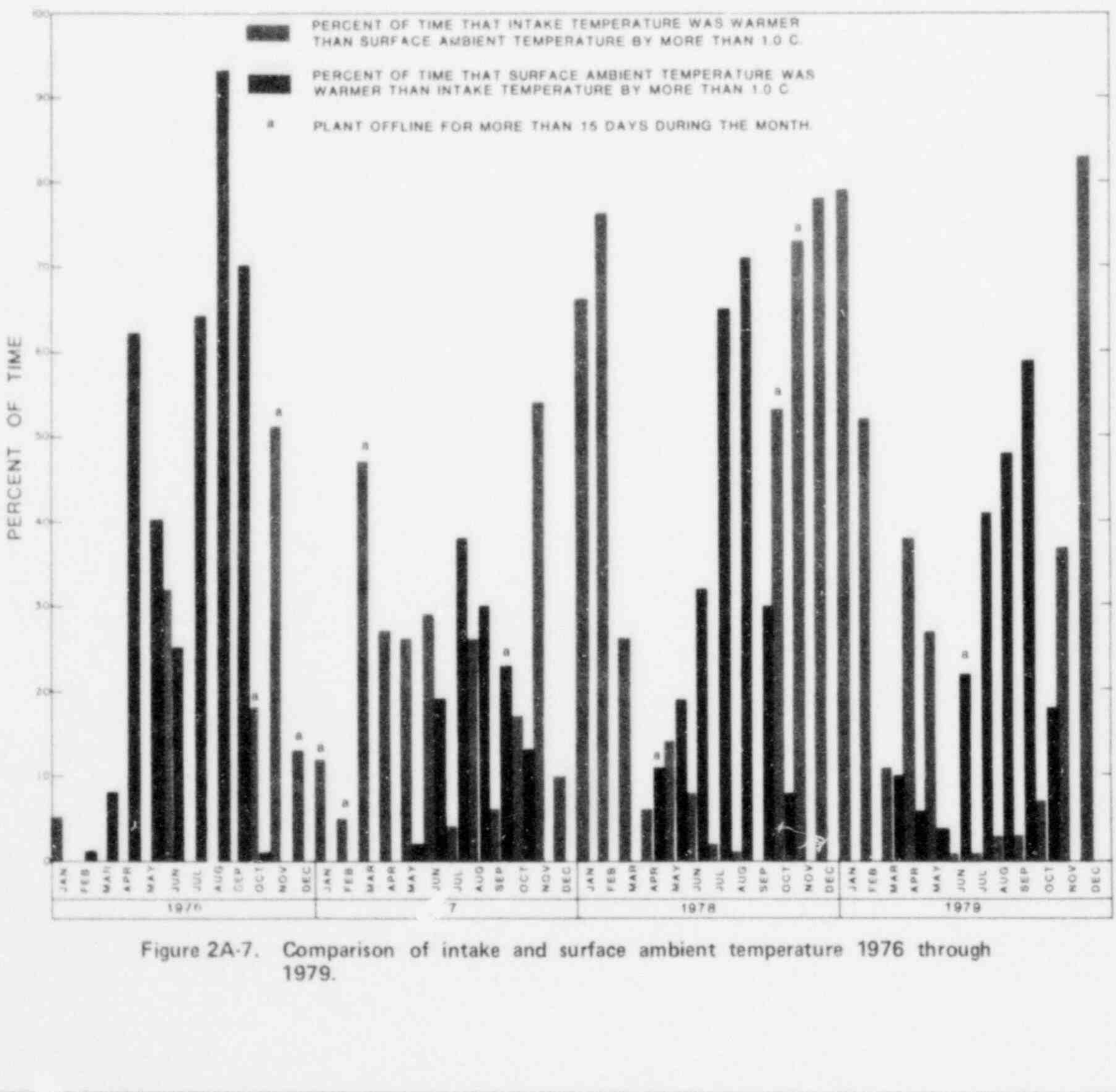

Figure 2A-7. Comparison of intake and surface ambient temperature 1976 through 1979.

A pronounced seasonal pattern is apparent on Figure 2A-7. During periods of water column temperature stratification, generally April through October, the surface waters were naturally warmer than middepth waters at the depth of the intake. This natural temperature stratification tends to mask any difference between ambient and intake temperature which may reflect recirculation conditions.

Middepth temperatures from Stations C22S and C2S were compared to intake temperatures, in addition to Station C22S surface. The data from these two locations were analyzed to provide a better estimate of the amount of recirculation. Table 2A-3 presents the results of the intake-ambient comparisons for these three ambient temperatures.

Due to the large natural spatial variability of temperature in the SONGS study area, the station closest to the intake is considered most representative of ambient conditions for intake temperature. Since the thermal plume is generally confined to the upper three meters of the water column, it is reasonable to expect that middepth (5 m) temperature at Station C2S were not affected by the thermal plume and, therefore, are the most representative of natural temperature conditions for the SONGS 1 intake. Figures I-2, I-5, I-8, I-11, I-14, I-17, I-20, and Figures I-22 through I-28 show that middepth temperatures at Station C2S were not affected by the thermal plume during any of the bimonthly field studies. Thus, Station C2S middepth is the location most representative of natural temperature conditions for the SONGS 1 intake.

During 1979, intake temperature exceeded that at Station C2S middepth by more than 1.0°C, 45% of the time. This indicates that some recirculation does occur for a significant part of the year. This recirculation generally increased intake temperature from 1 to 2°C.

Although recirculation occurs during almost half of the year, the increase in discharge temperature with respect to surface ocean ambient was greater than the difference between discharge and intake temperature only during periods of little natural stratification of temperature with depth. Monthly mean discharge temperatures were increased by 1.0 to 1.3°C during January, February, November, and December 1979, as shown in Table I-5.

OCEANOGRAPHIC CONDITIONS DURING BIOLOGICAL SAMPLING

Temperature is a good indicator of oceanographic and meteorological phenomena such as major currents, storms, and winds which can introduce a different water mass to the study area. Some of the large variations in daily mean natural

Table 2A-3. Percent of time intake and ambient temperatures differed by more than 1.0° C.

	Intake Exceeded			C22S Mid-depth Exceeded Intake		
Month	C22 Surface	C22S Mid-depth	C2S Mid-depth	C22S Surface	C22S Mid-depth	C2S Mid-depth
Jan	79	59	40	0	0	0
Feb	52	90	48	0	0	0
Mar	11	a	32	10	a	0
Apr	38	79	27	6	0	0
May	27	30	34	4	0	0
Jun	1	42	30	22	1	0
Jul	1	72	47	41	0	0
Aug	3	56	9	48	3	33
Sep	3	73	62	59	2	2
Oct	7	66	86	18	4	0
Nov	37	64	55	0	0	0
Dec	83	70	66	0	0	0
Year	28	64	45	17	1	3

[a] No C22S mid-depth data for March.

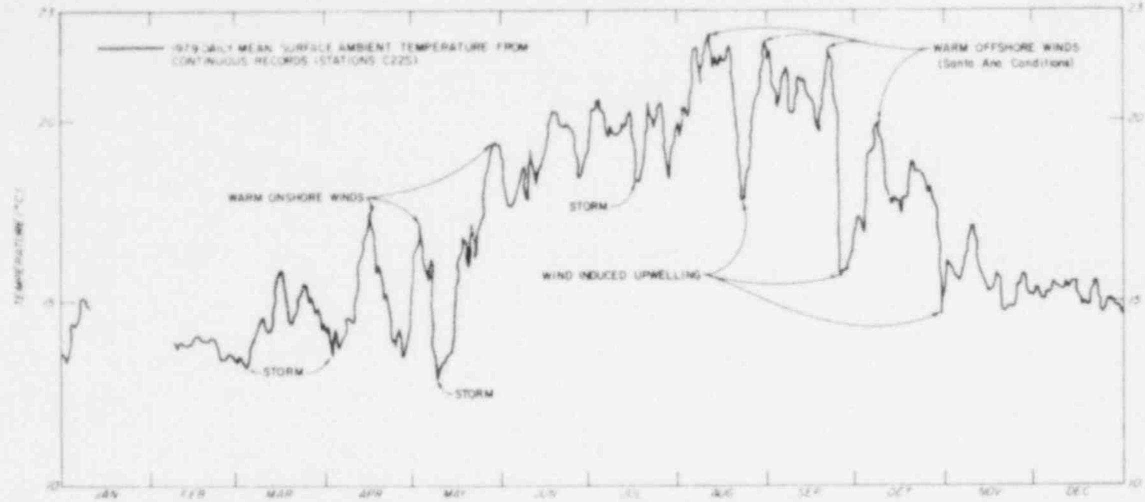

Figure 2A-8. Significant meteorological events affecting surface temperature during 1979.

surface temperature during 1979 appear to be the result of storms, onshore winds, and offshore (Santa Ana) winds as shown on Figure 2A-8. These meteorological disturbances introduce different water masses to the study area by altering the currents in the southern California area. Different water masses can have significantly different biological communities, especially among planktonic organisms which are transported by currents.

Temperature conditions during plankton, fish, and hard and soft bottom benthic surveys are compared to natural temperature conditions on Figure I-115 through I-118. Temperature measurements during biological sampling generally compared very well to natural temperature conditions at the downcoast control station with few exceptions.

Significant changes in natural surface temperature were observed between bimonthly plankton surveys (Figure I-114). Since dramatic changes in water temperature generally indicate changes in water mass, the plankton communities may have changed significantly between plankton surveys. Significant changes in water temperature occurred from within a few days to within a couple of weeks of plankton surveys.

Fish are mobile and, therefore, can adjust their distribution to changes in water mass. Temperatures observed during fish sampling surveys are shown on Figure I-116.

Changes in water mass do not directly affect the distribution of hard and soft bottom benthic communities, since they are basically immobile. Nevertheless, these communities must withstand variations in bottom water temperature to survive. Figures I-117 and I-118 illustrate some of the temperature changes experienced by the benthic communities.

SUMMARY

1. Natural surface temperature and the amount of vertical stratification of temperature generally followed the annual insolation pattern. Several shorter duration (one to thirty days) cooling and warming trends were observed within the annual cycle, and resulted in temperature fluctuations as large as the seasonal range (6°C).

2. The frequency of variations in natural temperature covered the entire range of the frequency spectrum, from seasonal fluctuations to fluctuations within a few hours. The larger natural variations were at frequencies with periods corresponding to 75, 37, 30, 20, 11, and 1 days. Fluctuations of various frequencies combined to result in 10°C changes in natural temperature within 30 days. Short term fluctuations in natural temperature (periods of a day to a week) were relatively small during the winter, on the order of 1.0°C and often quite large during the summer, resulting in 4 to 5°C variations. Tidal currents were responsible for diurnal and semidiurnal fluctuations in temperature.

3. Continuous temperature measurements revealed that temperature conditions at San Onofre were persistent for periods of a few days to two weeks. The integrated study approach of bimonthly surveys and continuous temperature measurements provided detailed spatial and temporal information on the distribution of temperature.

4. Continuous temperature measurements at two locations 1000 and 2000 m offshore revealed that surface temperature usually decreased with distance offshore during the first half of 1979, and then increased with distance offshore during the second half of the year. During bimonthly surveys of 1979 the difference in natural surface temperature with distance offshore ranged from 0.5 to 2.0°C, differences in monthly mean surface temperature between these two locations ranged from 0.2 to 1.3°C.

5. Results of continuous temperature measurements revealed that simultaneous temperature measurement at two locations can be significantly different depending on the amount of separation between locations. Daily, weekly, and monthly mean temperatures between continuous temperature sampling locations were often significantly different. Therefore, temperature measurements from far removed control locations do not accurately represent ambient conditions for the area of the generating station.

6. Although absolute temperature between locations are not always similar, the fluctuations in temperature between continuous sampling locations were often similar. Fluctuations in temperature that had periodicities of 0.5, 1, 2, 4, 12, and 20 days were coherent between continuous temperature sampling locations. Low frequency (long duration) fluctuations were usually more coherent than higher frequencies, with the exception of tidal frequencies. Longshore coherency in continuous temperature records was usually greater than offshore coherency.

7. The circulating cooling water system for SONGS 1 produced a surface thermal plume approximately three meters thick. Temperatures within this plume ranged from 0.5 to 2.2°C above natural temperature. The surface extent of the 1°F (0.5°C) elevated temperature field was contained within 1000 acres or less, 80 percent of the time. The 4°F (2.2°C) elevated temperature field was contained within 15 acres or less, 80 percent of the time and was not observed 30 percent of the time.

8. The large range in size of the elevated temperature field was due primarily to the variability in the amount of natural vertical temperature stratification, currents, and the rate of heat dissipation to the ocean and to the atmosphere.

9. The amount of recirculation of previously discharged warm water back through the circulating water system could not be accurately determined by the ambient temperatures specified in ETS due to the natural spatial,

temporal, and vertical variation in temperature. Middepth temperature from 610 m south of the SONGS 1 intake was used to estimate recirculation. Recirculation was sufficient to increase intake temperature by 1.0°C or more, 45 percent of the time. During periods of recirculation, the increase in intake temperature was usually between 1 and 2°C. Therefore, approximately one half of the time, 10 to 20 percent of previously discharged water is recirculated back through the generating station.

10. The thermal effect of SONG 1 was comparable to the natural temporal and spatial variation in water temperature in the SONGS study area. The variability caused by the thermal discharge was of the same magnitude (0.5 to 2.0°C) as spatial variations in natural temperature observed during bimonthly surveys. Thus, the thermal impact of SONGS 1 is considered negligible.

11. The natural spatial variability of temperature in the SONGS 2 and 3 study area was from 0.4 to 2.0°C during bimonthly surveys of 1979.

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CHAPTER 2B

TURBIDITY

The operation of the circulating seawater system of SONGS 1 affects the distribution of natural turbidity. SONGS 1 does not create turbidity within the cooling water system but rather redistributes middepth and bottom waters to surface waters. Middepth and bottom waters in the inshore area of SONGS 1 intake are often more turbid than surface waters. When this condition exists, bottom turbid water is distributed to the surface through the discharge plume.

The effect of the circulating seawater system for SONGS 2 and 3 on turbidity is potentially greater than SONGS 1, due to larger cooling water flows, the displacement of usually more turbid middepth and bottom waters from nearshore to offshore surface waters, and during slack current conditions, the potential offshore flow induced by diffusers for SONGS 2 and 3.

Turbidity is important to biological communities as well as for aesthetic reasons. Turbidity significantly affects the amount of light available to plant and animal communities and can therefore affect the productivity and diversity of marine organisms. Turbidity has the greatest direct effect on kelp and other marine plants by decreasing the amount of light available for photosynthesis but can also affect other organisms through alterations to the food web.

The dominant natural mechanisms which affect turbidity in the San Onofre area are terrestrial drainage, waves, and currents. The introduction of suspended material to the study area generally occurs during and after periods of precipitation (generally December through March). During periods of precipitation, San Onofre and San Mateo Creeks (located 2.3 and 3.6 km north of SONGS, respectively) contribute the greatest amount of suspended material from their combined 600 km^2 drainage area. During summer months, flows in these creeks are usually small, and there is comparatively little suspended material introduced to the ocean from them (CDWR 1967).

Waves, and the associated nearshore circulation, combine to affect the distribution and intensity of turbidity. As the energy in waves is expended on the bottom, sediment is resuspended in the water column and transported to other locations by currents.

Turbidity measurements at San Onofre began in 1963, 5-1/2 years prior to operation of SONGS 1, and have continued to the present. Turbidity is part of the ETS, NPDES, CMP, and PMP programs and was measured in all phases of the marine studies at San Onofre except ichthyoplankton.

The objectives of turbidity studies were to: 1) document spatial and temporal variations in turbidity throughout the study area, 2) determine the extent and intensity of the turbid plume from SONGS 1, 3) establish preoperational baseline conditions for SONGS 2 and 3, and 4) provide turbidity data for analysis and interpretation of biological findings.

METHODS

Continuous vertical profile measurements of percent light transmittance were obtained at 74 stations (Figure 2A-2) during bimonthly surveys. These light transmittance profiles were used to document horizontal and vertical variations in turbidity throughout the study area, the extent of the turbid plume from SONGS 1, the natural variation for SONGS 2 and 3, and the effects of offshore construction for SONGS 2 and 3.

Vertical profiles of percent light transmittance along a 1-meter path were measured with a Martek transmissometer and recorded by Brown and Caldwell's digital data processor. The transmissometer has a Wratten #45 filter which yields a relatively narrow (50 percent bandpass = 53 nm) spectral peak at 490 nm wavelength (near the wavelength of maximum penetration in clear ocean water). The transmittance of light is related to the volume attenuation coefficient (alpha) by the following: alpha = ln(1/T) where T is transmittance expressed as a decimal (Austin 1973). Observations of the depth of visibility of a white metal Secchi disc were also obtained at each station to document surface water clarity.

Concentrations of suspended and settleable solids at surface and four meters of depth were determined from water samples collected bimonthly at selected stations.

Aerial color photographs were obtained during bimonthly surveys to show the natural variability of turbidity in the study area, the extent of the turbid surface plume from SONGS 1, and the effects of offshore construction for SONGS 2 and 3.

Continuous light intensity was measured within 1 m of the bottom at five hard-bottom benthic stations beginning in September 1979. Continuous light intensity was measured onshore at the SONGS Visitor Information Center to record ambient light intensity. Continuous light intensity was measured in the 400 to 700 nm wavelength band (photosynthetically active radiation) by a LICOR PAR underwater sensor and was recorded and processed _in situ_ by a microprocessor.

A detailed description of instrumentation and methods used for turibdity measurements was presented in Volume 1, Oceanographic Data Report (SCE 1980a).

RESULTS

BIMONTHLY SURVEYS

Results of turbidity monitoring are separated into five sections: 1) bimonthly surveys, 2) natural variations, 3) horizontal extent of the turbid plume, 4) vertical extent of the turbid plume, and 5) effects of construction for SONGS 2 and 3.

Bimonthly surveys were conducted on 11 January, 14 March, 16 May, 11 July, 5 September, and 7 November 1979. An additional survey of SONGS 1 stations was conducted on 27 November 1979, because of an unscheduled plant outage during the 7 November 1979, survey. Data collected during these surveys were presented in tabular and graphical form in Volume 1, Oceanographic Data Report (SCE 1980a).

Results of bimonthly survey measurements are presented in tabular and graphical form in Appendix II. These results document the large spatial and temporal natural variations in turbidity throughout the study area, illustrate the extent of the turbid plume from SONGS 1 and the turbidity effects of offshore construction for SONGS 2 and 3, and establish natural conditions in the SONGS 2 and 3 offshore area.

NATURAL VARIATIONS

Turbidity varied between bimonthly surveys. Tables II-1 through II-4 present for each survey the mean, standard deviation, and range of surface and 4-m depth values of percent light transmittance, suspended and settleable solids, and Secchi disc depths of visibility for SONGS 1 and SONGS 2 and 3 stations (see Figure 2A-2 for delineation of stations). Spatial and temporal trends were observed in light transmittance data with greatest turbidity in January, and least in November. There was less turbidity at SONGS 2 and 3 stations than at SONGS 1 stations. Mean surface light transmittance at SONGS 1 stations ranged from 8 percent on 11 January to 41 percent on 27 November. Mean surface light transmittance at SONGS 2 and 3 stations ranged from 32 percent on 11 January to 74 percent on 7 November. At 4 m of depth, mean light transmittance at SONGS 1 stations ranged from 9 percent on 11 January t 1 percent on 7 November 1979, and at SONGS 2 and 3 stations from 36 percent . 11 January to 72 percent on 7 November.

This large variation in means of surface light transmittance (8 to 74 percent) covers the range of turbidity conditions from very turbid to very clear water. Mean surface and four meters of depth light transmittance at SONGS 2 and 3 stations ranged from 15 to 35 percent greater than means at SONGS 2 stations for corresponding surveys.

Results of Secchi disc observations show the same general temporal and spatial trends as light transmittance, with most turbid conditions in January, clearest conditions in March and November, and significantly higher Secchi disc values at SONGS 2 and 3 stations than at SONGS 1 stations.

Suspended and settleable solids data did not show the same seasonal and spatial trends as were observed in light transmittance and Secchi disc data. No seasonal trends were observed in suspended or settleable solids data. Spatial trends were limited to an increase in suspended and settleable solids close to shore and near the SONGS 1 discharge.

Vertical profiles of percent light transmittance documented the horizontal and vertical spatial variation in turbidity throughout the study area (SCE 1980a). The distribution of surface and four meters of depth percent light transmittance from all profiles during bimonthly surveys are shown on Figures II-1 through II-14.

The distribution of turbidity in surface waters in the study area is illustrated by contours of Secchi disc depth of visibility presented in Figures II-15 through II-21. The spatial distribution of surface and four meters of depth suspended and settleable solids concentrations during bimonthly surveys is shown on Figures II-22 through II-45.

The most evident feature of the surface and four meters of depth contours of percent light transmittance are the natural spatial variations in turbidity, especially with distance offshore. Surface percent light transmittance generally increased with distance offshore. The difference between surface values at inshore stations and those furthest offshore range from 40 to 75 percent during bimonthly surveys of 1979. At four meters of depth, the onshore-offshore range was approximately 50 to 70 percent during bimonthly surveys, except during the 5 September survey when natural light transmittance increased approximately 25 percent with distance offshore.

Natural variations in percent light transmittance and suspended solids concentrations alor hore were large, as illustrated in Figures II-46 through II-49. Differences between surface percent light transmittance during bimonthly surveys at C-line stations (9 m of water depth) unaffected by SONGS 1, ranged from 20 to 40 percent, except during the 5 September survey when the range of percent light transmittance between stations was approximately 10 percent. At four meters of depth, differences between unaffected C-line stations ranged from approximately 20 to 35 percent, except during the 5 September survey when differences between stations were approximately 10 percent.

The natural variation in percent light transmittance at SONGS 2 and 3 sampling stations and at stations in the vicinity of SONGS 2 and 3 diffusers was also large. The maximum spatial variation in surface and four meters of depth percent light transmittance in the SONGS 2 and 3 study area ranged from 15 to 40 percent during bimonthly surveys.

Contours of the depth of Secchi disc visibility (Figures II-15 through II-21) further illustrate the large spatial variations in water clarity within the study area. These variations in Secchi disc visibility, however, are not reflected in the contours of suspended and settleable solids concentrations (Figures II-22 through II-45), except in the nearshore area.

The natural variation in turbidity with depth is shown in isometric vertical cross sections of percent light transmittance (Figures II-50 through II-56). The natural vertical stratification of turbidity was most intense during the March, September, and November surveys. During these surveys, light transmittance at C-line stations decreased from between 40 and 60 percent at the surface to less than 10 percent at the bottom. During the January, May, and July surveys, there was less vertical stratification in natural turbidity. During these surveys, light transmittance at C-line stations decreased from between 20 and 30 percent at the surface to less than 1 percent at the bottom.

HORIZONTAL EXTENT OF THE TURBID PLUME

The horizontal extent of the turbid plume is illustrated by contours of percent light transmittance for surface and four meters of depth (Figures II-1 through II-14) and by color aerial photographs (Figures II-57 through II-71). A comparison of percent light transmittance and suspended solids concentrations at the surface and four meters of depth during bimonthly surveys at C-line stations is shown on Figures II-46 through II-49.

A surface turbid plume from the SONGS 1 discharge (indicated by decreased percent light transmittance) was observed during the March, September, and November surveys. The extent of this surface plume ranged from 1.2 to 1.8 km upcoast of the discharge during these surveys. No surface turbid plume was observed during the January, May, and July surveys, except in the immediate vicinity of the discharge.

No turbid plume was detected at four meters of depth except during the September survey, and then this effect is difficult to distinguish from natural variability.

Aerial photographs taken during the January, June, and July surveys show no turbid surface plume from the SONGS 1 discharge. A turbid surface plume from the SONGS 1 discharge was observed in the aerial photographs taken during the March, September, and the two November surveys. The intensity of these surface turbid plumes from the SONGS 1 discharge was less than, or equal to, the natural turbidity in the nearshore areas as shown in the aerial photographs.

The distribution of suspended and settleable solids at the surface and four meters of depth is shown on Figures II-22 through II-45. The SONGS 1 circulating seawater system did not affect the distribution of surface or four meters of depth suspended and settleable solids concentration during the January, May, and and September 1979 surveys. The distribution of surface concentrations of suspended and settleable solids was affected by SONGS 1 during the March, July, and November surveys. SONGS 1 did not affect the distribution of suspended and settleable solids at four meters of depth except at stations within 600 m of the discharge during the May survey.

VERTICAL EXTENT OF THE TURBID PLUME

The vertical extent of the turbid plume is illustrated in isometric vertical cross sections (Figures II-50 through II-56). These figures illustrate that, when present, the surface turbid plume was 3 to 4 m thick in the vicinity of the discharge and became thinner with distance from the discharge, similar to the surface thermal field.

EFFECTS OF CONSTRUCTION FOR SONGS 2 AND 3

The construction of the offshore conduits for SONGS 2 and 3 intake and discharge lines required excavation of a trench for placement of the lines and backfilling once lines were laid. Construction trestles were used to place the conduit sections out to the depth of the intake structure (9 m). Sections further offshore were constructed utilizing a special jack-up barge. By January 1979, offshore placement of the intake and discharge conduits for SONGS 2 had been completed and construction of SONGS 3 intake and discharge lines had commenced. The backfill of dredge material to SONGS 2 had been completed by July 1979.

The effect of offshore construction dredging operations on water clarity was limited to a relatively small area and short duration but was intense in its effects during dredging operations, as illustrated in aerial photographs taken during the September and November surveys.

DISCUSSION

Turbidity measurements during 1979 were fairly typical, exemplifying the large range of turbidity conditions usually found in nearshore coastal environments. Turbidity conditions ranged from turbid to clear and appear to be influenced primarily by rainfall, waves, tide, and currents.

TEMPORAL TRENDS

A seasonal pattern in the amount and distribution of turbidity was observed, with increased turbidity in winter when waves and rainfall are greatest, and decreased turbidity in the late fall before the onset of winter storms. Within this somewhat seasonal pattern, several large-scale fluctuations in turbidity were observed.

TEMPORAL VARIATIONS

A comparison of surface light transmittance values at turbidity, plankton, and fish sampling stations (Table II-5) shows differences in percent light transmittance each month, within three consecutive days of plankton surveys and within a few hours. Differences in turbidity between months were quite large. Surface light transmittance values at the same location were generally persistent for a few days, but some significant differences, as much as 30 percent, were observed between days and within a few hours. This shows that bimonthly surveys are not frequent enough to document the natural variations of turbidity at San Onofre.

SPATIAL TRENDS

The most dominant feature of turbidity data was the natural decrease in turbidity with distance offshore. This decrease is illustrated by the graph of yearly mean of light transmittance percentages, Secchi disc depths, and suspended solids concentrations for station lines parallel to shore (Figure 2B-1). Annual mean surface light transmittance increased from approximately 10 percent at A-line stations to 55 percent at M-line stations. A similar increase in light transmittance was observed at four meters of depth. The depth of Secchi disc visibility increased with distance offshore from approximately three meters at A-line stations to ten meters at M-line stations. The decrease in yearly average suspended solids concentration with distance offshore shows good correlation with the increase in light transmittance and Secchi disc values.

The logshore distribution of turbidity in the SONGS 1 and SONGS 2 and 3 study areas is illustrated in Figures 2B-2 and 2B-3, respectively. These figures show yearly mean values of percent light transmittance and suspended solids concentrations at the surface and four meters of depth, and mean Secchi depths for C-line stations in nine meters of water and J-line stations in seventeen meters of water. Comparison of these two figures also illstrates the greater water clarity in the offshore area, with light transmittance averaging approximately 25 percent at C-line stations and 50 percent at J-line stations.

At Stations C0, C2N, and C4N, the annual mean light transmittance at the surface was approximately 15 percent, while at other C-line stations, the mean was between 25 and 30 percent (Figure 2B-2). The lower percent light transmittance at Stations C0, C2N, and C4N was due to the combined effect of the turbid

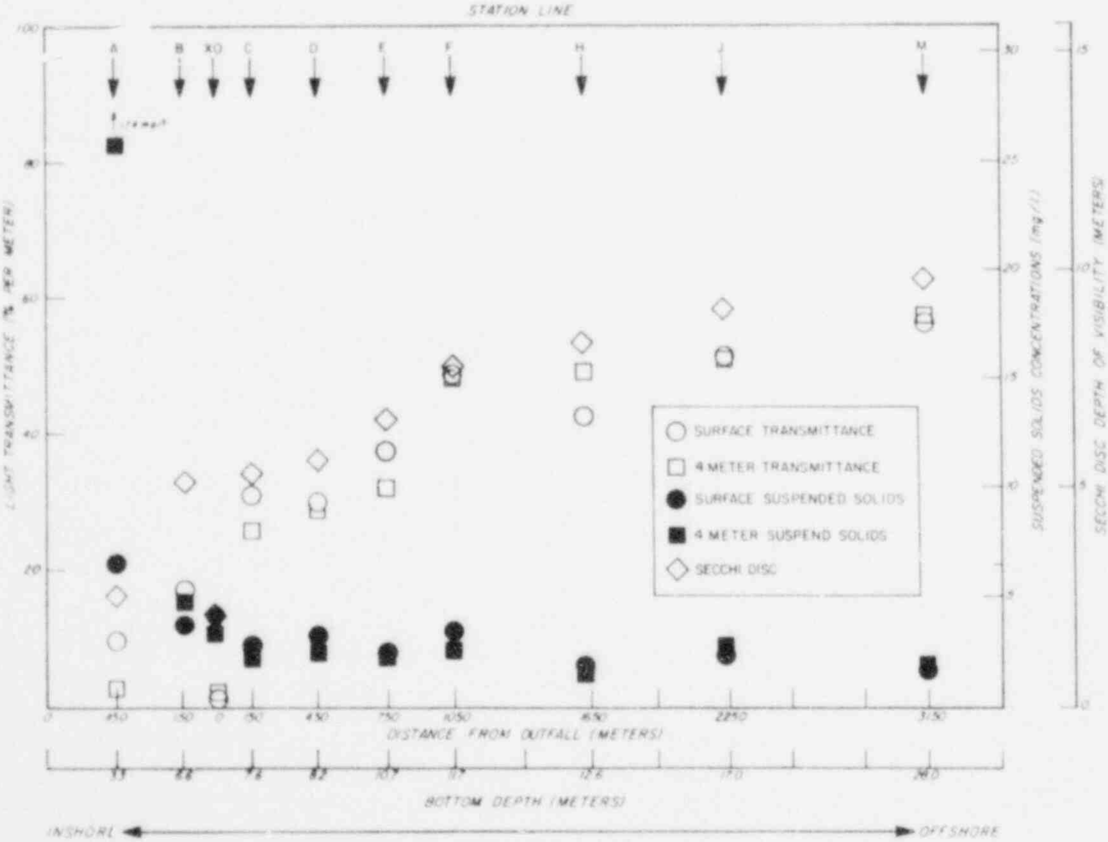

Figure 2B-1. On-Offshore distribution of yearly mean surface and mid-depth (4 m) light transmittance, suspended solids concentration, and Secchi disc values from stations on lines parallel to shore

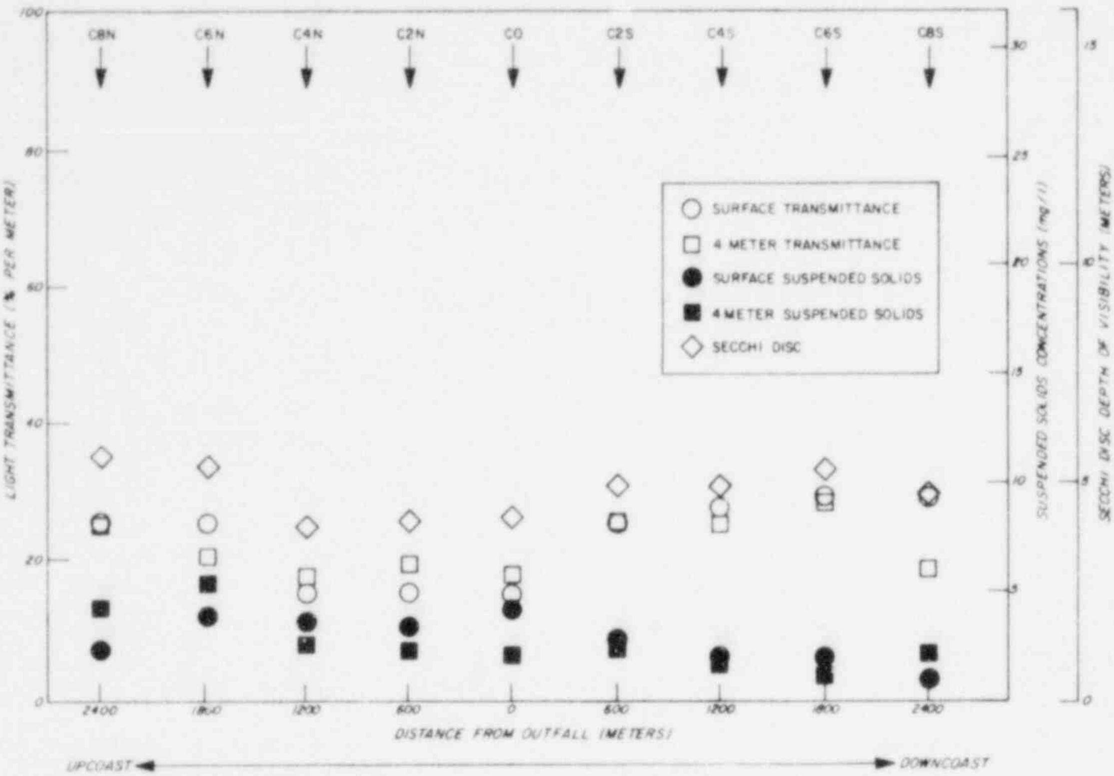

Figure 2B-2. Longshore distribution of yearly mean surface and mid-depth (4 m) light transmittance, suspended solids concentration , and Secchi disc values from stations in 8 m of water.

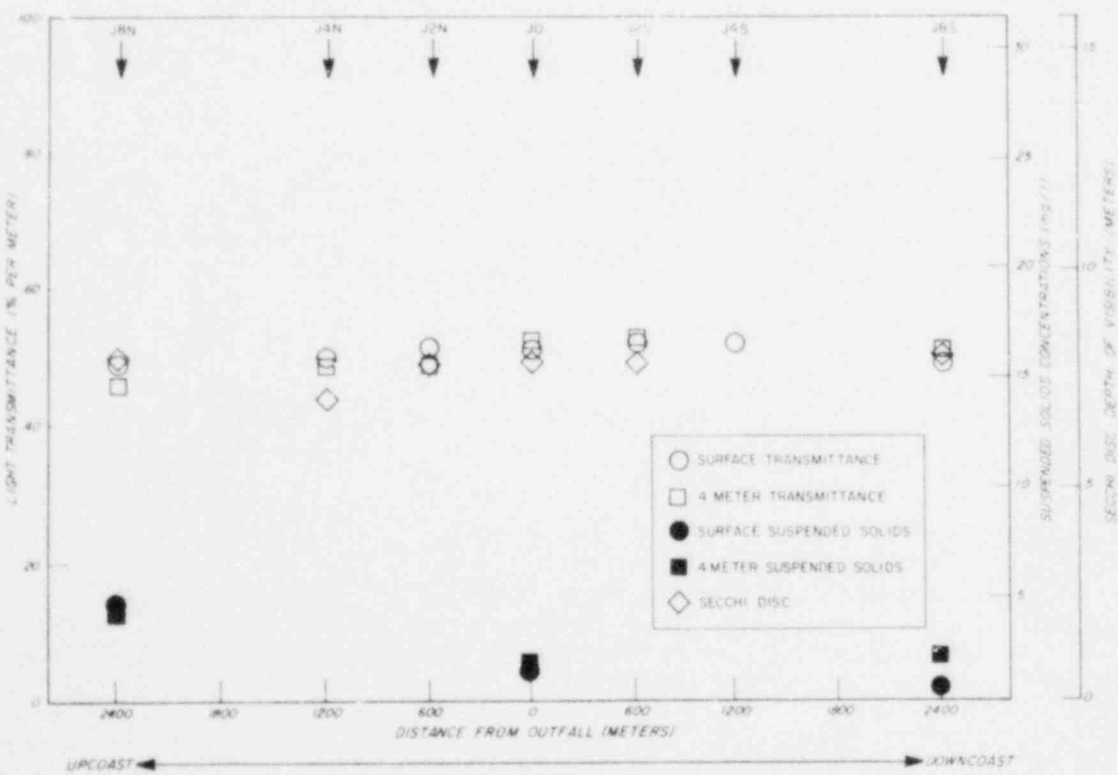

Figure 2B-3. Longshore distribution of yearly mean surface and mid-depth (4 m) light transmittance, suspended solids concentration , and Secchi disc values from stations in 17 m of water.

plume from SONGS 1 and breaking waves due to the changes in bottom topography inshore of these stations (Figure 2A-2). The relative effect of each source of turbidity is undetermined. Nevertheless, the yearly mean of surface light transmittance at Stations CO, C2N, and C4N were 2 to 5 percent less than those at four meters of depth, suggesting influence of a surface turbid plume.

At J-line stations in the offshore SONGS 2 and 3 study area, turbidity was considerably less than at the C-line stations. No significant longshore trends in the annual means were observed.

Turbidity usually increased with depth, except during periods of rain when surface waters were generally more turbid.

The large range observed in vertical turbidity structure was primarily due to waves and the amount of vertical mixing. Waves resuspend bottom sediment as they shoal. Higher and long period waves affect a larger area of bottom sediment than small, shorter period waves, and also induce more vertical mixing (Bowen and Inman 1974). Tide height significantly affects the area of the bottom over which the waves break and thus the areal distribution of turbidity. Density stratification also affects vertical mixing. These factors combine to create a complex pattern of vertical distribution of turbidity. When high waves or long period swells are present, whether due to local or distant storms, bottom material is resuspended and can be mixed throughout the water column, primarily in the breaker zone. When smaller waves are present, less bottom material is resuspended and less vertical mixing occurs, resulting in turbid conditions confined primarily to a layer of water near the bottom (Gibbs 1974).

SPATIAL VARIATIONS

The natural variability of turbidity in the SONGS 1 study area was large. Significant differences in turbidity were observed with distance offshore, with turbidity generally greatest in the nearshore area due to waves breaking on the shore. The offshore extent of the natural nearshore turbidity zone varied considerably.

Significant differences in natural turbidity were also observed alongshore in the SONGS 1 study area. Natural surface light transmittance at stations along a transect parallel to shore in nine meters of water ranged from 20 to 40 percent during bimonthly physical oceanographic surveys. Spatial variations at four meters of depth were similar.

Turbidity also exhibited large spatial variations in the SONGS 2 and 3 study area. In general, variations increased with distance offshore. The maximum range in surface and light transmittance values, including the area of the diffusers, was from 40 to 75 percent during bimonthly physical oceanographic surveys. These spatial variations in turbidity observed during bimonthly surveys were greater than natural seasonal variations.

INFLUENCE OF SONGS 1

Under certain natural conditions, the seawater circulating system for SONGS 1 affected the distribution of natural turbidity. SONGS 1 does not add appreciable amounts of turbidity to the cooling water flow but rather redistributes middepth and bottom waters to surface waters. Middepth and bottom waters are, at times, significantly more turbid than surface waters. When natural vertical stratification of turbidity occurs, the cooling water system transfers this turbid water to the surface, creating a turbid surface plume.

Three regimes of vertical turbidity conditions have been observed at San Onofre. The first regime exists when nearshore waters are vertically well mixed and relatively turbid throughout the water column. This regime is typical of winter conditions when increased wave energy and terrestrial drainage result in turbidity throughout the water column. Under these conditions, displacement of middepth and bottom waters by the circulating seawater system for SONGS 1 does not create a surface turbid plume, because the turbidity in surface waters is about the same as the turbidity of middepth and bottom waters. Conditions during the 11 January, 16 May, and 11 July 1979 surveys were typical of this regime. Light transmittance at stations in nine meters of water decreased from between 10 to 25 percent at the surface to less than 10 percent at the bottom during these surveys.

The second regime exists when there is a definite vertical stratification of turbidity with depth. During these conditions, the displacement of turbid middepth and bottom waters to clearer surface waters results in a pronounced turbid plume. The natural stratification of turbidity with depth during the 14 March, 5 September, 7 November, and 27 November 1979 surveys was typical of this regime. At stations in nine meters of water, light transmittance decreased with depth from between 40 and 60 percent at the surface to less than 10 percent at the bottom. Turbid surface plumes were observed in aerial photographs and turbidity data from these surveys. Light transmittance in the turbid plume near the discharge was depressed by 10 to 20 percent during these surveys. This effect decreased with distance from the discharge, and no depression of light transmittance was observed at stations greater than 1800 m from the discharge.

The third regime exists when the receiving waters are relatively clear throughout the water column. During these conditions, no turbid surface plume is created since there is no difference in turbidity between surface, middepth, and bottom waters. This regime was not observed during bimonthly surveys of 1979 but was observed during the 16 November 1978 survey.

During the occurrence of a turbid surface plume from the SONGS 1 discharge, the horizontal and vertical extent of the plume was influenced by currents, the amount of mixing in receiving waters, composition of suspended material, the rate of buoyant spreading of the plume, and amount of wave energy available to keep particles in suspension. Currents transport the turbid plume away from the discharge, and affects its horizontal extent. Mixing in receiving waters dilutes the turbid plume with ambient surface water, and the rate of mixing is affected by waves, current speeds, and thermal stratification (Waldichuk 1974, Cederwall 1970). The texture and composition of suspended material affects the rate at which material settles out of the plume (Lerman 1974). The temperature difference between the thermal plume and surrounding ambient surface temperature determines the rate of buoyant spreading of the plume, thus influencing the shape of the turbid plume.

Supportive oceanographic data for 1979 (waves, currents, winds, and precipitation) were presented in Volume 1, Oceanographic Data Report (SCE 1980a). Bimonthly surveys which occurred during periods of natural vertical stratification of turbidity, and during which surface turbid plumes were observed, were usually preceded by at least a 2-week period of little or no rainfall and swells of less than 1 meter in height. When there were periods of high winds and waves or appreciable rainfall in the San Onofre area within 2 weeks prior to bimonthly surveys, there was little vertical stratification of turbidity, and no turbid plume was observed.

IMPACT OF SONGS 1 ON TURBIDITY

In order to determine the impact of SONGS 1 on turbidity, the frequency, intensity, and extent of the turbid plume must be compared to natural variations in turbidity. Although the seawater circulating system operates continuously, a turbid surface plume is produced only when turbid water at middepth and near the bottom is entrained in the cooling water system. The frequency of occurrence of natural vertical stratification of turbidity cannot be determined from bimonthly surveys due to the natural variations in turbidity with time. Nevertheless, during 14 out of the 25 surveys from 1976 through 1979, natural vertical stratification of turbidity was sufficient to result in a measurable turbidity plume.

When a surface turbid plume was present, light transmittance near the discharge was decreased by 10 to 30 percent, and the amount of this depression decreased with distance from the discharge. This decrease in light transmittance in the plume was within the range of natural variation in nearshore waters observed during bimonthly surveys. It was also less than or equal to the natural variation in light transmittance (which ranged from 20 to 40 percent) between stations in nine meters of water during individual surveys of 1979.

The extent of the surface turbid plume from SONGS 1 was difficult to determine due to the comingling of the plume with turbid waters in the nearshore area but appeared to range in extent from about 200 to 1800 meters away from the discharge.

The influence of SONGS 1 on turbidity at San Onofre is relatively small when compared to the extremely large, natural variability of turbidity in space and time in the coastal environment at San Onofre.

INFLUENCE OF SONGS 2 AND 3 CONSTRUCTION

Dredging and backfill operations for offshore construction of SONGS 2 and 3 intake and discharge lines influenced the distribution of turbidity in a limited area for short periods of time. The effect of dredging operations was observed in suspended and settleable solids data and aerial photographs taken during bimonthly surveys. The effects of offshore construction on turbidity and sedimentation are presented in the section on sedimentology.

SUMMARY

1. Turbidity conditions varied significantly with waves and the amount of rainfall in 1979. The greatest effect on the amount of turbidity in the study area was stormwater runoff from San Onofre and San Mateo Creeks and large waves which resuspended bottom sediment. Bimonthly survey measurements document spatial variability of turbidity throughout the study area but were not frequent enough to document all the changes in the amount of turbidity with time, primarily due to the variability of wave and swell height.

2. Natural turbidity generally decreased with distance from shore and vertical distance above the bottom.

3. Intense vertical stratification of natural turbidity in the nearshore area occurs approximately one-half the time. The circulating seawater system of SONGS 1 created a distinguishable surface turbid plume only during periods of intense natural vertical stratification of turbidity.

4. The influence of SONGS 1 on the distribution of turbidity was significantly smaller than the natural variability of turbidity with space and time in the nearshore coastal environment and therefore the impact of SONGS 1 on turbidity was negligible.

5. Dredging activities for offshore construction of SONGS 2 and 3 circulating seawater system resulted in intense turbidity plumes of limited extent. The duration of these turbidity plumes was short due to the sporatic nature of dredging activities.

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CHAPTER 2C

WATER QUALITY

Water quality characteristics of dissolved oxygen, hydrogen ion concentration (pH), and specified heavy metals were measured bimonthly in the SONGS study area in compliance with the Environmental Technical Specifications (ETS) and the Preoperational Monitoring Program (PMP), as required by the Nuclear Regulatory Commission (NRC) and the National Pollutant Discharge Elimination System (NPDES) and permits issued by the National Environmental Protection Agency (NEPA) and administrated by the California Regional Water Quality Control Board, San Diego Region (CRWQCB). Receiving water nutrient concentrations were determined monthly in conjunction with the kelp tissue sampling program.

DISSOLVED OXYGEN AND pH

The objectives of the dissolved oxygen and pH studies were to: 1) assure that natural dissolved oxygen and pH levels are maintained, 2) continue to increase the data base that has been established, 3) indicate the extent to which the operation of SONGS 1 affects dissolved oxygen and pH concentrations in the receiving waters, and 4) provide a preoperational receiving water data base prior to operation of SONGS 2 and 3, which will subsequently be compared to operational conditions to determine the effects of SONGS 2 and 3 on the receiving waters.

The requirements for dissolved oxygen and pH, as specified in the ETS, are the same as those required by the Water Quality Control Plan for Ocean Waters of California (WQCP). The requirements state that dissolved oxygen concentrations shall not at any time be depressed more than ten percent 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 of southern California, with lower concentrations in winter and higher concentrations during spring (Allan Hancock Foundation 1965; SCCWRP 1973). Requirements also state 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, is 7.3 to 8.5. Allan Hancock Foundation (1965) reported a range of surface pH of 7.5 to 8.6 in coastal waters near San Onofre, with an average pH of 8.1.

HEAVY METALS

The objectives of heavy metals studies required by ETS, NPDES, and PMP were to: 1) detect any measurable increase in heavy metals concentrations in receiving waters or ocean bottom sediments in the vicinity of the SONGS 1 discharge; and 2) provide a receiving water and ocean bottom sediment predischarge data base for SONGS 2 and 3, to be used as a reference to aid in subsequent determination of operational effects of SONGS 2 and 3 on the concentration of heavy metals in the environment.

Monitoring of heavy metals concentrations in receiving waters and ocean bottom began in 1975 as part of the SONGS 1 ETS program. Samples were collected quarterly at four stations in the SONGS 1 study area and analyzed for copper, chromium, nickel, and iron concentrations. In May 1978, five sampling locations were added in the SONGS 2 and 3 study area in compliance with PMP, sampling frequency was changed to bimonthly, and samples were also analyzed for titanium.

NUTRIENTS

Receiving water nutrient sampling in, adjacent to, and offshore of the SONGS study area kelp beds was conducted to provide data for comparison to nutrient concentrations in the kelp plants. A major limiting factor to kelp growth is the availability of nutrients in the seawater.

METHODS

Methods for measurement of dissolved oxygen, pH, and heavy metals are presented in detail in Volume 1 of the Oceanographic Data Report (SCE 1980a). The following presents a sysnopsis of methods used in water quality studies.

DISSOLVED OXYGEN AND pH

Vertical profiles of dissolved oxygen and pH in the receiving waters were measured bimonthly at the 74 stations shown on Figure 2A-2. Dissolved oxygen and pH were measured and recorded simultaneously with temperature and light transmittance profiles using the Brown and Caldwell water quality data acquisition system. Measurements of dissolved oxygen were made by a polarographic gold/silver electrode which automatically compensates for changes in temperature. Accuracy of the dissolved oxygen sensor is + 0.2 ppm. The pH sensor is a glass and silver/silver chloride electrode which determines pH to an accuracy of + 0.1 units with a resolution of 0.01 units.

Calibration of the dissolved oxygen sensor was performed in the field by comparison with a modified Winkler titration analysis of dissolved oxygen. Winkler titrations were also performed on surface water samples from required SONGS 1 and SONGS 2 and 3 stations. Calibration of the pH sensor was performed prior to each survey. Standardized buffer solutions of a known pH were used in the calibration procedure, and all information was recorded in the calibration log book. Calibration was also checked in the field with pH buffer solutions.

HEAVY METALS

Middepth water and ocean bottom sediment samples were collected by divers and analyzed by atomic absorption spectroscopy to determine the concentrations of chromium, copper, nickel, iron, and titanium. Sample analyses were conducted in compliance with guidelines established by the U.S. Environmental Protection Agency (EPA 1969). The minimum detectable limits for analysis of water column samples were 0.0005 mg/l for chromium, copper, nickel, and iron, and 0.05 mg/l for titanium. The mimimum detectable limits for analysis of sediment samples were 0.05 mg/kg for copper, chromium, and nickel, and 0.5 mg/kg for iron and titanium. All values are reported to two significant figures.

NUTRIENTS

Water samples at each station were collected with a Van Dorn bottle. Samples were chilled in an ice chest and returned to the laboratory where they were frozen until analysis. Nutrient analysis was performed using standard spectrophotometric procedures, outlined in Strickland and Parsons (1968).

RESULTS

Results of water quality monitoring are separated into four sections: 1) dissolved oxygen, 2) hydrogen ion concentration, 3) heavy metals, and 4) nutrients. Data collected during bimonthly surveys were presented in tabular and graphical form in Volume I, Oceanographic Data Report (SCE 1980a). Results of bimonthly survey measurements are presented in tabular and graphical form in Appendix III.

DISSOLVED OXYGEN

Surface dissolved oxygen concentrations at required SONGS 1 operational and SONGS 2 and 3 preoperational monitoring stations are presented in Table III-1. Dissolved oxygen concentrations at required stations ranged from 7.1 to 9.8 mg/l with a yearly mean of 8.3 mg/l for all stations. Survey mean dissolved oxygen concentrations for required SONGS 1 stations ranged from 7.7 mg/l on 11 January and 5 September to 9.0 mg/l, on 16 May. Survey mean dissolved oxygen concentrations for required SONGS 2 and 3 stations ranged from 7.9 mg/l on 11 January and 7 November to 9.4 mg/l on 16 May.

Dissolved oxygen concentrations at the intake (Station C0) and discharge (Station X0) for SONGS 1 ranged from seven percent less than, to 13 percent greater than the downcoast control station (C22S). Surface dissolved oxygen at the control station was less than or equal to the concentration at the discharge during two surveys (11 July and 5 September). Mean dissolved oxygen concentrations at SONGS 2 and 3 preoperational Stations J2N, J2S, and J4S ranged from five percent less than, to one percent greater than the concentration measured at control Station F22S.

Percent saturation of surface dissolved oxygen concentration at required SONGS 1 operational and SONGS 2 and 3 preoperational monitoring stations is presented in Table III-2. Percent saturation of dissolved oxygen at SONGS 1 stations ranged from 94 to 119 percent, and at SONGS 2 and 3 stations, ranged from 93 to 120 percent. Percent saturation at the discharge was greater than or equal to tha that at the control station (C22S) during all surveys due to the dependency of oxygen saturation on temperature. Mean dissolved oxygen percent saturation at preoperational stations ranged from eight percent less than, to two percent greater than percent saturation at control Station F22S.

HYDROGEN ION CONCENTRATION

Surface pH at required stations ranged from 7.95 to 8.34 with a yearly mean of 8.12. No seasonal patterns in pH values were apparent, but spatial variations were least during fall and winter surveys and greatest during spring and summer surveys. Surface pH values at required SONGS 1 operational and SONGS 2 and 3 preoperational monitoring stations are presented in Table II-3. Values of pH at the SONGS 1 intake ranged from 0.05 units less than, to 0.19 units greater than valves at control Station C22S. Values of pH at the SONGS 1 discharge ranged from 0.08 units less than, to 0.15 units greater than values at control Station C22S. Mean pH values at SONGS 2 and 3 preoperational stations ranged from 0.08 units less than, to 0.12 units greater than values at the control station (F22S).

HEAVY METALS

The range, mean, and standard deviation of receiving water and ocean bottom sediment heavy metals concentrations at each required SONGS 1 sampling station are presented in Table III-4. The same parameters at each required SONGS 2 and 3 sampling stations are presented in Table III-5.

Receiving Waters

Receiving water copper concentrations at required SONGS 1 stations ranged from 0.001 mg/l to 0.12 mg/l. Yearly mean receiving water copper concentration at the discharge was higher than at the control station (C22S), but lower than the yearly mean at Station D4S. The maximum receiving water cooper concentration occurred at Station D4S and was about two times greater than the highest concentration measured at the SONGS 1 discharge in 1979 (0.066 mg/l).

Receiving water chromium concentrations at required SONGS 1 stations ranged from less than 0.001 mg/l to 0.040 mg/l. Yearly mean receiving water chromium concentration at the control station was approximately three times that at the discharge. Maximum concentration occurred at Station C22S and was about five times greater than the highest receiving water chromium concentration measured at the SONGS 1 discharge in 1979.

Yearly mean and maximum concentrations of iron in the receiving waters at required SONGS 1 stations were both highest at the discharge. Iron concentrations ranged from 0.07 mg/l to 1.2 mg/l. The yearly mean receiving water iron concentration at the discharge was approximately twice that of other SONGS 1 sampling stations. Maximum concentration of iron at the discharge ranged from three to four times greater than the maximum concentrations measured at Stations C22S, D4N, and D4S.

Receiving water concentrations of nickel ranged from less than 0.001 mg/l to 0.048 mg/l. The yearly mean receiving water nickel concentration at the discharge was approximately one and one-half times that of other SONGS 1 stations. The maximum concentration of nickel at the discharge ranged from two to three times greater than the maximum concentrations measured at Stations C22S, D4N, and D4S.

All receiving water titanium concentrations were less than the detectable limit (0.1 mg/l) at SONGS 1 and also at SONGS 2 and 3 sampling stations.

Yearly mean middepth heavy metals concentrations varied little between SONGS 2 and 3 stations, with the exception of copper which had a higher yearly mean at Station J0. Copper concentrations ranged from 0.001 mg/l to 0.19 mg/l; the maximum concentration was measured at Station J0, and was several times greater than concentrations measured at Stations J2S, J4N, J4S, and J22S. Chromium concentration ranged from 0.001 mg/l to 0.011 mg/l; the maximum concentration was at Station J0, and was about two times greater than concentrations measured at Stations J2S, J4N, J4S, and J22S. Nickel concentrations ranged from 0.001 mg/l to 0.026 mg/l; the maximum concentration was at Station J2S, and Stations J0 and J4S had similar maximum concentrations.

Receiving water iron concentrations at required SONGS 2 and 3 stations ranged from 0.04 mg/l to 0.35 mg/l. Station yearly mean and maximum iron concentrations were about the same at all SONGS 2 and 3 sampling stations.

Differences in receiving water heavy metals concentrations were observed between onshore SONGS 1 stations and offshore SONGS 2 and 3 stations. Yearly mean receiving water copper concentrations were usually greater at offshore stations than at onshore stations. Yearly mean iron concentrations were usually greater at SONGS 1 stations, especially at Station X0. Yearly mean receiving water nickel concentrations were usually greater at onshore sampling stations than at offshore sampling stations. Receiving water concentrations of other metals showed no on-offshore trends.

Ocean Bottom Sediments

Sampling station yearly mean and maximum ocean bottom sediment concentrations of all sampled heavy metals were greater at the discharge (Station X0) than at the control Station C22S, but yearly mean concentrations at the discharge were similar to those at Stations D4S and D4N. Sediment texture at the control station was much coarser than at other SONGS 1 stations for five of the seven oceanographic surveys.

Offshore at SONGS 2 and 3 stations, the station yearly mean and maximum usually were slightly higher at Stations J0 and J2S than at other SONGS 2 and 3 stations.

The concentrations of ocean bottom sediment heavy metals are related to grain size of the sediment. Sediment grain size data are presented in Volume I, Oceanographic Data Report (SCE 1980a). Onshore sediments were generally more coarse than offshore sediments. Coarse sediments have less surface area per unit volume for adsorption of heavy metals than do fine sediments, thus heavy metals concentrations in coarse sediments should be less if all other variables are equal. This relationship between sediment grain size and heavy metals concentrations was observed during 1979 in the SONGS study area. Sediments at inshore Stations X0 and C22S were coarser, and the concentrations of all metals were slightly less than at respective offshore Stations J0 and J22S. This relationship did not occur at inshore Stations D4N and D4S when compared to respective offshore Stations J4N and J4S because grain size distributions were similar at those stations.

NUTRIENTS

Results of the analyses of surface and bottom nutrient samples from inside and adjacent to the three major kelp beds in the general vicinity of San Onofre and one offshore station are presented in Volume I, Oceanographic Data Report (SCE 1980a). Yearly mean seawater nutrient concentrations for individual kelp bed stations ranged from 0.44 µg-at/l to 0.48 µg-at/l for phosphorus, 1.13 µg-at/l to 1.78 µg-at/l for nitrate plus nitrite, and 0.41 µg-at/l to 0.61 µg-at/l for ammonia. At the offshore station, mean seawater nutrient concentrations were 0.64 µg-at/l for phosphorous, 3.92 µg-at/l for nitrate plus nitrite, and 0.48 µg-at/l for ammonia.

DISCUSSION

Water quality parameters measured during bimonthly surveys of 1979 were typical of the southern California nearshore marine environment. Dissolved oxygen, pH, heavy metals, and nutrient concentrations were measured in the San Onofre study area to determine effects of the SONGS 1 discharge on water quality, and background conditions prior to operation of SONGS 2 and 3.

DISSOLVED OXYGEN

Dissolved oxygen concentrations were not reduced by more than 10 percent due to the operation of SONGS 1 and are therefore in compliance with ETS, NPDES, and WQCP requirements. A general decrease in dissolved oxygen concentration was observed with increasing depth. Higher surface dissolved oxygen concentrations are mainly due to gaseous exchange with the atmosphere at the surface. Surface waters are generally at or near the oxygen saturation point. Photosynthetic activity of marine algae and phytoplankton in the photic zone adds to surface dissolved oxygen concentrations. Density stratification also contributes to the vertical dissolved oxygen gradient by inhibiting mixing of surface and bottom waters.

The vertical dissolved oxygen gradient at offshore SONGS 2 and 3 sampling stations was usually greater than at inshore SONGS 1 sampling stations because of greater depth offshore. Surface dissolved oxygen concentrations were not significantly different during bimonthly surveys at offshore SONGS 2 and 3 sampling stations. During the last five years of monitoring dissolved oxygen in the vicinity of SONGS, concentrations have always been typical of nearshore waters of southern California.

HYDROGEN ION CONCENTRATION

Surface pH was within the normal range previosuly observed in the vicinity of SONGS. Surface pH was not altered by more than 0.2 units due to the operation of SONGS 1 and therefore is in compliance with ETS, NPDES, and WQCP requirements. There were no spatial variations among required SONGS 2 and 3 sampling stations nor between inshore SONGS 1 and offshore SONGS 2 and 3 sampling stations. A general decrease in pH with increasing depth has been observed in the SONGS study area. This characteristic is typical of waters over the southern California Continental Shelf (SWPCB 1959).

HEAVY METALS

Heavy metals concentrations in middepth water samples and ocean bottom sediments at the four required SONGS 1 have been determined for the past five years (1975 through 1979). Results of this heavy metal monitoring are shown graphically in Figures III-1 through III-10. No persistent measurable increase in sediment concentrations of copper, chromium, iron, or nickel has been observed during the last five years of heavy metal monitoring. No persistent increase in receiving water concentrations of copper, chromium, or nickel has been observed during the last five years.

A measurable increase in receiving water iron concentrations has occurred during the last five years. This measurable increase was observed throughout the SONGS 1 study area, including the control station located 6700 m downcoast of the discharge. A measurable increase in receiving water iron concentrations from SONGS 2 and 3 preoperational monitoring stations was also observed during 1978 and 1979. Since this measurable increase has been observed throughout the SONGS 1 study area, including the control station, and in the SONGS 2 and 3 study area, it is not attributed to SONGS 1 operation.

Middepth receiving water iron concentrations at the discharge station were higher than at other stations during 1979. These higher values at the discharge station may have been the result of nearby (200 meters away) construction activities for placement of SONGS 2 and 3 intake and discharge lines. Oxidation of ferrous metals in the temporary steel construction trestles for SONGS 2 and 3 intake and discharge lines may have caused higher iron concentrations in the water column at the discharge.

Since there has been no measurable consistent increase in heavy metals concentration in both the receiving waters and ocean bottom sediments during the past five years, it is anticipated that the heavy metals monitoring for SONGS 1 will be discontinued in accordance with ETS specification 3.1.1.a.(2).

NUTRIENTS

Nutrient concentrations inside and adjacent to the San Mateo, San Onofre, and Barn kelp beds varied between surveys of 1979, but yearly mean concentrations showed no significant spatial variations between kelp beds. Inorganic phosphorous, and nitrogen as nitrate plus nitrite concentrations were from two to three times greater at the offshore sampling station than at the kelp beds. Offshore ammonia concentrations were about the same as at the kelp beds.

Inorganic nitrogen concentrations were three times greater than ammonia concentrations in and adjacent to the kelp beds. Ammonia is converted into inorganic nitrogen (nitrate and nitrite) by bacteria and therefore is expected to be less concentrated than the latter two unless there was a large input of ammonia into the receiving waters.

Nutrient concentrations generally increased with depth. Dead organisms sink to the bottom where they decompose and add nutrients to the bottom waters. Sediments resuspended by currents and waves also release nutrients into bottom waters and may have affected nutrient concentrations in the study area. Surface nutrient concentrations are often reduced through uptake by marine algae and phytoplankton.

SUMMARY

1. The operation of SONGS 1 did not depress dissolved oxygen (DO) by more than 10 percent, nor did it alter hydrogen ion concentration (pH) by more than 0.2 pH units, and thus was n compliance with regulatory requirements for DO and pH.

2. An increase in receiving water iron concentration has been observed throughout the SONGS 1 study area, including the control station, from 1975 to 1979. These changes are attributed to natural variability in concentration and not the operation of SONGS 1.

3. During the past five years, there has been no consistent measurable increase in receiving water or ocean bottom sediment heavy metals concentrations due to SONGS 1 operation. It is therefore anticipated that heavy metals sampling for SONGS 1 will be discontinued in accordance with ETS.

4. Nutrient concentrations at the kelp beds varied between surveys of 1979 but mean concentrations showed no significant differences between kelp beds.

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CHAPTER 2D

SEDIMENTOLOGY

INTRODUCTION

This chapter describes the marine geological setting of the San Onofre Nuclear Generating Station (SONGS) area and summarizes and discusses the results of the third 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 SONGS Units 2 and 3 (Figure 1-1). The findings are the result of quarterly sediment investigations conducted from February 1979 through December 1979. The sediment monitoring work was conducted in conjunction with the biological infaunal studies described in Chapters 4A and 5A.

Environmental studies of San Onofre intertidal and subtidal areas began in the fall of 1963 and have continued through the construction and operation of Unit 1. The oceanographic and biological consulting firms involved in field investigations and data analyses 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).

Previous construction-related studies (LCMR 1974) emphasized the effects of cliff excavation and related construction activities on the beach environment. Recent investigations (1977-1980) were concerned with the effects of dredging operations on both the offshore and beach environments. The purpose of the present sediment monitoring is to 1) assess the effects of sand dispersal during construction and dredging operations associated with the addition of SONGS Units 2 and 3 to the existing generating facility, and 2) to provide information on physical variables previously identified as being major controllers of the marine biology of the site.

Sedimentological investigations were conducted in both the intertidal and subtidal nearshore environments adjacent to SONGS.

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 SONGS Unit 1.

Two contiguous trestles were constructed from July through December 1976 for the installation of intake and discharge conduits of Unit 2. From the onshore staging area, the trestles extend approximately 1006 m offshore. After the Unit 2 cooling water conduit installation was completed, the trestles were removed and installed slightly downcoast for emplacement of cooling water conduits for SONGS Unit 3. The trestles seaward of the intake structure of Unit 3 were removed in 1979; the remaining portion of the Unit 3 trestle is scheduled to be removed ca. June 1980.

During site preparation, approximately 1,739,923 m^3 of spoil material was excavated from the bluff adjacent to SONGS Unit 1 (SCE 1978). Nearly 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 sheet-pilings. The pad area was utilized as a material and equipment staging area during the construction of the offshore conduits. Eventually, 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 2D-1). In addition to the dredge material deposited on the beach, dredge material was used as conduit backfill between July 1977 and November 1977 (69,314 m^3) and between January and December 1978 (Table 2D-1).

Dredge activity during 1978 was high in the winter and spring (January to May) with displacement averaging over 25,996 m^3/month (SCE 1979), and decreased during the summer, fall, and early winter months (June to November) with a monthly average displacement of just over 11,469 m^3. Dredge placement activity was considerably greater just inside the 6 m and 9 m isobaths (Figure 2D-1.

In 1978 and 1979, dredged material was deposited inshore on the south side of the trestles for the Unit 3 cooling conduit (Figure 2D-2) in order to compensate for interruption of the natural sand transport path by the construction laydown pad on the beach.

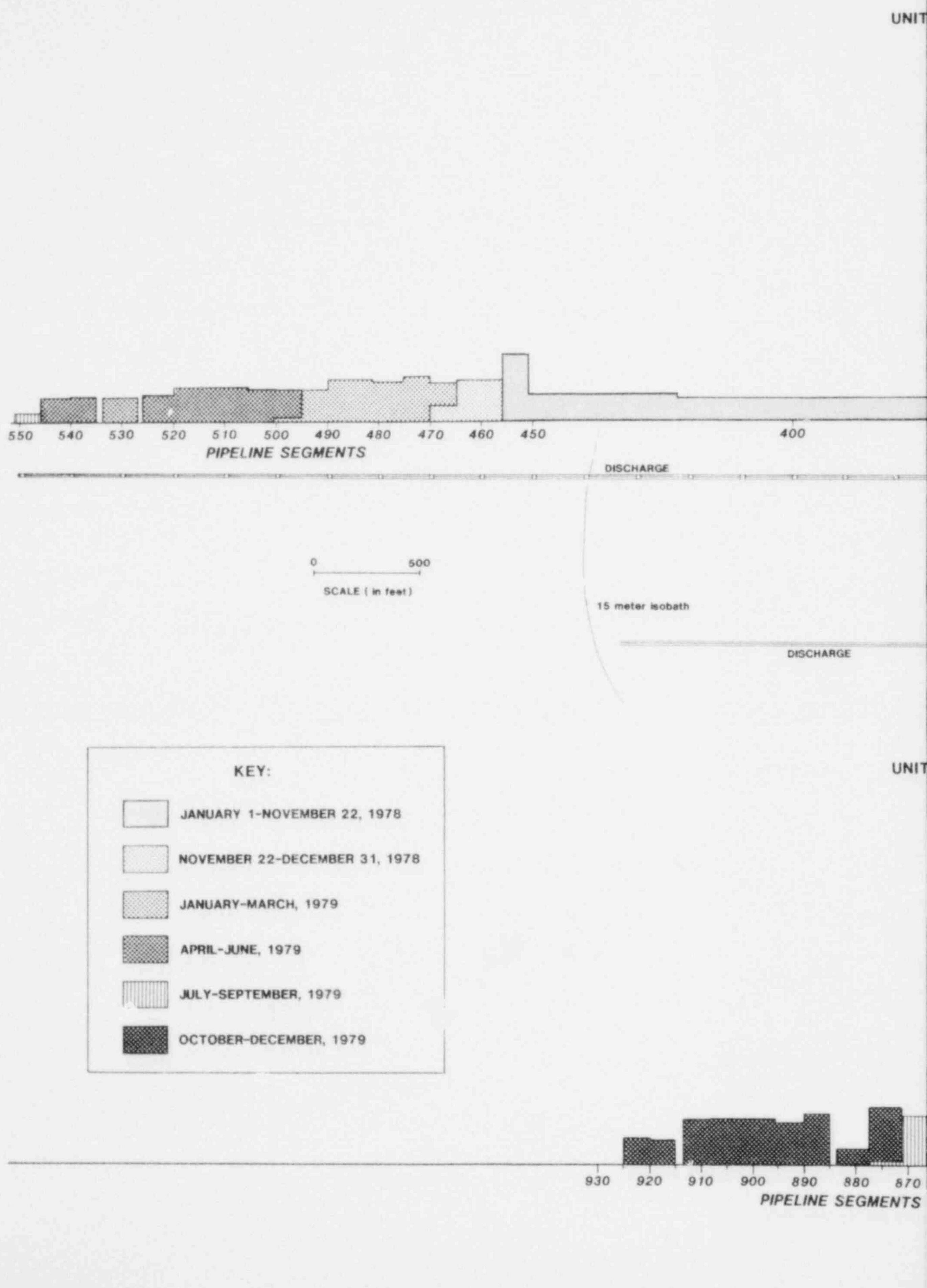
A summary of the dredge material displacement at SONGS during 1977 to 1979 is presented in Table 2D-1 with the quantity, location, and time of placement shown in Figure 2D-1.

Table 2D-1. Volume and disposition of disposed sand (m^3) 23 March 1977 through December 1979.

Month	Offshore Conduit/ Backfill Placement	Beach Placement	Littoral Zone
1977			
Mar	-	7,692	
Apr	-	11,842	
May	-	9,467	
Jun	-	12,852	
Jul	7,248	19,603	
Aug	-	63,763	
Sep	27,597	37,734	
Oct	12,125	43,142	
Nov	22,434	9,410	
Dec	-	25,800	
1978			
Jan	8,334	16,171	
Feb	13,257		
Mar	22,089		
Apr	42,039		
May	29,942		
Jun	14,680		
Jul	13,763		
Aug	11,010		
Sep	2,753	6,346	
Oct	7,187	5,368	
Nov	-	8,182	
Dec	6,117	8,831	
1979			
Jan	31,856		
Feb	22,220		
Mar	27,242		
Apr	23,550		
May	26,821		
Jun	7,420		9,008
Jul	8,983		17,832
Aug	40,281		
Sep	38,357		
Oct	35,939		
Nov	20,528		
Dec	8,719		

MARINE GEOLOGICAL SETTING

The SONGS site is located on a coastline oriented approximately N55°W in a region where waves approach through directional windows between the California coast and Santa Catalina and San Clemente Islands. Westerly swells are the most frequent long-period waves to reach the site, but contributions come from sea waves approaching the NW to WNW and from sea and swell from the SSE to SW. The wave climate in the vicinity of the SONGS site is shown in Figure 2D-3. These waves generate a net littoral transport toward the SE of about 100,000 yd^3 of sand per year (State of California 1977). Other estimates (State of California 1976) are over


UNIT
550 540 530 520 510 500 490 480 470 460 450 400
PIPELINE SEGMENTS
DISCHARGE
0 500
SCALE (in feet)
15 meter isobath
DISCHARGE
UNIT
KEY:
JANUARY 1-NOVEMBER 22, 1978
NOVEMBER 22-DECEMBER 31, 1978
JANUARY-MARCH, 1979
APRIL-JUNE, 1979
JULY-SEPTEMBER, 1979
OCTOBER-DECEMBER, 1979
930 920 910 900 890 880 870
PIPELINE SEGMENTS

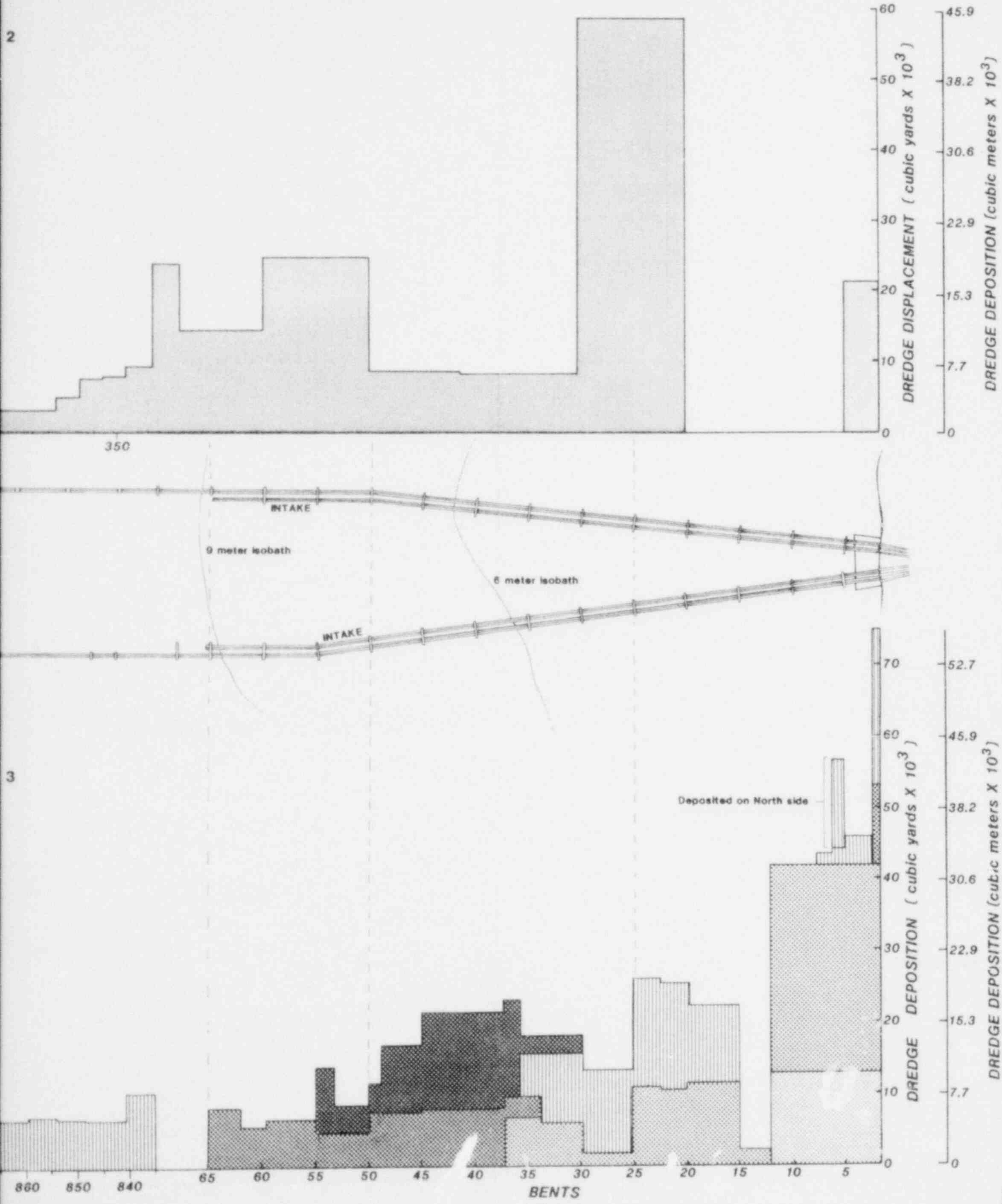


Figure 2D-1. Dredge spoil displacement quantities along SONGS Units 2 and 3, discharge, and intake structures.

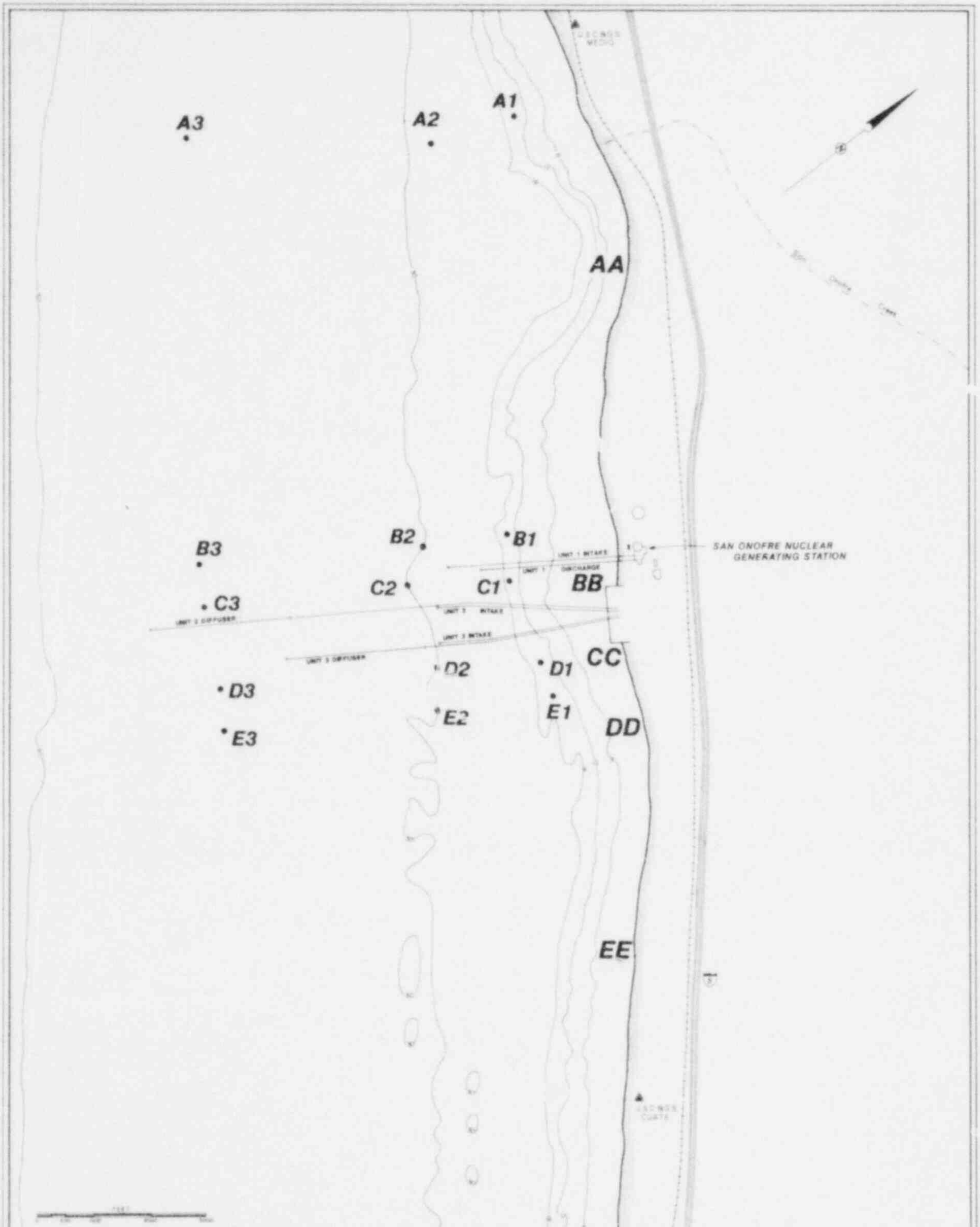


Figure 2D-2. Intertidal and subtidal sampling locations.

twice that amount. The sand moves through the littoral cells extending from Dana Point to La Jolla Submarine Canyon (interrupted by jetties at Camp Pendleton and Oceanside). These relationships are shown in Figure 2D-4 taken from State of California (1977). The source of sediments within the littoral cell are San Juan Creek, San Mateo Creek, San Onofre Creek and other small streams, and the cliffs and bluffs from Dana Point to San Onofre. San Juan Creek has a drainage area of 116 square miles and has delivered about 56,000 yd^3 of coarse sediment per year to the littoral cell. San Mateo Creek has a drainage area of 133 square miles and delivers about 32,000 yd^3 of sediment per year. San Onofre Creek has a drainage area of about 46 square miles and delivers about 5,000 yd^3 of sediment per year. The rock in the bluffs and cliffs are soft tertiary marine sandstones that weather to provide an

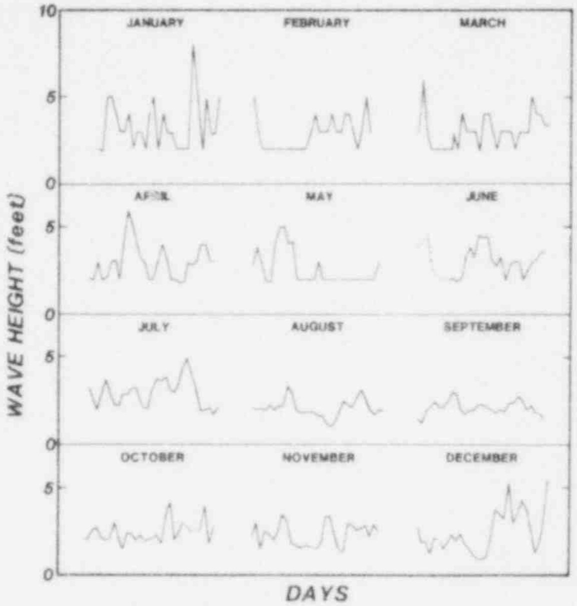


Figure 2D-3. Daily maximum significant wave height each quarter in the vicinity of the SONGS site for the year 1979.

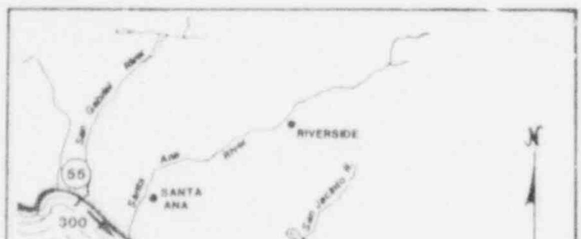


Figure 2D-4. Rates of longshore transport of sand in the SONGS area (State of California 1977).

unknown, but probably significant amount of sand to the littoral drift. The major supply of sand to the littoral cell is not uniform or even periodic on a yearly basis. The streams debouch their stored bedload of sediment only during floods induced by infrequent severe rainstorms.

Sediments from the sources are distributed laterally along the littoral cell as beach drift and littoral drift. Wave action in the surf zone and shoreward winnows fine material from the sediment, leaving sand and gravel fractions in the intertidal zone. The suspended fines are carried seaward by rip currents and tidal ebb flow and probably to a lesser extent by wind-induced seaward currents. The pattern of sediments in the area reflects the effects of these processes. Sand and coarser material should occur in the intertidal zone; coarsest material is to be found where available wave energy (proportional to the square of the wave height) is a maximum along the shore. Such places are at headlands where refraction concentrates wave energy or downcoast of a barrier to littoral drift where waves expend energy in erosion rather than in maintaining suspended or tractive transport.

Because of the turbulent energy at the point where waves break, the coarsest offshore material is found there. The coarsest sediments on the beach occur on the winter berm because only the highest waves of the season can reach the berm elevation and deposit sediment.

Seaward of the surf zone, deposition of finer material (fine sand, silt, and under particularly quiescent conditions, floculated clays) occurs during the summer season. Seaward of about 10 m, only the finest material delivered by streams is deposited.

A seasonal shift in the offshore transfer of sediment occurs in response to the changes in waves from summer (long low swell) to winter (short, high storm waves). Winter storm waves tend to remove material from the littoral zone and deposit it just seaward. Summer swell, able to move sediment particles in deeper water, gradually move the material shoreward. Such seasonal changes are usually restricted to water depths less than 10 m. The entire process is complicated by the natural irregularity of the coastline and bathymetric contours, and by the variability of the wave climate. Also, the transport of suspended material can be in a direction opposite to that of tractive transport (transport by rolling, sliding, or bouncing along the bottom) at various points normal to the coast under certain wave conditions (Komar 1976).

The onshore-offshore patterns of sediment movement caused by waves leads to a fractionation of sizes in the sediment. Coarse material is transported shoreward tractively at rates proportional to their grain size, while fine material is carried seaward in suspension. The general sediment pattern is expected to conform to the effects such a fractionation of sizes.

The actual pattern of sediments in the intertidal and subtidal zones is a time-dependent result of all the processes described above. Variability in sediment supply and in wave energy can be expected to produce patchiness in the pattern of sediments at SONGS. The littoral drift at the site is among the lowest estimated for littoral cells in California (it is 1/10 of the maximum observed at Oxnard in Ventura County according to U.S. Army CERC 1973). This coupled with the fact that the coastline is emergent, as indicated by several elevated ancient strand (beach) lines onshore between Carlsbad and Cardiff-by-the Sea (State of California 1960), suggests that a thick layer of recent marine sediments (sands and silts) cannot be expected in the SONGS area. Indeed, the areas of cobbles observed offshore and mapped by the side-scan sonar technique, probably represent a substrate of extremely coarse material that is not completely buried by the modern sediment cover.

With an understanding of the expected natural pattern of sediments in the SONGS area, the kinds of changes expected to be induced by construction of SONGS Units 2 and 3 can be deduced. They are of several kinds:

1. Impediment or diversion of littoral drift by beach structures. The construction of a laydown pad bulkhead on the beach causes a groin effect that retards littoral drift. Sand accumulates upcoast (NW) and tends to be eroded downcoast (SE). The tendency reverses temporarily during the arrival of southerly waves. As a new equilibrium is approached (i.e. as the groin fills) the local beach strand should shift seaward. The lower intertidal region off the bulkhead can be expected to be one of sand accumulation.

2. Bathymetric changes caused by underwater excavation and dumping of dredge spoil. Expected changes would derive from the redirection of bottom currents and the alteration of wave refraction patterns. Such effects should be extremely local. Positive bathymetric changes should induce local scouring and

removal of fine fractions from sediments; negative changes would act as sediment traps that should accumulate fines from suspension and sediments moving by traction.

3. Dislocation of sediment facies. Sediment dislocated by dredging operations would not be at equilibrium with the local hydraulic regime if material is placed at a depth different from that where it was removed. In the case where subtidal sediment is deposited on the beach, the effect would be temporary because of vigorous reworking by breaking waves there. In the reverse case, coarser facies would remain intact and only gradually be covered by finer sediments.

4. Changes in natural sediment supply. Installation of bulkheads, retaining walls, parking areas, and structures tends to inhibit the erosion of bluffs at the site. The effect is minor as relatively small amounts of sediment are introduced to the littoral zone from the SONGS site. However, denudation of cliffs by removal of vegetation during earthmoving operations connected with construction can accelerate erosion by winter rains and thereby increase the supply of sediment from the cliffs and bluffs. In either case, the effects of changed sediment supply would be noticed downcoast from the construction site, if at all. In all cases, short-term changes in the pattern of sediments should be difficult to perceive because of the natural variability of the environment. Long-term changes might be discernable by examining the patterns developed from extended observation of the environment.

MATERIALS AND METHODS

Sediment characteristics of the intertidal and subtidal areas adjacent to SONGS were sampled during four quarterly surveys from February through December 1979 (Appendix IV).

Thirty-five intertidal sampling stations along 5 transects and 18 subtidal stations along 6 transects were established (Figure 2D-2). Sampling was initiated in December 1976, four months prior to commencement of dredging, and continued quarterly through December, 1979. The results, analysis, and interpretations presented herein are based on data collected during quarterly surveys conducted in 1979. The results of prior sediment studies were presented in a 1978 and 1979 annual report (MBC 1978, SCE 1979).

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

INTERTIDAL SEDIMENTS

Measurement of the beach profile, collection of samples for sediment grain size analysis, and sampling of the intertidal biota was conducted along five permanently established transects and perpendicular to the shoreline (Figure 2D-2). Transects were located with respect to a reference transect situated midway between the cooling water conduits of Units 2 and 3. Sample size, replication, and spacing were determined from the results of experiments designed to measure loss of information limits for a minimal sampling pattern.

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

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, and were surveyed in from the reference mark to MLLW. Sampling sites were established at 1 ft elevation intervals from +6 ft to MLLW.

Along each transect, core samples for sediment grain size analysis were collected at 0, +1 (0.3 m), +2 (0.6 m), +3 (0.9 m), +4 (1.2 m), +5 (1.5 m), and +6 ft (1.8 m) tidal elevations (MLLW). Five replicate samples were taken at each intertidal level at each of the five beach transects. Sediment cores were collected to a depth of 30 cm except when cobble prevented core penetration. Material for the analysis was removed from the entire length of the core.

Grain Size Analysis

Grain size distributions of each sample were determined by using a settling tube similar to that described by Gibbs (1974). The device uses a differential transformer to sense the load exerted by sediment as it settles and accumulates in a pan near the base of the settling column. The strip chart output from the load sensor was converted to a cumulative frequency plot of the sizes of the particles constituting the samples. Sizes were reported in phi units (phi = $-\log_2$ diameter in millimeters). A list of size measures is presented in Appendix IV.

Grain size data was converted to the cumulative frequency of the occurrence of grain size classes. Statistical parameters (mean grain size, sorting, skewness, and kurtosis) of each grain size distribution was extracted using moment measures (Krumbein and Pettijohn 1938, Sharp and Fan 1973).

SUBTIDAL SEDIMENTS

Samples for sediment characterization and determination of sedimentation rates were collected during biological infauna surveys 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 2D-2). 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. Three replicate samples were collected at 6 m isobath stations; four replicate samples were taken at the 9 and 15 m isobath stations.

Each sample consisted of a single core (minimum penetration depth 10 cm) Cores were collected adjacent to the area of biological sampling.

Grain Size Analysis

The sand and gravel grain size distributions of each replicate sample 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).

Sedimentation Analysis

At each station, a sediment trap for determining deposition rates of suspended sediments was attached to a monument as shown in Figure 2D-5.

The sediment traps used in the study were made from thin-wall ABS plastic pipe 52 cm long and with a diameter of 10.6 cm. 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. Weaver (1978) has shown that resuspension of trapped sediments is avoided if the tube length exceeds 4 times its diameter. A clear plastic liner in which the sediments were collected was fitted inside the trap housing. 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.

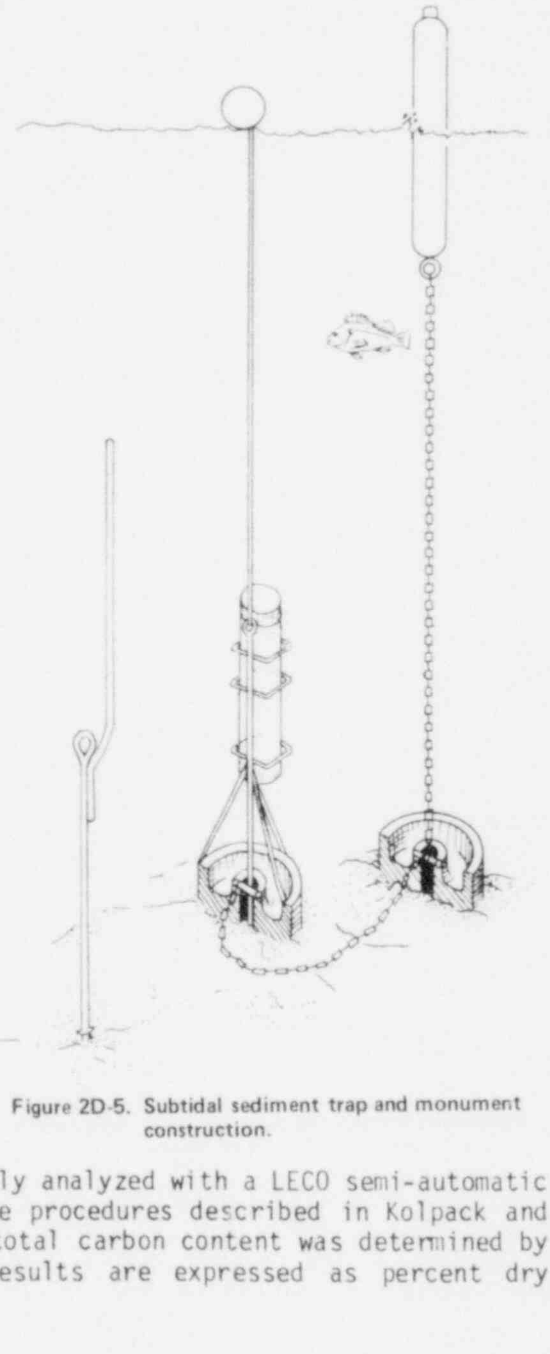


Figure 2D-5. Subtidal sediment trap and monument construction.

Organic Carbon Analysis

The organic carbon content of the sediments was measured to determine the amount of organic nutrients available to infaunal species. Samples for organic carbon analysis were collected from the sediments adjacent to each biological sampling station and frozen in the field. Three replicate samples were collected at the 6 m isobath stations; 8 replicates were taken at the 9 and 15 m isobath stations. A total of 114 samples were taken each quarter. 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.

DATA PRESENTATION

Raw grain size analysis data, physical measurement data, and organic carbon analysis data are included in Volume 1. Oceanographic Data (SCE 1980).

ANALYSIS RATIONALE

To detect and evaluate the effects of construction for Units 2 and 3 on intertidal and subtidal sediments at SONGS, it is necessary to first identify the natural state of the sediments there, then seek evidence of anomalous sediment conditions attributable to construction effects. Both the natural state and construction-induced perturbations of the sediment environment are dynamic in nature. They reflect the influence of the energy of water motion upon the supply, transportation, and deposition of sedimentary materials. It is important to employ descriptive sediment measures that reflect the dynamics of sedimentation so that the processes active in the environment are characterized.

The measures chosen were the sediment grain size population statistics found in a sediment sample. The premise was that a discrete size distribution function describes the aggregation of detrital sediment particles from its origin during erosion of rocks, during transport, and at rest in a sedimentary deposit. The conventional distribution function used in sedimentology is the log-normal model. As used, it is a two-parameter function (characterized by mean and variance), but actually it is a particular member of the general Weibull distribution, a three-parameter function commonly used to describe the products of comminution. As an aggregation of sediment particles is acted upon dynamically by agents of transport (fluviatile, aeolian, and marine), the aggregate's distribution function changes. The statistical parameters that define the function reflect those changes in ways that permit interpreting the sedimentological processes active in the environment. The parameters are:

1. Mean Grain Size. This statistic summarized the power available to move sediment particles to and through the environment.

2. Coarse Fraction Percentage. The coarsest material in the sediment reflects the maximum transportive or erosive energy affecting the environment. This measure was important because the most rapid sediment erosion transport occurred during storm wave events. The coarse fraction thus provided a significant estimate of the vigorousness of the wave climate in the littoral zone.

3. Sorting. This is a measure of the standard deviation of the particle aggregation which reflects the combined effects of variability in the sizes of sedimentary material supplied to the environment and of the variability in the energy transport. Highly turbulent flow in river flood water and in breaking storm waves leads to poor sorting (high variability), while oscillatory motion during periods of regular swell produces a well-sorted sediment.

4. Skewness. This measure of the assymetry of the sediment size distribution reveals the presence or absence of extremely fine or coarse particles and indicates an admixture of atypical materials to the sediment or an atypical removal of extreme-sized grains. Skewness indicates selective processes operating in the sedimentary environment by comparing the degree of sorting of coarse materials to that of the fine fraction.

5. Kurtosis. This measure of the peakedness of the size distribution compares the degree of sorting of the central sizes to that of the extremes. Normal distribution curves have a kurtosis value of $K_g = 1.00$. Platykurtotic curves, $K_g < 1.00$, suggest the incomplete fusion of two or more distinctly different sediment types. Values of $K_g > 1.00$ are leptokurtotic and thus indicate the relative absence of size extremes resulting from selectivity in transport and reworking of sediment deposits.

Sediments occurring in the intertidal and subtidal zones have been subjected to several cycles of transport and deposition and have moved as tractive bedload, in suspension or both. These cycles tend to segregate sediment types within the littoral zone, while at the same time integrating the effects of extreme variability in the energy affecting the environment. As a consequence, marine sediments tend to occur in facies, each of which is characterized by a particular ensemble of values for the statistical properties of the size distribution. The objectives of the sedimentology study were addressed by examining naturally-occurring facies at the SONGS site to allow recognition of anomalous sediment conditions caused by construction activities.

The examination of the ensembles of statistical parameter values extracted for each sediment sample was facilitated by two techniques: correspondence factor analysis and agglomerative hierarchical classification (cluster analysis). These analyses were performed using a digital computer programmed with the Ecological Analysis Package of Smith (1977).

Correspondence Analysis

Correspondence analysis, a type of 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 most efficiently summarizes associations among the stations and variables. Each station and each variable is represented by a point; 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 is proportional to the distance between them in the space. The space can be viewed from 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. Plots of these point projections (called scores), and station associations are examined for environmental relationships.

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. A hierarchy can be developed for the factor and thus 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.

Interpretative information is extracted by plotting the scores of the two most important factors on orthogonal axes. Stations tend to form groups; sediments at those stations are interpreted to be the result of the same environmental process. Sediment variables plot such that their proximity to one another indicates correlation between them, and their proximity to station groups indicates the sediment variables that characterize the facies to which the station group belongs. The definition of such relationships is refined by considering subgroupings revealed by plotting scores of factors having subsidiary importance (those that account for lesser amounts of variance in the data). The net result of the correspondence analysis is the identification of the sedimentological processes active in the environment and the distribution of the sediment samples affected by those processes.

Classification Analysis

Agglomerative hierarchical classification analysis was applied to the sediment textural data collected at subtidal stations 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 (β = 0.25) of Lance and Williams (1966).

This analysis provides a verification of the segregation of stations into distinct facies groups. Secondarily, the classification analysis of sediment variable data yields an estimate of redundancy in the choice of sediment statistic variables by identifying those variables with consistently high similarity with each other.

RESULTS

The results of the measurements and analyses of the geomorphic and sedimentological properties of the SONGS intertidal and subtidal zones are presented with particular regard to those features that indicate: 1) natural conditions and 2) effects of construction.

THE INTERTIDAL ZONE

Beach Profiles

One intertidal transect (AA) was located about 1187 m upcoast (NW) of the SONGS site and one (BB) was located just upcoast of the site. Three transects (CC, DD, and EE) were located downcoast (SE) of the site at distances of 236 m, 629 m, and 1187 m (Figure 2D-1). Topographic profiles were measured at each transect in each quarter of 1979. Data obtained from beach profile measurements are presented in Table 2D-2. The profiles were plotted (Figure 2D-6) to show the changes in beach morphology during successive measurements.

Table 2D-2. Beach characteristics.

	Beach		Upper Beach Slope		Lower Beach Slope		Beach		Upper Beach Slope		Lower Beach Slope	
	Profile Area (m^2)	Width (m)	Cotangent of Slope	Degrees	Cotangent of Slope	Degrees	Profile Area (m^2)	Width (m)	Cotangent of Slope	Degrees	Cotangent of Slope	Degrees
			Transect AA						Transect DD			
Feb	-*	-	-	-	1.9	27.8	-	-	-	-	1.3	37.6
May	269.2	75.0	36.4	1.6	9.1	6.3	343.3	116.0	7.4	7.7	20.4	2.8
Aug	260.8	95.0	18.9	3.0	15.1	3.8	236.9	77.0	8.1	7.0	11.3	5.1
Nov	277.2	106.0	26.6	2.2	14.9	3.8	298.0	106.0	8.6	6.6	17.2	3.3
			Transect BB						Transect EE			
Feb	-	-	-	-	2.7	20.3	-	-	-31.4	-1.8	1.5	33.7
May	481.6	142.0	97.4	0.6	13.9	4.1	173.3	59.0	-31.4	-1.8	9.1	6.3
Aug	492.9	139.0	148.1	0.4	11.6	4.9	203.7	75.0	-263.7	-0.2	10.6	5.4
Nov	503.8	140.0	102.9	0.6	16.9	3.4	185.5	58.0	-40.9	-1.4	7.2	7.9
			Transect CC									
Feb	-	-	-	-	1.9	27.8						
May	294.8	85.0	10.9	5.2	10.0	5.7						
Aug	407.2	138.0	17.4	3.3	16.2	3.5						
Nov	229.8	77.4	9.7	5.9	15.0	3.8						

*not measured

The profiles show that the least change from beach erosion or accretion occurred at Transects (AA and EE) most distant from the SONGS site. The most changes occurred at Transect CC just downcoast of the site. Considerable changes occurred also at Transect DD, 629 m downcoast of the site.

Substantial accretion occurred at upcoast transects (AA and BB) over the first half of 1979; accretion at Transect BB was about 3 times that at Transect AA. Little change occurred at either transect in the last half of 1979.

During the first half of 1979, net erosion occurred at Transect CC, particularly below 3 m (MLLW) and above 5 m (MLLW). Accretion prevailed during the third quarter of 1979 and erosion resumed during the last quarter. It is noteworthy that only at Transect CC did appreciable erosion occur at upper elevations (>5 m) on the beach. Elsewhere, the upper beach (backshore) was characterized by little or no change; this was especially marked at Transect BB. The tendency for erosion and accretion at Transect CC was just the opposite of that at Transect DD.

Substantial accretion in the first half of 1979 was virtually removed by August and only partially re-accreted in the last quarter of 1979.

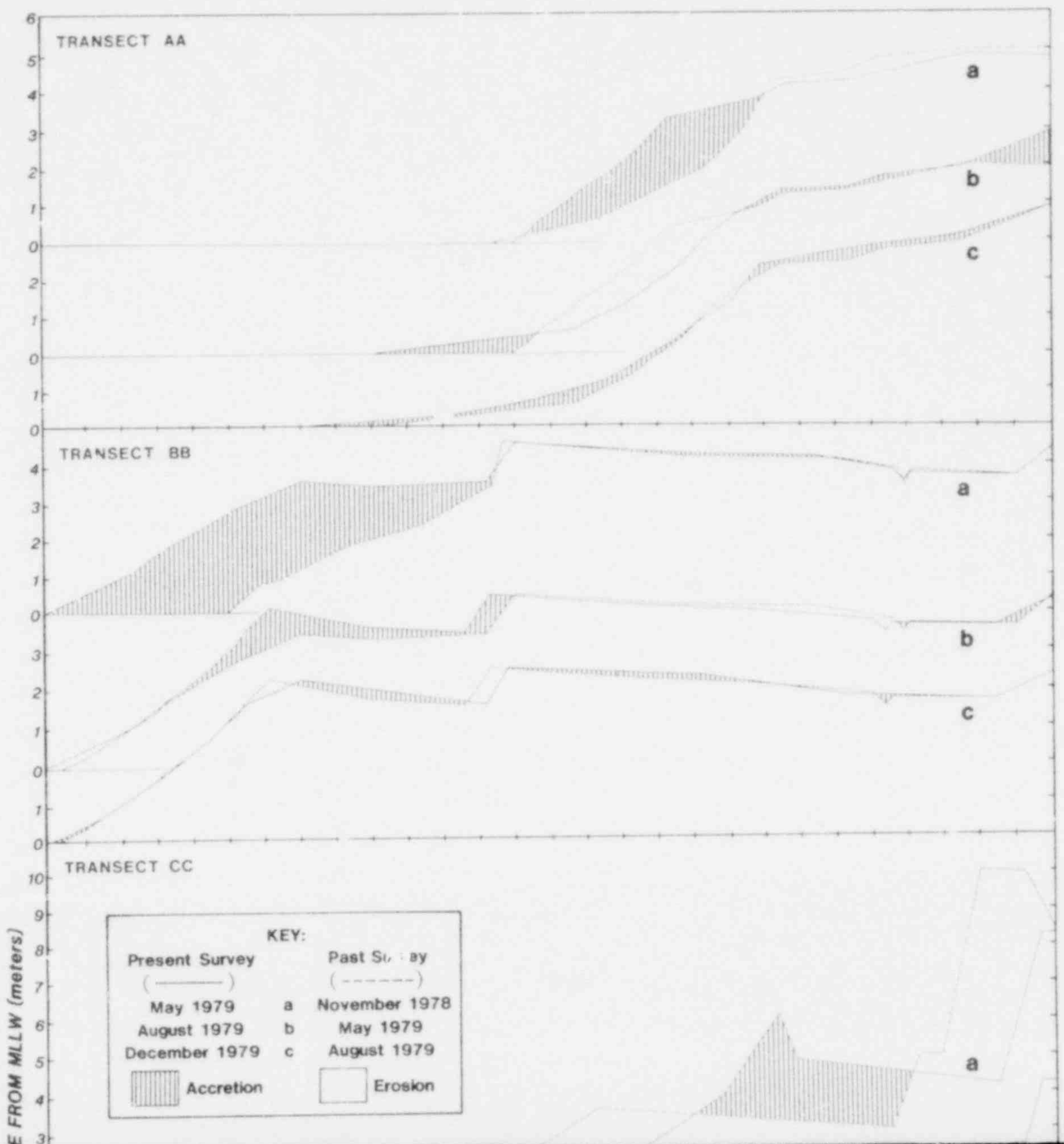
Changes at Transect EE were minor. Erosion of the beach face in the first half of 1979 was followed by accretion in the third quarter. The erosion of the beach face resumed in the last quarter of 1979.

The slopes of the foreshore and of the backshore at each transect remained remarkably constant throughout the year despite erosion and accretion. The only exception occurred at Transect DD where the foreshore slope steepened in August and remained so in December.

A comparison of quarterly profiles emphasized seasonal changes in beach morphology; to obtain information on long-term trends of shoreline transgression or regression, yearly profiles measured at similar times of the year must be compared. An appropriate comparison should be made on profiles measured after winter storms have eroded the beach and before summer waves have caused appreciable restoration. Alternatively, profiles measured after summer accretion is complete but before winter erosion commences also would be suitable. However, only the November 1978 and December 1979 profiles span the year, so they were used for the purposes of examining the yearly change in the beaches (Figure 2D-7).

Profiles upcoast of the construction pad were marked by accretion during 1979. The beach at Transect AA transgressed about 27 m at MLLW and about 6 m at the mid-level of the beach face. The beach at Transect BB advanced about 25 m at MLLW and about 33 m at mid-level of the beach face. This represented the maximum net accretion observed in 1979. The broad backshore at Transect BB showed little net change.

Shoreline regression was substantial at Transect CC. The shore eroded 30 m at MLLW and 27 m at mid-level of the beach face. The high backshore at Transect CC disappeared during 1979. Approximately 15 m x 15 m of beach cross-section was removed. A small amount of accretion (1.5 m x 18 m) occurred near the berm. The shoreline at Transect DD advanced 39 m at MLLW and 18 m at mid-level of the beach face. Net accretion was measured along the entire profile but to a lesser extent at the upper half of the beach. The net change in the shoreline was slight at Transect EE. Regression of about 6 m affected the entire beach face; little net change occurred at the backshore.


TRANSECT AA
TRANSECT BB
TRANSECT CC
a
b
c
KEY:
Present Survey
(————)
May 1979 a November 1978
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December 1979 c August 1979
Accretion
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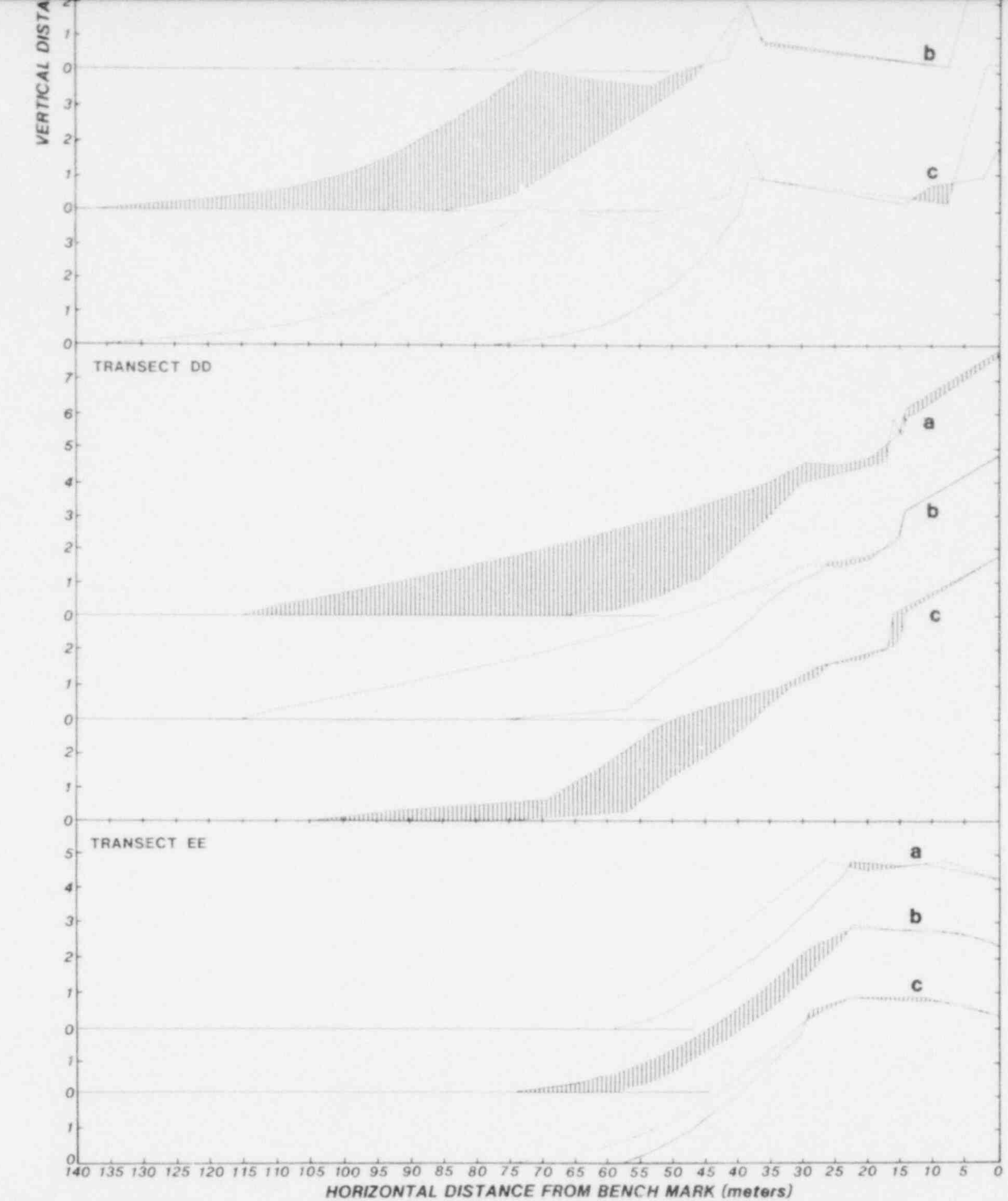


Figure 2D-6. Beach profiles at intertidal transects.

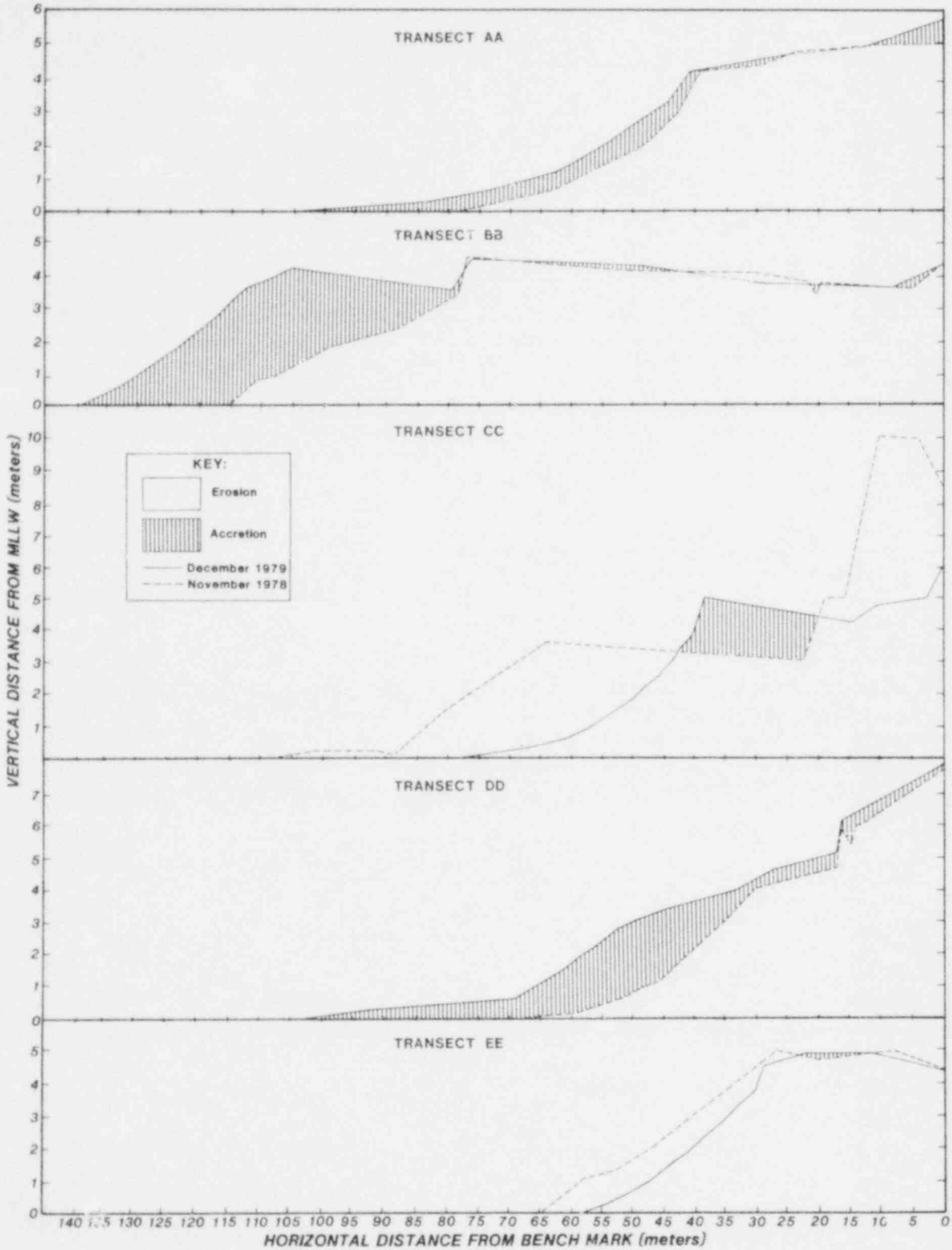


Figure 2D-7. Annual changes in intertidal beach profiles.

Summarizing the changes for the year at the site, the shore advanced upcoast (especially immediately upcoast) of the construction pad and retreated slightly at Transect EE. The beach retreated just downcoast of the pad. Considerable advance occurred at Transect DD, 629 m downcoast of the construction pad. These net changes were interpreted as the effects of a groin-like interruption of the natural southerly beach drift past the site. Sand was impounded upcoast of the construction pad forming a broad backshore; erosion downcoast caused fluctuation in the position of the shoreline. A slight net regression downcoast of the site probably was related to the interruption of the beach drift also.

Pertinent changes in beach profile area (Figure 2D-8) included:

1. Profiles farthest from the SONGS site (Transects AA and EE) showed relatively little change in area from November 1978 to December 1979.

2. Profiles just downcoast from the site (Transects CC and DD) showed considerable variation in area during the year.

3. The profile just upcoast of the site showed the least change in area from May to December 1979; the change from November 1978 to December 1979 suggests that the area increased asymptotically toward a maximum. The maximum area of this profile is almost twice that of the average area of the other profiles.

Beach slopes (Table 2D-2) changed little during the year at the upper part of the beach (berm and landward), which were nearly flat at transects farthest from the SONGS site (Transects AA and EE) and at the transect just upcoast of the site (BB). Upper slopes at downcoast transects (CC and DD) sloped gently (5° and 7°, respectively) seaward.

The lower beach slopes (seaward of the berm) showed a dramatic change from February 1979 when they were quite steep at all transects to May 1979 when the slopes at all transects became gentle (3 to 6°) and remained so for the rest of the year. The lower slope at the transect farthest downcoast (EE) steepened to nearly 8° in December 1979.

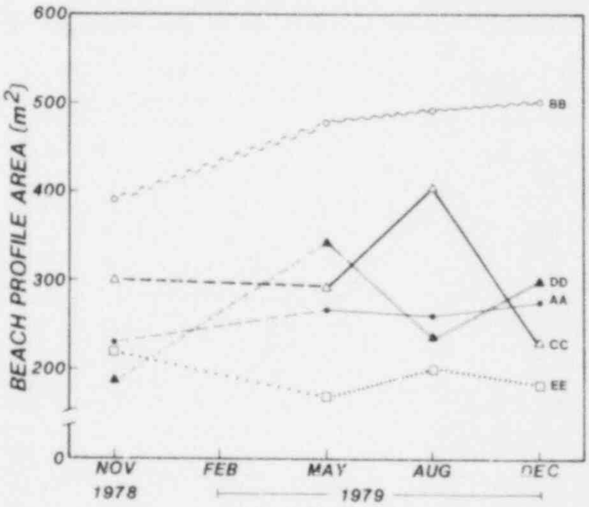


Figure 2D-8. Changes in intertidal beach profile area.

<u>Beach Sediment Characteristics</u>

The statistical parameters calculated from grain size analyses of the intertidal sediment samples were plotted (Figures 2D-9 through 2D-13). The mean grain size of all replicates at each transect (elevations from 0 to +6 ft MLLW) are shown in Figure 2D-9. Transect BB sediments showed the least change over the year, while Transect AA exhibited the most change. In general, variation in mean grain size was less at upper elevations (+4 to +6 ft) than at lower elevations (0 to +3 ft), that were situated in the zone of active wave swash and backwash over half the time (mean tide level is 2.7 ft above MLLW). The upper elevations were reached by waves only during high tides or times of high waves (usually the winter), so it was expected that less change would be noted. A tendency

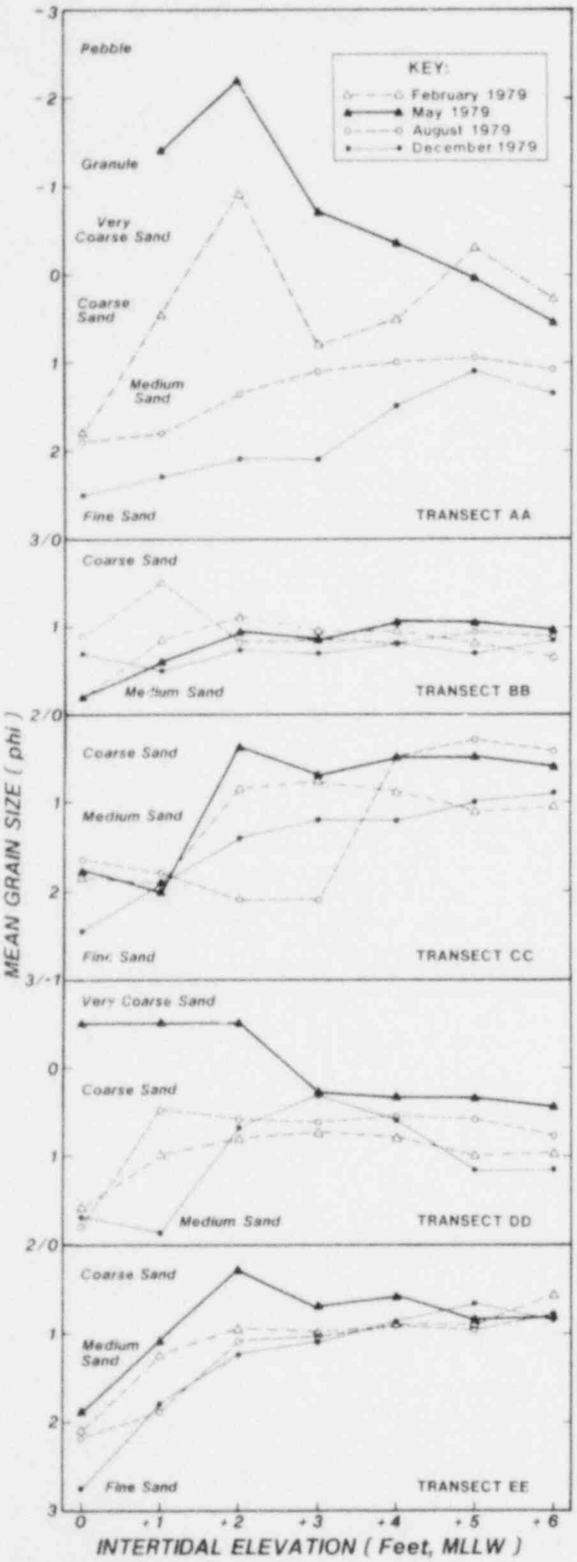


Figure 2D-9. Mean grain size profiles by level for each survey period.

for coarser mean grain sizes at high beach elevation was evident. This also conformed to the expectation that these sediments were transported and deposited there by high winter waves.

No distinct pattern was apparent in the quarterly succession of changes in mean grain size at the transects. Mean grain sizes tended to be higher at elevations below +4 ft in May 1979 (elevations 0 and +1 on Transect CC and elevations 0 to +3 ft on Transect BB are exceptions), and may be associated with storms (waves 5 ft high or greater) that occurred through April 1979 (Figure 2D-3). The highest waves occurred in January 1979, yet February mean grain sizes, although generally coarse, were not as coarse as those observed in May. Samples taken several days after the co-occurrence of storm waves and heavy rainfall might not be as coarse as those obtained after a storm in the absence of rainfall because of the considerable fine fraction introduced to the littoral drift by stream runoff. Lacking rainfall or runoff data, this supposition cannot be tested.

The gravel content (grain diameter exceeding 2 mm, or -1 phi) of the samples (Figure 2D-10) indicated that the variability in mean grain size was caused by the presence of gravel at Transect AA in February and May 1979, and at Transect DD in May. In all other cases the gravel content was low and varied little with elevation. This suggested that most of the variability in mean grain size (Figure 2D-9) was caused by variation in the proportions of coarse, medium, and fine sand components.

The sorting (Figure 2D-11) exhibited by the intertidal samples varied most at Transect AA in February and May. Transect BB sediments changed little and were moderately-well to moderately sorted. The remaining samples were moderately-well to poorly sorted with no distinct seasonal pattern. Generally, the sorting

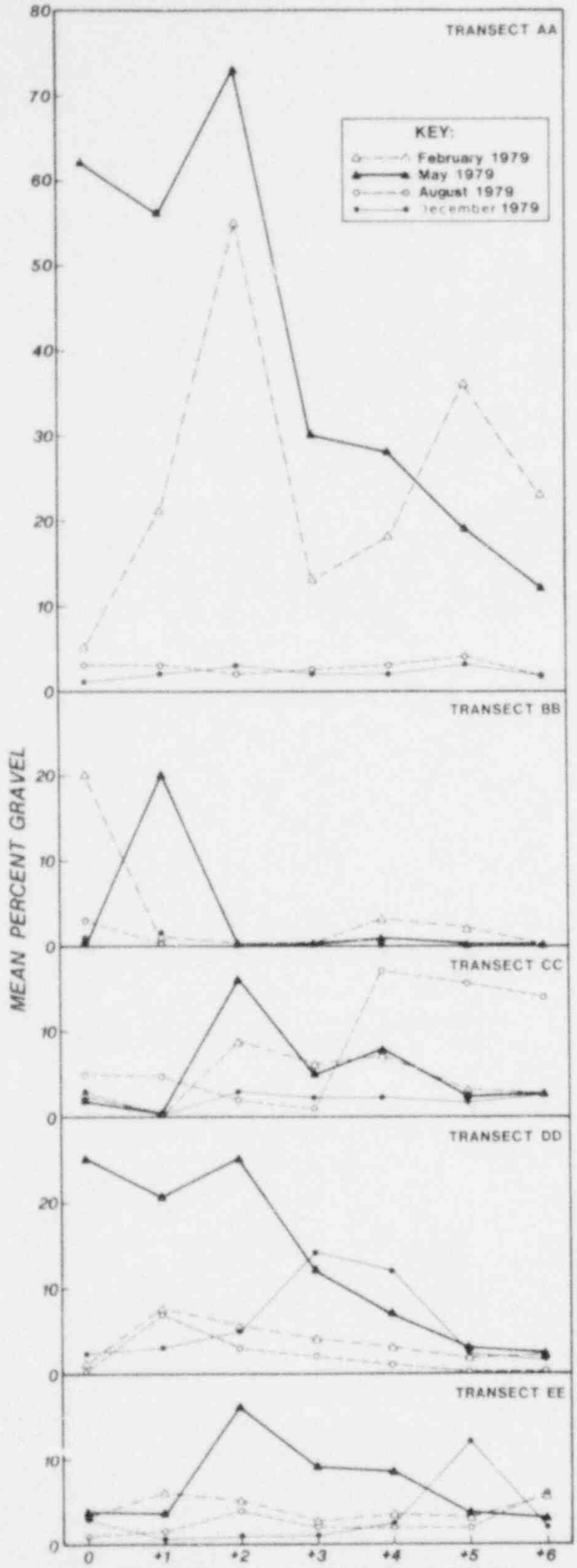


Figure 2D-10. Gravel content by level at each transect during each survey period.

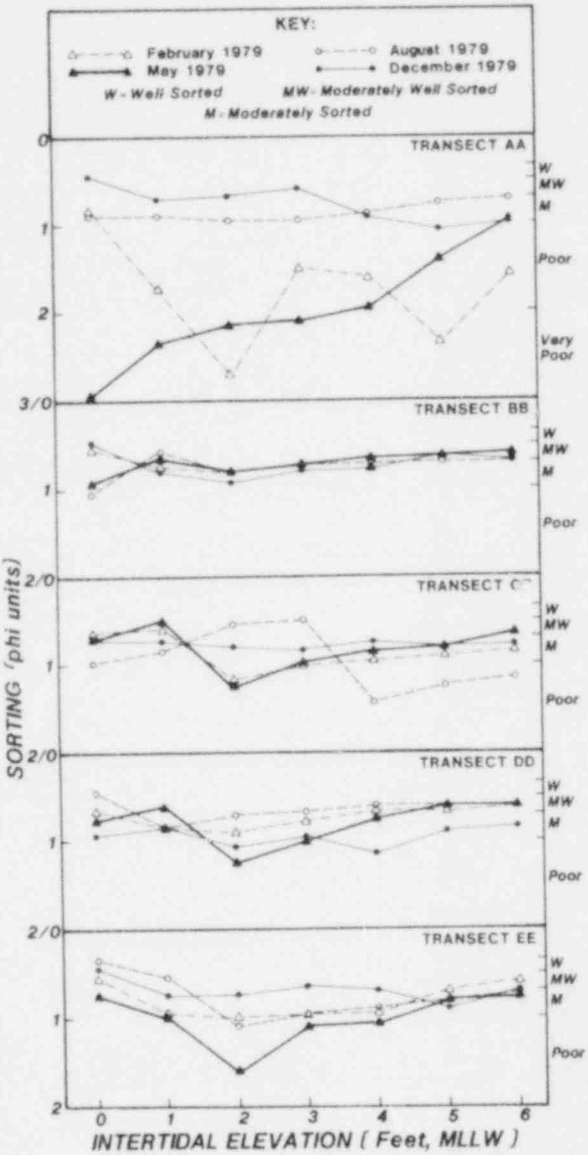


Figure 2D-11. Quarterly (sorting) values at intertidal transect elevations. Plotted values are the mean of five replicate samples.

appeared to be improved somewhat with elevation above +3 ft on the transect. In most cases the best sorting is found at 0 ft elevation. The sorting varied inversely with gravel content where gravel exceeded 10% of the sample. This suggested that large proportions of gravel were introduced in relatively unsorted sediments rather than representing residual sediments from which finer materials were winnowed by wave action. This was supported by skewness values (Figure 2D-12). An excess of fines (relative to a symmetrical, log-normal distribution sizes) was observed in the poorly-sorted samples,

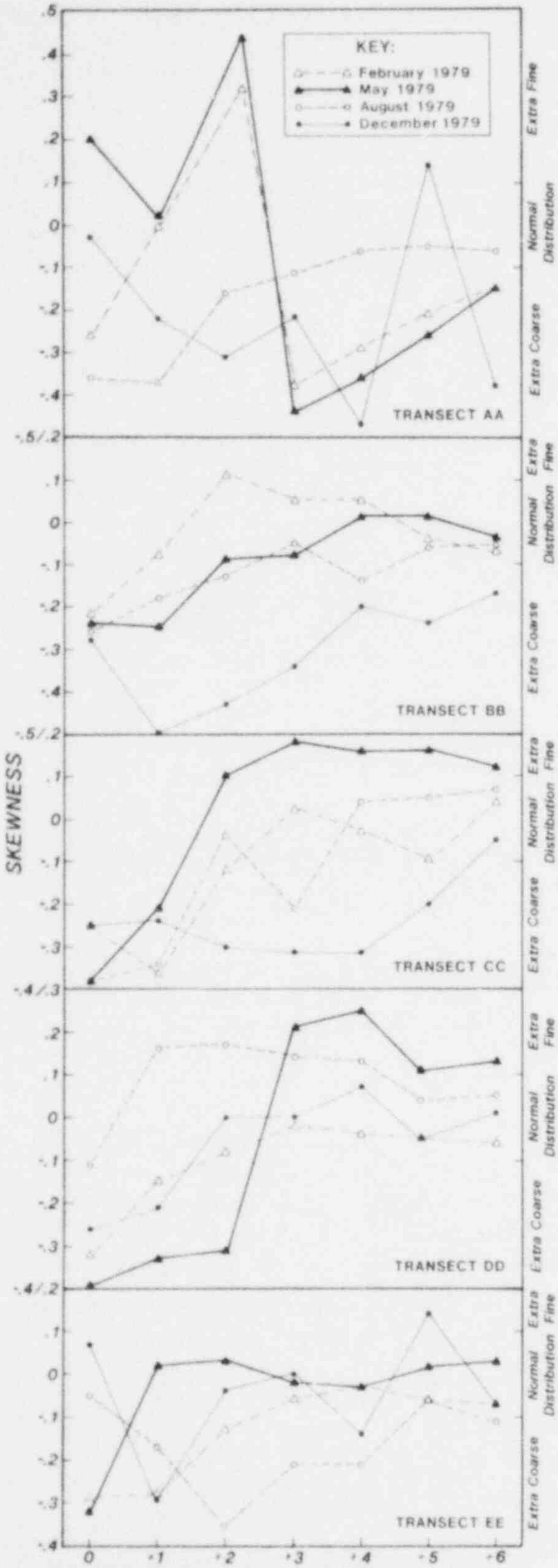


Figure 2D-12. Intertidal sediment skewness by level and transect for each survey period.

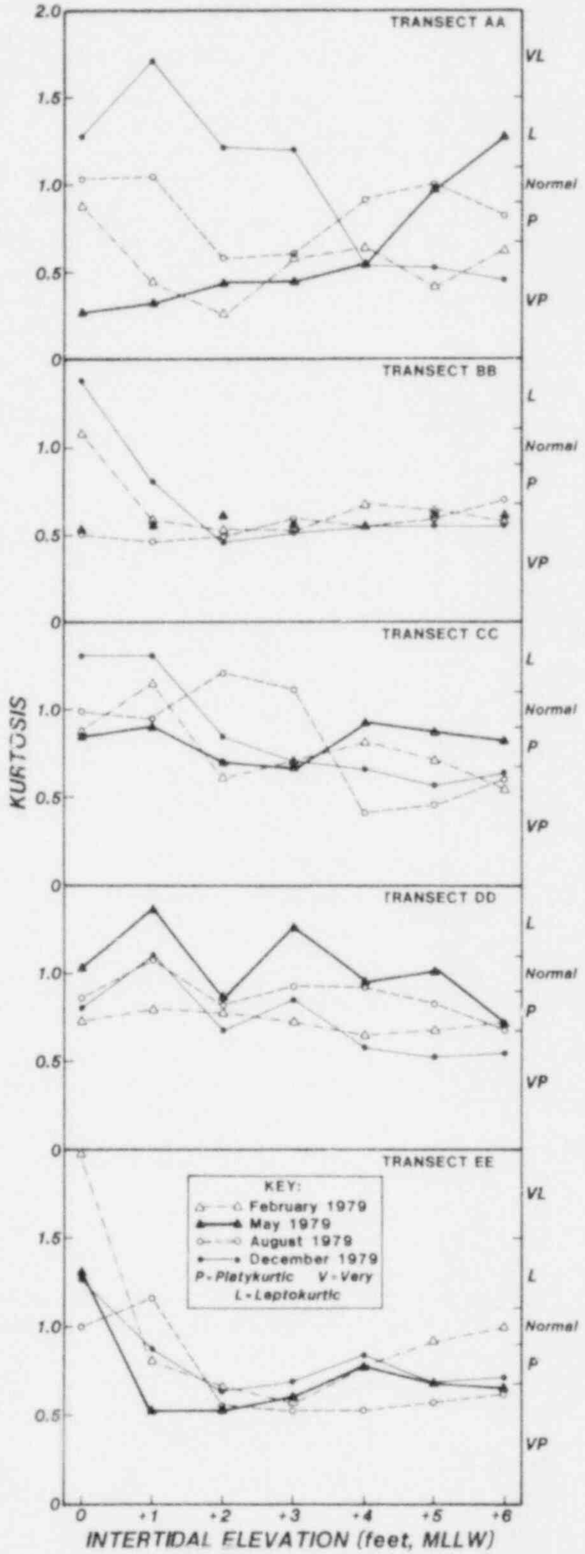


Figure 2D-13. Quarterly (kurtosis) values at intertidal transect elevations. Plotted values are the mean of five replicate samples.

particularly at Transect AA in February and May. In all other cases the trend in skewness was from an excess of coarse material (winnowing) at lower elevations to symmetry (neither fines nor coarse fractions in excess) at higher elevations. This was consonant with removal of fines by wave action at the strand and deposition of suspended load at the upper reaches of the swash zone.

The kurtosis values (Figure 2D-13) reflected the trends identified by the statistical parameters. Transect BB showed the least variation in kurtosis and Transect AA the most (especially in February to May). Kurtosis tended to vary with elevation on Transects CC, DD, and EE such that the sediments at low elevations were symmetrical to peaked (deficient in both fines and coarse extremes) and sediments at high elevations were excessive in both coarse and fine extremes. This also corresponded to the effects of winnowing at the strand and indiscriminant deposition of all suspended load toward the berm. The sediments along Transect BB showed no such trend; they were characterized by excess extreme sizes all year. No distinct trend in kurtosis was evident at Transect AA.

The several statistical parameters just discussed were examined collectively in the results of cluster analysis and correspondence analysis. The variations and trends in the individual parameters are combined to separate groups of samples that responded similarly to the littoral process measured indirectly by each parameter. Cluster analysis of sediment variables showed that beach width and beach profile area were redundant. Subdivision of pebble sizes tended to be redundant also (Figure 2D-14). In the future, it should suffice to class all material coarser than -2 phi as one size and to eliminate beach width measurements.

February Intertidal Sediments. Two individual samples, A2 and A5, and three groups of samples were identified by comparing gravel content versus the ratio of fine sand content to coarse sand content (Figure 2D-15). Samples A2 and A5 were polymodal and contained pebbles as large as 32 mm (1-1/4") in diameter. They also contained appreciable quantities of fine sand. The lowest (0 elevation) sample of each transect formed a group distinguished by its fine sand content. This group represented a facies (I) of sediments present in the zone of active wave action. The remainder of the samples on Transect AA formed a separate group (Facies II) on the factor plot. This group was characterized by an excess of coarse materials as shown in the Facies II histogram. Examination of this group using a third factor axis representing the relative proportions of coarse pebbles versus granules (i.e. gradation in the coarsest sizes in the sediment) revealed that the sediments at Transect AA were richest in granule sizes at elevations +1 and +6, and less rich at elevations +3 and +4.

The rest of the transect samples for a third group (Facies III) were characterized by their medium sand and coarse sand content. Projection on the third factor axis separates the group into four subgroups: Facies IIIa was comprised of Transect BB sediments which were rich in coarse pebbles and of intermediate elevation sediments at Transect CC which were rich in granule sizes. Facies IIIb was separated into sediments from the upper elevations of Transect DD and into a subgroup of sediments at +2 and +3 ft elevation on Transects BB and DD plus +4 and +6 ft elevation on Transect EE. Such refined subgroupings were not considered of major significance. The salient features of the February intertidal sediment assemblage were: 1) the distinction of Transect AA sediments as differing from all other sediments and 2) the existence of a fine facies in the zone of active wave action.

May Intertidal Sediments. Cluster analysis and correspondence factor analysis indicated the existence of five groups of sediment facies in the May assemblage (Figure 2D-15). All sediments from Transect AA, except those at the

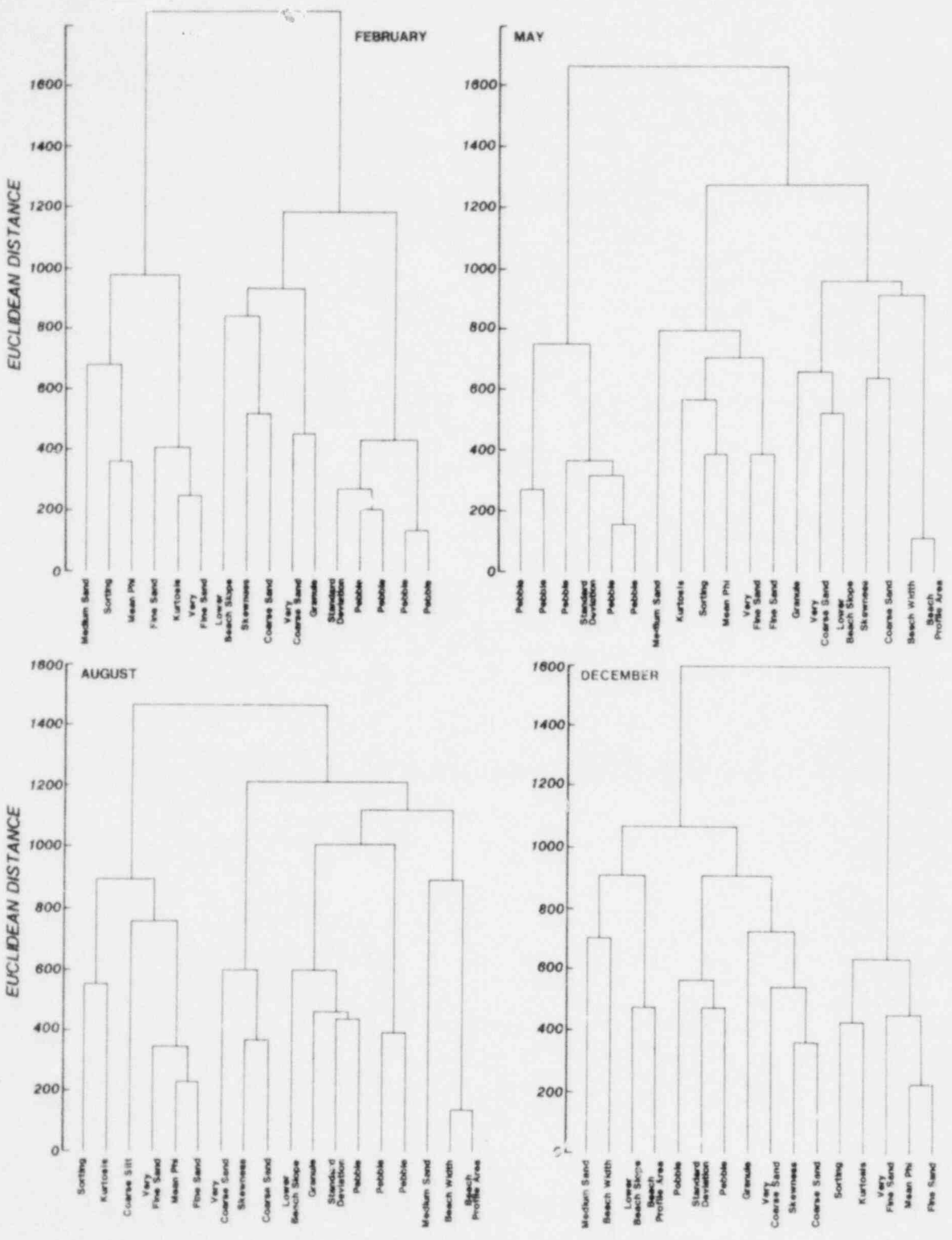


Figure 2D-14. Cluster analysis of intertidal sediment variables.

two highest elevations, were included in two groups characterized by their pebble-sized components. The histograms of these two groups (Facies IV and V) resembled those of the same facies in the February assemblage, and suggested that the processes responsible for these facies persisted until May. The fine sand facies existed as two groups (I and II) that included sediments from the lowermost elevations of Transects BB, CC, and EE. The low-elevation sediments at Transect DD were found in a coarse to very coarse facies (IIIb), as discriminated by a third factor which compared the relative proportions of medium sand versus granules in the sediment. The remaining samples were grouped in Facies III, which was characterized by its content of coarse to very coarse sand content. This facies probably represented the modal beach sand found in May.

August Intertidal Sediments. Cluster analysis and correspondence analysis grouped the August assemblage of sediment samples into facies similar to those of previous quarters (Figure 2D-15). The fine sand facies (I) included the 0 and +1 ft elevation samples of Transects AA and EE. Two granule facies (IV and V) similar to the pebble facies of May and February were indicated. One (IV) included sediments from the lowest four elevations on Transect CC, and the other included all of Transect BB sediments and the rest of Transect CC sediments. Examination of facies (IV) on a third factor axis, based on the relative amounts of very coarse sand versus medium sand, separated upper elevation Transect CC (coarser) sediments from upper elevation Transect BB sediments (less coarse). Lower elevation (0, +1, and +2 ft), Transect BB sediments, were intermediate.

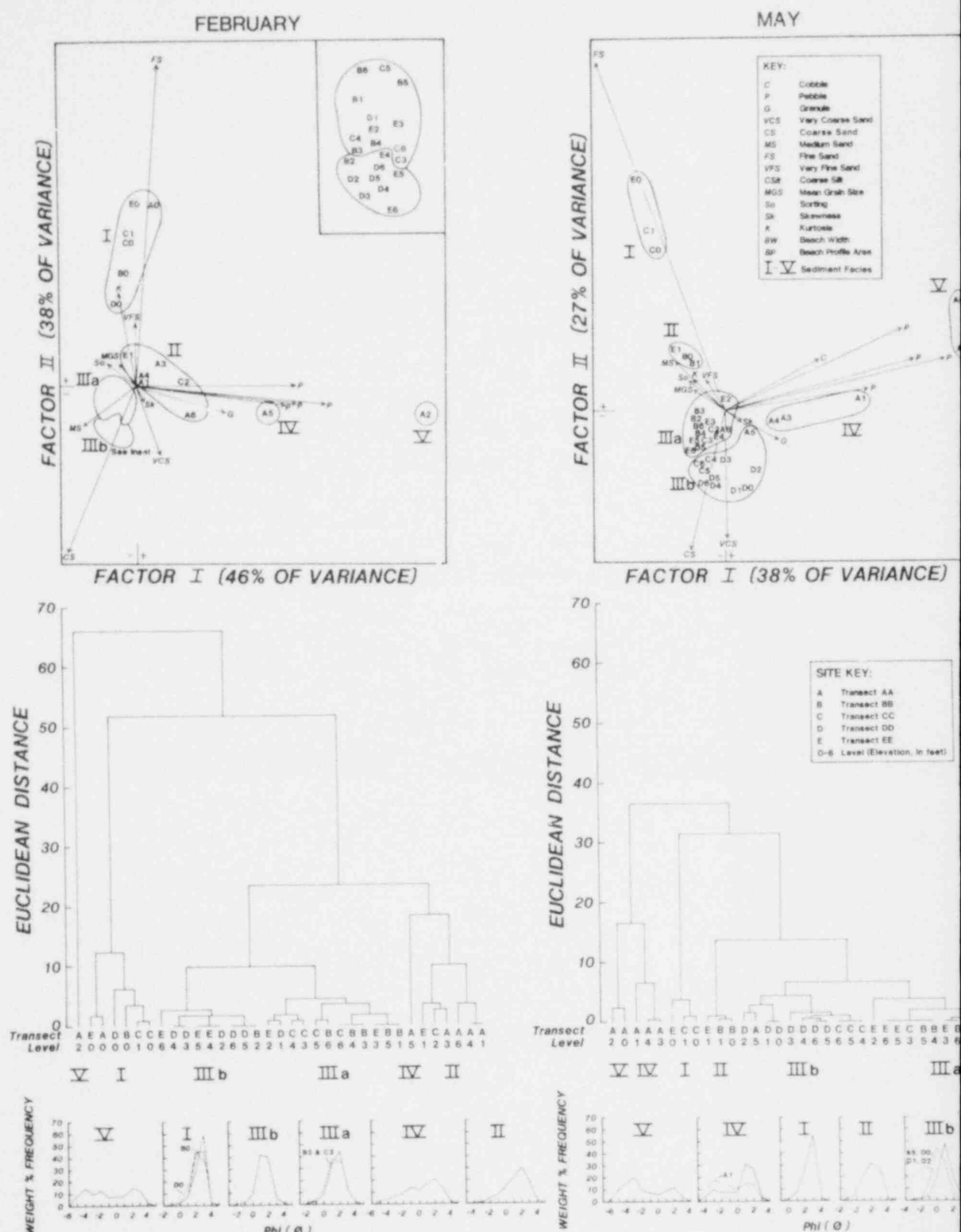
The sediments of Transect DD and the sediments at the upper two (+5 and +6 ft) elevations on Transect EE, formed a separate facies (III) discriminated by the coarse sand content. The remainder of the sediments from Transects AA and EE formed a separate facies (II) characterized by its medium sand content. Facies II and III were probably representative of modal beach sand for August. A single sample, the lowest from Transect DD was distinct from any of the facies, and the histogram showed a marked excess of coarse sand. This sediment possibly represented dredged material placed in the nearshore area during June and July (see Table 2D-1).

December Intertidal Sediments. The facies developed by cluster analysis and correspondence analysis of the December intertidal sediment assemblage were shown on Figure 2D-15. The sediments of Transect CC were contained in two facies (IV and V) which are distinct from other facies on the basis of the beach width parameter versus the beach profile area. The two facies were separated from each other on the basis of grain size. Sediments from the lower two elevations of Transect CC contained in Facies IV were finer grained than Transect CC sediments which occured in Facies V.

The fine sand facies (I) contained the sediment at the lowest elevation of Transect EE and the sediment from the lower four elevations of Transect AA. The coarse sand facies (III) contained sediments from elevations +2 to +6 at Transects BB, DD, and EE. Examination of a third factor based on sorting separated Facies III into three subfacies, one for each transect, with sorting increasing in the order BB to DD to EE. Facies II contained the sediments from the lower two elevations of Transects BB and DD, from elevation +1 on Transect EE, and from elevations +4 and +6 on Transect AA. The facies appeared to be an intermediate between Facies I and III, and distinguished by its degree of sorting.

Recapitulation of Intertidal Sedimentology and Discussion. The various analyses of the intertidal sediment statistics has established the existence of five major sediment facies. They were:

Facies I: A fine sand facies usually found at low elevations on the transect. It included those sediments that were actively worked by waves.



FEBRUARY
MAY
FACTOR II (38% OF VARIANCE)
FACTOR I (46% OF VARIANCE)
FACTOR II (27% OF VARIANCE)
FACTOR I (38% OF VARIANCE)
KEY:
C Cobble
P Pebble
G Granule
VCS Very Coarse Sand
CS Coarse Sand
MS Medium Sand
FS Fine Sand
VFS Very Fine Sand
CSilt Coarse Silt
MGS Mean Grain Size
So Sorting
Sk Skewness
K Kurtosis
BW Beach Width
BP Beach Profile Area
I-V Sediment Facies
EUCLIDEAN DISTANCE
SITE KEY:
A Transect AA
B Transect BB
C Transect CC
D Transect DD
E Transect EE
0-6 Level (Elevation, in feet)
Transect
Level
WEIGHT % FREQUENCY
Phi (Ø)

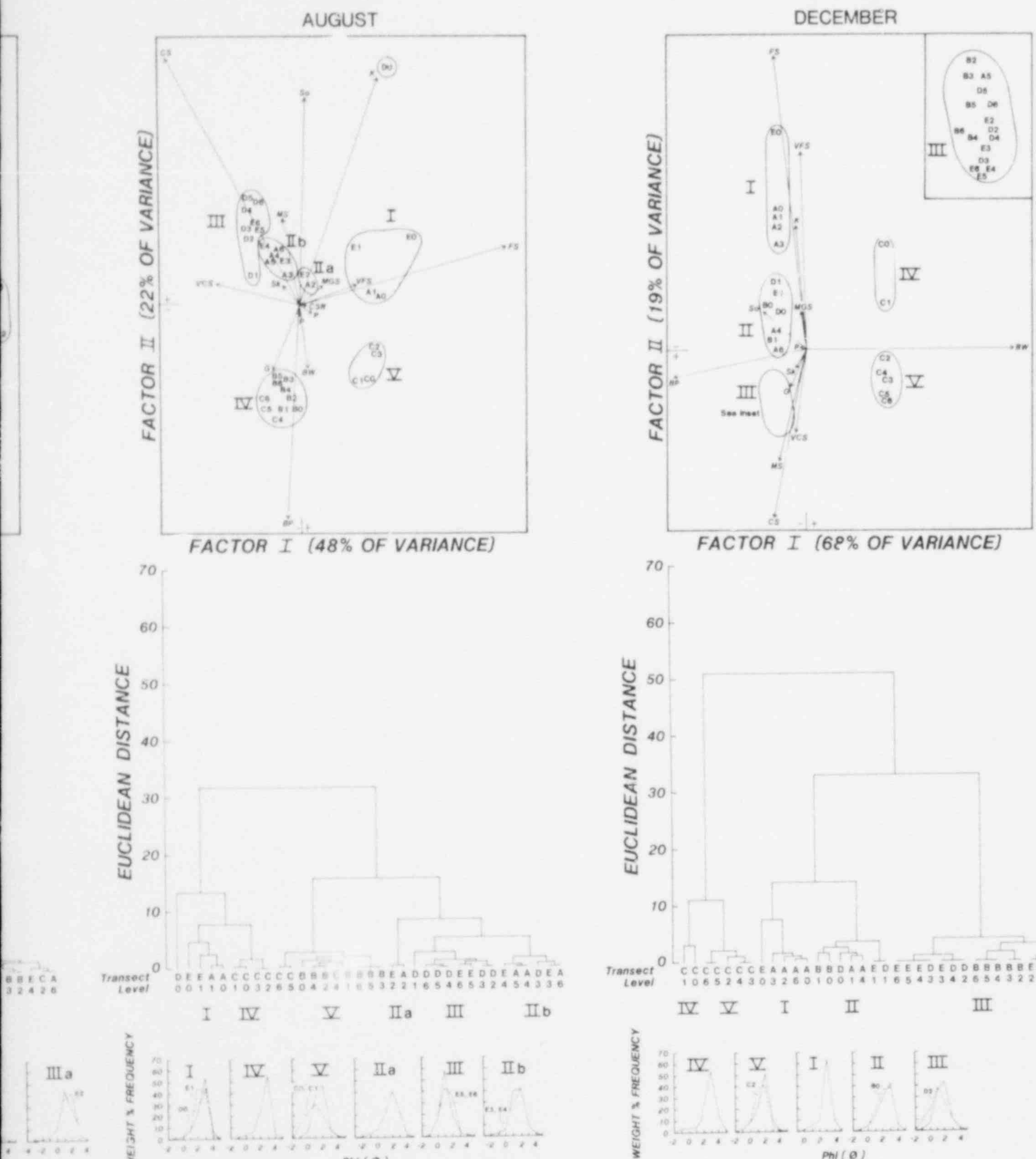


Figure 2D-15. a) Intertidal station and variable coordinates on correspondence Factors I and II and b) dendrogram portraying classification produced by similarity analysis of grain size data with percent frequency polygons of grain size distributions characterizing each cluster.

Facies II: A facies characterized by its coarse sand content the first half of the year and by sorting in the last two quarters of the year. The facies showed affinities with Facies I and III and was probably transitional between them.

Facies III: A coarse sand facies characterized by the presence of pebble and granule sizes in the first half of the year and by coarse to very coarse sand the last half of the year.

Facies IV: A granule facies characterized by polymodality in the first half of the year, but was unimodal with excess granules and very coarse sand in the last half of the year.

A single sample, from elevation 0 on Transect DD in August, appeared anomalous. It belonged to a coarse sand facies that was not represented elsewhere in the intertidal sediments, and might represent material introduced by dredging.

The distribution of the facies was shown schematically on Figure 2D-16. The pattern of distribution was a background of coarse beach sand (Facies III) against which appeared finer sands (Facies I and II) and gravels (Facies IV and V). The distribution pattern changed with time. In February, fine sands were confined to the active wave zone low on the beach and the coarsest material was observed at the upcoast transect (AA). In May, the upcoast transect (AA) still had the coarsest material; it occurred farther downcoast in the successive two quarters being replaced by finer material (Facies II) upcoast. The finer material showed the effects of blending of facies through the year. Facies II appeared to be gradational between the fine sands of the active wave zone and the coarser material (higher on the beach) that was the product of working by more vigorous (higher) waves of the previous winter.

The pattern of intertidal sediments was interpreted as being characteristic of natural beach processes. The sediments reflected the seasonal change in the wave climate and the downcoast progression of sediment types in response to littoral and beach drift. Coarse material that appeared at the upcoast transect early in the year was observed to be sorted and redistributed downcoast during the rest of the year.

Only two effects associated with construction at the SONGS site were evident:

1. The extremely small variation of sediment statistics at Transect BB, upcoast of the SONGS 2 and 3 construction pad, were attributed to the groin effect of the pad. The sediment at Transect BB was impounded by the pad and was not subject to the free littoral transport that occured elsewhere near the site.

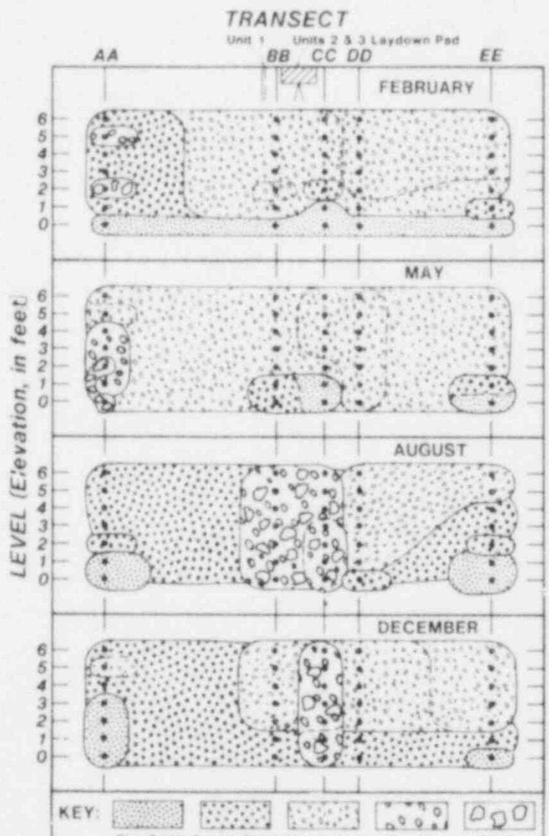


Figure 2D-16. Schematic illustration of intertidal sediment facies distributions.

2. The occurrence of the anomalous sediment at the lowest elevation on Transect DD in August might have represented the result of dredging activity in June and July. This sediment was not observed again, indicating that it was reworked by waves and converted to a sediment more in equilibrium with the existing beach environment.

THE SUBTIDAL ZONE

Sedimentation Rates and Changes in Sea Floor Elevations

The weight of sediment accumulated in the sediment traps each month was converted to monthly sedimentation rates and are presented as the uppermost of the pair of curves in Figure 2D-17. The lower curves in Figure 2D-17 are the elevations of the seafloor measured with reference to a fixed elevation on each trap.

The sedimentation rate was generally maximal and most variable at inshore (6 m) stations and minimal and least variable at offshore (15 m) stations. Intermediate stations (9 m) had intermediate rates.

The pair of curves were related by expressing the sedimentation rate in terms of an equivalent amount of monthly sedimentation. Using 2.5 as the density of dry sediment, 1 cm/month of sediment accumulation was equivalent to 833 $g/m^2/day$ of sedimentation. The equivalent accumulation scale was shown on the right of the upper curve for each pair on Figure 2D-17. The changes in sea floor elevation (shown numerically on the lower curves in Figure 2D-17) were often greater than those indicated by the sedimentation in traps a meter or so above the sea floor, indicating that the changes in the elevation of the sea floor, both erosion and accretion, were caused by material moved laterally at the bottom, presumably by the tractive effect of passing waves.

The net change in sea floor elevations is shown in Table 2D-3. The apparent overall effect of erosion was probably an artifact caused by comparing changes from January to December. Early winter storms (one occurred early December 1978) would have caused accretion that would be moved shoreward during the year, giving the appearance of the gradual and net erosive tendency shown by many of the curves in Figure 2D-17.

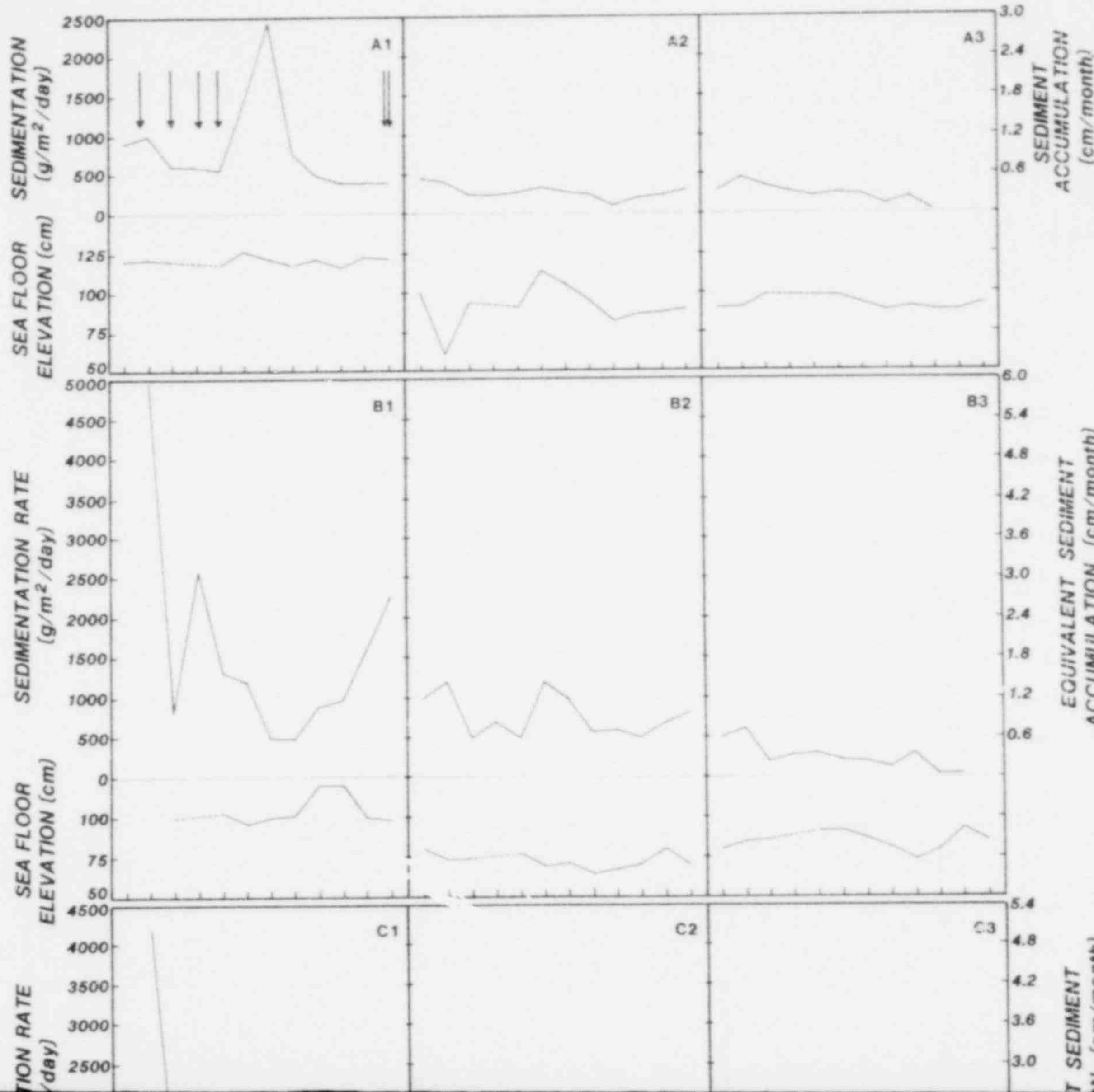
The occurrence of high (>5 ft) waves at the site is shown in Figure 2D-17. No obvious correlation between storm waves and sedimentation rate or change in sea floor elevation was detected. Several epochs of high sedimentation were observed, but no pattern of occurrence was suggested. Apparently sedimentation rates were related to factors that were not measured such as occurrence and location of rip currents on the beach or stream runoff rates. Also, the lack of grain size data on material retrieved from sediment traps prevented examining possible modes of transport of the trapped sediments.

Subtidal Sediments

Grain size data obtained for subtidal sediments were treated by cluster analysis and correspondence analysis to investigate sediment facies relationships comparable to those developed in the 1978 study (SCE 1980).

Four sediment facies were identified in the subtidal zone from sediment samples collected in 1978. They were:

1. A variable facies of fine to very fine sand usually found at shallow (6 m) or occasionally deeper (9 m) water depths.


SEDIMENTATION (g/m²/day)
SEA FLOOR ELEVATION (cm)
SEDIMENT ACCUMULATION (cm/month)
A1
A2
A3
SEDIMENTATION RATE (g/m²/day)
EQUIVALENT SEDIMENT ACCUMULATION (cm/month)
B1
B2
B3
C1
C2
C3

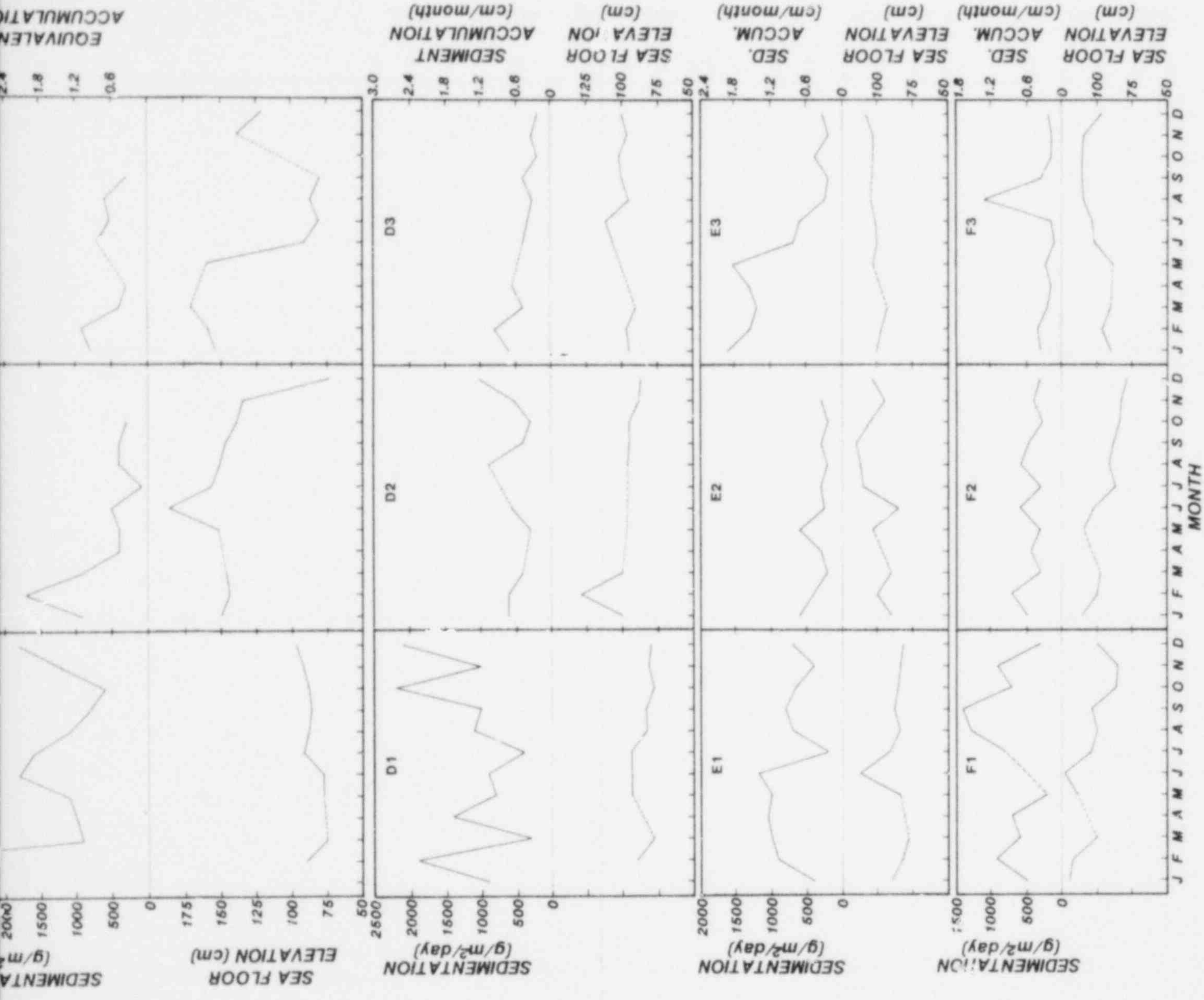


Figure 2D-17. Sedimentation rates and changes in sea floor elevation at subtidal stations. (Arrows indicate the occurrences of waves 5 ft. high.)

Table 2D-3. Net change in sea floor elevations during 1979.

Station	Net Change (cm)	Station	Net Change (cm)
A1	0	D1	-10[b]
A2	-2	D2	-13
A3	4	D3	5
B1	-2[a]	E1	-9
B2	-6	E2	14
B3	8	E3	8
C1	15[b]	F1	-20
C2	-68	F2	-31
C3	-34	F3	7

[a] estimated March to December

[b] estimated February to December

2. A mixed facies of silt and fine sand. This facies tended to occur at all depths and was characterized by median grain sizes.

3. A facies of coarse silt that tended to coalesce with Facies B and usually occurring at deepest (9 m) stations.

4. A facies of medium to coarse polymodal sand interpreted to be of relict origin.

These facies were recognized in the sediments sampled in 1979 at the established stations. In addition, one facies not observed in the 1978 study was identified in 1979. Only the first two factors were required to make facies determinations in virtually all cases. Cluster analysis of subtidal sediment variables indicated that individual clay sizes (finer than 9 phi) correlated closely (Figure 2D-18). Future analyses would not suffer if such material were grouped as a single size class.

February Subtidal Sediments. The results of the cluster analysis and correspondence analysis of February sediment statistics are shown on Figure 2D-19. The coarse Facies IV (D in 1978) was found at Station E3 where it occurred consistently the previous year. The sediment at Station C2 (9 m) also belonged to this facies even though it was not bimodal, as shown in the histograms. The coarse silt Facies V (C in 1978) was found at the deepest stations along Transect B, C, D, and F just as in March and June of 1978. The fine to very fine sand Facies III (A in 1978) was found at stations where it occurred in March 1978 (B1, C1, D1, D2, E1, and F1). It did not occur at Stations A1 or C2 as it did previously, but continued to be a shallow water (6 m and occasionally 9 m) facies. Sediments at all three depths along Transect A formed Facies IIa. Sediments at intermediate depths (9 m) along Transects E and F formed Facies IIb. Both these facies were the equivalent of the mixed silt and fine sand facies (B) identified at those stations in 1978. Facies IIb was considered distinct because of a second mode in the medium to coarse sand sizes. Facies IIb might be transitional between Facies IIa and the relict Facies IV if both contemporary and relict sediment were included in the samples from Stations E2 and F2.

May Subtidal Sediments. The results of cluster analysis and correspondence analysis of May subtidal sediments are shown on Figure 2D-19. The coarse polymodal facies (IV) of relict sediment persisted at Station E3 (9 m). In addition, it occurred at Station D3 where it was found in September 1978. The fine to very fine sand facies (III) occurred at the same stations as in February except at B1 (6 m). There a unimodal, and nearly pure (93%), fine sand was found. Its histogram resembles those of Facies III except that it is not as well sorted. Sediment at Station B1 represented a separate facies (I). The deep-water coarse silt facies (V) continued to occur at Stations B3, C3, and F3. Facies II was no longer distinguishable as two separate subfacies as it was in Feburary. This facies occurred at the same stations as in February and also at Station D2. The former mixed contemporaneous-relict nature of the sediments at E2 and F2 was no longer apparent.

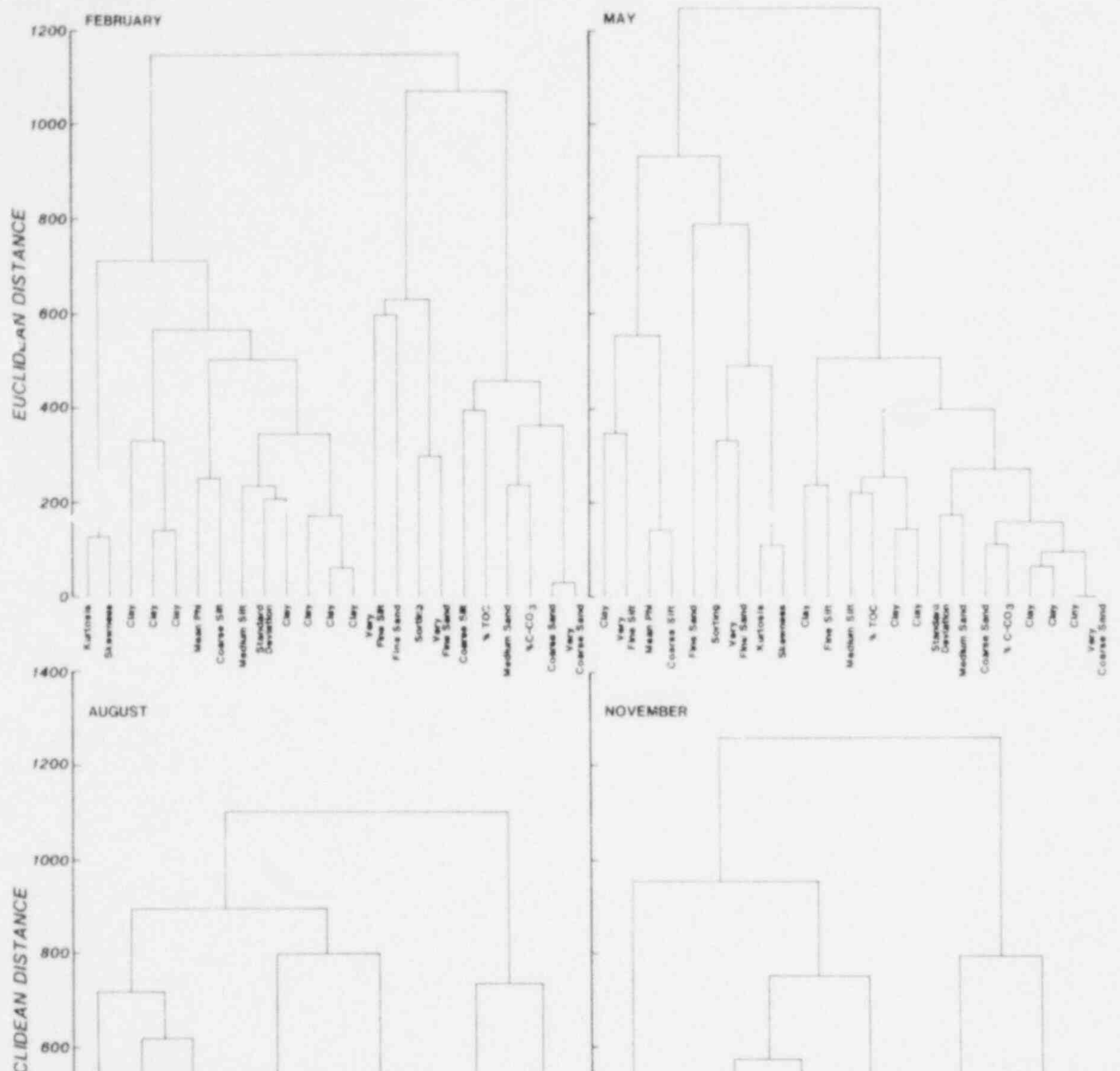
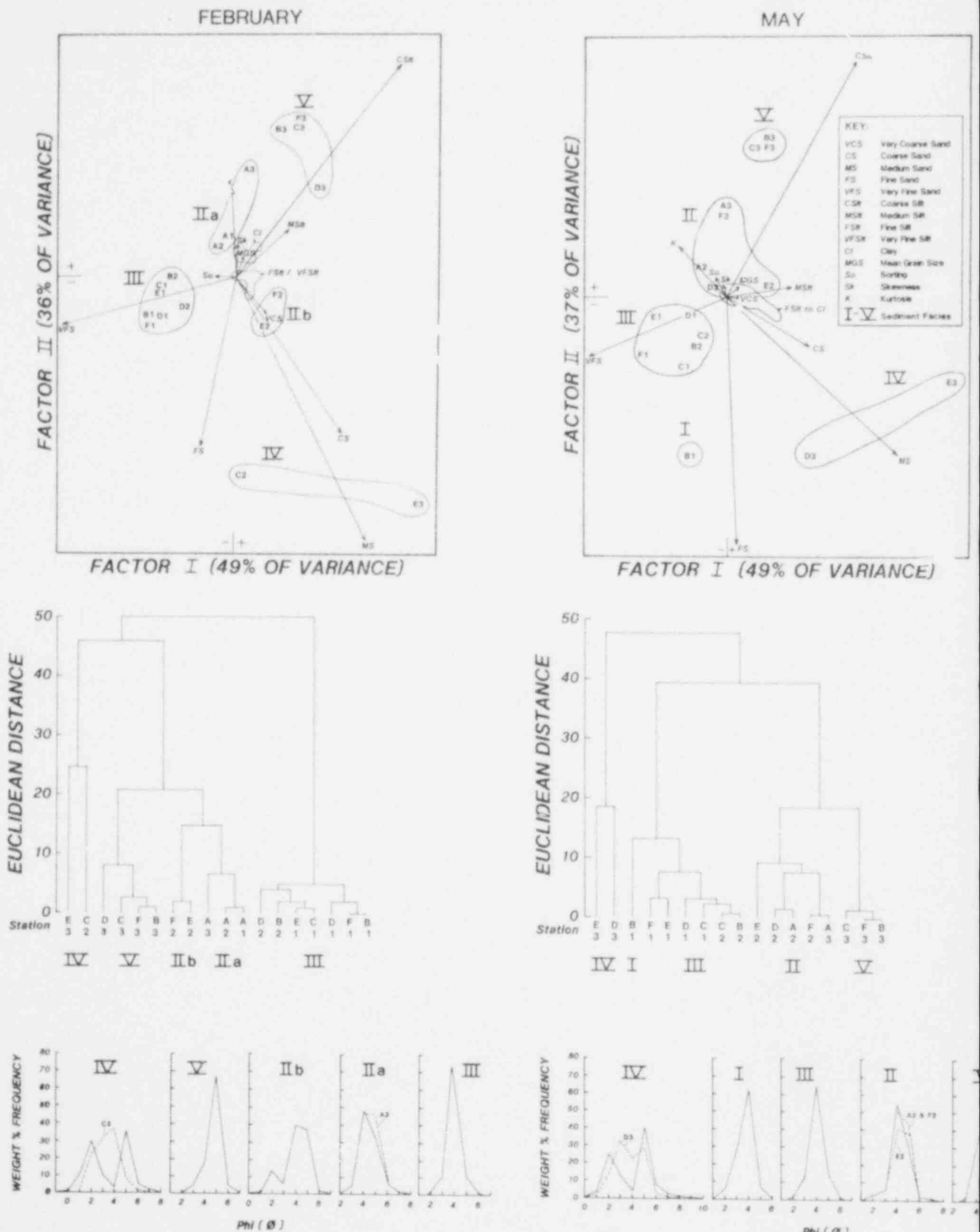


Figure 2D-18. Cluster analysis of subtidal sediment variables.



FEBRUARY
MAY
FACTOR II (36% OF VARIANCE)
FACTOR II (37% OF VARIANCE)
FACTOR I (49% OF VARIANCE)
KEY:
VCS Very Coarse Sand
CS Coarse Sand
MS Medium Sand
FS Fine Sand
VFS Very Fine Sand
CSlt Coarse Silt
MSlt Medium Silt
FSlt Fine Silt
VFSlt Very Fine Silt
Cl Clay
MGS Mean Grain Size
So Sorting
Sk Skewness
K Kurtosis
I-V Sediment Facies
EUCLIDEAN DISTANCE
Station
WEIGHT % FREQUENCY
Phi (Ø)

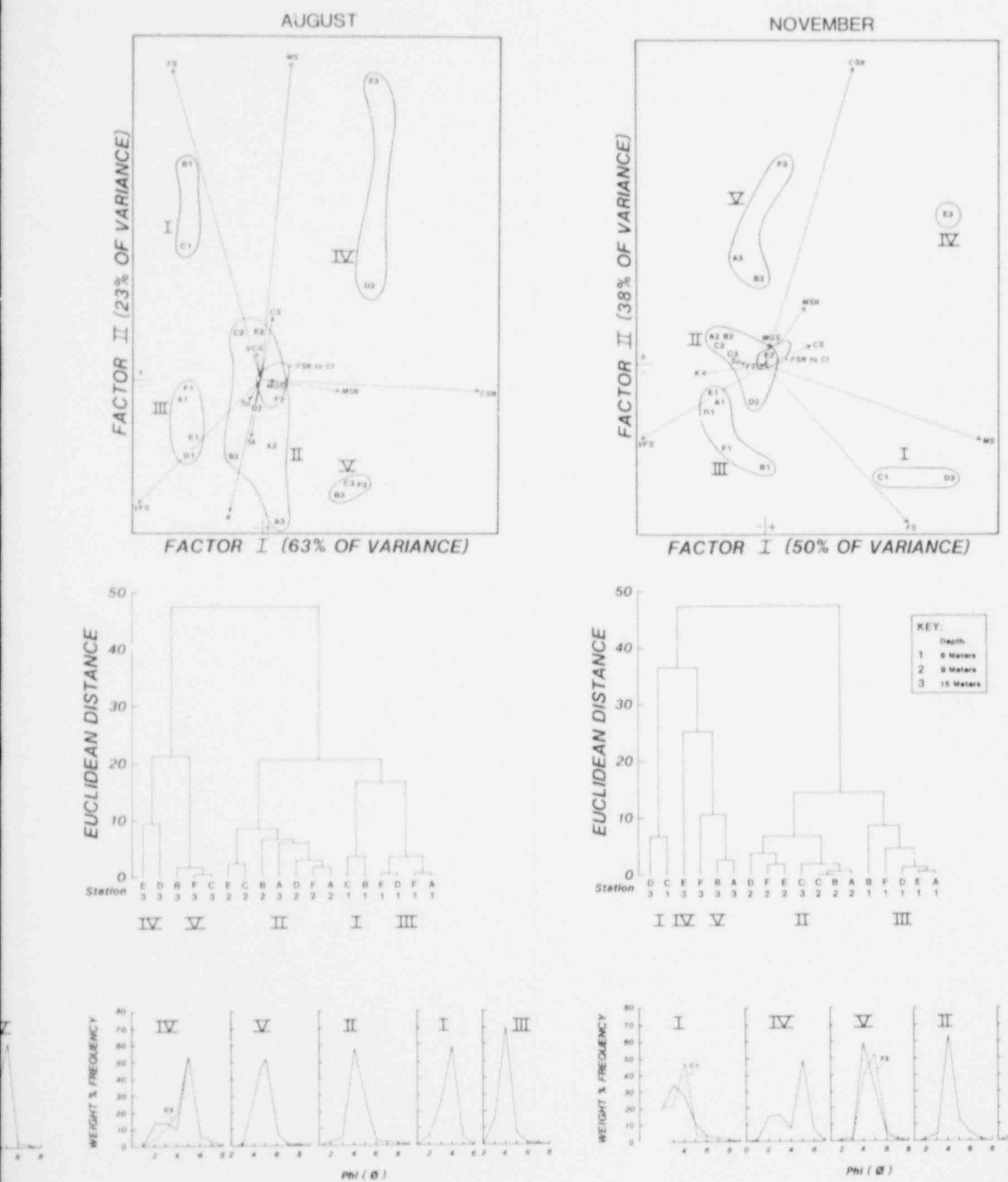


Figure 2D-19. a) Subtidal station and variable coordinates on correspondence Factors I and II and b) dendrogram portraying classification produced by similarity analysis of grain size data with percent frequency polygons of grain size distributions characterizing each cluster.

August Subtidal Sediments. Figure 2D-19 shows the results of the analyses of statistical parameters of the August subtidal sediments. The coarse relict facies (IV) persisted at Stations E3 and D3. The new, fine sand facies (I) continued to occur at Station B1, but was also found at Station C1. The processes producing this facies extended downcoast during this quarter. The shallow water, very fine sand facies (III) continued to occur at Stations D1, E1, and F1, and also appeared at Station A1. Every shallow (6 m) station at the site yielded sediments of the very fine (III) or fine (I) sand facies. The coarse silt facies (V) continued to occur at the same three deep (15 m) stations (B3, C3, and F3) as in May. The mixed silt-fine sand facies (II) continued to occur at the same stations as in May, but also occurred at Stations B2 and C2, formerly sites of the very fine sand facies (III).

November Subtidal Sediments. The results of the cluster analysis and correspondence analyses of these sediments are shown on Figure 2D-19. The coarse relict facies (IV) persisted only at Station E3. The fine sand facies (I) occurred at two different locations, C1 and D3 at 6 m and 15 m, respectively. The very fine sand facies (II) persisted at the same shallow water (6 m) stations as in August, but in addition, it was found at another shallow water station, B1, formerly occupied by Facies I. The deep water, coarse silt facies (V) persisted at Stations B3 and F3, but not at A3. Instead, it appeared at Station A3 formerly occupied by Facies II, the mixed silt-fine sand facies. Facies II continued to occur at all intermediate depth (9 m) stations. In addition, it occurred at Station C3, formerly a site of the deep water coarse silt facies (V).

Recapitulation of Subtidal Sedimentology and Discussion. The subtidal sediment facies identified in the 1978 study were all recognized in the 1979 study results. The differences noted in the present study were primarily in the distribution of the facies during the year (Figure 2D-20).

Several general tendencies were evident. The facies tended to distribute according to depth with the coarsest material closest to shore and the finest (coarse silt) offshore. This general distribution pattern was stable; and remained essentially the same in 1978 and 1979.

The facies were effective in indicating the effects of natural sedimentary processes at the SONGS site, so that variations from quarter to quarter and station to station were interpreted in terms of causative processes. A slight seasonal shift of facies normal to shore was evident. In February, the sand facies derived from littoral wave action was distributed among onshore and intermediate depths, except at the stations farthest upcoast. As the year progressed, the material became restricted to the shallowest stations. The causative process appeared related to the seasonal change in wave climate. Winter waves removed finer material from the beach and deposited it offshore. The material was returned during the summer when longer, less steep waves prevailed.

The relict sediment location at Station E3 was remarkably constant during both 1978 and 1979. Station B1, which yielded relict sediment in June 1978, was occupied by the relatively coarse Facies I. This facies also occurred at stations adjacent (at the same depth) to those where relict sediment occurred, suggesting that the relict sediment was mixed with finer sediment in the course of the shifting of sediments during normal littoral movement.

The only evidence of the effect of construction in the subtidal sediment distribution pattern was the presence of sediments coarser than expected at intermediate depths B2 and C2 in May and at C3 in November. Possibly the SONGS Units 2 and 3 construction pad bulkhead caused littoral transport to be displaced seaward and shifted the sediment-depth pattern seaward as well. The

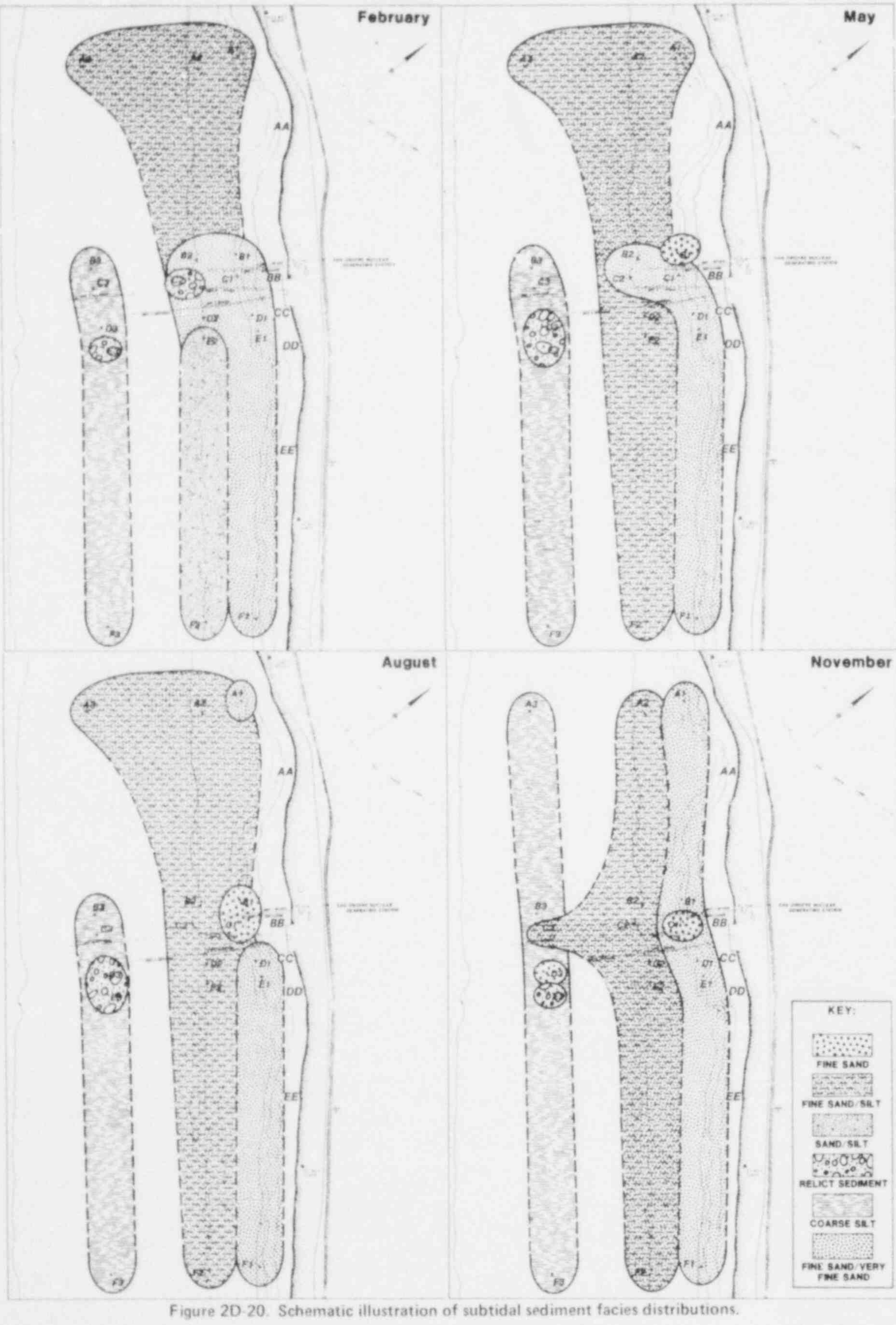


Figure 2D-20. Schematic illustration of subtidal sediment facies distributions.

dilution of the relict sediment at Station D3 by Facies II material displaced seaward might have been caused in this manner. The subtidal sediments offshore and downcoast of the construction pad should be monitored further to verify and evaluate the ultimate extent of this effect.

OTHER PHYSICAL AND CHEMICAL MEASUREMENTS

Sediment Organic and Carbonate Carbon

Samples collected from the upper 2 cm of bottom sediments were analyzed for total carbon and carbonate carbon ($C\text{-}CO_3$). Total carbon is a general indicator of faunal or secondary productivity. The difference between total carbon and $C\text{-}CO_3$ 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 $C\text{-}CO_3$ values may range substantially higher than sediment organic carbon values.

Organic carbon values in contemporaneous sediments showed little consistent variation over a range from 0.03 to 0.24%; most values were near 0.15% (Table 2D-4). There was a slight tendency for the deepest (finest) sediments to have the highest values at each transect. Carbonate carbon values in contemporaneous subtidal sediments also showed little variation over a range of 0 to 0.14%. There was only a slight tendency for the deepest stations to yield highest values.

The relict sediments at Station E3 and C2 showed dramatically higher values of carbonate carbon and, at Station E3 in February and May, rather high values of organic carbon. Apparently organic productivity past and/or present, characterized the relict sediment. The diluted relict sediments of Facies I were not significantly higher in either type of carbon at Stations B1 and C1 or at Station B3 in May. The dilution was sufficient to mask the carbon content in those sediments. It was not a case of burial of relict sediment by contemporaneous littoral drift materials because the grain size affinities to relict sediments were evident in the facies.

Table 2D-4. Results of subtidal sediment carbon analysis (mean of replicates).

Station	Feb	May	Aug	Nov	Station	Feb	May	Aug	Nov
A1	.16/.02	.20/.03	.10/.03	.12/.06	D1	.11/.02	.10/0.0	.19/.02	.14/.01
A2	.14/.14	.16/.08	.14/.13	.14/.06	D2	.17/.08	.11/.05	.18/.04	.21/.07
A3	.16/.02	.13/.03	.18/.02	.15/.03	D3	.21/.20	(.14/.12)	(.11/.87)	[.09/.67]
B1	.09/.10	[.12/.10]	[.08/.05]	.09/.13	E1	.11/.01	.15/.02	.14/.03	.11/.02
B2	.09/.12	.14/.08	.13/.04	.11/.10	E2	.15/.11	.15/.08	.14/.13	.25/.09
B3	.21/.05	.16/.04	.24/.01	.20/.08	E3	(.32/.48)	(.39/.52)	(.14/.44)	(.13/.43)
C1	.09/.03	.10/.05	[.05/.02]	[.03/.07]	F1	.24/.05	.08/0.0	.03/.07	.06/.03
C2	(.11/.31)	.19/.07	.16/.05	.14/.06	F2	.16/.01	.11/.11	.13/.05	.11/.03
C3	.17/.02	.19/.04	.16/.06	.14/.13	F3	.17/.02	.13/.01	.11/.03	.11/.06

NOTES: Values in body of table are: % organic carbon/% carbonate carbon
( ) Occurrence of relict sediment (Facies IV)
[ ] Occurrence of diluted relict sediment (Facies I)

DISCUSSION

The description of the marine geological setting presented in this report augments and summarizes the general description of the natural geologic and oceanographic phenomena affecting the SONGS area presented in the 1978 report (SCE 1979). Having recapitulated the findings of the 1978 sedimentological studies, interpretations of the 1979 intertidal and subtidal results will be discussed next.

The beach profile measurements in 1979 indicated that the impoundment of beach sand at the construction pad was complete by mid-year. A wide beach formed just upcoast of the pad and the sediments changed little during the year. Most of the impounded material was effectively removed from transport by beach drift (lateral tractive transport of sand in the swash-backwash zone). Downcoast of the pad, the beach stability was reduced and erosion and accretion modified the intertidal zone in response to changes in the direction of wave attack. Sediment passing by the construction pad was not sufficient to prevent such fluctuations in the adjacent downcoast beach zone. All other changes in the intertidal zone appeared referable to natural seasonal and episodic changes in the littoral environment.

The granulometric and statistical analyses of intertidal sediments sampled in 1979 have permitted the characterization of the active processes as natural and expected in the intertidal regime. The facies developed by the analyses were typical of the intertidal environment of the United States west coast. The groin effect of the construction pad was perceived in its stabilization of statistical measures of the sediments upcoast of the pad. An anomalous sediment type that appeared just following nearshore dumping of dredge spoil was pe .eived by recognizing that its statistical properties were those of a sediment not at equilibrium with the littoral processes active at its location. The sediment anomaly vanished within one quarter; and it was surmised that the recovery to such a perturbation of the intertidal zone occured over an interval of time of that order of magr cude. No evidence of permanent change was seen.

The sedimentology of the subtidal zone at the SONGS site was characterized to the extent that the distribution of sediments in that zone can be predicted with confidence and anomalous conditions analyzed to determine if effects of construction were present. Evidence of the seaward deflection of the littoral drift past the construction pad was discerned. The effects of dredging and backfilling were not distinguishable by this approach because the grain size characteristics of the dredged material were not known.

Studies of sedimentation rate established that the erosion and accretion of the sea floor was caused by tractive processes active at the sediment-water interface.

The measurement of inorganic carbon (carbonate) in the subtidal sediments was valuable as a discriminator of relict sediments even though the parameter failed to correlate with that facies in the correspondence factor analyses. The relict sediment mixed with contemporaneous sediments, a phenomenon that was significant to the benthic ecology of the site in that relict substrate areas were subject to temporal disappearances. Organic carbon content of subtidal sediments, though probably important to the benthic infauna, provided no usable information regarding natural or artificial processes active in the subtidal zone.

SUMMARY

The sedimentology of the intertidal and subtidal materials in the vicinity of the SONGS site was studied as part of the monitoring of the oceanographic effects of the construction of Units 2 and 3. The parameters examined were physical and chemical sediment properties, sedimentation, distribution of sediment types, water clarity and temperature, and the morphology of the intertidal zone. The examination revealed the following:

1. The impoundment of sand by the Unit 2 and 3 construction pad was discriminated as a response of the littoral regime to a groin-like impediment.

2. The impoundment was complete but littoral sediment passing the pad did not prevent substantial fluctuations in intertidal morphology immediately downcoast.

3. Perturbation of the intertidal zone by nearshore dredge spoil dumping apparently was dispelled within one quarter. No permanent change to the intertidal zone was perceived or seems likely to have been caused by such dumping.

4. Evidence of the deflection seaward of littoral transport by the construction pad was obtained by interpreting the pattern of distinctive and temporally stable sediment facies in the subtidal sediments. The facies pattern was useful for discriminating the effects of construction.

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CHAPTER 3

PLANKTON

INTRODUCTION

The purpose of this chapter is to analyze and interpret the 1979 data collected by the combined ETS-PMP plankton program. This includes 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.

The marine monitoring studies reported in this chapter are being conducted to meet objectives approved by the Nuclear Regulartory 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 objective of the Preoperational Monitoring Program is to provide a baseline to determine 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 station. These studies are also being conducted in compliance with the National Pollutant 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 1979 biological data used in this analysis were presented in the Annual Operating Report, San Onofre Nuclear Generating Station, Volume III, Biological Data-1979 (SCE 1980c).

APPROACH

Data 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 1979 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 effects of long-term physical oceanographic events on the plankton offshore of SONGS is discussed.

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 in the marine environment which may affect the distribution and abundance of plankton include water temperature, nutrients, turbidity, and currents. Water temperature generally decreases 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 water temperatures in the summer may be 17 to 22°C, while temperatures at a depth of 10 m are two to three degrees cooler (IRC 1973, LCMR 1976d, SCE 1979a). Chemical nutrients are distributed in a typical pattern, with low concentrations at the surface which increase with depth. During winter, nutrient values may be relatively uniform from the surface to the bottom at 15-16 m (SCE 1979c). 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 increased turbulence and wave action stirring up and suspending bottom materials (Raymont 1963). Turbidity in the San Onofre area increases both nearshore and nearbottom (LCMR 1976d, SCE 1979a). Current speed offshore of SONGS typically ranges from 5 to 40 cm/s and averages 10 cm/s. These coastal currents vary in direction and speed as a result of winds and tides (EQA/MBC 1973).

The present plankton studies in the San Onofre area have evolved from a qualitative examination of plankton in 1964, followed by quantitative semiannual plankton studies conducted 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 data collected from 1965 to 1972 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 composition 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). Very localized (up to 500 m from the discharge) changes in the vertical distribution of some species have been observed and attributed to the entrainment and upward transport of nearbottom water by the Unit 1 discharge plume (MRC 1979). The total abundance in the area, however, was unchanged.

The 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. This study was designed to assess area-wide effects rather than nearfield intake/discharge effects. 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 the historical studies was initiated in July 1978.

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 comprise the array of plankton sampling stations included in the combined Unit 1 ETS and Units 2 and 3 PMP programs (Figure 3-1). These

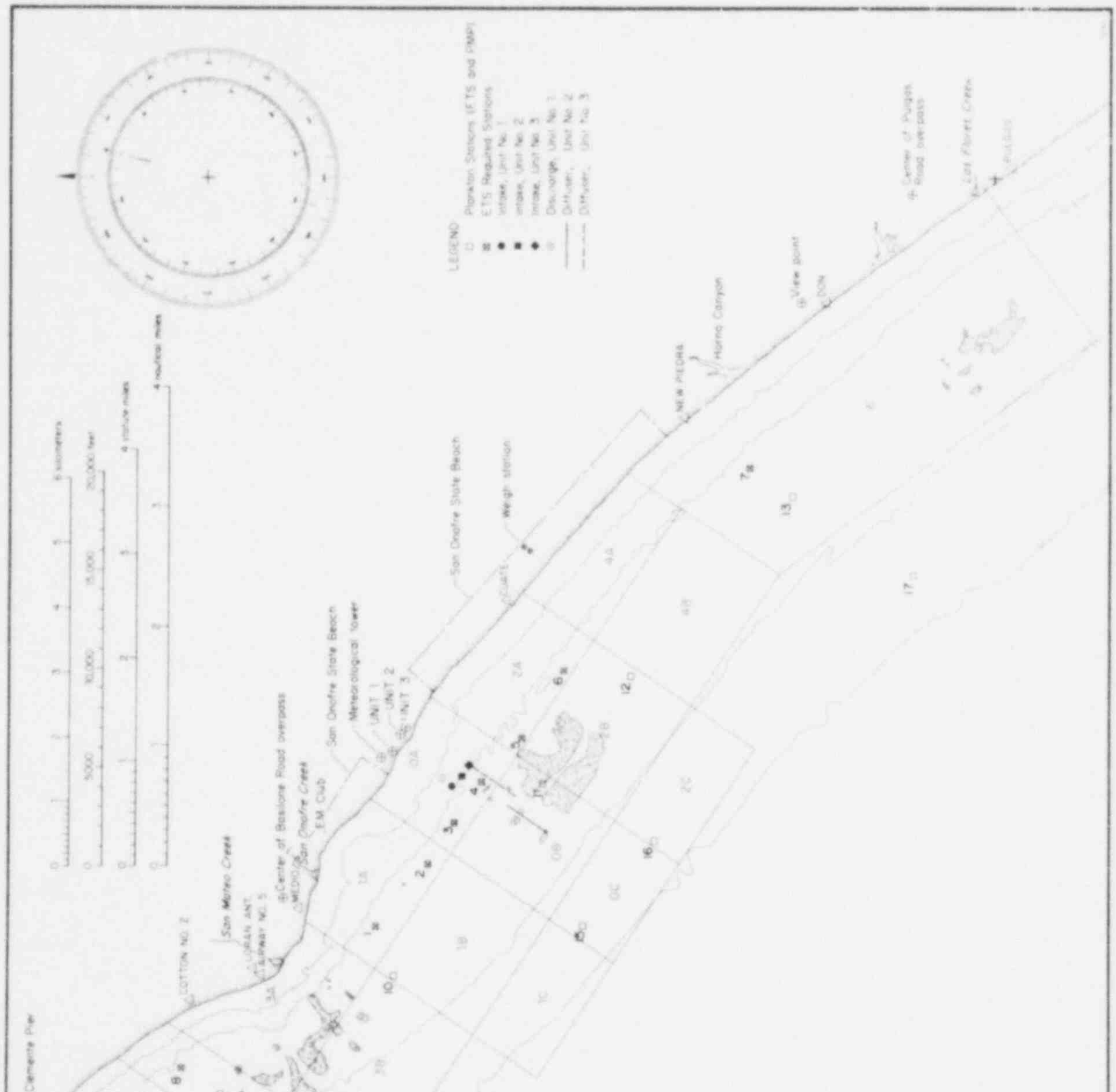

Figure 3-1. ETS and PMP plankton receiving water station locations at San Onofre Nuclear Generating Station. Shaded areas represent the areal extent of the kelp canopies sampled in December 1978.

are arranged along three isobaths, each isobath being oriented parallel to the coastline. Each isobath includes stations located directly offshore of SONGS and stations extending upcoast and downcoast from SONGS. Eight stations (Stations 1-8) lie along the 10-m isobath, five stations (Stations 9-13) lie along the 15-m isobath, and the remaining four (Stations 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 concentration. These are collected concurrently at each station using a plankton pump system. Samples are collected from two strata within the water column at each station. The upper stratum extends from the surface to the 5-m depth for the stations located along the 10-m isobath and from the surface to the 8-m depth at stations long 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. Zooplankton samples are concentrated by filtering through a 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 water prior to passage 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.

Physical data are collected concurrently with biological sampling. Temperature and transmissivity measurements are taken at 1-m intervals using a Martek XMS temperature-transmissivity unit. During 1979, transmissivity-depth profiles were obtained at each plankton station occupied during the January, March and May surveys. Transmissivity profiles were taken only at selected stations during the remaining surveys. Temperature-depth profiles were obtained each time a station was sampled. 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, are obtained each time a station is occupied.

Plankton surveys were conducted on a bimonthly basis during 1979: on 17, 18, 19 January; 14, 15, and 16 March; 16, 17, and 18 May; 10, 11, and 12 July; 5, 6, and 7 September; 6, 8, and 9 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 fluorometer 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 taxa selected 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 of San Onofre (LCMR 1978c). These select taxa consist of Penilia avirostris, Podon polyphemoides, Acartia tonsa, Acartia spp. copepodites, Corycaeus anglicus, Euterpina acutifrons, Labidocera trispinosa copepodites, Oithona oculata, Paracalanus parvus, Paracalanus parvus copepodites, Clausocalanus spp., 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 also enumerated. Generally, zooplankton abundances are sufficiently high that sample abundances are estimated from subsamples obtained with a Stempel pipette. When abundances are very low a Folsom plankton splitter is used and aliquots of the whole sample are enumerated.

Total zooplankton biomass is measured for each zooplankton sample. 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 ANALYSIS

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 homogenity of variance required by 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, for 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 among stations and depths. Onshore-offshore and upcoast-downcoast distributions of zooplankton abundance, biomass, chlorophyll, and phaeopigment concentrations were examined. The ANOVA design 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 depths (i.e., two strata), transects (i.e., onshore-offshore lines of stations), and isobaths (i.e., lines of similar-depth stations). Two samples were taken each day for each combination of main effects. These were considered to be duplicates and 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 design allowed the variability between sampling days to be used to test for differences between the other main effects. Duncan's multiple range test (Steel and Torrie 1960) was used to locate significantly different station groups. Analyses were carried out separately by survey since seasonal fluctuations could serve to confound otherwise meaningful results.

RESULTS

In this section each of the biological parameters examined is considered in terms of gross spatial and temporal patterns observed during 1979. The following subsections present summary figures and tables which show the distribution of abundance and concentration data at each station by survey. Ninety percent confidence intervals placed about the geometric mean, are based on all samples collected at that station and depth range and visually demonstrate general trends and patterns. Salient features of each survey are pointed out and temporal trends noted. Following the summary presentation the data were then analyzed by ANOVA. The results of these analyses are presented and important results noted. For rigorous statistical testing, the 95% significance level was retained.

The ANOVA design 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 five transects as depicted in Table 3-1. 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 design employed is that short term variability (i.e., between days) has been included. The fact that nearly every analysis conducted showed significant difference between days, demonstrates the highly transitory nature of the nearshore plankton populations off San Onofre. This feature was present for all biological parameters studied, and indicates that patchiness may greatly affect the interpretation of data collected on a single day, as well as spatial and temporal patterns.

Table 3-1. Stations grouped by isobath and transect included in the statistical model employed in the analysis of variance of ETS/PMP data.

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

PHYTOPLANKTON

Chlorophyll a and phaeopigment concentrations and phytopigment ratios were measured as a method of assessing phytoplankton populations. Mean values of these variables by survey, isobath, and depth stratum are presented in Figure 3-2.

Chlorophyll a

The distribution of chlorophyll a at each station for each survey is presented in Figure 3-3. A distinct seasonal pattern in chlorophyll a concentration is evident. Mean concentrations were lowest in January (0.61 mg/m^3) and March (0.49 mg/m^3). Chlorophyll a concentrations were progressively higher during May (2.97 mg/m^3) and July (10.61 mg/m^3), with the highest concentrations of the year occurring in September (12.04 mg/m^3). Mean chlorophyll a concentrations declined to 6.29 mg/m^3 in November.

Results of analysis of variance (ANOVA) for chlorophyll a are presented in Table 3-2. Significant differences in chlorophyll a concentration between depth strata were detected during the January, March, July, September, and November surveys. During the January survey the concentration of chlorophyll a was greater in the upper stratum than in the lower stratum, while the reverse was the case during other surveys (Figures 3-2 and 3-3). Significant differences in chlorophyll a concentration among transects were detected during the January, March, May, and November surveys. During March a trend toward increased chlorophyll a concentration in the upcoast direction was observed while the opposite was present in May. No patterns were observed during other surveys. A persistent gradient of chlorophyll a with concentrations lower offshore was generally present, with significant differences detected in both January and November. Significant differences in chlorophyll a concentration among days of a survey were detected in March, May and July, and between samples collected on the

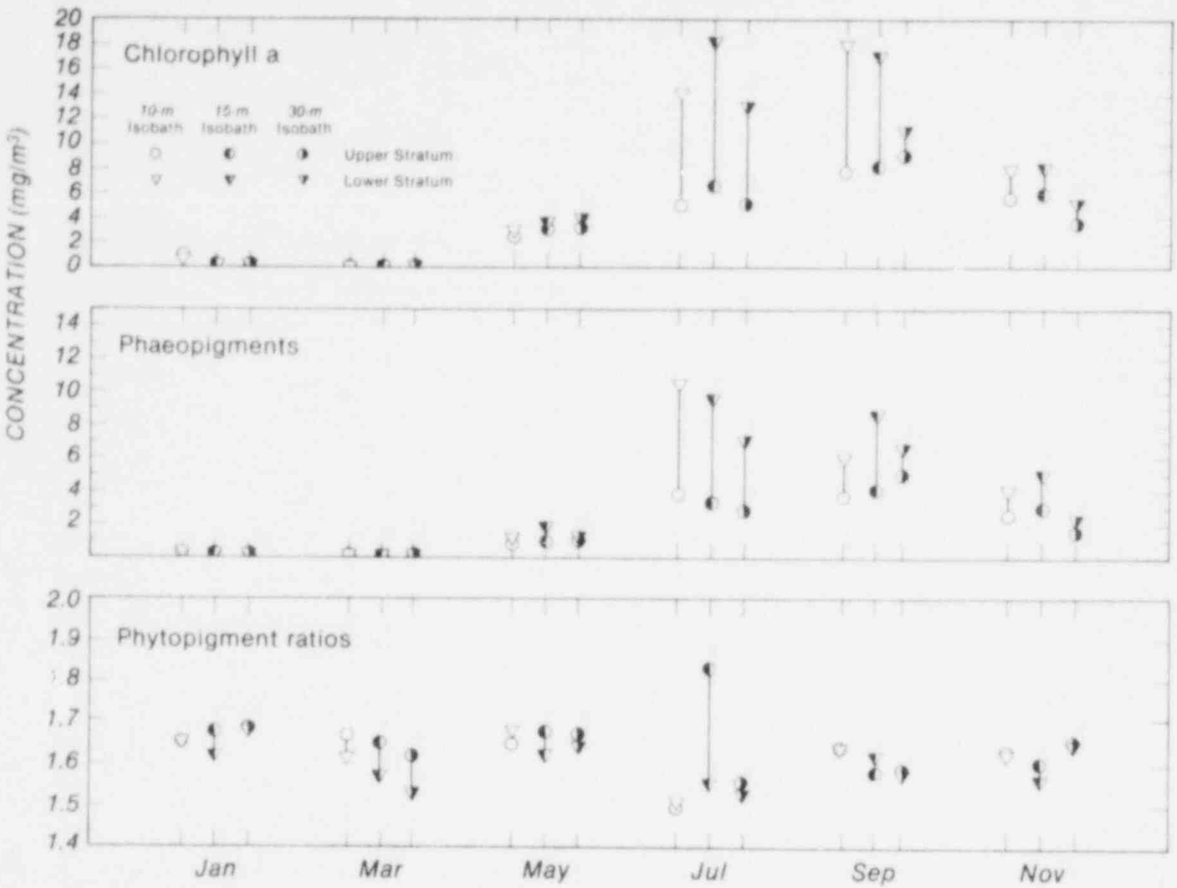

Figure 3-2. Arithmetic means of concentrations of chlorophyll *a*, phaeopigments, and the ratio of phytopigment fluorescence during 1979.

Table 3-2. Results of analysis of variance for 1979 ETS-PMP chlorophyll *a* data.

Source	Survey					
Main Effects	Jan	Mar	May	Jul	Sep	Nov
Depth (D)	***	***	n.s.	***	***	***
Transect (T)	*	**	*	n.s.	n.s.	*
D x T	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Isobath (I)	***	n.s.	n.s.	n.s.	n.s.	*
D x I	n.s.	n.s.	n.s.	n.s.	*	n.s.
T x I	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
D x T x I	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Day	n.s.	***	***	*	n.s.	n.s.
Nested Effects						
Duplicate	n.s.	n.s.	*	n.s.	n.s.	*
Day x Duplicate	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

n.s. Not significant ($P > 0.050$)
* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

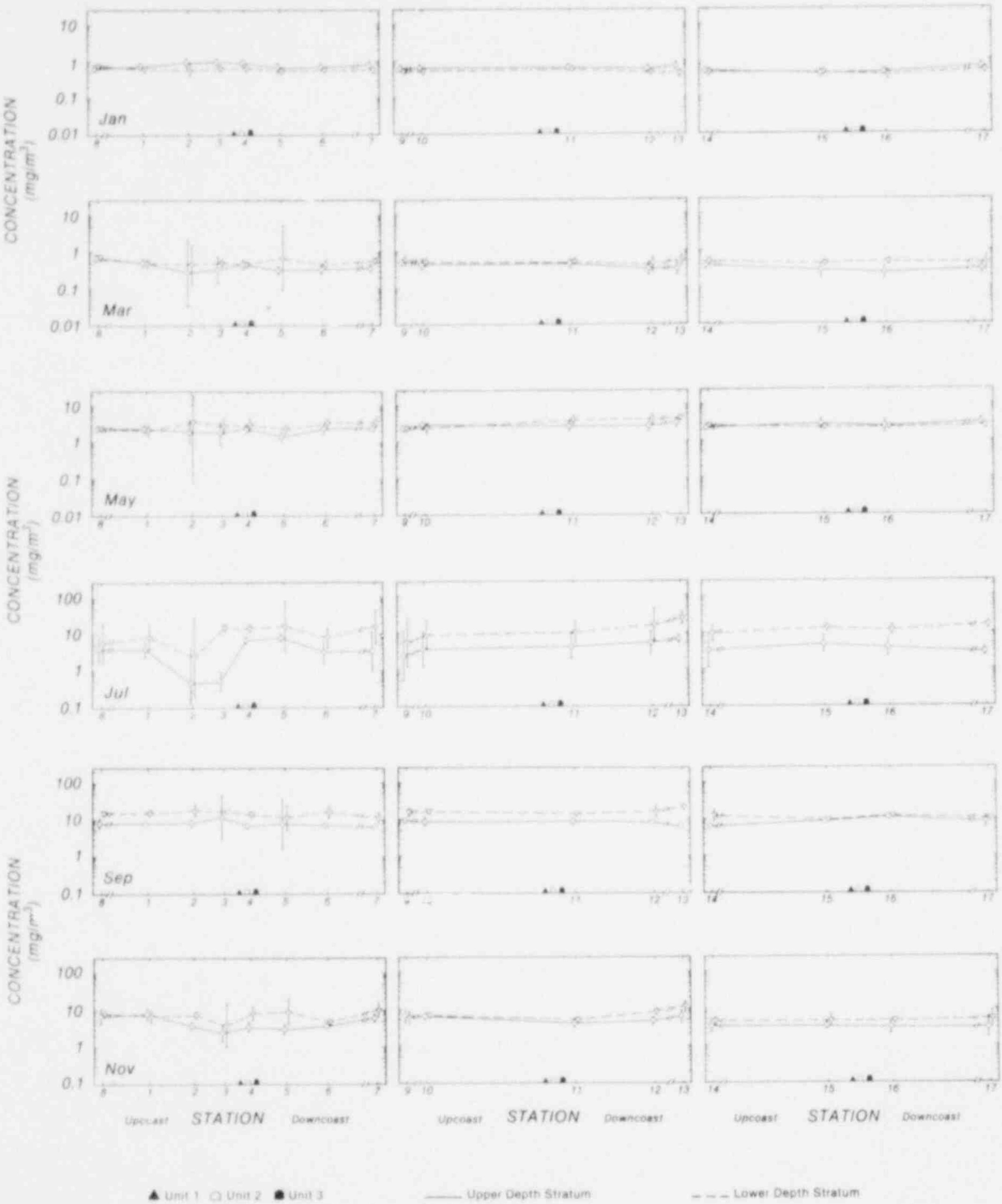

Figure 3-3. Chlorophyll *a* concentration (geometric mean and 90% confidence interval) for each station by survey for 1979. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3, respectively. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

same day they occurred in May and November. Interaction between depth and isobath was significant in September.

Phaeopigment

The seasonal pattern of phaeopigment concentration observed during 1979 is summarized in Figure 3-2, and for each station by survey in Figure 3-4. Because of the relationship between chlorophyll and phaeopigment, the distribution of these two variables was usually similar. Mean phaeopigment concentrations were very low in January (0.24 mg/m^3) and March (0.28 mg/m^3). A slight increase in concentration was present in May (1.15 mg/m^3) and the highest concentration observed during the year occurred in July (6.33 mg/m^3). Phaeopigment concentrations declined slightly in September (5.53 mg/m^3) and decreased to 3.19 mg/m^3 by November.

Results of analyses of variance for phaeopigment data are presented in Table 3-3. Phaeopigment concentrations were significantly higher in the lower depth stratum for all but the January survey. Significant differences among transects were detected in January and November but no pattern of distribution was exhibited. Concentrations among isobaths were significantly different in January, September, and November, with higher concentrations at the 10 and 15-m stations than at the 30-m stations. Much variability in phaeopigment concentration was present within a single survey. Significant differences between days were detected for all surveys except September and between samples collected on the same day in July, September, and November. Interaction was present in September and November data.

Table 3-3. Results of analysis of variance for 1979 ETS-PMP phaeopigment data.

Source		Survey					
	Main Effects	Jan	Mar	May	Jul	Sep	Nov
	Depth (D)	n.s.	***	***	***	***	***
	Transect (T)	*	n.s.	n.s.	n.s.	n.s.	*
	D x T	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Isobath (I)	***	n.s.	n.s.	n.s.	*	***
	D x I	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	T x I	n.s.	n.s.	n.s.	n.s.	*	*
	D x T x I	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Day	***	***	***	***	n.s.	***
	Nested Effects						
	Duplicate	n.s.	n.s.	**	n.s.	*	*
	Day x Duplicate	n.s.	n.s.	n.s.	n.s.	n.s.	*

n.s. Not significant ($P > 0.050$)
* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

Phytopigment Fluorescence Ratio

The ratio of the fluorescence of a phytopigment sample before and after acidification is one method used to assess the physiological state of phytoplankton populations. Chlorophyll a phaeopigment fluorescence ratios are summarized in

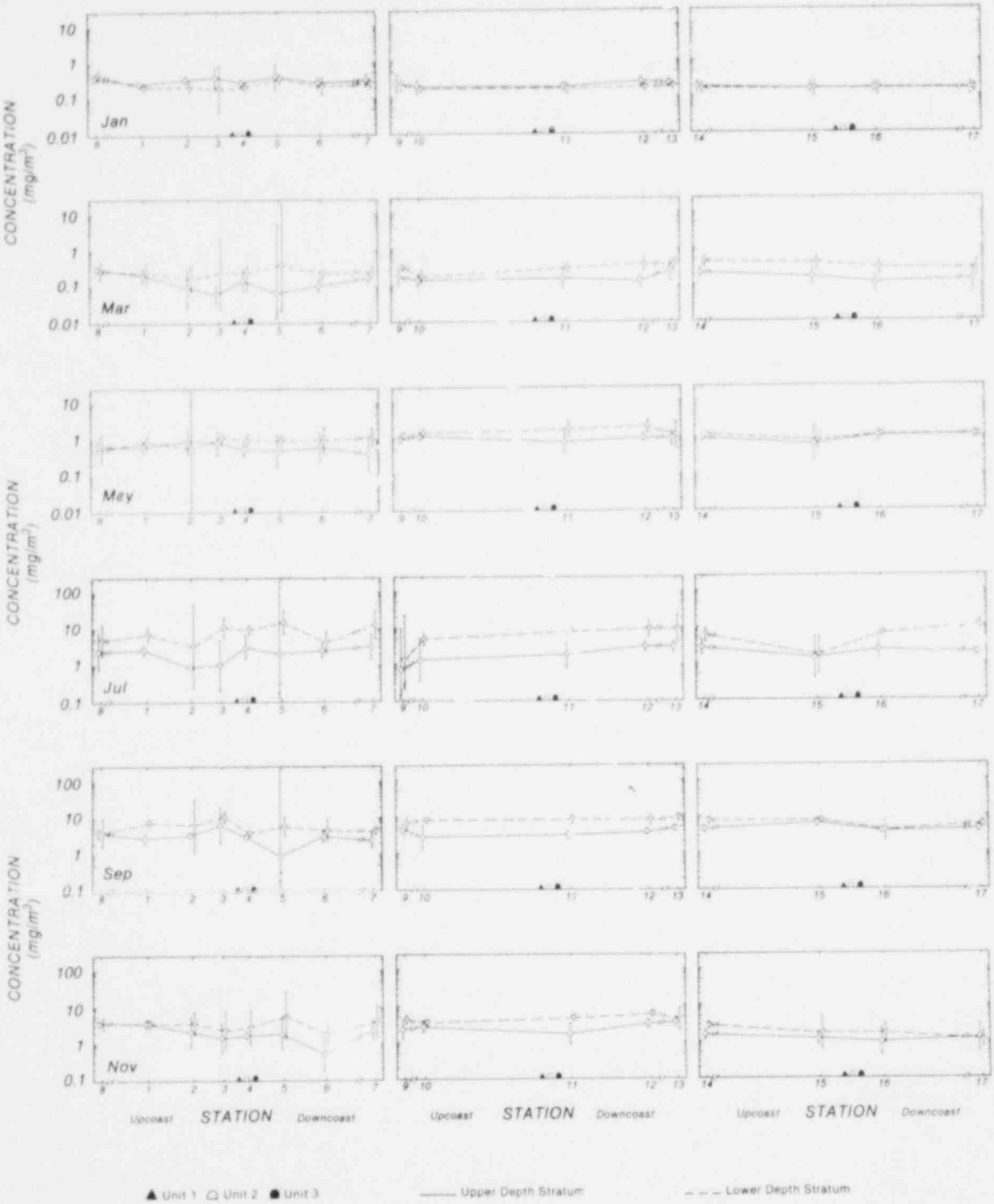

Figure 3-4. Phaeopigment concentration (geometric mean and 90% confidence interval) for each station by survey for 1979. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3, respectively. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

Figure 3-2 by depth stratum and isobath for each survey. The phytopigment fluorescence ratio remained quite constant throughout the year except in July. During this survey a sl ht decline was observed at all isobaths and in both depth strata, except at the lower strata of the 15-m stations which exhibited unusually high mean phytopigment ratios.

ZOOPLANKTON

Total zooplankton abundance, dry weight biomass, species composition, and community structure were examined for the zooplankton community offshore of SONGS. Mean total zooplankton abundance and biomass for each of the 1979 surveys is summarized by isobath and depth stratum in Figure 3-5.

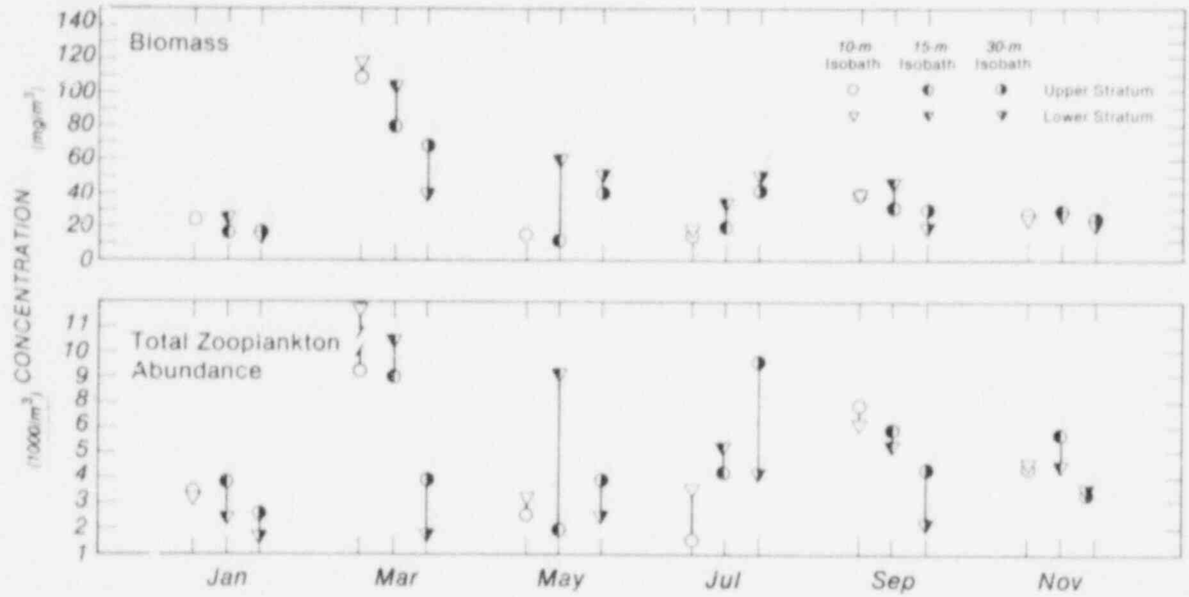

Figure 3-5. Arithmetic mean of total zooplankton abundance and concentration of dry weigh biomass during 1979.

Total Abundance

The 1979 total zooplankton abundance estimates reveal several patterns in distribution (Figure 3-5 and 3-6). Along a given isobath, abundance was generally greater at stations nearest SONGS (Transects 2, 3, and 4). Stations off San Mateo Point (Transect 5) consistently had the lowest abundance estimates for a given isobath. Mean total abundance was generally lower at stations on the 30-m isobath. The lowest mean total abundance was recorded in January (2,684/m³) and the highest mean value was recorded in March (8,056/m³).

Results of analyses of variance for total zooplankton abundance are presented in Table 3-4. Significant differences in mean total zooplankton abundance between depth strata were observed during the January, May, and September surveys. Mean total zooplankton abundance was higher in the upper stratum during January and September and higher in the lower stratum during May. Significant differences were detected among isobaths during the January, March, July, and September surveys. A gradient of increasing abundance in the onshore direction was present during the January, March, and September surveys, while the reverse was observed during the July survey. Transect differences were significant during the March, July, September, and November surveys. During the March, September, and November surveys the upcoast reference transect exhibited the lowest mean total abundance estimate. There was also generally a gradient of decreasing abundance proceeding downcoast along all transects, except the upcoast reference transect, during these surveys (Figure 3-6). Zooplankton abundance estimates between days of the survey were significantly different during March, May, and November. Only during November were significant differences in zooplankton abundance detected between replicates. Significant depth-isobath interactions and significant transect-isobath interactions were present during the March, May, and July surveys, respectively.

Table 3-4. Results of analysis of variance for 1979 ETS-PMP total zooplankton abundance data.

Source	Survey					
Main Effects	Jan	Mar	May	Jul	Sep	Nov
Depth (D)	**	n.s.	**	n.s.	*	n.s.
Transect (T)	n.s.	***	n.s.	**	*	*
D x T	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Isobath (I)	**	***	n.s.	**	**	n.s.
D x I	n.s.	**	**	**	n.s.	n.s.
T x I	n.s.	n.s.	*	**	n.s.	n.s.
D x T x I	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Day	n.s.	*	***	n.s.	n.s.	***
Nested Effects						
Duplicate	n.s.	n.s.	n.s.	n.s.	n.s.	**
Day x Duplicate	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

n.s. Not significant ($P > 0.050$)
* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

Biomass

Biomass determinations were conducted for each survey of 1979. These data are presented in Figures 3-5 on a seasonal basis and for each station by survey on Figure 3-7. Distributional patterns for total mean biomass concentrations for 1979 were similar to those for zooplankton. The lowest mean biomass was found in January (21 mg/m^3) while the highest mean biomass level was observed in March (88 mg/m^3). Along the 10-m isobath, biomass was generally highest upcoast with a decreasing gradient downcoast. Along both the 15 and 30-m isobath, a general pattern of high biomass concentration near SONGS with decreased concentration away from this area was present throughout 1979.

Results of analysis of variance for zooplankton biomass data are presented in Table 3-5. Differences in biomass between depth strata were significant during the May, July, and November surveys. Higher concentrations were observed in the lower stratum during May and July while in November higher biomass concentrations were found in the upper stratum. Significant differences in biomass concentration among transects were observed during the March, July, and September surveys. During March biomass concentration was lowest at the upcoast reference transect and highest near SONGS (Transect 4), with a gradient downcoast from that point. No obvious patterns were present during either the July or September surveys. Biomass concentrations among isobaths were significantly different during March, May, July, and September. A gradient of increasing biomass concentration in the inshore direction was present during the March and September surveys while a gradient of increasing concentration in the offshore direction

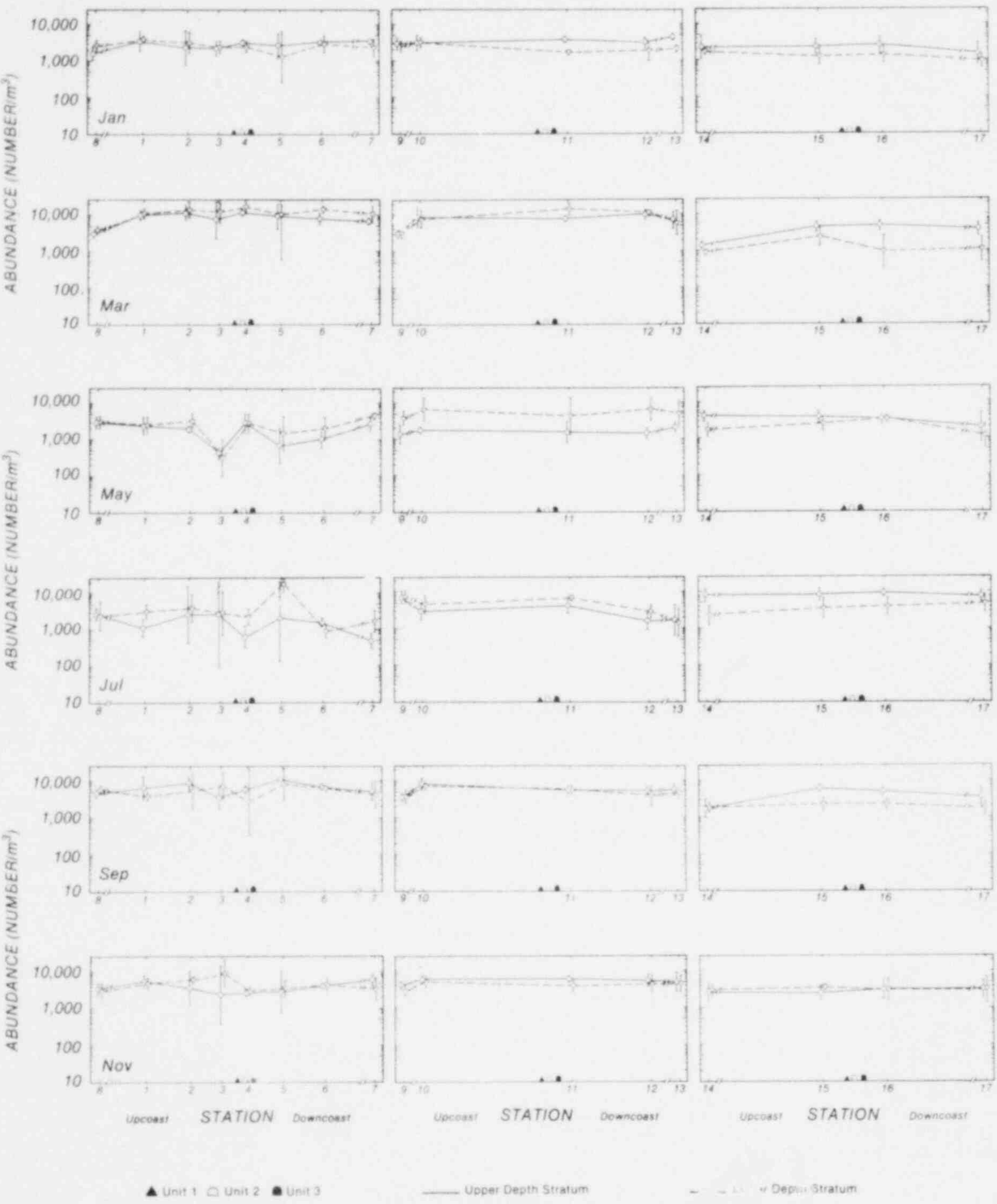

Figure 3-6. Total zooplankton abundance (geometric mean and 90% confidence intervals) for each station by survey for 1979. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3, respectively. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

was evident during May and July. Only during November were significant differences in biomass concentration among days of the survey detected. Differences between replicates were not significant during any survey. Significant transect-isobath interaction was present in July and September while depth-isobath and day-replicate interactions were each significant during September.

Table 3-5. Results of analysis of variance for 1979 ETS-PMP zooplankton biomass data.

Source	Survey					
Main Effects	Jan	Mar	May	Jul	Sep	Nov
Depth (D)	n.s.	n.s.	***	**	n.s.	*
Transect (T)	n.s.	**	n.s.	***	**	n.s.
D x T	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Isobath (I)	n.s.	***	*	***	**	n.s.
D x I	n.s.	***.	n.s.	n.s.	*	n.s.
T x I	n.s.	n.s.	n.s.	*	*	n.s.
D x T x I	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Day	n.s.	n.s.	n.s.	n.s.	n.s.	***
Nested Effects						
Duplicate	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Day x Duplicate	n.s.	n.s.	n.s.	n.s.	**	n.s.

n.s. Not significant ($P > 0.050$)
* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

Mean Zooplankton Biomass

A useful index of the relative food value of the zooplankton community to potential predators is mean weight per organism. This value is calculated by taking the ratio of mean biomass to total number of organisms. Although these data were not amenable to statistical analysis, visual interpretations are useful. Results of this analysis for each survey are summarized in Figures 3-8 and 3-9.

There is a general trend toward larger organisms along the 30-m isobath during March, May, and November. With regard to transects, Transect 5 always had higher mean individual biomass values than did Transect 4 and also had the highest mean individual biomass values of all transects during the March, May, July, September, and November surveys. The mean size of organisms found in the lower stratum was larger during all surveys except March. Differences in mean biomass values between surveys are quite pronounced, with largest values observed in March and smallest in November. A general trend of decreasing mean size was observed from March through November.

Abundance of Select Taxa

The mean abundance of each of the taxa enumerated is presented in Table 3-6. The abundance and distribution of the select taxa is summarized for each survey in Figure 3-10 by depth and isobath. Analysis of variance for each species did not reveal consistant patterns of spatial distribution. However, some trends were evident from examination of graphical data in conjunction with statistical analyses.

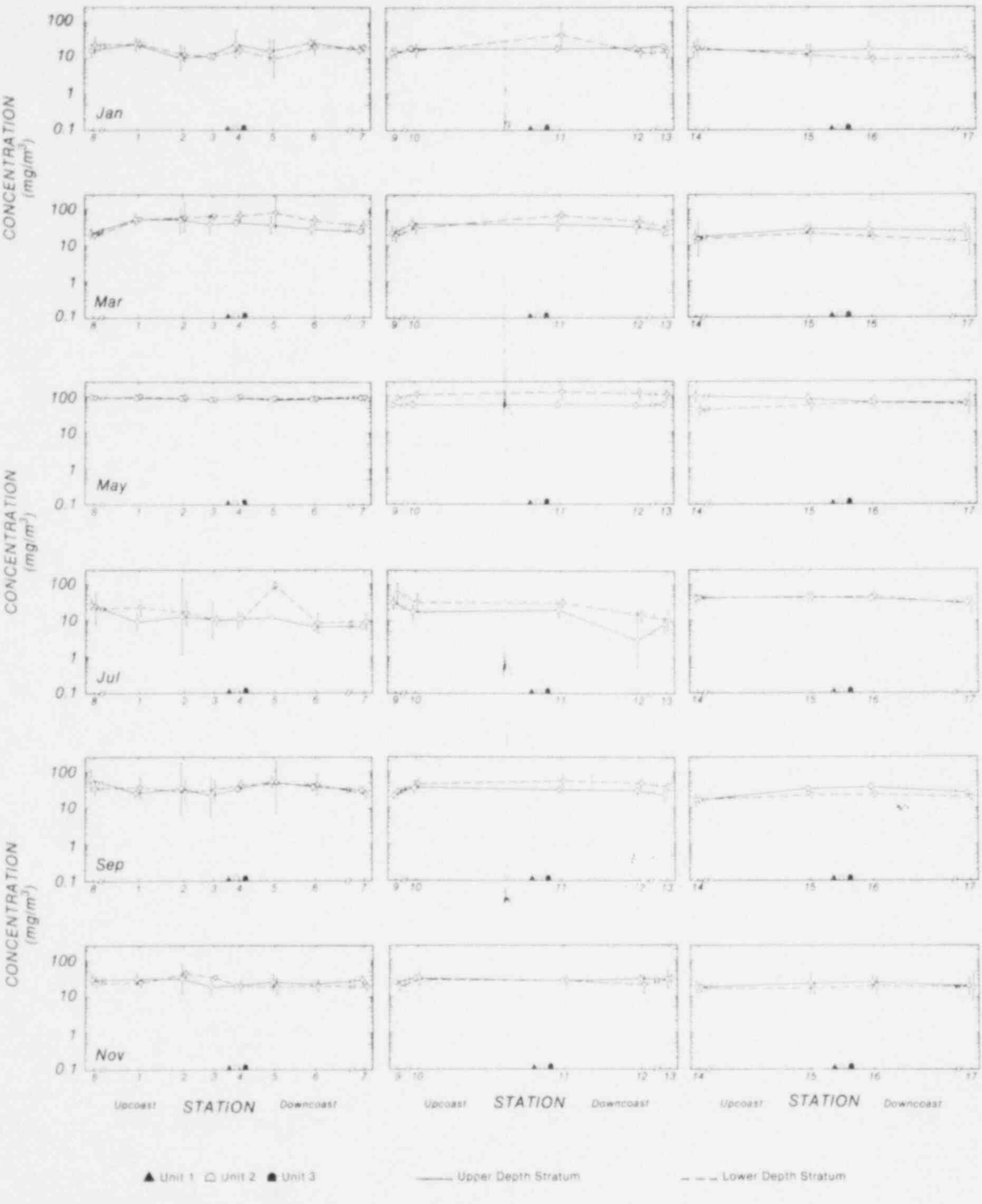

Figure 3-7. Zooplankton dry weight biomass concentration (geometric mean and 90% confidence interval) for each station by survey for 1979. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3, respectively. Station locations are scaled to distance from SONGS. Stations 2, 3, and 5 were sampled on one day, all others were sampled on three days.

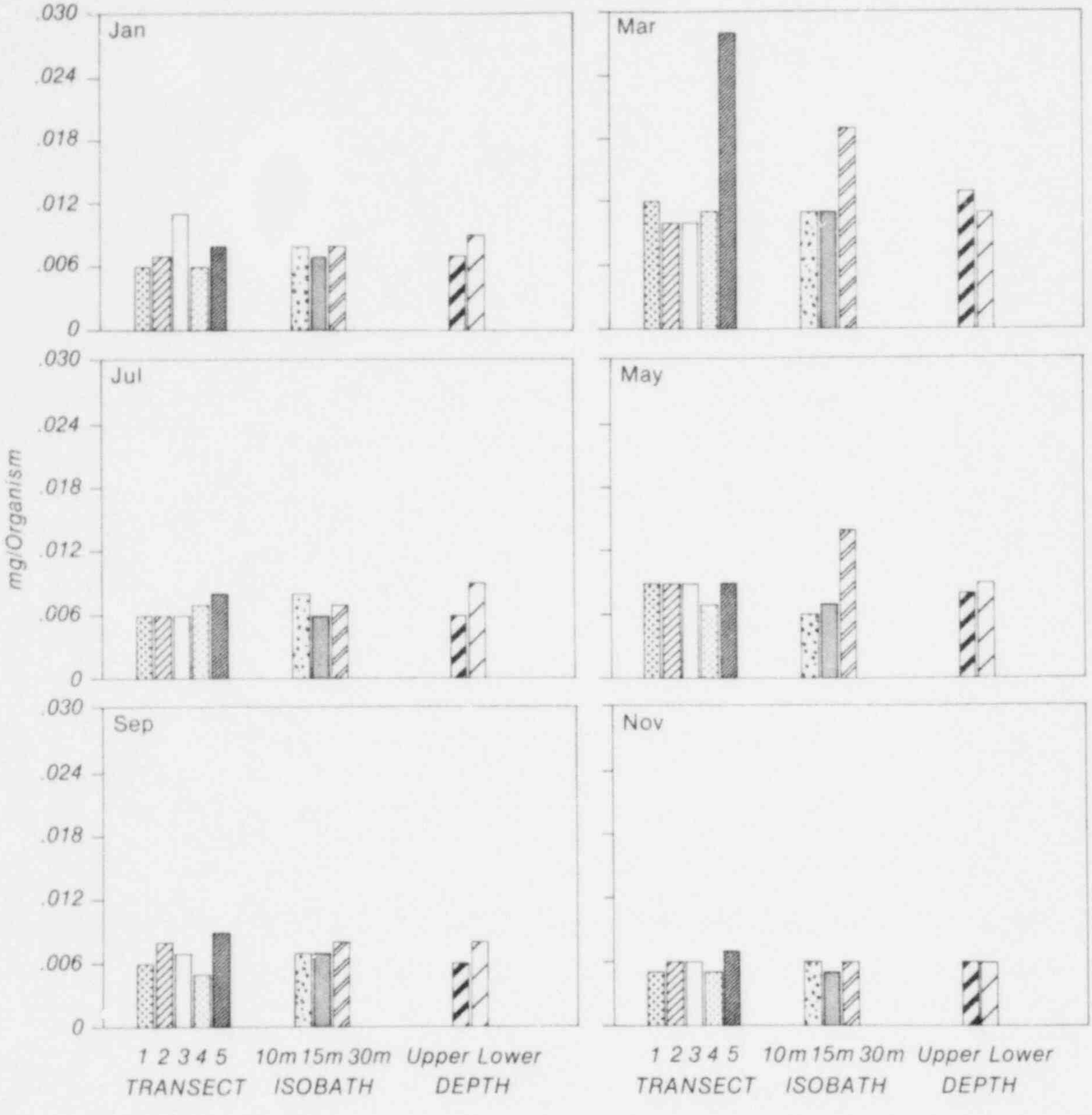

Figure 3-8. Mean organism weight (mg) by transect, isobath, and depth stratum.

Acartia tonsa showed a general pattern of distribution characterized by a trend towards greater abundance at stations along the 10 and 15-m isobath than along the 30-m isobath. Abundance was significantly greater in the upper stratum in January but no consistent pattern of depth distribution was present for other surveys. Transect differences, when significant, did not show consistent trends in distribution. Acartia spp. copepodites were found to demonstrate a distinct onshore-offshore pattern of distribution with decreasing abundance proceeding from 10, to 15, to 30-m stations. These differences were significant for four of the six surveys. Acartia spp. copepodites were found in significantly greater numbers in the lower depth stratum during all surveys except January when they were found in significantly greater numbers in the upper stratum. Differences among transects showed no consistent pattern.

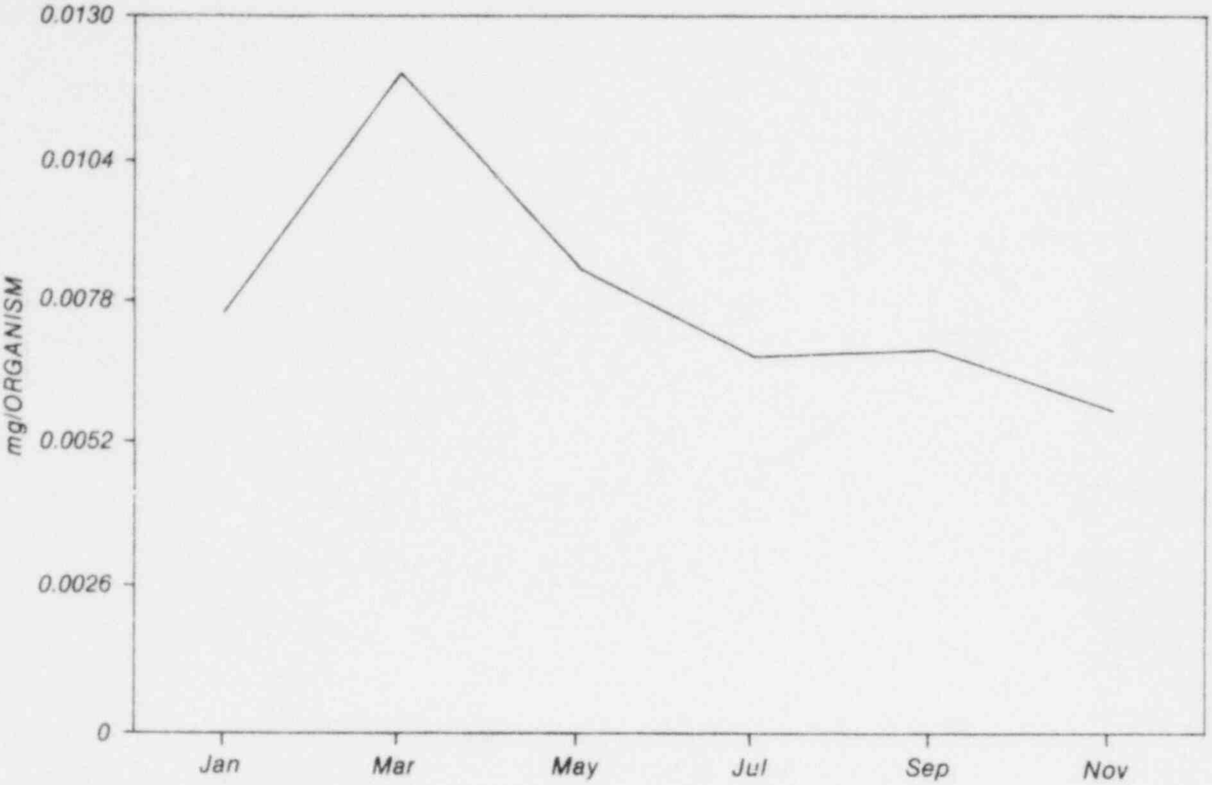

Figure 3-9. Mean organism weight (mg) for each survey of 1979.

Paracalanus parvus showed no distinct pattern of distribution for most surveys, but trends were present in May and July with respect to both vertical and onshore-offshore distribution. Paracalanus was generally more abundant in the lower stratum and showed a gradient of increasing abundance proceeding from 10 to 15 to 30-m stations. Transect differences, when significant, did not show any consistent pattern. Paracalanus parvus copepodites showed distributional patterns of abundance similar to those described for adults of this species, although the abundance of copepodites was generally greater than adults.

Clausocalanus spp. was seasonal in occurrence. In January it was present in about equal numbers at all three isobaths and in both depth strata. It was less abundant in March and present in only small numbers in May. In July it was present in small numbers at 10 and 15-m stations and in moderate numbers at the 30-m stations. Clausocalanus was abundant in the upper stratum at all three isobaths in September and November. No upcoast-downcoast pattern was apparent.

Labidocera trispinosa copepodites showed a distinct trend being more abundant in the upper depth stratum during all surveys. An onshore-offshore gradient with decreasing abundance proceeding from 10 to 15 to 30-m stations is evident for all surveys except July and November.

Oithona oculata was present throughout all surveys in small numbers. This copepod tended to be consistently more abundant at the 10 and 15-m stations than at the 30-m stations. No distinct seasonal, vertical, nor upcoast-downcoast pattern was evident.

Table 3-6. Rank order of abundance of select taxa collected off SONGS, from 1975 to 1979.

	Rank					Annual Mean (no/m³)				
Taxa	75*	76	77	78**	79	75*	76	77	78**	79
Acartia spp. copepodites	1	1	1	1	1	2105	797	1005	613	817
Acartia tonsa	5	3	3	4	3	98	480	164	195	365
Penilia avirostris	†	2	4	8	1	†	523	151	84	43
Paracalanus parvus copepodites	3	9	2	2	2	127	89	2153	514	546
Sagitta spp.	2	7	5	9	6	148	98	118	72	239
Corycaeus anglicus	7	4	9	6	7	60	165	62	159	235
Cyphonautes larvae	8	6	6	10	8	56	102	114	72	129
Paracalanus parvus	9	5	8	3	4	55	108	87	209	333
Labidocera trisponos copepodites	4	8	10	7	9	110	98	56	92	106
Podon polyphemoides	10	10	7	5	13	21	75	94	167	21
Euterpina acutifrons	6	11	11	11	10	63	64	52	63	69
Clausocalanus spp.	††	††	††	††	5	††	††	††	††	298
Oithona oculata	††	††	††	††	12	††	††	††	††	31
Cypris larvae	††	††	††	††	14	††	††	††	††	14

* 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.
†† Taxon not a major contributor to total in these years.

The group enumerated as "all other copepods not among the select taxa considered as an aggregate" was consistently more abundant in the lower depth stratum than the upper. No other pattern was evident for this group.

Penilia avirostris was absent from the May survey, present in very low numbers in July, and abundant in January and September. Penilia was more abundant in the upper depth stratum during the two surveys when it was abundant.

Podon polyphemoides was absent from the January survey, and present only in small numbers during other surveys. A slight tendency towards greater abundance in the upper depth stratum was the only pattern present.

Cypris larvae were present in small numbers in 1979. A slight trend towards greater numbers in the lower depth stratum was the only obvious pattern.

Cyphonautes larvae were generally more abundant at the 10 and 15-m stations than at the 30-m stations. In January and March they were more abundant in the upper depth stratum but this was not evident in subsequent surveys.

Corycaeus anglicus, Sagitta spp., and Euterpina acutifrons displayed no distinct trends with regard to survey, depth, onshore-offshore, or upcoast-downcoast distributions during 1979.

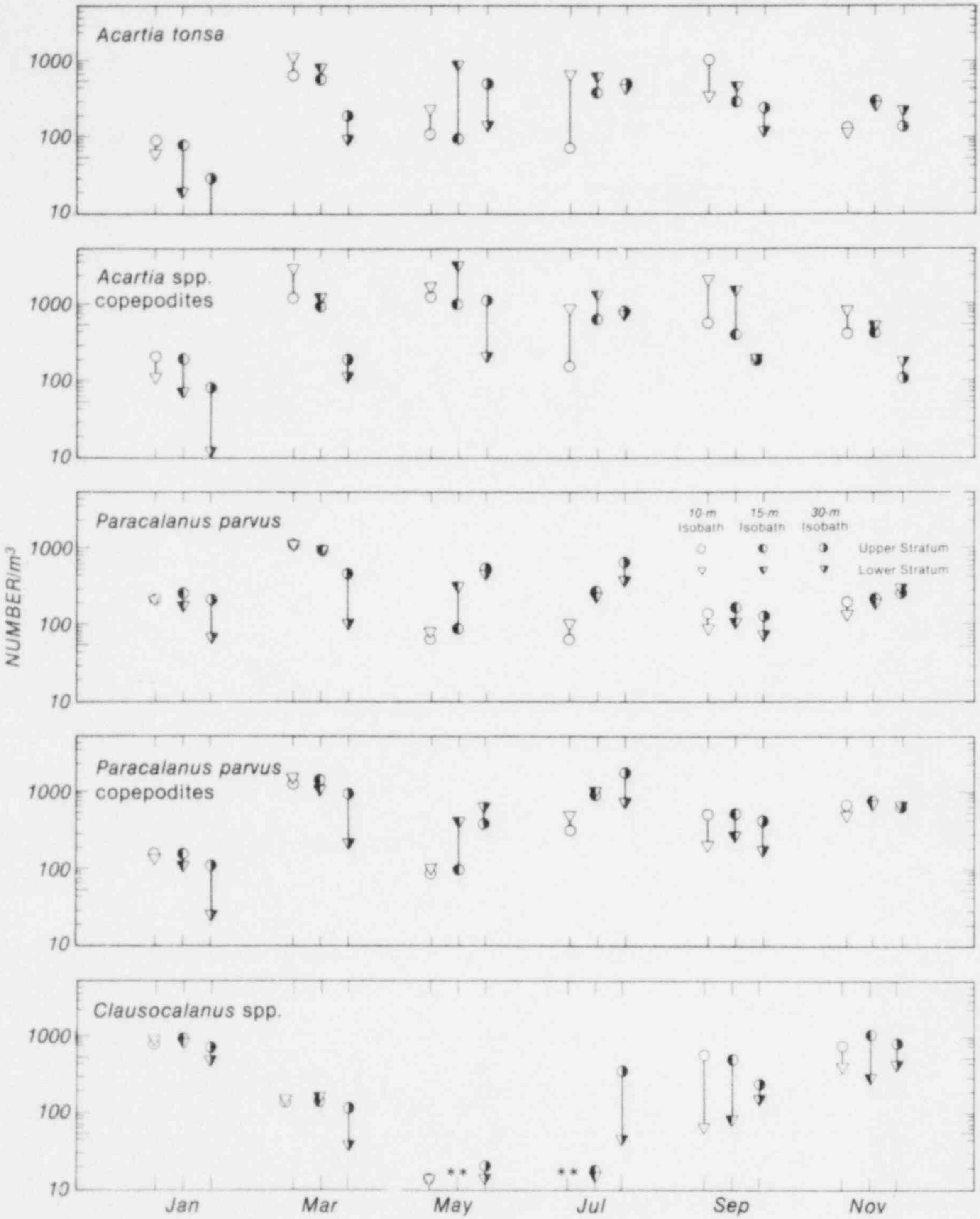

Figure 3-10. Abundance of select taxa distributed by isobath, depth, and survey during 1979. An * indicates no organisms present, a ** indicates present in small numbers.

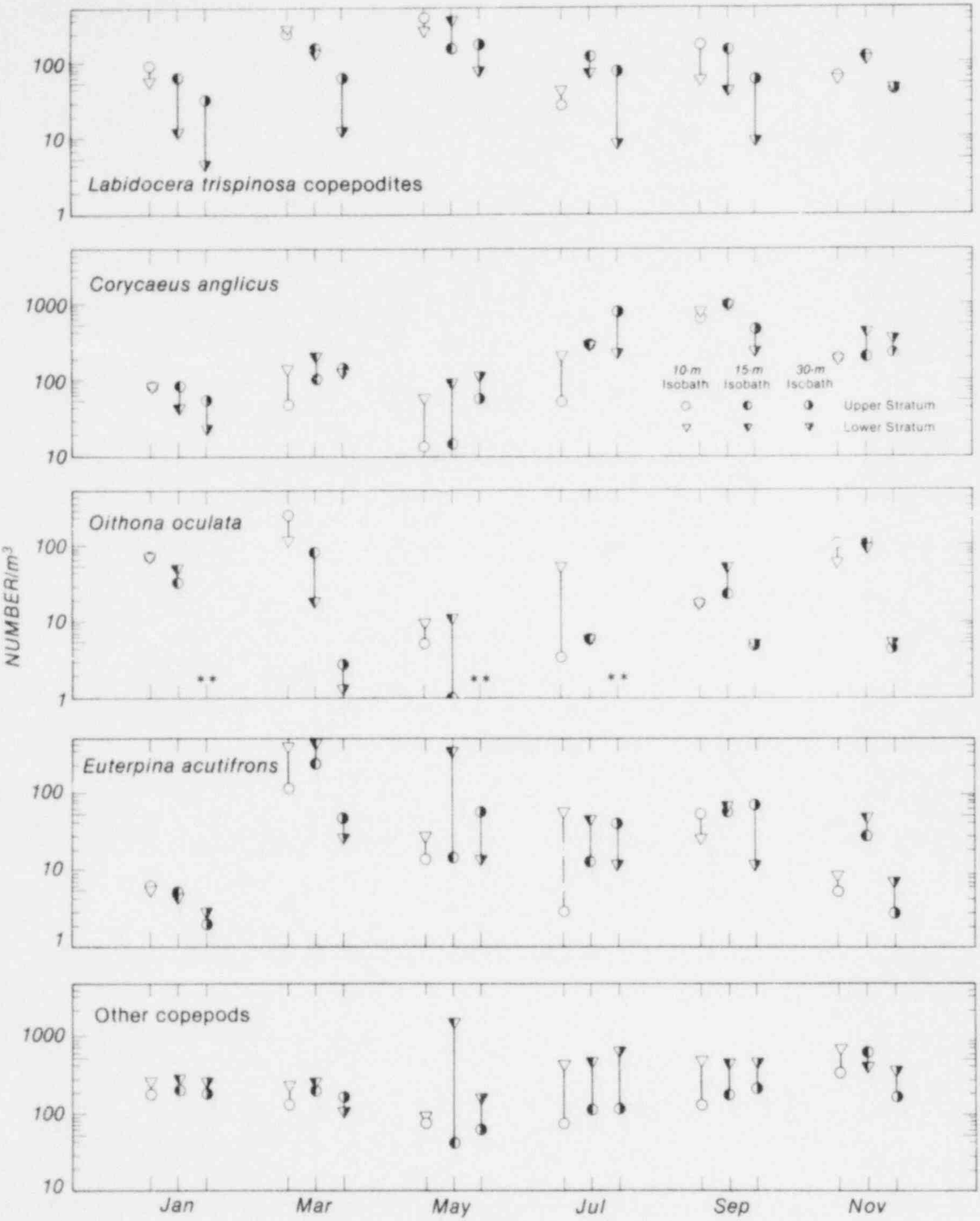

Figure 3-10. (Continued)

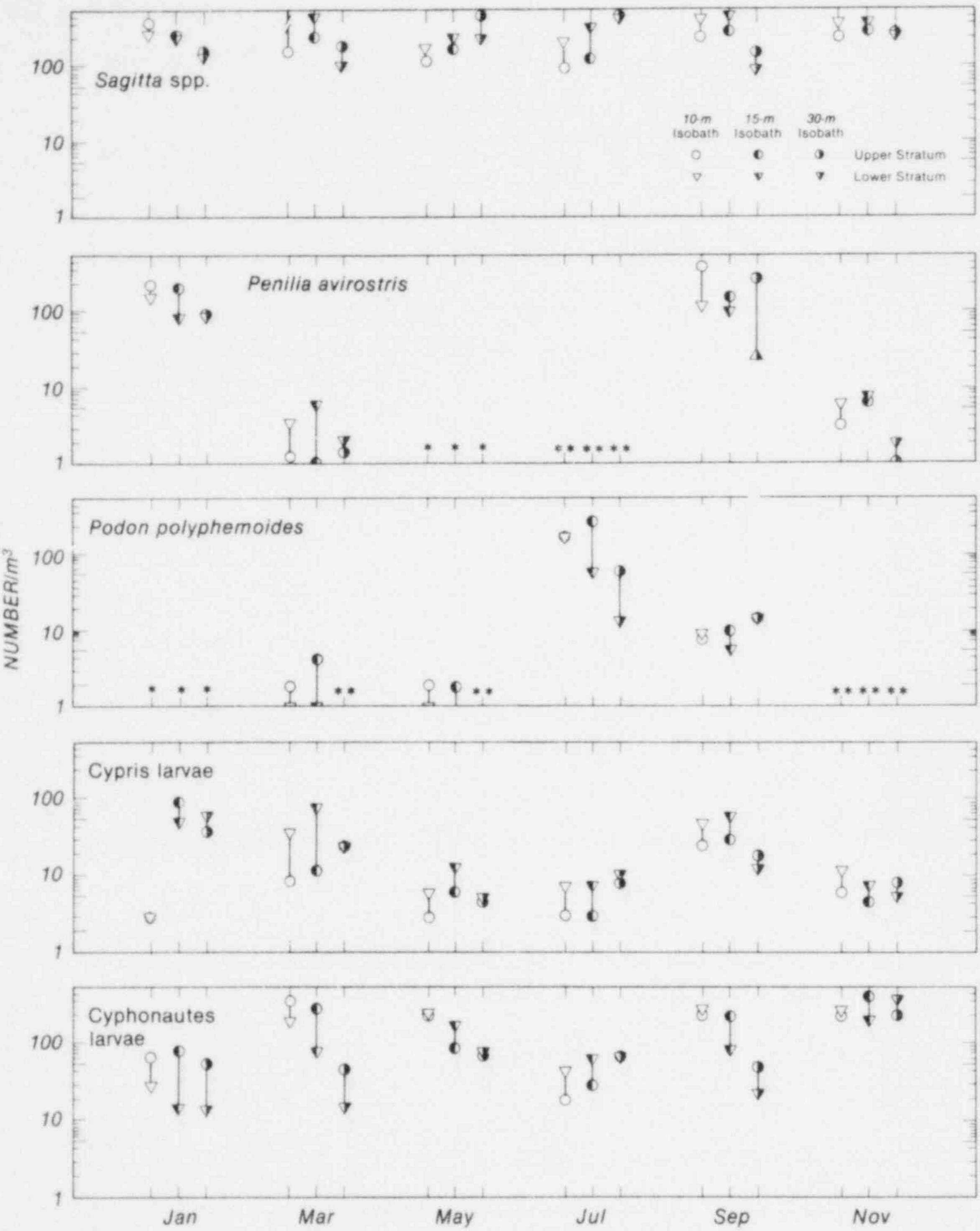

Figure 3-10. (Continued)

DISCUSSION

This section addresses specific topics that pertain to the establishment of 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.

An important feature of the design employed is that short term variability (i.e., between days) has been included. The fact that nearly every analysis conducted 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, and indicates that patchiress may greatly affect the interpretation of data collected on a single day, as well as spatial and temporal patterns.

SPATIAL AND TEMPORAL PATTERN OF PHYTOPIGMENT DISTRIBUTION

Chlorophyll a

There is considerable ecological importance in examining phytoplankton in the waters adjacent to the SONGS complex. Phytoplankton forms the base of most food webs in the sea, and is important as a limiting factor for the support of higher trophic levels. Some factors which influence phytoplankton communities, that may be altered by SONGS operation are temperature, redistribution of nutrients, and light. Elevated water temperatures resulting from the SONGS 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, another limiting factor for phytoplankton growth, may be influenced by redistribution of turbidity by SONGS operations, which 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 generating station cooling water discharge may also affect the quantity and quality of the phytoplankton communities near the generating station.

Significantly greater chlorophyll a concentrations occurred in the lower stratum during four of the six 1979 surveys. In May the pattern was similar but not statistically significant. In January the reverse of the typical pattern occurred, with chlorophyll a concentration higher in the upper stratum, however, the magnitude of the chlorophyll a concentration was so low that this difference is probably of no biological significance.

Since the beginning of the SONGS plankton monitoring programs in 1975, only three surveys (November 1975, March 1978, and January 1979) exhibited higher chlorophyll a concentrations in the upper stratum (LCMR 1977b). Higher chlorophyll a concentrations in the lower stratum may reflect greater overall phytoplankton concentration (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). Phytoplankton cells in the lower stratum may contain more chlorophyll a than those in the upper stratum, even though the number of cells is similar. A gradient of decreasing chloropyll a concentrations with increased distance from shore was frequently observed. However, even when significant differences were present, the 10 and 15-m stations were not significantly different from each other. Rather, the difference is usually between the 30-m stations and all inshore stations. The significant differences in chlorophyll a concentration among isobaths observed for January and November surveys correspond to the general pattern observed for the other 1979 surveys, and for the three ETS/PMP surveys conducted in 1978. During all surveys, chlorophyll a concentration was lower at the 30-m stations than at the 10 or 15-m stations, although the differences were not always great enough to be statistically significant. The persistent onshore-offshore gradient of chlorophyll a occured in each survey and is characteristic of most near shore marine environments. This pattern has been shown to occur throughout the Southern California Bight region (Eppley, Sapienza and Rengen 1978) including nearby areas upcoast (Dana Point) and downcoast (Del Mar) from SONGS. 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. The explanation for higher chlorophyll values near shore may be a function of increased turbidity causing lower light levels, and not necessarily grater abundances of phytoplankton. Phytoplankters are known to compensate for low light by increasing the amount of chlorophyll per cell (Odum, McConnell, and Abbott 1958).

Variability observed among the transects may be attributed to the patchy distribution of phytoplankton. Although significant differences among onshore-offshore transects occurred in all surveys except July and September, no consistent pattern could be defined. Multiple range testing failed to delineate any transect or group of transects that were consistently higher or lower in chlorophyll a concentration. The upcoast-downcoast variation present for the four surveys with significant differences appears unrelated to any other biological or physical/chemical variable measured. In other regions, patchiness in the distribution of phytoplankton over areas similar in size to the SONGS study area, has been shown to be responsible for much observed variability (Denman and Mackas 1978, Platt 1978, Pugh 1978).

Chlorophyll a concentrations in July and September were about twice as great as the mean value recorded on any survey between 1975 and 1979. The extremely high chlorophyll a concentrations may have resulted from periods of upwelling which occurred prior to the July and September surveys. Examination of continous temperature records (SCE 1980a) shows that a marked decrease in surface temperature occurred during the last week of June, the first week of July, and the third week of August 1979. These periods of apparent upwelling preceeded the July and September surveys and may have been responsible for the elevated phytoplankton biomass observed during these periods. Available nutrient data (SCE 1980b) from the the SONGS area indicates a high nitrate concentration in the water column during May but not in subsequent months. This corresponds to a marked increase in chlorophyll a concentration following low concentrations in January and March. It is possible that large populations of phytoplankton incorporated most available nitrate into their cells which resulted in the low water column values. The high chlorophyll a concentrations appear unrelated to zooplankton abundances.

The seasonal periodicity of phytoplankton peaks offshore of SONGS over long time periods, based on nearly five years of chlorophyll a data, appears to be closely related to oceanographic events rather than occurring at definite times of the year. Tont (1976) has shown diatom biomass to be correlated to sea surface anomalies. Sea level anomalies are short term deviations of measured sea level from the true value of mean sea level. Off Southern California these deviations occur when shoreward movement of typically offshore water masses "pile up" water against the coast creating positive anomalies, or when intrusion of cool California Current water into the nearshore region causes isostatic adjustments to sea level and the development of negative sea level anomalies. Figure 3-11 shows mean chlorophyll a values plotted for the upper and lower stratum of each survey from 1975 through 1979, with monthly mean sea level anomalies (La Jolla NOAA data) also indicated. Periods of negative sea level anomaly occur when colder water and northern California Current water is present (Tont 1976). This brings nutrients into the coastal zone and can result in diatom blooms. Chlorophyll a data from the region around SONGS shows a relationship to this parameter. The annual peak in chlorphyll a concentration (September 1975, January 1976, January and March 1977, November 1978, and July and September 1979) occurred during or immediately following, perods of relatively low sea level values. Similarly, periods of prolonged positive sea level anomaly such as July 1976 through January 1977 and September 1977 through March 1978, are associated with generally low chlorophyll a concentrations. Such anomalies are generally associated with surface water masses originating from the west or south which are depleted of nutrients and therefore not able to support high standing crops of phytoplankton.

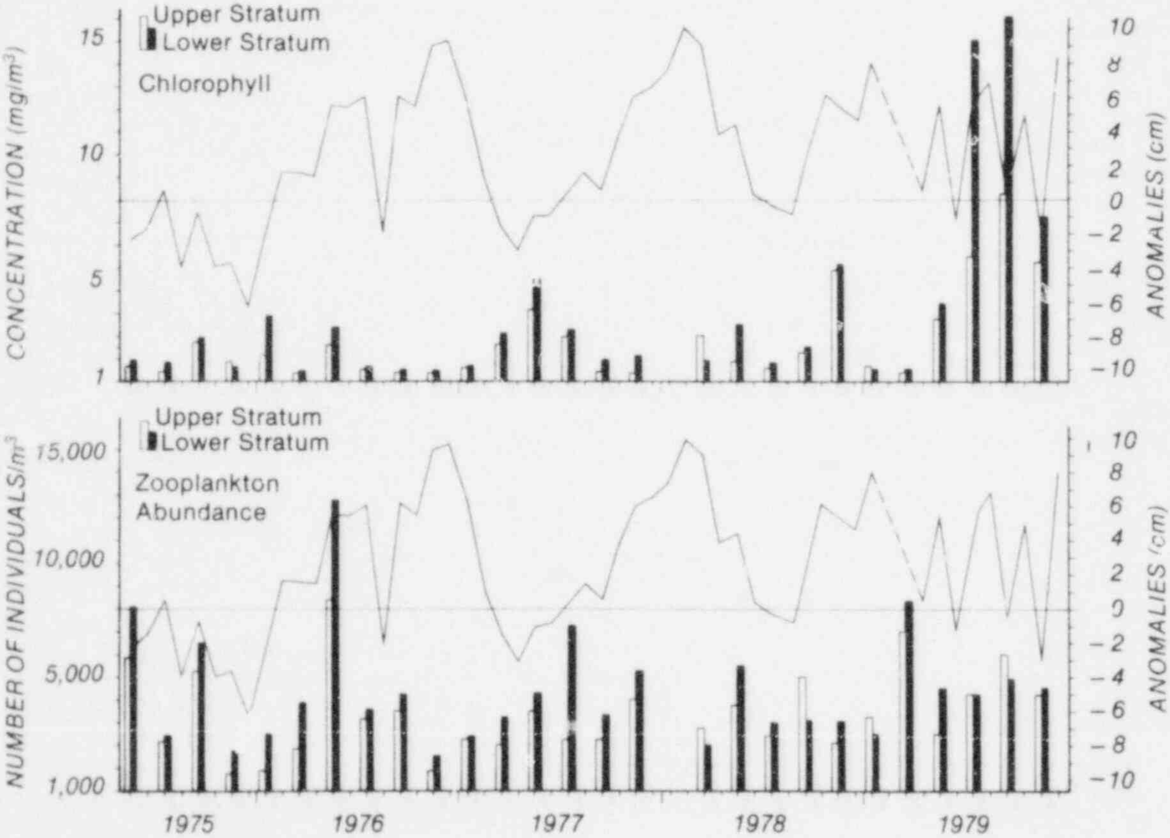

Figure 3-11. Mean chlorophyll a and total zooplankton abundance by depth stratum for each ETS/PMP survey from 1975 through 1979 with monthly mean sea surface anomalies shown for the same period. PMP studies were initiated in July 1978.

Phaeopigment

Phaeopigments are degredation products of chlorophyll. Therefore the pattern observed for spatial and temporal distribution of phaeopigment usually is similar to that seen for chlorophyll (Kawarada and Sano 1972). The pattern observed during 1979 for phaeopigment concentration off San Oncfre was very similar to that observed for chlorophyll a.

Like chlorophyll a, phaeopigment was higher in concentration in the lower stratum. This was even more definitive than was seen for chlorophyll a with significantly greater concentrations present in the lower stratum for all surveys except January. In January phaeopigment was also higher in concentration in the lower stratum, but the difference was not statistically significant. This corresponds to the only 1979 survey in which chlorophyll a concentration was higher in the upper stratum. The vertical pattern of distribution of pheaopigment in the study area may be explained by three factors. First, the normal breakdown of chlorophyll as pnytoplankton cells die or become senescent will contribute phaeopigment to the ecosystem. This will occur in proportion to the amount of chlorophyll present. Since chlorophyll is generally present in higher concentrations in the lower depth stratum, phaeopigment will follow the same pattern. Second, an increase in the lower stratum will occur as phaeopigment originating in surface waters sinks. Third, the ingestion of phytoplankton by herbiverous zooplankters will generate phaeopigment which will settle into the lower depth stratum. Herbiverous zooplankton have been shown to degrade nearly all chlorophyll ingested to phaeopigment in their digestive tract (Shuman and Lorenzen 1975). Therefore, zooplankton fecal pellets are an important contributor to the phaeopigment content of the water column. This material also sinks into the lower depth strata.

Significant transect differences observed for phaeopigment concentration in January and November were also significant for chlorophyll a concentration. The upcoast-downcoast variation in phaeopigment concentration appears unrelated to that of chlorophyll a or any other factor measured.

The relationship between phaeopigment concentration and isobath was also much like that seen for chlorophyll a. Both variables exhibited significant differences among isobaths for January and November, but phaeopigment concentrations were also significantly different in September. During January and November lower phaeopigment concentration at the 30-m stations than at 10 or 15-m stations reflects the chlorophyll distribution for those surveys. The September phaeopigment concentrations were higher at the 15 and 30-m stations rather than at the 10 or 15-m stations as seen in other surveys. This may have been due to the presence of a significant statistical interaction between the factors isobath and transect.

Phytopigment Fluorescence Ratio

The ratio between the fluorescence of chlorophyll and phaeopigment water samples can be used to assess the physiological state of phytoplankton populations. The ratio may vary between zero and two although a ratio of 1.7 is regarded as typical of healthy phytoplankton stocks (APHA 1976). Ratios below 1.7 result from greater amounts of phaeopigment being present than would be measured in phytoplankton stocks in an optimal physiological state. The mean ratios determined for SONGS phytoplankton seldom declined below 1.5 and averaged between 1.6 and 1.7 most of the year. The presence of ratios below 1.7 during the year probably reflects the fact that some pheopigment enters the water column from degredation of chlorophyll in the digestive tract of herbivorous zooplankton and not from the presence of dead or senescent phytoplankton cells. The generally smaller ratios in the lower stratum result from proportionately higher phaeopigment concentrations that occur due to sinking of dead phytoplankton cells or zooplankton fecal pellets from the upper stratum to the lower. No explanation is readily available for the higher mean ratio for surface waters of the 15-m stations in July.

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". 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 of population size.

The distribution of plankton is decidedly non-random in nature (Barnes 1949, Barnes and Marshall 1951, Cassie 1959). Much of the longshore variability in zooplankton abundance may be attributed to natural patchiness in distribution. Studies in other areas show that zooplankton is distributed in a patchy manner even in relatively small areas (Cushing and Tungate 1963, Mackas 1977, Steele and Henderson 1977, Denman and Mackas 1978). Those factors which influence the distribution of plankton are summarized by Stavn (1971) as follows: (1) physical/chemical boundry conditions (i.e., gradients of nutrients, temperature, salinity, light, temperature, food source); (2) advective effects (wind induced transport and turbulence); (3) behavior patterns (photo-, chemotaxis, etc.); (4) reproductive rates; and (5) factors determined by competition.

The distribution of zooplankton is expected to be closely associated with and reflect the distribution of its phytoplankton food source (Harvey, et al. 1935, Raymont 1963). The phytoplankton should in turn reflect the distribution of its nutrient source as determined by physical and chemical boundry conditions (Parsons and Takahashi 1973). The major sources of nutrients in the southern California nearshore region are: detrital decomposition, municipal discharges, terrestrial runoff, and periodic upwelling of nutrient rich waters from below the euphotic zone. The normal pattern of longshore transport and nearshore currents will tend to restrict the bulk of the nutrients to the nearshore area. Thus, a gradient of decreasing nutrients in the offshore direction would be expected. This in turn should establish gradients of phytoplankton and subsequently a similar gradient of zooplankton. Conversely, in the longshore direction, the sporadic nature and location of nutrient input sources would tend to cause a patchy distribution of the related biotic factors. These associations, though simplistic, are useful as the basis for relating the observed physical, chemical, and biological data.

A spatial relationship between chlorophyll a and zooplankton appears to be evident during most of 1979. During the January, March, September, and November surveys, the 30-m isobath stations had significantly lower zooplankton abundance estimates than did the 10 and 15-m isobath stations. In May, abundances along the 30-m isobath were intermediate in value. These observations correspond to the concentration gradients obsered for chlorophyll a. Only during July were anomalous zooplankton distribution patterns observed. Although chlorophyll a continued to be more concentrated inshore in July, zooplankton were found in significantly greater numbers offshore. This inverse relationship may reflect an increase in zooplankton standing stocks at the expense of the phytoplankton. However, the relationship between chlorophyll a and zooplankton abundance is further obscured by the presence of significant depth-isobath and transect-isobath interaction in July. Differences in total zooplankton abundance with respect to transects were pronounced throughout 1979. There is generally a gradient of decreasing abundance proceeding from upcoast to downcoast. During five of the six surveys the transect located upcoast of San Mateo Point had either the highest or the lowest estimated mean abundance. The transect located between SONGS and San Mateo Point had significantly different abundance estimates than San Mateo Point (Transect 5) during four of the six surveys. Considering the nature of the coastline near San Mateo Point, these differences are probably attributable to differences in the hydrography of the two areas. Transects at, and downcoast of SONGS were generally intermediate in abundance for a given survey. Also, considering the proximity of the transects nearest SONGS, it is not surprising to find only one occasion (November) when abundances were significantly different among these transects. The above results indicate that the factors responsible for the distribution of zooplankton are operating with relative uniformity throughout that part of the study area lying downcoast of San Mateo Point.

The seasonal pattern of total zooplankton abundance for 1979 differs slightly from that observed in the previous four years. In these years maximum abundance values were found in May (1975, 1976, 1978) and July (1977) with a second peak observed four months later in September and November, respectively. During 1979 however, maximum abundance was observed in March, followed six months later by a second peak in September. Although extremely high chlorophyll a maxima occurred in July and September, concomitantly high numbers of zooplankton were not found.

A factor complicating the delineation of relationships between the various components of the plankton and the abiotic/biotic environment is the time lag between the occurrence of an event and the response of an organism to the event. The magnitude of the lag time is dependent on the intrinsic ability of an organism to respond, as well as the nature and magnitude of the stimulus. The most rapid growth rates for phytoplankton may be on the order of several hours but one or more days may be needed for a doubling of the population size (Parsons and Takahasi 1973). Temperate zooplankton may take as long as two to three months to reach maturity (Parsons and Takahasi 1973). Therefore, peaks in abundance of phytoplankton would not be expected to yield substantial increases in zooplankton until some period of time later. Conversely, reductions in plankton stocks due to physical perturbations are not expected to be detectable until after a lag period. For this reason, measurements of temperature, nitrates, and phosphates failed to produce a significant regression on total abundances. However, when measurements of the variables temperature, nitrate, and phosphates taken one month prior to sampling were included with those taken close to the time of sampling, a significant regression was generated. The highest simple correlations occurred with chlorophyll a measurements taken at the time of sampling and two months prior to sampling. Due to this relationship and because of the transitory nature of plankton communities, the seasonality of observed total plankton abundances in the study area is probably the result of water conditions beyond the area of influence of SONGS.

Zooplankters, unlike most phytoplankters, possess the ability to vertically migrate. Thus, zooplankton are less restricted by the physical/chemical boundary conditions of their environment. Diel, seasonal, and ontogenetic vertical migrations are known to occur in many holoplankters (Sverdrup, Johnson and Flemming 1942, Bary 1967, Longhurst 1976) while others, particularly meroplankters, are closely bound to particular water layers and the origin and fate of these groups are largely determined by hydrographic events (Banse 1956). The efficient mixing of the water column achieved by the SONGS discharges may therefore have significant impact on recruitment success of the plankton community.

The typical pattern of vertical migration results in planktonic organisms swimming to depths at the onset of morning light. Due to the shallowness of the SONGS study area ($\leq$ 30 m) this should result in a compression of abundance toward the bottom. However, when thermal stratification is lacking, wind and current induced mixing over the extent of study area is not unexpected.

Significant differences in total zooplankton abundance between depth strata were observed during the January, May, and September surveys. Plankton were found in higher numbers in the lower stratum in May and July and in the upper stratum in September. Examination of temperature data indicates that the water column was stratified during each of these surveys. Thermal stratification was not evident when higher abundances were found in the upper stratum during the January, March, and November surveys. With this one exception (September), the vertical distribution appears to be as expected. The reason for the anomalous condition noted for September is unknown.

Zooplankton Biomass

Biomass measurements of zooplankton are based not on the number of the organisms present, as are abundance values, but rather on the mass of the organisms present. As such, the analysis of biomass values may yield different information regarding the zooplankton communities. Therefore, zooplankton biomass is very important for food chain considerations since it forms the link between the primary producers, phytoplankton, and the secondary consumers, e.g., fish.

The distribution of biomass was, in all areas, very similar to the distribution of zooplankton abundance. During each survey in which abundance was significantly lower along the 30-m isobath than along the 10 and 15-m isobaths (January, March, September, and November), biomass was also found in significantly lower concentrations along the 30-m isobath. In July biomass was and total abundance were greater along the 10 and 15-m isobaths although not significantly so. In May, although abundance was greater along the 10 and 15-m isobaths, significantly higher biomass concentrations were found along the 30-m isobath. The vertical distribution of total biomass reflects the distribution of total abundance for all surveys except September. In September, total abundance was greater in the upper stratum but biomass was higher in the lower stratum.

Some differences in biomass concentration between samples may be explainable because of the inclusion of silt and detritus. However, in some cases the differences among the various station groupings noted above result because of the presence of larger organisms enumerated as "other taxa". For this reason it is useful to use a ratio of biomass to abundance as an estimate of the mean biomass per organism.

The higher mean individual biomass values observed in the lower stratum throughout the year are probably indicative of the higher detritus and silt content associated with water near the bottom.

The March survey had not only the highest abundance and biomass values (Figure 3-5) but also the highest mean individual biomass values (Figure 3-9). Together these values indicate that the zooplankton community in March was relatively more concentrated and of higher food value than during the remainder of 1979. The March increases in both abundance and individual biomass may have been associated with an undetected phytoplankton bloom occurring in February or early March.

Select Taxa

All of the designated select taxa occurred in plankton samples. Since numerical abundance and widespread temporal occurrence was used as a criterion for determining the select taxa, it would be unusual if any select taxon were absent throughout the year. Two taxa were absent from one survey. Podon polyphemoides was not found in January and Penilia avirostris was not present in May. The rank order of select taxa for zooplankton data collected off SONGS from 1975 through 1979 as part of the ETS and PMP monitoring studies is presented in Table 3-6. It is apparent that during this period no major changes have occurred with regard to which taxa are the most abundant. Acartia spp. copepodites ranked first in abundance throughout the period that these studies have been conducted. This species occurs widely in the coastal waters of both the east and west coasts of North America where it is commonly the most abundant organism in the zooplankton community (Howey 1971). Other changes which have occurred in rank order of zooplankton may be attributed to the expansion of the sampling program in July 1979 to include stations farther offshore along the 15 and 30-m isobaths. This has resulted in an increase in the relative abundance of two taxa as shown in Table 3-6. Paracalanus parvus ranked third and fourth in abundance in 1978 and 1979 respectively. Previously it ranked no higher than fifth in abundance. This is related to the natural distribution of this species which is distributed, with the center of abundance located farther offshore than was sampled in the ETS program. This agrees with results of other studies off SONGS (MRC 1979), which collected zooplankton samples from greater distances offshore than the PMP studies, and considered Paracalanus parvus as an offshore species. The taxon Clausocalanus spp. was enumerated during 1979 because of the high abundance in January 1979 and the fact that it had been enumerated for July 1978 as seasonally abundant comprising over 30% of the organisms in most samples. During 1979 this taxon ranked fifth in abundance. Clausocalanus is an offshore species and its increased importance in 1979, in terms of rank abundance, results from the expansion of the SONGS plankton studies farther offshore with the implementation of the PMP studies.

Mean annual abundance provides a gross means of comparing changes in abundance from year to year. Table 3-7 shows the annual mean abundance for selected zooplankton taxa for the duration of the ETS and PMP studies. These data show that despite rather large year to year fluctuations of up to three-fold in magnitude, the rank abundance has not changed markedly. An obvious feature shown by this table is the dramatic increase in abundance of Paracalanus parvus, P. parvus copepodites, and Clausocalanus spp.. Paracalanus parvus was three to four times more abundant in 1978 and 1979 than from 1975 to 1977; P. parvus copepodites were two to five times more abundant; and Clausocalanus spp. was more than ten times more abundant.

Table 3-7. Mean abundance of select taxa (no/m^3) by survey for 1979.

Select Taxa	Jan	Mar	May	Jul	Sep	Nov	Annual Mean Total
Acartia spp. coppepodites	135.9	1213.7	1361.7	785.8	981.5	423.6	817.0
Acartia tonsa	58.9	661.2	320.4	513.5	446.7	191.5	365.4
Penillia avirostris	112.3	2.5	0	0.2	140.1	4.4	43.3
Paracalanus parvus copepodites	133.9	117.4	231.1	806.2	358.1	634.7	546.9
Sagitta spp.	177.7	325.7	173.1	242.7	267.3	248.5	239.2
Corycaeus anglicus	52.5	132.2	50.8	306.0	621.0	248.7	235.2
Cyphonautes larvae	38.6	153.3	130.9	43.6	155.5	249.5	128.6
Paracalanus parvus	194.2	992.0	208.6	245.2	122.1	235.6	332.9
Labidocera trispinosa copepodites	63.7	140.7	212.2	58.8	91.1	68.5	105.8
Podon polyphemoides	0	1.5	1.0	116.7	8.7	0.3	21.4
Euterpina acutifrons	4.2	240.7	68.8	37.3	47.8	16.1	69.2
Clausocalanus spp.	704.8	168.3	12.3	53.5	259.8	586.8	297.6
Oithona occulata	1.3	85.9	5.5	12.6	21.2	61.7	31.4
Cypris larvae	1.8	30.8	5.8	6.0	31.7	9.0	14.2

The results of ETS/PMP studies conducted thus far agree in general with other studies of zooplankton in the area of SONGS by the MRC (1979). Even though the PMP study area does not extend into the offshore zone defined by the MRC studies as from 4 to 7 km offshore, the pattern described for select taxa correspond.

Certain long-term cyclic oceanographic phenomena seem to be related to the onshore-offshore distribution of certain zooplankton taxa. The movement of offshore water masses closer to shore as a response to current shifts or shoreward drift of offshore surface waters is demonstrted by the periodic abundance of the copepod Clausocalanus spp. over a five year period. Figure 3-12 shows the mean abundance of Clausocalanus spp. by survey and monthly sea level anomalies. The cyclic pattern of sea level anomaly corresponds generally to the abundance of this copepod in the study area. High positive anomalies correspond to shoreward intrusion of offshore waters (Tont 1976) with their associated zooplankters. The abundance and composition of plankton off SONGS may vary periodically as the oceanographic regime in the region undergoes periodic changes.

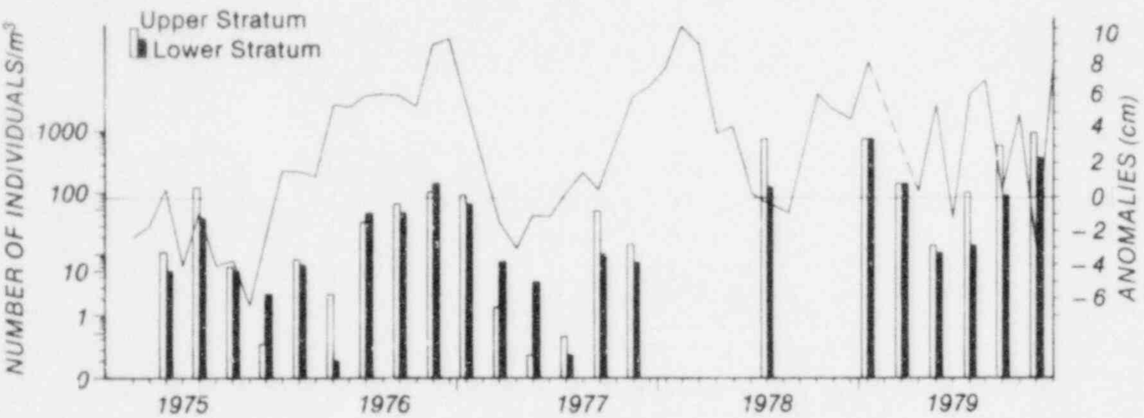

Figure 3-12. Mean abundance of the copepod *Clausocalanus* spp. by depth stratum for each ETS/PMP survey from 1975 to 1979, with monthly mean sea surface anomalies shown for the same period. PMP studies were initiated in July 1978. This taxon was only enumerated in July during 1978.

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 significant effect on the vertical distributional patterns of chlorophyll a, phaeopigments, total zooplankton abundance, or zooplankton biomass at the ETS-PMP plankton stations. Unit 1 was operational during all surveys except November, when the plant was offline during the second and third days of the survey. There were no apparent differences in the biological data related to this event.

Based on the analysis of the 1979 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 area than previously obtained. Analysis of data has revealed spatial and temporal patterns of distribution of phytopigments and zooplankton that contribute toward establishement of baseline plankton data sets.

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 important throughout the year.

SUMMARY

An analysis of the data and a comparison with 1975 through 1978 results indicated the following.

1. Chlorophyll a concentrations were lowest in March and highest in September. Chlorophyll a concentration was also high in July. The peaks of chlorophyll a concentration in July and September were not present in previous years and they are not obviously related to any other physical or biological event which might be responsible for such large peaks. No consistent pattern of upcoast-downcoast variability was present for chlorophyll a.

2. Phaeopigment concentrations showed a pattern of spatial and temporal distribution similar 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. Phytopigment fluorescence ratios indicate that phytoplankton stocks in the study area were in a healthy state during all surveys.

4. Mean total zooplankton abundance was lowest in January and highest in March. Except for July, zooplankton was more abundant at the 10 and 15-m stations than at the 30-m stations. However, in July the reverse pattern was found. The total zooplankton abundance at the upcoast reference transect tended to be either higher or lower than other transects. Otherwise, no consistent upcoast-downcoast pattern of total abundance was observed.

5. Zooplankton species composition and rank order of abundance for select taxa was similar to that observed in previous studies from 1975 to 1978. Deviations from this pattern during 1979 may be attributed to the inclusion of additional stations located farther offshore in the combined ETS-PMP studies.

6. Zooplankton dry weight biomass was lowest in January and highest in March, paralleling the pattern of total abundance. No consistent upcoast-downcoast pattern of biomass was detected.

7. Significantly higher values of chlorophyll a, phaeopigments, total zooplankton abundance, and zooplankton biomass were observed for the lower depth stratum.

8. Periodic climatic patterns which affect local oceanographic phenomena, such as upwelling and intrusion of offshore surface water, appear related to biological patterns of plankton observed offshore of SONGS from 1975 to 1979.

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

10. The inherent variability within the planktonic community offshore of SONGS 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 by the State Water Quality Control Board for the EPA. Entrainment studies are an integral part of the ongoing 316(b) demonstration.

In order to reduce redundant efforts and regulate duplication between the NRC and EPA a formal request to delete the NRC requirement was forwarded to the Commission on 15 November 1979.

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CHAPTER 4

INTERTIDAL

INTRODUCTION

The communities inhabiting the narrow boundary between land and sea which is alternatively covered and left exposed by the tide are remarkably tolerant of variations in their environment. Both an infaunal community and a rock epibiotal community are present in the intertidal zone near SONGS. Although both communities must deal with the same rigors imposed by their intertidal situation, the species composing the two communities differ considerably. In consequence, they are discussed separately below

CHAPTER 4A

SANDY INTERTIDAL

INTRODUCTION

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 extends uninterrupted from San Mateo Point to Oceanside. The coastline faces southwest and is exposed to the full force of oceanic swells from the west and south.

Studies of the impact of construction associated with SONGS Units 2 and 3 on the sandy intertidal habitat and its biota were initiated in 1974 by the Lockheed Center for Marine Research (Lockheed Aircraft Service 1974), and continued on a quarterly basis through mid 1976. In December 1976, a modified study plan was undertaken by Marine Biological Consultants, Inc. (MBC 1978). These studies were performed as a condition of the construction permit for the San Onofre Units 2 and 3 project issued by the Regional Water Quality Control Board, San Diego Region.

The primary objective of the continued monitoring of the sandy intertidal habitat and its biota is the detection and description of any impacts resulting from construction of SONGS Units 2 and 3. Secondary objectives include: 1) definition of the natural variability of the habitat and its biota; 2) documentation of recovery from any detected impacts following completion of construction activities; 3) detection of impacts on the habitat and its biota from SONGS Unit 1 operation; and 4) provision of pre-operational background data for interpretation of effects of SONGS Units 2 and 3 operation.

The data and analyses presented in this report are from the third year of intertidal monitoring with present methods. Field surveys were conducted on 22-23 February, 16-17 May, 6-7 August, and 4-5 December 1979. Construction of the cooling water intake and discharge conduits for SONGS Unit 2 and Unit 3 was completed in 1979, and the shallow-water disposal of dredge spoils was terminated in July (see also Chapter 2D, Sedimentology). Removal of the construction support pi[illegible] continued into 1980.

Raw biotic data were presented in the 1979 Annual Operating Report, Volume II, (SCE 1980) and are not included here. Raw abiotic data were presented in Volume I of the same report (S[illegible]).

Biotic parameters presented and discussed in this report 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 were correlated to abiotic factors in the study area, and analyzed to detect 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 using a self-leveling surveyor's 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 4A-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 DD were 236 and 629 m southeast of the midpoint, respectively. At each transect, five replicate biological core samples were collected at seven tidal elevations (levels), ranging from 0 to +6 ft above MLLW. The 15.24 cm diameter by 30 cm (5 liters) core samples 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 obtained in October 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, therefore, this level of replication was adopted.

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

Along each transect, a core sample for sediment grain size analysis was collected adjacent to each of the five replicate biological cores at each sampled tidal elevation. This practice, initiated in February 1979, differed from that used previously. In 1976, 1977, and 1978, only one grain size sample was collected at every other level (0, +2, +4, +6). This modification was instituted to provide more complete information on the characteristics of intertidal sediments, and to allow use of sediment data in multivariate discriminant analysis of biotic data.

Sediment cores were collected to a depth of 30 cm, except where cobble would not allow core penetration. Estimates of water temperature, and wave period, height, and direction were also recorded.

Grain size distributions were determined by three complementary analytic techniques. Sediment particles in the gravel range (between -6 and -1 phi) were separated into size classes by mechanical sieving through different sized meshes. The retained portions were weighed and proportionally related to the total sample weight. Sediment particles in the sand range (-1 to 4 phi) were evaluated with the settling tube system described by Felix (1969) and Gibbs (1974). Input from the two sources was combined and analyzed using moment measures (Krumbein and Pettijohn 1938). A discussion of the phi scale, grain size statistical parameters, and their derivation is presented in Chapter 2D, Sedimentology.

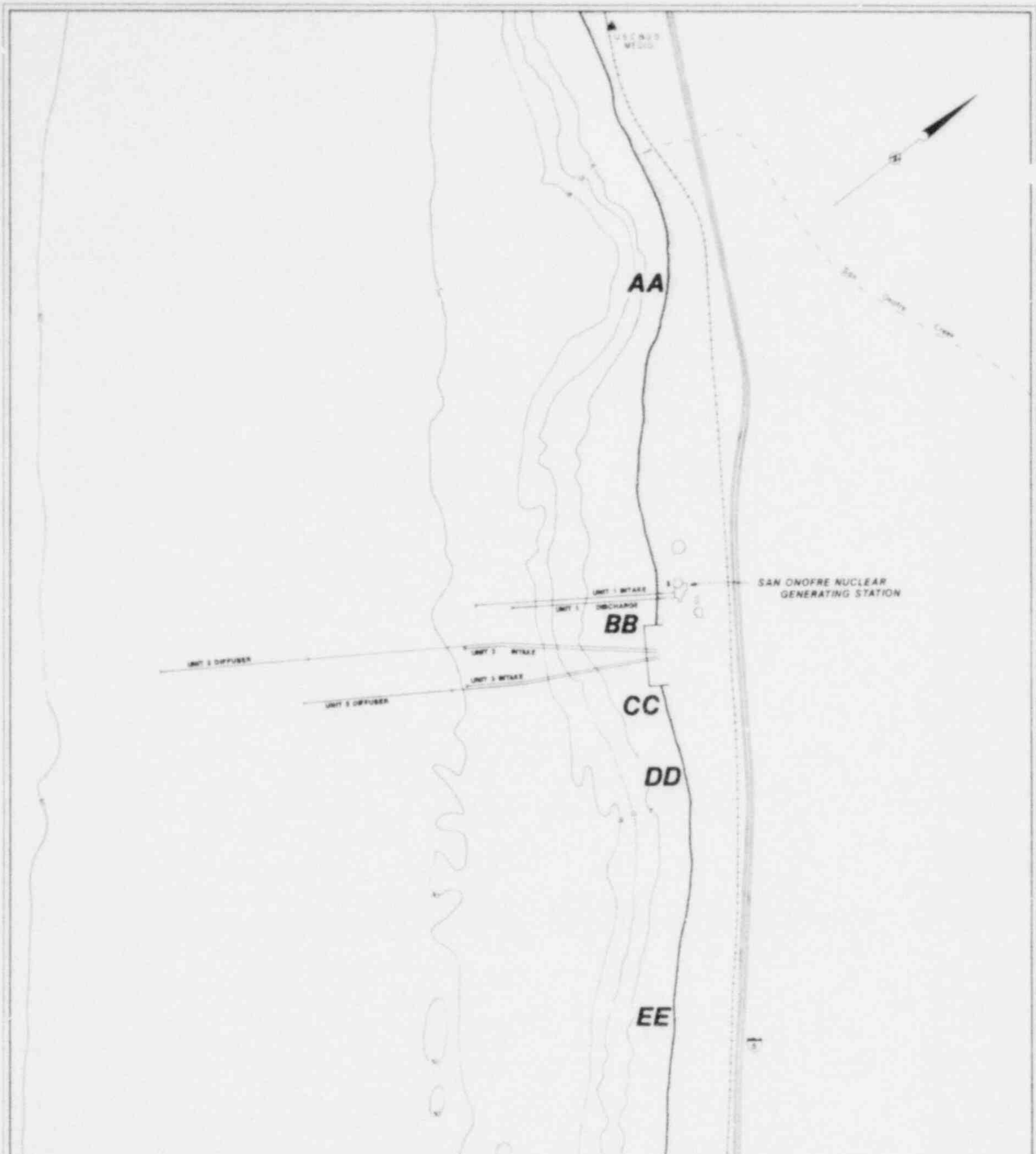

Figure 4A-1. Intertidal transect locations.

DATA ANALYSIS

Three analytic techniques were applied to the intertidal data: classification analysis, principal components analysis, and weighted multiple discriminant analysis.

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 based on their 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, the flexible sorting strategy (β=.25) was used to generate dendrograms from a Bray-Curtis dissimilarity matrix. Prior to the analyses, raw data were transformed by square root to reduce the effect of extremely skewed data points, and standardized as a percentage of each species' maximum abundance (Smith 1976).

The "step-across" procedure of Williamson (1978), as modified by Smith (in preparation) to accept quantitative data, was applied to the similarity matrix used in both the classification and weighted multiple discriminant analyses.

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.

Discriminant Analysis

Weighted multiple discriminant analysis, as described by Smith (1976 and 1978), was employed to determine the potential influence of measured abiotic variables on the distribution of the biota. These distributional differences were pre-defined by the station classification results previously discussed. The discriminant analyses produced a linear combination of measured abiotic variables, (e.g. physical sediment features) which maximized the differences between the predefined groups. These linear combinations were then used to produce discriminant axes. The proportional contribution of each abiotic variable to the discriminant axis was indicated by its coefficient of separate determination (Hope 1969, Smith 1976), and was expressed as a percentage of the total for each axis. The higher the coefficient, the more influence that variable had on the formation of the discriminant axis. The dominant variables on each axis were then interpreted as factors which directly or indirectly related to the ecology and distribution patterns of the community.

Weighted multiple discriminant analysis presents distinct advantages over an unweighted analysis (Smith 1978). In an unweighted analysis only the group membership information derived from the classification analysis is considered in formation of the discriminant axes. Application of proportional weighting makes available information on the strength of group membership of each group component, group cohesiveness, and the order and strength of inter-group similarities.

Principal Components Analysis

The composition of intertidal sediments at SONGS was complex and ranged from cobble to silt-sized particles (MBC 1978). Synoptic measures such as mean grain size may not truly represent the sediment features that animals select. Subcomponents of the sediment size range (e.g. the fine sand 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).

Varimax rotation was employed to delineate the patterns of correlation in the factor matrix. This process attempts to rotate the space so that the variable correlations for an axis are either close to zero or very far from zero (i.e. maximize high and low correlations and minimize middle level correlations; thus, clearly defining the correlational patterns). After the varimax rotation, the axis scores are no longer necessarily independent.

The reduction of sediment variables streamlines data handling and interpretation while eliminating certain problems inherent in analyzing many potentially redundant variables.

The PCA with varimax defines a low dimensional abiotic 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 a factor matrix, which contained the correlations between each variable and each axis. The patterns of correlations with each axis were valuable in interpreting a more general sediment factor defined by the axis in question.

RESULTS

SPECIES COMPOSITION

A total of 32 taxa were identified from the 700 five liter cores collected in 1979. Annelids and arthropods, represented by 14 and 11 taxa, respectively, comprised 99% of the fauna. Two other phyla, Mollusca and Nemertea, were represented by two taxa each. The sand crab, *Emerita analoga*, was more widely distributed, and an order of magnitude more abundant than any other taxon (Table 4A-1).

Fifteen taxa ranked among the five most abundant species during one or more surveys (Table 4A-2). The fauna was particularly depauperate in February, with five taxa, each represented by a single individual, tied for fifth in the abundance ranking. None of the five were numerically important during the year overall, or in any other quarter.

Five species ranked high in abundance in more than one quarter: *Emerita analoga*, *Hemipodus borealis*, *Pisione remota*, *Microspio acuta*, and *Eohaustorius washingtonianus*. *Emerita* (the sand crab) and *Hemipodus* (a polychaete worm) were consistently the most abundant species, ranking first and second in each quarter, and during the year overall. The small amphipod *Eohaustorius*, although not

Table 4A-1. Intertidal transect summary table for 1979 collections by survey.

	Transect AA	Transect BB	Transect CC	Transect DD	Transect EE	All Transects
February 1979						
Number of Species	2	4	3	3	4	9
Number of Individuals	5	24	7	9	23	68
Number of Emerita	4	18	0	6	8	36
% Individuals: Emerita	80.0	75.0	0.0	66.7	34.8	52.9
Species Diversity (H')	0.22	0.34	0.35	0.37	0.42	0.57
May 1979						
Number of Species	4	2	7	3	5	10
Number of Individuals	307	357	190	35	19	908
Number of Emerita	302	356	173	16	6	853
% Individuals: Emerita	98.4	99.7	91.1	45.7	31.6	93.9
Species Diversity (H')	0.04	0.01	0.19	0.45	0.55	0.14
August 1979						
Number of Species	7	3	15	12	8	20
Number of Individuals	103	50	56	175	114	498
Number of Emerita	92	47	33	143	101	416
% Individuals: Emerita	89.3	94.0	58.9	81.7	88.6	83.5
Species Diversity (H')	0.21	0.12	0.74	0.37	0.24	0.38
December 1979						
Number of Species	9	3	6	7	7	17
Number of Individuals	34	18	6	29	40	127
Number of Emerita	14	15	1	12	13	55
% Individuals: Emerita	41.2	83.3	16.7	41.4	32.5	43.3
Species Diversity (H')	0.71	0.24	0.78	0.69	0.63	0.86

Table 4A-2. Rank, percent of collection total, and percent replicate occurrence of the five most abundant species overall and in each survey.

Month	Rank/Species	%[1]	Cum. %[2]	% Occur[3]
Feb	1 Emerita analoga	52.9	52.9	20.6
	2 Hemipodus borealis	29.4	82.3	10.3
	3 Excirolana kincaidi	7.4	89.7	2.3
	4 Microspio acuta	2.9	92.6	1.1
	5 Euzonus dillonensis	1.5	94.1	0.6
	5 Excirolana sp.	1.5	95.6	0.6
	5 Lumbrineris japonica	1.5	97.1	0.6
	5 Olivella biplicata	1.5	98.6	0.6
	5 Spionidae, unid.	1.5	100.0	0.6
May	1 Emerita analoga	93.9	93.9	44.6
	2 Hemipodus borealis	3.2	97.1	15.4
	3 Eohaustorius washingtonianus	1.2	98.3	3.4
	4 Pisione remota	0.6	98.9	2.3
	5 Donax gouldii	0.3	99.0	0.6
	5 Nemertea, unid.	0.3	99.3	0.6
Aug	1 Emerita analoga	83.5	83.5	58.5
	2 Hemipodus borealis	3.4	86.9	9.7
	3 Orchestoidea minor	2.4	89.3	4.6
	4 Eohaustorius washingtonianus	2.0	91.3	1.1
	5 Lepidopa californica	1.2	92.5	3.4
Dec	1 Emerita analoga	43.3	43.3	21.7
	2 Hemipodus borealis	13.4	56.7	9.7
	3 Eohaustorius washingtonianus	12.6	69.3	3.4
	4 Microspio acuta	7.9	77.2	4.0
	5 Pisione remota	3.9	81.1	2.3
1979	1 Emerita analoga	84.9	84.9	36.4
	2 Hemipodus borealis	5.2	90.1	11.3
	3 Eohaustorius washingtonianus	2.3	92.4	2.0
	5 Pisione remota	0.8	93.2	1.6
	5 Microspio acuta	0.8	94.0	1.4

1 Percent of collected specimens.

2 Cumulative percent of collected specimens.

3 Percent occurrence in replicates.

collected in February, was ranked third in May, fourth in August, third in December, and third overall. The polychaete worms Pisione and Microspio tied for fifth in the overall abundance ranking. Each ranked fourth or fifth in two of the quarterly surveys (Table 4A-2). Other taxa relatively abundant during a single survey were: the bean clam Donax gouldii and unidentified nemertean worms in May; and in August, the beach hopper Orchestoidea benedicti and the mole crab Lepidopa californica.

Half of the species exhibited restricted vertical distributions (Table 4A-3). All of the five most abundant species, however, were collected 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 zone and had primarily subtidal populations. Several of the species distributed independent of tidal height are known to migrate up and down the beach in response to changes in the tide (Cubit 1969, Bowers 1964).

SPECIES DISTRIBUTION

The number of taxa collected per survey ranged from 9 in February to 20 in August (Table 4A-1). No single transect was markedly more speciose than the others throughout the year (Figure 4A-2). The average species number per transect ranged from 3.0 /survey at Transect BB to 7.8/survey at Transect CC. Geographic gradients in average species number per transect (increasing downcoast of the construction lay-down pad, and decreasing upcoast of that structure) occurred in only the August survey, and were probably an artifact. Average numbers of species per transect were similar at all tidal levels in February and May. In August and December, however, the average number of species per transect was higher at MLLW than at the other sampled levels (Figure 4A-3). Average values ranged from 3.0 species at level +5 to 8.0 species at level 0 (MLLW).

No consistent pattern in distribution of species numbers by transect or quarter was evident (Figure 4A-2). Transect BB was, however, lower in species richness than the other transects during all surveys after February.

Table 4A-3. Vertical zonation patterns of intertidal species.

Distribution Height Independent	Level	Zone	Distribution Height Dependent
			High only
	+6		Orchestoidea benedicti
*Emerita analoga Eohaustorius washingtonianus *Euzonus dillonensis *Hemipodus borealis Microspio acuta *Orchestoidea minor *Pisione remota		A	
	+5		Overlap Mid-High
			Excirolana kincaidi Orchestoidea columbiana *
	+4		Mid only
		B	None
	+3		Overlap Low-Mid
			None
Sporadic Occurrence	+2		
			Low only
+Carinoma mutabilis			
	+1	C	*Archaeomysis maculata *Dispio uncinata *Donax gouldii *Lepidopa californica +Lumbrineris japonica +Lumbrineris zonata *Nephtys californiensis *Nephtys ferruginea
	0		+Olivella biplicata +Polyopthalmus pictus +Rhepoxynius epistomus Saccocirrus papillocercus *Scoloplos armiger

A = upper beach
B = mid beach
C = lower beach
* = same distribution as in 1978
+ = species not encountered in 1978

Several collections in each survey, except August, contained no organisms (Figure 4A-3). Most vacant levels occurred high in the intertidal zone (levels +5 and +6), but some collections at all levels, except MLLW, contained no organisms. Absences occurred on all transects, but were most common along Transects CC (7) and AA (5).

Species turnover between sampling periods was examined to measure qualitative temporal stability of the SONGS sandy intertidal community. Species were lost from the community along all five transects between November 1978 and February 1979, then gained from February through August. One species was added to the Transect AA fauna between August and December 1979, but species were lost along the remaining transects during that period. Because of the small species pool, the physical stress associated with the sandy beach habitat, and the patchiness of the fauna, species turnover was high. Turnover at individual transects ranged from 67% (Transect DD between February and May) to 300% (Transect DD between May and August). Net turnover between November 1978 and December 1979 was similar to or lower than turnover between successive quarters, indicating that the majority of the change was seasonal. Despite the preponderance of seasonal change, cumulative change was also evident. At least half of the species observed at each transect in November 1978 were absent in December 1979.

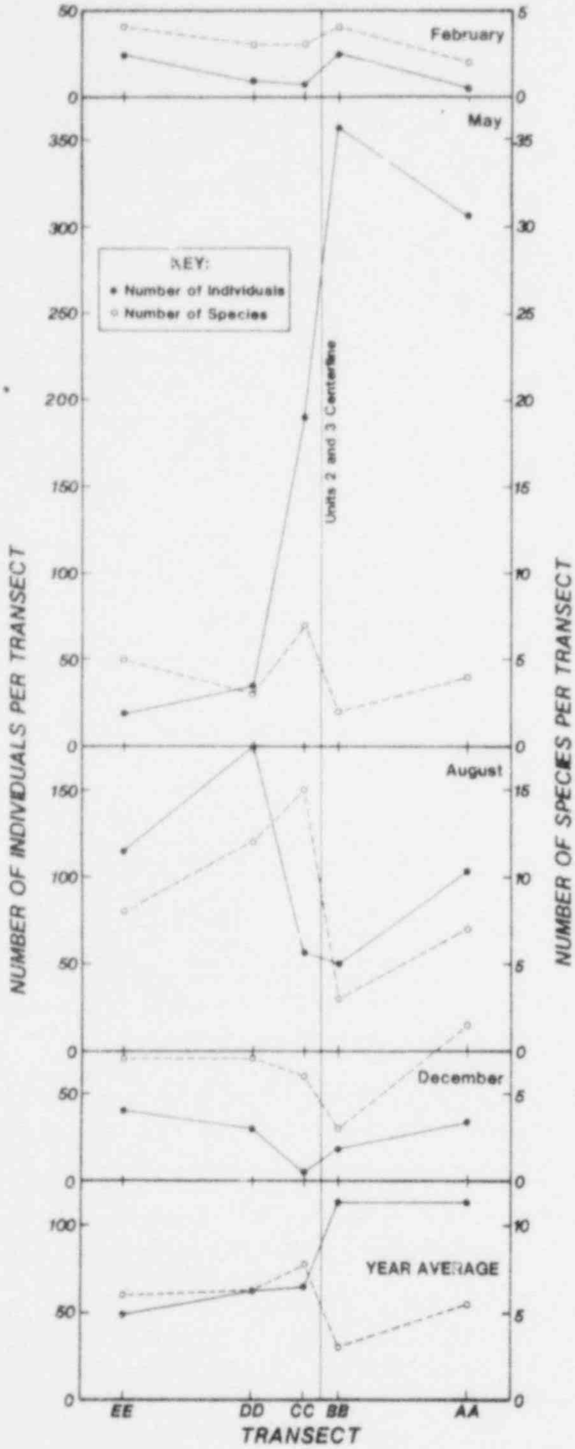

Figure 4A-2. Survey total and annual average number of individuals and species by transect.

COMMUNITY DENSITY

Density is a measure of abundance per unit area or volume. The density values reported herein are abundance per five 5 liter replicates (station density, or each level at each transect), or abundance per 35 replicates (transect density). Equivalent surface area is approximately $0.36 m^2$ per five replicates or $2.6 m^2$ 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 4A-2) that the data were also analyzed without Emerita (Figure 4A-4), to summarize density trends for other community members.

A total of 1601 specimens were collected in the 700 replicate cores taken in 1979, an average density cf 11.4 per station (2.3 per replicate). Excluding Emerita, the total number of individuals collected was 241, an average density of 1.7 per station (0.3 per replicate).

Community density (Emerita excluded) by quarter averaged 12.1 per transect and ranged from 6.4 in February to 16.4 in August. Density by transect was greatest along Transect DD (17.8 individuals/quarter) and least along Transect BB (3.3 individuals/quarter). Quarterly densities ranged from 32 along Transect DD in August to 1 along Transect AA in February and Transect BB in May (Figure 4A-4).

Community density did not follow a trend of simple increase or decrease with increasing tidal height over the year, or in any quarter (Figure 4A-3). Density at MLLW averaged 20.5/quarter for the year because of relatively high August and December values at that level. Annual average density/quarter at the other four levels were less than half that at MLLW.

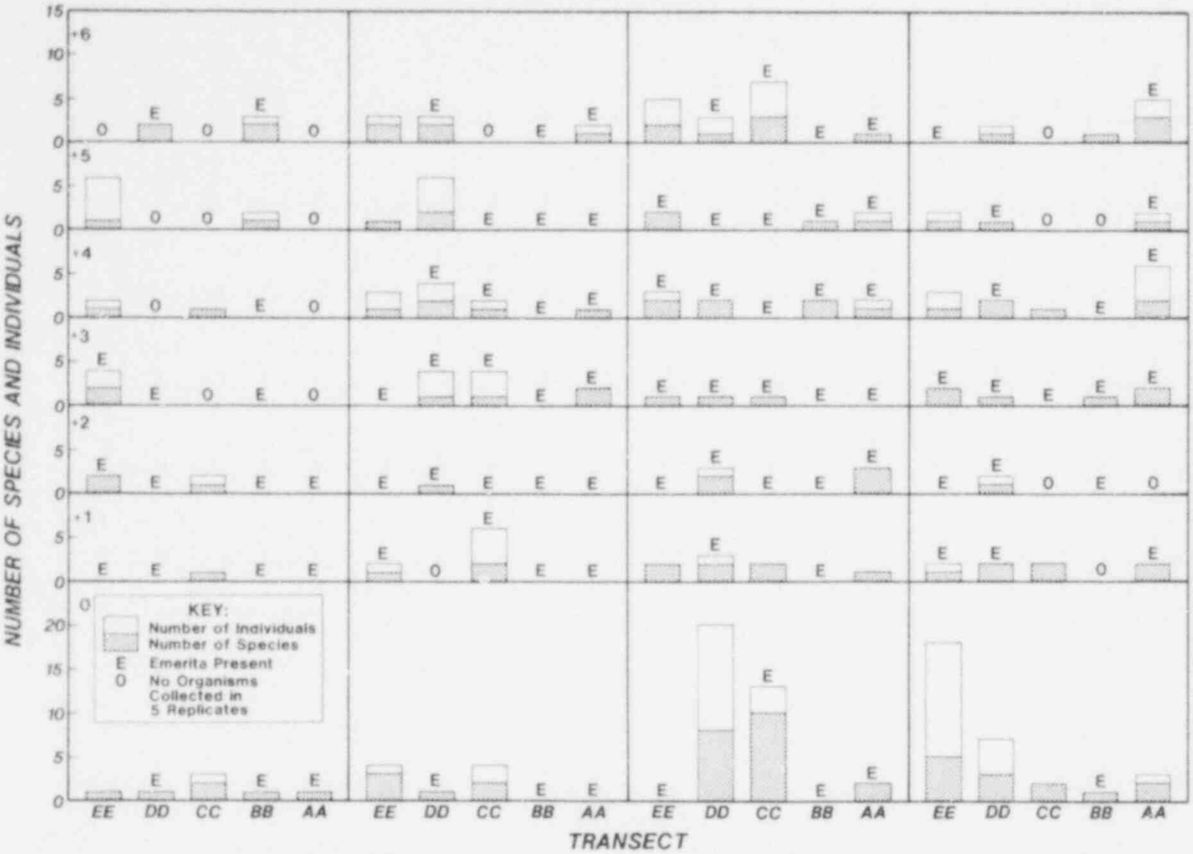

Figure 4A-3. Community composition by transect, level, and survey.

Inclusion of Emerita counts in the analysis changed the geographic pattern of density distribution (Figure 4A-2). Transect BB, which was the least densely inhabited transect with Emerita excluded, had the highest average density of any transect after Emerita were included. Transect BB was replaced by Transect EE as the lowest average density transect when Emerita was included. This average pattern was not displayed in any of the four quarters, but was approximated in May. Density distribution differed in each quarter, and no underlying pattern was detected.

DISTRIBUTION OF EMERITA

Emerita numerically dominated the intertidal community in each quarter and overall during the year. It was the most abundant organism along Transects AA, BB and DD during each quarter. Emerita was displaced as the dominant species by Hemipodus borealis along Transects CC and EE in February, and along Transect EE in May. The third ranked Eohaustorius washingtonianus dominated the community along Transect EE in December, while the community along Transect CC had no dominant species in December.

Emerita was encountered along all transects in all four quarters (except Transect CC in February), and occurred in 36.4% of the cores collected in 1979. The percentage of replicates in which Emerita occurred ranged from 2.9% along Transect CC in December to 80.0% along Transect DD in August. Lowest density was observed in February when 36 individuals were collected in 175 cores (0.2/replicate). Density increased to 853 (4.9/replicate) in May with collection of new recruits. Recruitment probably continued through June (Auyong, 1977) but density declined to 416 (2.4/replicate) by August.

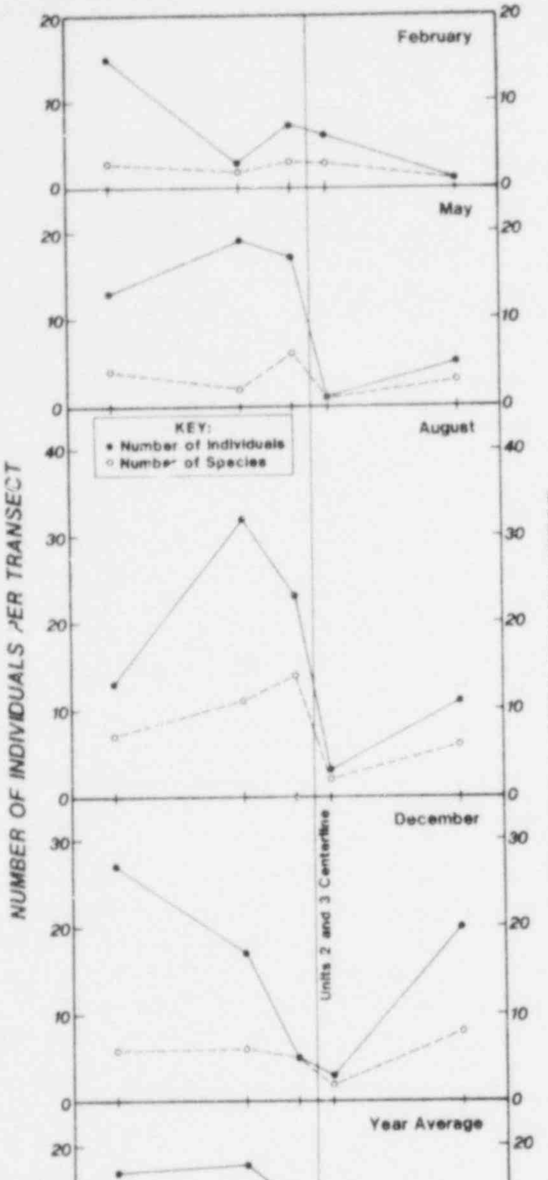

Figure 4A-4. Survey total and annual average number of individuals and species by transect (Emerita excluded).

Emerita was most abundant along Transect BB in February, May and December, and along Transect DD in August. Transect totals for the year were very similar at Transects AA and BB, and declined along a downcoast gradient from Transect BB to Transect EE (Table 4A-1).

No definite pattern of vertical distribution was exhibited by Emerita (Figure 4A-5), although the population was centered somewhat higher in the intertidal zone along Transect EE than elsewhere. Emerita was collected from all seven tidal levels during each survey, with replicate occurrence ranging from 8% along levels +5 and +6 in February and MLLW in December, to 84% along level +2 in August.

Size frequency data (Figure 4A-6) indicated major recruitment occurred along Transects AA, BB, and CC between February and May, and along Transects DD and EE between May and August. The presence of 0 to 5 mm size class individuals throughout the year indicated sporadic or continuous low level recruitment outside the normal March-June spawning season (Auyong, 1977). Over-wintering individuals in the 10 to 15 and 15 to 20 mm size classes were present in February along all transects except CC, with highest density along Transect BB.

SPECIES DIVERSITY

Species diversity, as measured by the Shannon-Wiener Index (H') was calculated to permit comparison with other studies (Table 4A-1). Such a comparison is most valid with reference to previous data collected near SONGS (MBC 1978, SCE 1979:79-RD-54) collected by the same methods. H' values in Table 4A-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. 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; EQA-MBC 1978) and elsewhere (Dexter 1969, Fedra 1977).

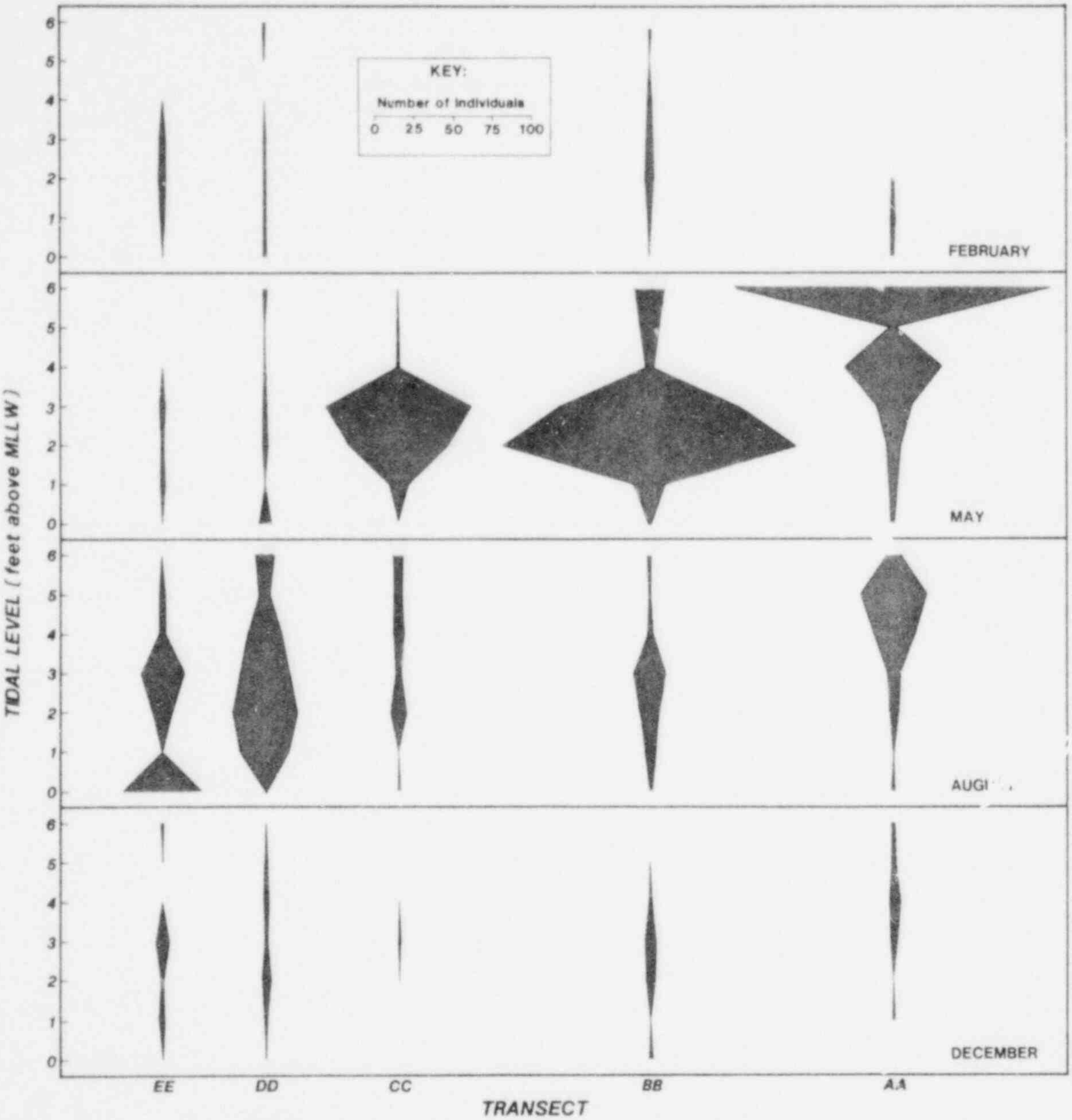

Figure 4A-5. Emerita distribution by transect, level, and quarter.

Intertidal organisms collected at SONGS were separated into different trophic groups based on food aquisition behavior, the nature of food consumed, or a combination of both (Table 4A-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 mutually exclusive, since some species can obtain food in more than one way, or use more 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 on small living Emerita (carnivory) or on pieces of organic debris carried through the intertidal zone by tidal and current movements (omnivory).

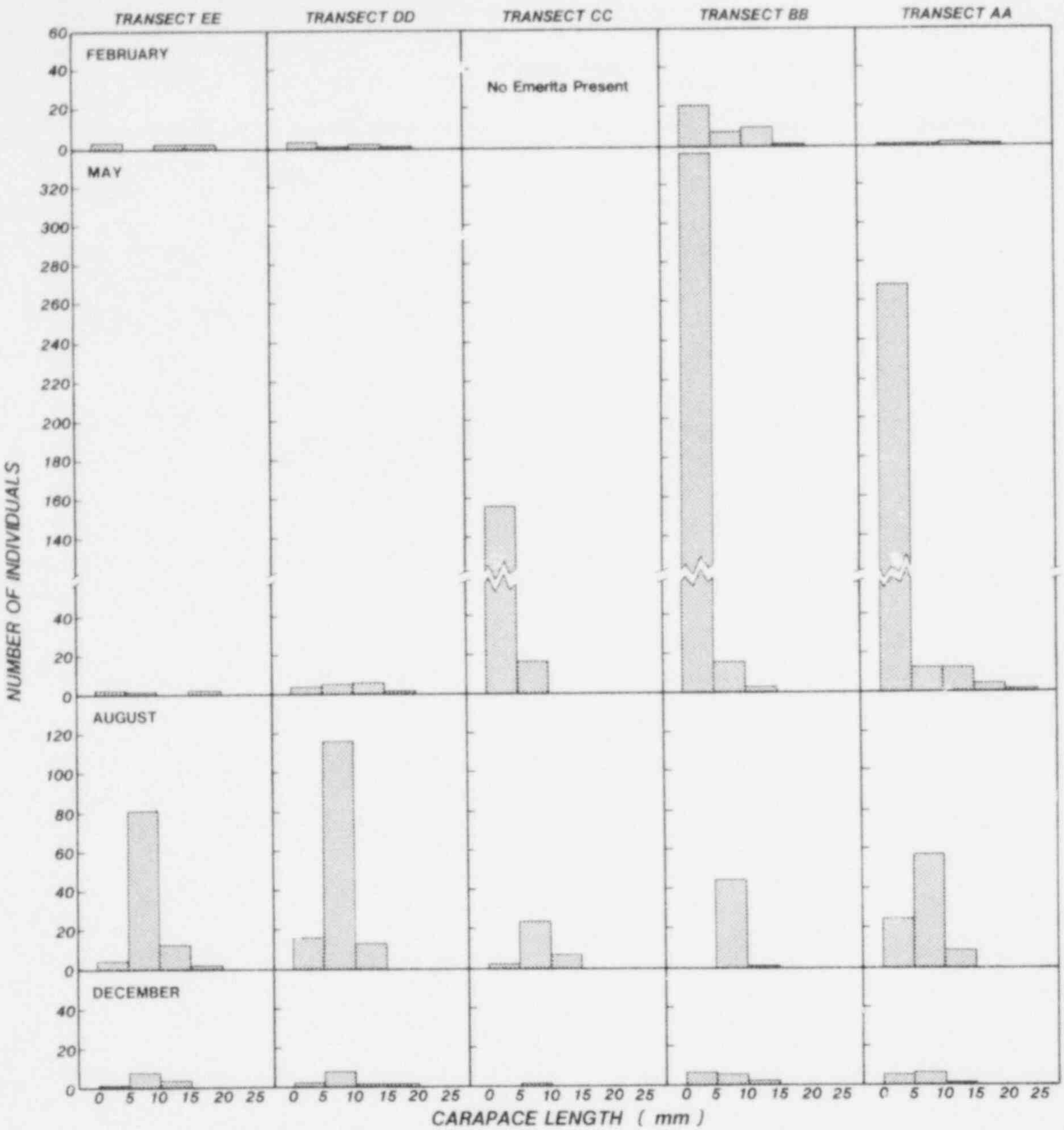

Figure 4A-6. Emerita size-frequency by transect and survey.

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, less selective and usually ingest the sediment, digest organic constituents, and excrete the inorganic residue.

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 4A-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 consistently occurring community members, appearing along only Transect CC during all four quarters, and in two or less quarters along the remaining transects. The greatest variability in trophic composition occurred along Transect BB, where no two quarters were similar in either the identity of represented groups or relative group importance. Transect EE was the most trophically stable transect, with four of the five trophic groups represented in each quarter and surface deposit feeders present in half the surveys. The trophic complexity of Transect AA increased progressively through the year, with one group added to the community during each quarter. No trophic group clearly dominated the species composition of the community.

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

Species Name	Trophic Group
Archaeomysis maculata	C
Caprella equilibra	unassigned (contaminant)
Carinoma mutabilis	C
Dispio uncinata	SF/SDF
Donax gouldii	SF
Emerita analoga	SF
Eohaustorius washingtonianus	SF/SDF
Euzonus dillonensis	SSDF
Excirolana kincaidi	O
Excirolana sp.	O
Hemipodus borealis	SSDF
Hemipodus sp.	SSDF
Insecta, unid.	unassigned
Lepidopa californica	C/O
Lumbrineris japonica	SSDF
L. zonata	SSDF
Microspio acuta	SF/SDF
Nemertea, unid.	C
Nephtys californiensis	SSDF/C
N. ferruginea	SSDF/C
Olivella biplicata	C/O
Orchestoidea benedicti	O
O. columbiana	O
O. minor	O
Pisione remota	SSDF/C
Podocerus brasiliensis	unassigned (contaminant)
Polychaeta, unid.	unassigned
Polyopthalmus pictus	SSDF
Rhepoxynius epistomus	SF/SDF
Saccocirrus papillocercus	C
Scoloplos armiger	SSDF
Spionidae, unid.	unassigned

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

Suspension feeders averaged 45% or more of the individuals at each transect during the year. Their percentage contribution to the total catch was greatest along Transect BB (89%) and least along Transect DD (46%). Subsurface deposit feeders (represented primarily by Hemipodus, the second most abundant species) were the second most abundant trophic group with average percentage contribution ranging from 3% (Transect BB) to 30% (Transects DD and EE).

Annual average variation between transects was relatively small for suspension feeders and omnivores. A geographic pattern was evident, however, in the average percent contribution of carnivores and both types of deposit feeders. Both transects upcoast of the construction laydown pad contained markedly fewer individuals of deposit feeder and carnivore species on the average than the three transects downcoast of the structure. These differences were most evident along Transect BB. Transects CC, DD, and EE as a group averaged over four times the number of carnivores and subsurface deposit feeders, and over twice as many surface deposit feeders as did Transects AA and BB. The downcoast transects were very similar in their average proportions of each of the five trophic groups. Transects AA and BB formed a less consistent group, but were much closer to each other than to the downcoast transects in average trophic structure.

SITE CLASSIFICATION

The five pooled replicates at each level of each transect were considered a "site" in the quarter classification analysis (Figure 4A-8), resulting in 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 4A-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.

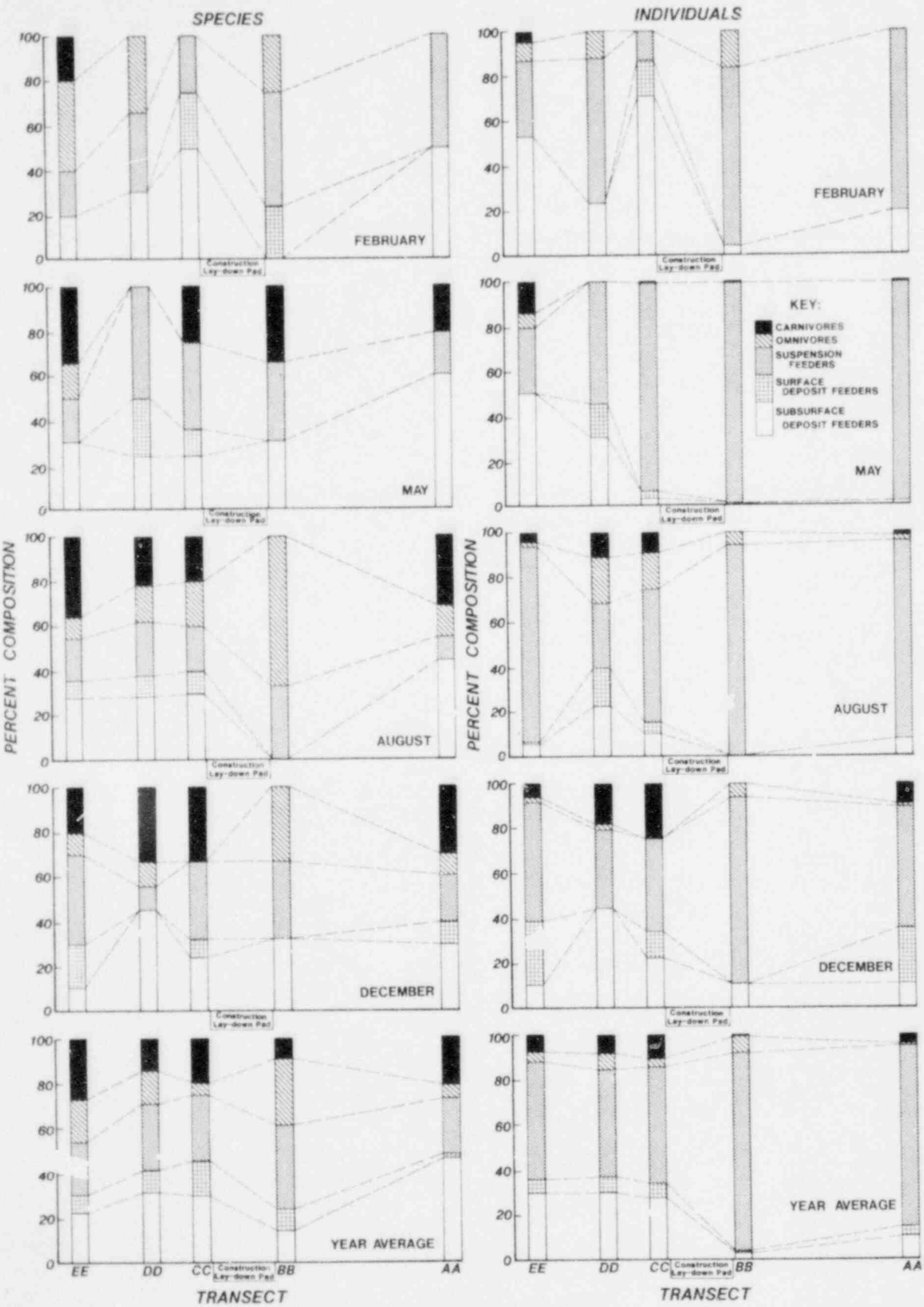

Figure 4A-7. Community trophic composition.

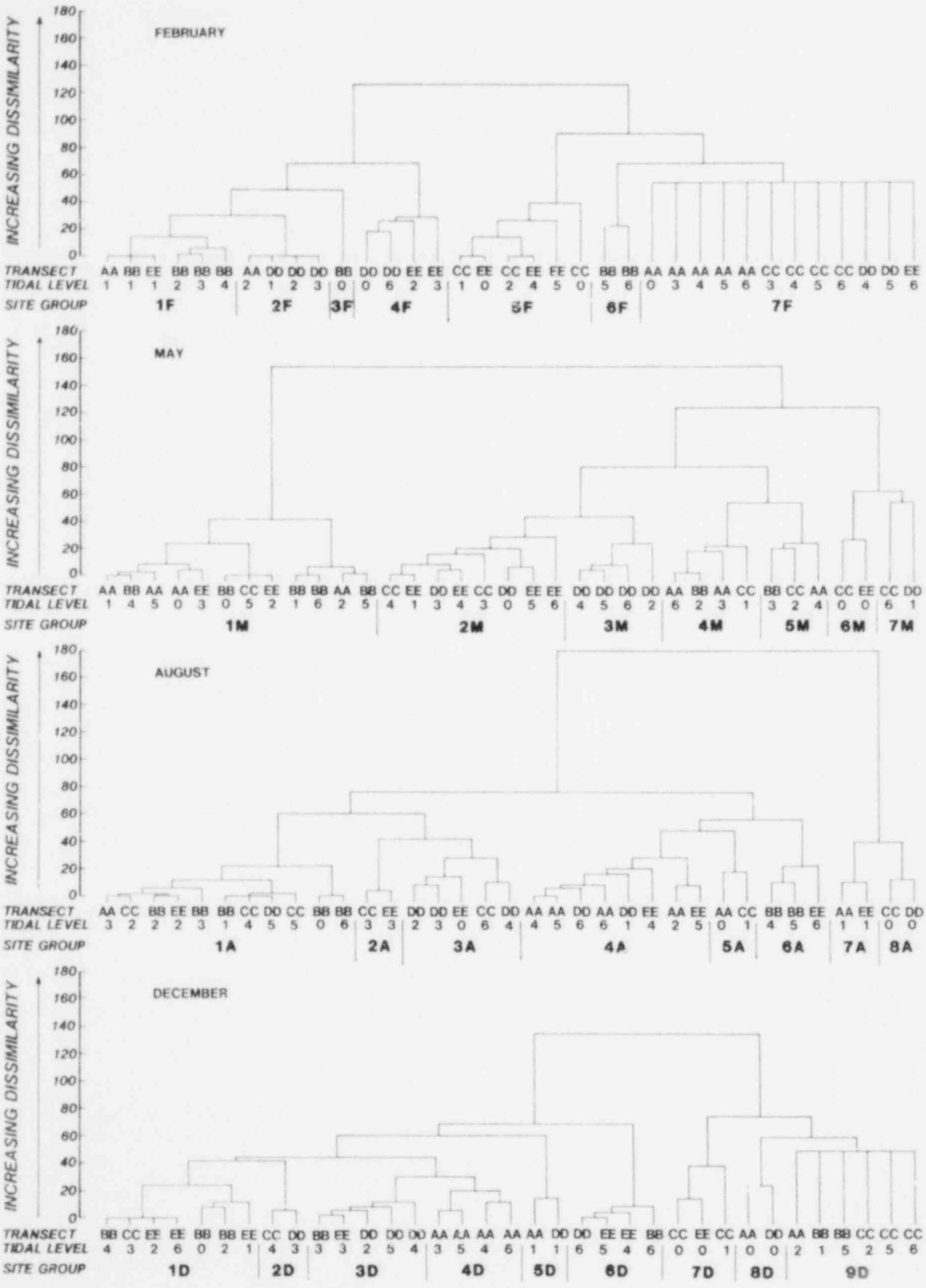

Figure 4A-8. Site classifications for each quarter.

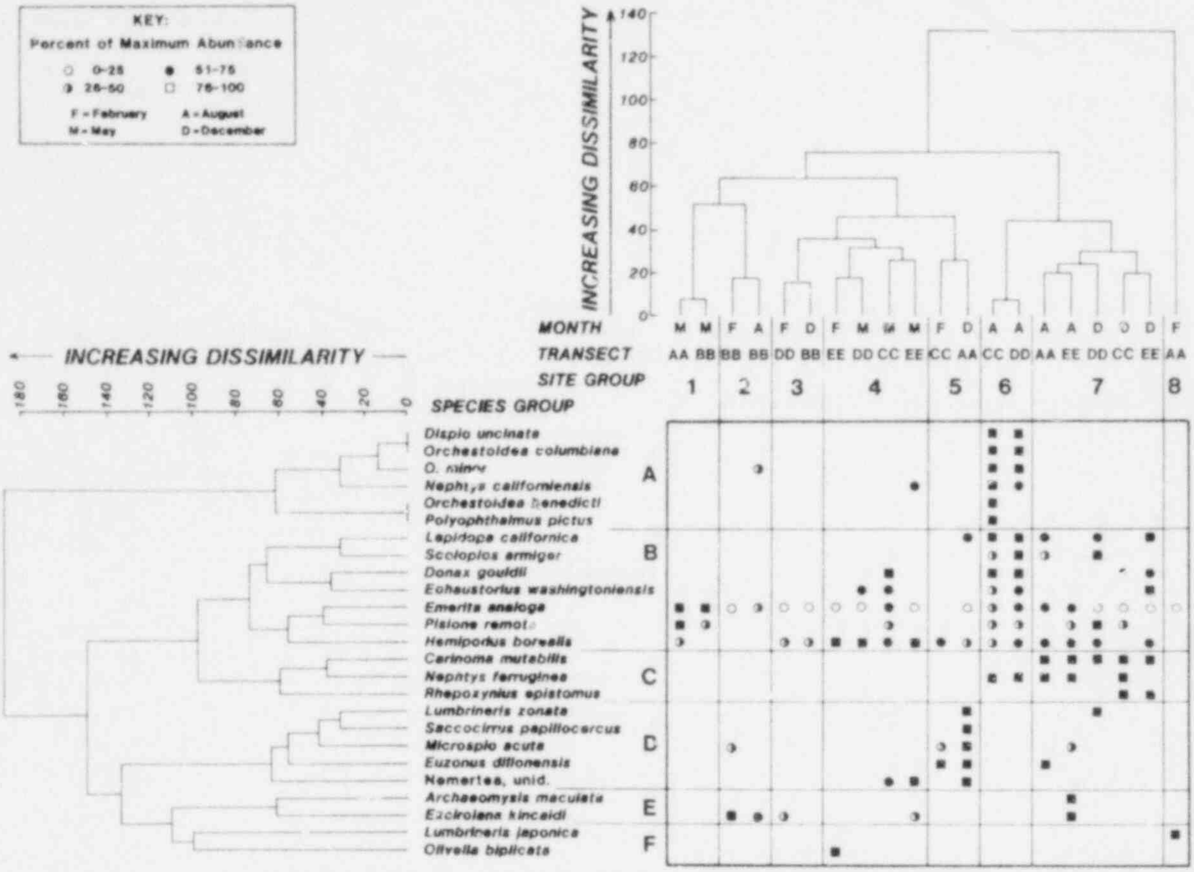

Figure 4A-9. Annual site and species classification with resultant two-way table.

Quarterly site classifications (Figure 4A-8) clustered the sites into seven (February and May), eight (August), and nine (December) groups. Sites were more often grouped by tidal level or beach zonation (as defined in Table 4A-3) than by transect. Grouping by transect was most prominant in February, when two groups consisting of sites along Transect BB were formed. Four of the seven tidal levels at Transect DD in May and Transect AA in December formed single groups. All groups in the August dendrogram contained sites from more than one transect.

Group formation by sites at a single tidal level (7 groups) and sites within a single zone (8 groups) were equally prominent. Three groups of each type occurred in August, and two of each type in December. Groups containing only vacant sites (7M, 9D) were also present in the dendrograms.

The annual site dendrogram (Figure 4A-9) clustered into eight groups. Some clustering along both transect and month lines was evident, with group 2 containing Transect BB during February and August, and groups 1 and 6 containing on[illegible] May and August sites respectively. Both the latter groups consisted of [illegible]ent transects. The primary dichotomy separated Transect AA in February from a[illegible] other collections. The secondary dichotomy separated out most August and December collections along Transects CC, DD, and EE, but also included Transect AA in August.

SPECIES CLASSIFICATION

Records of all taxa were used in the species classifications for individual quarters (Figure 4A-10). Single occurrences and multispecific taxa were retained

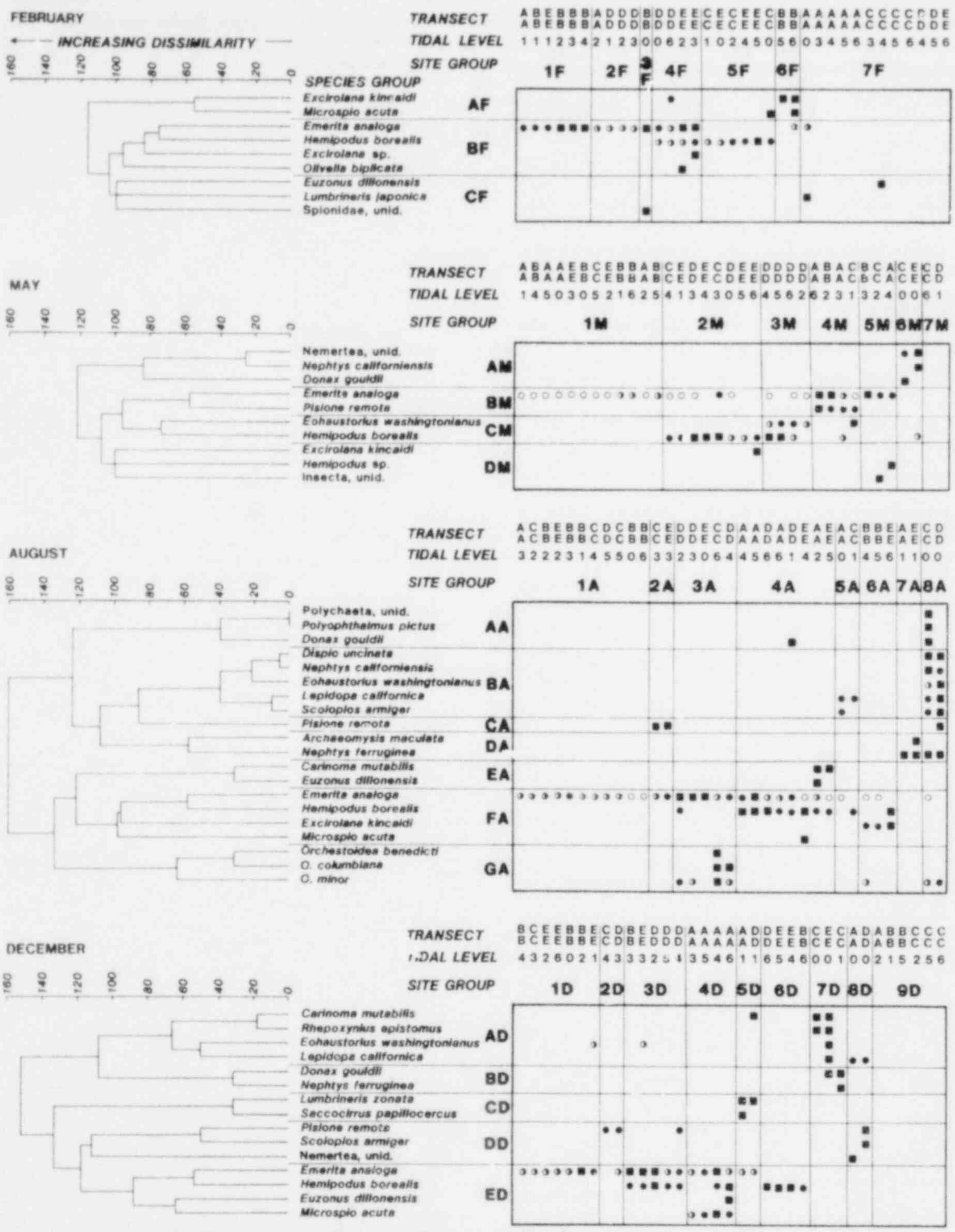

Figure 4A-10. Species classification and two-way tables formed by apposition of species and site classification for each quarter.

to maximize the classificatory base. In the annual classification (Figure 4A-9), where more species were available, occurrances of taxa not identifiable to specific level (except Nemertea, unidentified) were deleted to eliminate redundant records and clarify the classification. Taxa such as <u>Hemipodus</u> sp. and unidentified Spionidae (August), were assumed to represent specimens too damaged or immature to allow more definitive determination which belonged to species occurring in the area. Two obvious subtidal contaminants (Table 4A-4) were deleted from both the quarterly and annual species classifications.

In the quarterly species classifications, between three (February) and seven groups (August) were identified. As in the site classifications, group membership varied between quarters. A group including Emerita and Hemipodus, the two most abundant and widely distributed intertidal species, was evident throughout the year (BF, BM-CM, FA, FD). Two other species grouped with Emerita and Hemipodus in each quarter, but only Microspio acuta grouped with them in more than one (August and December).

Less common species separated into groups of more variable membership. Groups primarily reflected vertical zonation patterns (AM, AA, DA, AD, BD, CD). No species groups characterized a single transect, although group AA species occurred only at sites on adjacent transects (CC and DD). At least two of the species groups (CF and DM) consisted of species which occurred sporadically in low numbers, and were related to each other primarily by their lack of distributional relationships with other species.

Six groups were formed in the annual species classification (Figure 4A-9). Emerita and Hemipodus again clustered together forming a dominant species group (B) present in all site clusters. Group A contained species which primarily occurred along Transects CC and DD in August. Group C consisted of low to medium density species from the low intertidal in August and December. Low to medium density species from lower tidal levels also characterized group D, but their temporal distribution was broader. With the exception of Excirolana kincaidi, which occurred in three of the quarters, groups E and F consisted of low density species collected in a single quarter.

TWO-WAY TABLES

The two-way tables illustrate the patterns of occurrence and abundance of the species at the sites (Figure 4A-10). They represent the data matrix reorganized according to the normal and inverse classifications. Species were considered to be at high relative abundances when they occurred at 50% or more of the maximum for the species. Medium and low relative abundances were considered to be between 26 and 49% and 1 to 25% of the species maximum, respectively.

One site group in May and August, and two in February were defined by the presence of Emerita only. No other site groups were characterized by a single species. Some site groups occupied by a single species group occurred in each quarter (1F, 2F, 1M, 6M, 7A, 4D, 6D). Most other site groups contained two species groups, some differentiated only by differences in relative abundance (i.e. 3M and 4M, both containing sites characterized by species in groups BM and CM). Sites in group 8A had a particularly diverse fauna drawn from six of the seven species groups.

In the annual two-way table (Figure 4A-9), site group 1 was occupied only by species from group B. Group B species were not, however, restricted to sites in group 1, and occurred in all eight site groups. No site group contained members from all six species groups. High relative abundance, particularly of species in group A, characterized site group 6. Similarly high relative abundances in species groups C and D characterized other site groups (7 and 5, respectively). The remaining site groups were defined primarily by various density combinations of Emerita, Hemipodus, and Pisione (all in species group B).

Discriminant Analysis

Multiple discriminant analysis was employed to identify those abiotic features which were associated with biotic distribution patterns. The variables used in the analyses and their abbreviations are listed in Table 4A-5. They consist of sedimentological factors (abundance of grain size classes and distributional statistics), descriptors of beach structure, and surf temperature.

Table 4A-5. Variables considered in the multiple discriminant analyses.

Variable	Abbreviation
Beach cross-sectional area	A
Lower beach slope	S
Surf temperature	T
Beach Width	W
Tidal level	L
Sediment factor 1	SF1
Sediment factor 2	SF2
Sediment factor 3	SF3
Sediment factor 4	SF4
Sediment factor 5	SF5
Sediment factor 6	SF6

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 is indicated by the magnitude of its coefficient of separate determination (Table 4A-6). The most important variables are indicated on the discriminant axes which depict group separations (Figures 4A-11a-e). A vector diagram is presented on each discriminant figure indicating 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 resulting from the PCA and the varimax rotation (Table 4A-7). 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 important variables are interpreted in relation to community structural and distributional differences.

Table 4A-6. 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).

	Axis 1	Axis 2	Axis 3
February			
Lower beach slope	8.1	21.8	54.6
Surf temperature	20.5	57.0	25.8
Sediment factor 1	2.2	2.4	14.4
Sediment factor 2	5.5	1.3	4.3
Tidal level	63.7	17.4	0.9
May			
Beach cross-sectional area	39.2	9.4	11.8
Lower beach slope	14.2	11.6	2.3
Surf temperature	15.3	5.4	31.2
Sediment factor 1	17.5	0.8	12.7
Sediment factor 2	1.8	3.5	10.3
Sediment factor 3	2.5	6.8	14.0
Sediment factor 5	9.1	49.5	15.7
Tidal level	0.4	13.1	1.9
August			
Beach cross-sectional area	18.3	29.8	24.8
Lower beach slope	1.8	2.6	6.2
Surf temperature	20.9	40.9	11.5
Sediment factor 1	38.0	12.0	15.3
Sediment factor 2	3.5	1.2	2.9
Sediment factor 3	3.8	4.5	0.6
Sediment factor 4	0.2	0.4	0.4
Sediment factor 5	6.3	2.4	36.3
Sediment factor 6	1.1	2.8	0.7
Tidal level	6.1	3.4	1.3
November			
Beach cross-sectional area	1.1	9.8	0.0
Lower beach slope	0.3	46.4	0.0
Beach width	18.8	5.2	0.1
Surf temperature	0.1	2.4	0.2
Sediment factor 1	65.6	9.6	6.8
Sediment factor 2	12.6	7.3	12.0
Sediment factor 3	0.5	1.5	5.4
Sediment factor 4	0.9	5.4	41.6
Tidal level	0.2	12.4	33.8

The biotic site classifications rely on variations in species composition and relative abundance for site clustering. The small number of species in the community, their generally low density and frequency of occurrence, and the tidal height independence of most abundant species all contribute to group overlap in the discriminant plots. Despite the transformation and standardization of biotic data prior to analysis, the presence and relative abundance of Emerita dominated the classification analyses. The broad areas of

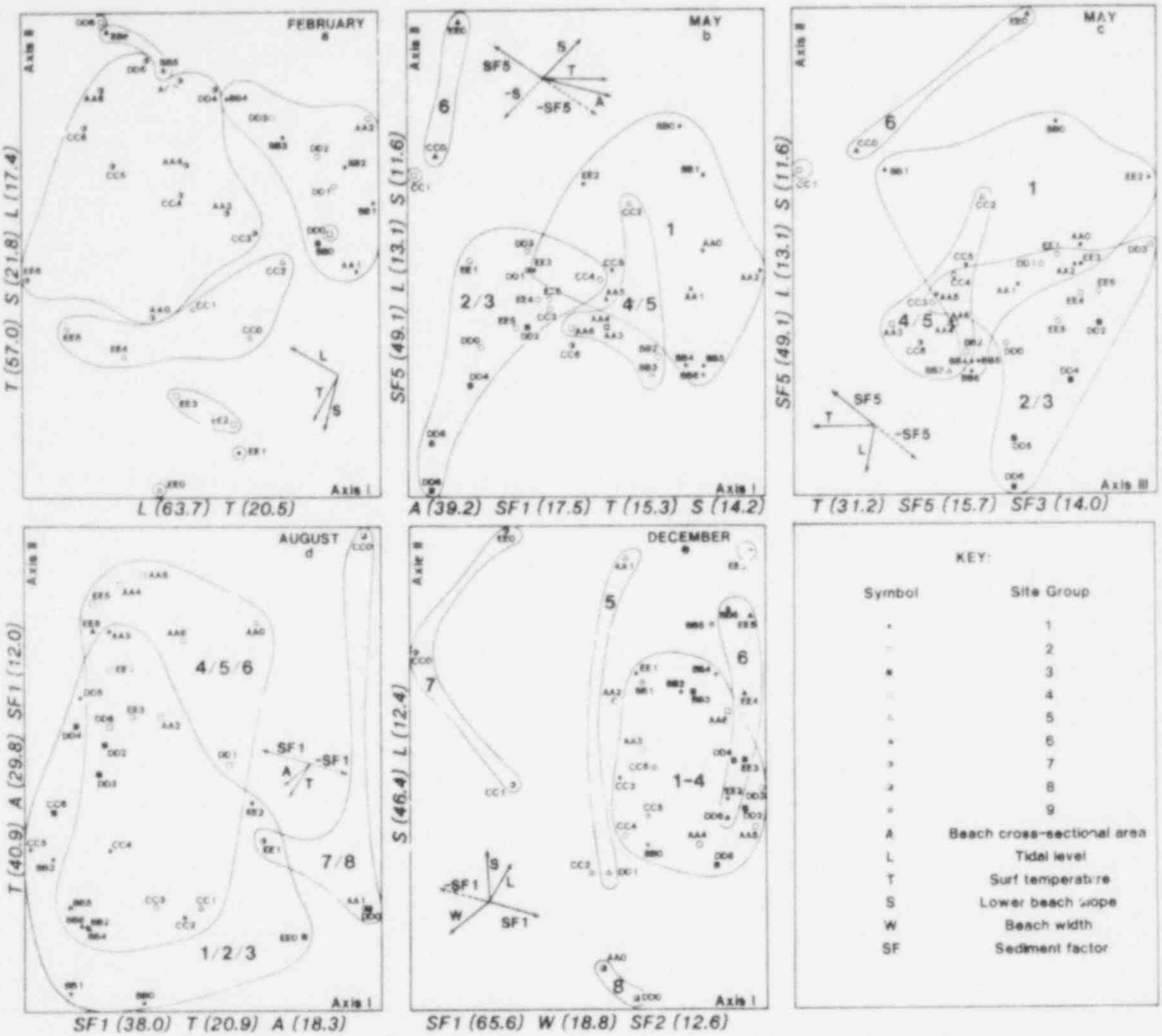

Figure 4A-11. Plots of sampling sites in discriminant space defined by abiotic parameters.

group overlap in the discriminant plots (Figures 4A-11 a-e) are a result of this domination. Such overlaps generally reflect the location of the Emerita population center in the discriminant space.

Two discriminant axes adequately separated the seven station groups defined in the classification analysis of February data (Figure 4A-11a). Axis 1 accounted for 71.2% of the between group variance, while Axis 2 acounted for 23. % (Table 4A-8). The dominant variables on the first axis were tidal level and surf temperature (Table 4A-6). The same two variables along with lower beach slope were important on Axis 2. None of the sediment factors contributed appreciably to the February analysis, nor were they secondarily correlated with the more important factors. The sites were separable along isobaths of tidal height, particularly above the +3 level. The February catch was so low that distortion from random sampling error undoubtedly occurred.

Three discriminant axes were required for separation of the seven station groups produced by classification analysis of the May biological data (Figure 4A-11 b and c). Axis 1 accounted for 72.9% of the between group variance with Axis 2 accounting for 15.4%, and Axis 3 accounting for 9.2% (Table 4A-8). Dominant variables on the first axis were beach cross-sectional area, sediment

Table 4A-7. Sediment factors derived from principal components analysis and varimax rotation.

	Phi Class	Sediment Factor 1				Sediment Factor 2				Sediment Factor 3			
		Feb	May	Aug	Dec	Feb	May	Aug	Dec	Feb	May	Aug	Dec
Small cobble	-7< -6		0.28				0.02				-0.04		
Very coarse gravel	-6< -5	0.98	0.48			-0.03	-0.02			0.02	-0.04		
Coarse gravel	-5< -4	0.98	0.81	-0.03		0.06	-0.03	-0.03		0.16	0.10	0.92	
Medium gravel	-4< -3	0.92	0.92	-0.23	-0.11	0.07	-0.03	-0.13	0.20	0.26	-0.03	0.92	0.04
Fine gravel	-3< -2	0.84	0.95	-0.01	-0.01	0.08	-0.03	-0.92	0.57	0.48	0.04	0.05	0.48
Granule	-2< -1	0.32	0.36	0.15	0.15	0.11	-0.45	-0.83	0.11	0.89	0.67	-0.13	0.93
Very coarse sand	-1< 0	-0.07	-0.16	0.55	0.55	0.43	0.11	-0.33	0.62	0.82	0.91	-0.03	0.42
Coarse sand	0< 1	-0.35	-0.54	0.96	0.90	0.77	0.40	0.18	0.17	-0.14	0.05	-0.05	0.04
Medium sand	1< 2	-0.43	-0.26	0.05	0.76	0.45	0.05	0.05	-0.26	-0.64	-0.89	-0.18	-0.41
Fine sand	2< 3	-0.01	-0.17	-0.95	-0.95	-0.95	-0.33	0.12	-0.09	-0.06	-0.28	0.12	-0.04
Very fine sand	3< 4	0.00	-0.29	-0.79	-0.86	-0.89	0.15	0.07	-0.04	-0.23	-0.02	0.24	0.01
Coarse silt	4< 5			-0.20				-0.04				-0.04	
phi (moment)		-0.68	-0.74	-0.90	-0.91	-0.57	-0.04	0.29	-0.23	-0.43	-0.39	0.06	-0.32
phi (Moment)		0.71	0.93	-0.09	-0.17	-0.00	0.15	-0.88	0.87	0.67	0.09	0.28	0.12
Skewness phi (Moment)		0.28	-0.04	0.84	0.90	0.90	0.39	0.02	0.06	0.03	0.11	-0.08	0.21
Kurtosis phi (Moment)		-0.15	-0.45	-0.30	-0.73	-0.86	-0.79	0.25	-0.46	-0.34	0.13	-0.04	0.46
Sharp & Fan Sorting (25 ints)		-0.46	-0.86	-0.19	-0.43	-0.28	-0.37	0.85	-0.88	-0.80	-0.21	-0.07	0.03

	Phi Class	Sediment Factor 4				Sediment Factor 5				Sediment Factor 6			
		Feb	May	Aug	Dec	Feb	May	Aug	Dec	Feb	May	Aug	Dec
Small cobble	-7< -6		-0.84				0.07						
Very coarse gra l	-6< -5	0.05	-0.86				0.01						
Coarse gravel	-5< -4	-0.03	-0.41	-0.18			-0.06	-0.07				-0.07	
Medium gravel	-4< -3	-0.06	-0.25	0.03	-0.95		-0.14	0.07				0.04	
Fine gravel	-3< -2	-0.16	-0.09	0.15	-0.50		-0.15	0.03				0.19	
Granule	-2< -1	-0.19	0.14	-0.42	-0.04		-0.13	-0.08				-0.07	
Very coarse sand	-1< 0	0.29	0.13	-0.58	-0.10		-0.19	-0.18				-0.34	
Coarse sand	0< 1	0.49	0.12	-0.00	-0.05		-0.66	0.02				0.10	
Medium sand	1< 2	-0.32	0.19	0.91	0.26		0.01	-0.16				-0.17	
Fine sand	2< 3	-0.21	0.03	-0.16	-0.08		0.86	0.11				0.14	
Very fine sand	3< 4	0.20	-0.03	-0.18	-0.04		0.89	0.48				0.14	
Coarse silt	4< 5			-0.07				0.95				-0.05	
phi (Moment		-0.13	0.37	0.20	0.04		0.39	0.15				0.16	
phi (Moment)		-0.15	-0.23	-0.10	-0.33		0.02	0.07				[illegible]	
Skewness phi (Moment)		0.03	-0.51	-0.21	0.18		-0.47	-0.05				-0.43	
Kurtosis phi (Moment)		0.26	0.03	-0.15	-0.07		0.29	-0.05				0.84	
Sharp & Fan Sorting (25 ints)		0.16	0.09	0.03	0.01		0.01	0.00				0.40	

factor 1, surf temperature, and lower beach slope (Table 4A-6). The gravel size classes, particularly fine and medium gravel had strong positive correlations with sediment factor 1, while sand fractions (particularly coarse sand) were negatively correlated (Table 4A-7). Sediment factor 5 was the dominant variable on Axis 2. Fine and very fine sands had high positive correlations with this sediment factor, while coarser fractions (particularly coarse sand) were negatively correlated. Discriminant Axis 3 primarily represented variation in surf temperature.

Two axes separated the eight site groupings in the August classification (Figure 4A-11d). Axis 1 accounted for 89.1% of the variance between groups while Axis 2 accounted for 4.5% (Table 4A-8). Dominant variables on Axis 1 were sediment factor 1, surf temperature, and beach cross-sectional area. Surf temperature and beach cross-

Table 4A-8. Percent of group separation accounted for by each discriminant axis.

Survey	Axis	Percent	Cumulative Percent
February	1	71.2	71.2
	2	23.8	95.0
	3	3.[illegible]	98.6
	4	1.[illegible]	99.9
	5	0.1	100.0
May	1	72.9	72.9
	[illegible]	15.4	88.[illegible]
	3	9.2	[illegible].5
	4	1.4	98.9
	5	0.9	99.8
	6	0.2	100.0
August	1	89.1	89.1
	2	4.5	93.6
	3	4.3	97.9
	4	1.0	98.9
	5	0.7	99.6
	6	0.3	99.9
	7	0.1	100.0
November	[illegible]	88.3	88[illegible]
	2	5.7	94.[illegible]
	3	3.0	97.1
	4	1.9	99.0
	5	0.7	99.6
	6	0.3	99.9
	7	0.1	100.0

sectional area also dominated Axis 2. Sediment factor 1 had high positive correlations with coarse and very coarse sands, and high negative correlation with fine and very fine sands (Table 4A-7).

Two discriminant axes separated the nine groups identified in the December site classification (Figure 4A-11e). Axis 1 accounted for 88.3% of the between group variance, while Axis 2 accounted for 5.7% (Table 4A-8). Dominant variables on Axis 1 were sediment factor 1 and beach width. Lower beach slope dominated Axis 2 (Table 4A-6). Larger sand size classes (particularly coarse and medium sands) had high positive correlations with sediment factor 1, while small sand size classes (fine and very fine sands) had strong negative correlations (Table 4A-7). Beach width, which was eliminated as a variable prior to discriminant analysis in May and August because of very high correlation with beach cross-sectional area (r=.97 in May, r=.96 in August) was included in the December discriminant analysis. In December the correlation with beach cross-sectional area decreased and reversed sign, thus both variables were used in the analysis.

DISCUSSION

The sandy intertidal habitat is typified by wide fluctuations in temperature and substrate stability caused by the interaction of changing tides, oceanographic conditions, and local meteorology. Such rigorous environments are usually inhabited by communities which are physically accomodated rather than biologically accomodated. That is, the composition and structure of the community are primarily determined by physical habitat variability rather than biological interactions between species (i.e. predation and competition).

The sandy intertidal community at SONGS conforms to these generalizations. It is depauperate, since few species have successfully adapted to the harshness of the sandy intertidal habitat, and displays wide temporal fluctuations as do the beaches. As discussed previously (SCE 1979), the community inhabiting the beaches near SONGS is fairly typical of sandy intertidal communities elsewhere in the southern California area (as described by Straughan 1977). The two species which differentiated the SONGS community from that at other local sites in 1978, *Pisione remota* and *Excirolana kincaidi*, remained prominent in the community in 1979.

SPECIES COMPOSITION AND RICHNESS OF THE COMMUNITY

The species composition of the community in 1979 was similar to that observed in previous years (MBC 1978, SCE 1979). The majority of the species turnover between quarters and between years apparently resulted from additions and deletions of predominantly subtidal species on low tide terraces. The true intertidal species were present in the community in 1979 and have been numerically important since the study began. Vertical distribution of community members in 1979 was also similar to that recorded in 1978 (Table 4A-3).

Geographic distribution of the community did not follow a longshore gradient with numbers of species per transect increasing unidirectionally, nor was a radial pattern centered on the construction lay-down pad evident. Most and least diverse transects generally differed in identity from quarter to quarter. The community along Transect BB was, however, less diverse than that at other transects except in February. On the average, transects downcoast of the construction lay-down pad were slightly more speciose than either of the upcoast transects. Transect CC, closest to the shallow water dredge spoil deposition and site of onshore spoil distribution, was on the average more speciose than any other transect, even if its high August species count (15) was not included. During both May and August, 70% or more of the species in the community were encountered along Transect CC. Over the year species richness was depressed upcoast of the construction lay-down pad (Transect BB), and enhanced downcoast (Transects CC and DD). Transects at greater distances from the pad, both upcoast and downcoast, appeared unaffected.

DENSITY OF THE COMMUNITY

The number of individuals collected on sandy beaches near SONGS has decreased during each sampling year; from 4543 in 1977 (grunion eggs excluded), to 2085 in 1978 and 1601 in 1979. This represents a 54% decrease between 1977 and 1978, and a 23% decrease between 1978 and 1979. The net decrease approximates 65% over the two year period.

This might be interpreted as a result of reduced settlement of Emerita, which, as the community dominant, contributed the majority of the total abundance. Emerita abundance has declined in each year; by 57% between 1977 and 1978, and by 21% between 1978 and 1979, for a net decline of 66% over the period. The rest of the community has not, however, remained static; declining a net of 53% over the period (27% between 1977 and 1978, 35% between 1978 and 1979). The density decline is thus a feature of the entire community and not just of the Emerita population. During the course of the construction program the rate of either larval settlement, recruitment success, post recruitment mortality, or some combination of these factors has changed in the SONGS area.

Patterns of density over time were examined by transect to see if the decline in density was related to construction. The percentage decline in density between 1978 and 1979 was higher than the area average along Transects CC and DD for community density, Emerita density, and density of species other than Emerita. Transect BB had increased community density and Emerita density between 1978 and 1979, but had a higher than average decrease in density of species other than Emerita during that period. All of the above observations pertain to total abundance for each year. Despite the low 1979 catch none of the three transects closest to the construction activity had a higher than average net decline between 1977 and 1979 in any of the three density parameters.

RELATIONSHIPS BETWEEN THE INTERTIDAL BIOTA AND ITS PHYSICAL ENVIRONMENT

Most of the physical variables considered in the multivariate discriminant analysis are correlated with the prevailing oceanographic factors of wave force, period, and direction. These three variables, together with tidal movements, current patterns, and meteorological conditions control the amount, direction, and net result of sediment flux.

The physical structure of the SONGS beaches (expressed as beach width, upper and lower beach slope, and beach cross-sectional area) is produced by the interaction of the above oceanographic factors with the local sediment patterns. A variety of grain size statistical parameters ($\bar{x}$ phi, σ phi, skewness, kurtosis, sorting) were included in the analyses, as were the proportion by weight of the sediments belonging to each phi interval grain size class.

Such sedimentological features have been suggested as important factors in the distribution of infaunal organisms. Sediment selectivity by newly settling larval forms (Wilson 1952), as well as by adults, has been reported (Nichols 1970, Gray 1974, Johnson 1971). Since these organisms are dependent on the substrate as habitat, and in many instances as their food supply (deposit feeders), such selectivity is not surprising. Emerita, for instance, strains suspended material from returning wave swash (Efford 1966), and, therefore, must maintain a feeding site in the swash zone. Emerita can respond to changes in sediment fluidity caused by variations in swash (Cubit 1969), however, the sediments must also permit rapid burrowing or the crabs will lose their position. If sediments are too compact (either too fine, or too poorly sorted) to allow rapid penetration, or too coarse for the crabs to move, then they are washed downslope by the returning swash. Sediment grain size can thus have a major influence on intertidal infauna, even those with both high motility and no dependence on the sediments for food.

The relationship between sediment grain sizes and the distributions of intertidal organisms in the Los Angeles-Long Beach Harbor area was examined by Straughan and Patterson (1975) and Straughan (1975). Their data indicated a strong relationship between sediment parameters ($\bar{x}$ phi, and sorting) and the distributions of the species using Spearman's Rank Correlation analysis. Further analysis using individual grain size classes was not attempted.

Water content of the sediments, suggested as a major habitat variable for intertidal species by Straughan (1977), was not measured in this study. Present sampling protocol of collection on a receding tide at the upper edge of the swash zone should ensure that interstitial water was at or near saturation levels regardless of sampling height.

Organic carbon levels were not evaluated for intertidal sediments, since Auyong (1977) found no correlation between availability of organic carbon and either density or distribution of organisms at San Onofre. Smith and Straughan (1979, however, reported organic material to be significantly related to Emerita analoga density on a size specific basis from analysis of Santa Monica Bay collections.

The discriminant analyses based on the variables discussed above produced some unexpected results. Preliminary expectations based on previous correlative and discriminant analyses were that beach structural features and sedimentological parameters would be the important physical factors influencing the distribution of the biota. This was clearly not the case in February 1979 when tidal level and surf temperature were the dominant physical variables. The paucity of biotic data (only 68 individuals were encountered, 36 of them Emerita) probably contributed to the observed pattern. Difficulties with a classification based on so little data are evident from the number and position of isolated group members in the discriminant space. The large central group (group 7 in Figure 4A-11a) contained sites lacking any organisms (except CC4 and AA0, which had one and three individuals, respectively). Despite the small collections, biotic data such as the distribution of Emerita predominantly at lower tidal levels is not unusual in winter. Since Emerita are protandric hermaphrodites (Efford 1966) which overwinter as females, and females are reported primarily from low intertidal and subtidal areas (Efford 1965), the majority of the population should occur at lower levels in winter.

The May discriminant analysis was based on a classification using much more biotic data. Since almost 94% of the collected organisms were Emerita, group overlap was apparent (Figures 4A11-b,c). Although tidal level and surf temperature retained some importance in the analysis, beach structural and sediment parameters dominated the first two axes (Table 4A-6). Best separation was of sites in group 6 (Figures 4A11-b,c). Emerita absence, absence or presence in low density of Hemipodus, and presence of a few low tide terrace species found at no other sites (Figure 4A-10) characterized these sites biologically. The sites were physically characterized by low beach cross-sectional area, lower surf temperatures, relatively higher mean grain size and percentage fine sands, and decreased concentrations of coarse sediment fractions.

The three remaining groups overlapped, even after rotation to include the third discriminant axis (Figure 4A-11c). The Emerita population was centered in the region of the discriminant space typified by sites in the 4-5 group (Figure 4A-11b), although Emerita were collected at sites in all groups except 6 and 7 (which consisted of two vacant sites). Physical factors correlated with increased Emerita abundance on the first two axes were decreased mean grain size accompanied by addition of some coarse material to the sediments; wider beaches of large cross-sectional area, relatively flat lower beach slopes, and relatively warmer water. Pisione occupied much the same central area as did Emerita. Center-points in the Axes 1-2 discriminant space of the Hemipodus and Eohaustorius populations were both shifted towards sites typified by sandier sediments of higher mean grain size with few coarse elements; and relatively flat and cool lower beaches on narrow beaches of low cross-sectional area. Examination of Axis 3, although it accounted for an additional 9.2% of the variance (Table 4A-8), did not appreciably improve the coherence or separability of the groups overlapping near the center of the discriminant space (Figure 4A-11c).

The August discriminant analysis was separable into three partially overlapping groups. Overlap between the 1-2-3 composite group, and the 4-5-6 composite group was considerable, while the 7-8 composite group was virtually separate (Figure 4A-11d). Emerita and Hemipodus were both almost absent from sites in the 7-8 group, which had a biota drawn primarily from species groups AA, BA, CA, and DA (Figure 4A-10). Physical variables separating sites in the 7-8 composite were those negatively correlated with sediment factor 1; increased mean grain size and larger percentages of fine and very fine sands. All of the four sites in the group were low intertidal sites at either the +1 ft or MLLW levels. All transects except BB were represented in the group. Since the sediment size classes important at the 7-8 composite group sites also typify the inshore sublittoral zone (Chapter 2D) the group might be construed as representing low tide terraces constructed of fine sublittoral sands moved onshore by long-period summer waves. Examination of August beach profiles (Figure 2D-6) revealed that all transects except BB did indeed have some sort of very flat low tide terrace, with those along Transects AA, CC, and EE being accretional. The biota also supported this interpretation, as the majority of the species were restricted to the lower beach zone and represented intertidal extentions of primarily subtidal populations (Table 4A-3).

The remaining group composites 1-2-3 and 4-5-6 had a less vertically restricted fauna of true intertidal species (Figure 4A-10). Emerita was a characteristic species at sites in both composites. The occurrence of Emerita in over half of the replicate cores (Table 4A-2) and its numerical dominance (83.5% of the August collection) contributed to the large overlap between the groups (Figure 4A-11d). Hemipodus was restricted to sites in the 4-5-6 composite, except for site DD2 which was in the overlap area. The physical variables important on Axes 1 and 2 were the same, but their relative importance differed. The size and distribution of the composite groups in the resulting discriminant space obscured any pattern of relationship in the August data.

The results of the December discriminant analysis were more readily interpreted. Four groups and one group composite (groups 1,2,3 and 4) were adequately separated by the first two axes. Group 9 is not shown in Figure 4A-11e because it consisted of vacant sites. Group 7 was biologically characterized by two species groups of low intertidal terrace taxa, as was composite group 7-8 in August. As in August fine and very fine sands were the most important sediment classes at sites in the group. Sites in group 8 were also well separated in the discriminant space, with relatively flatter slopes than any other group, and coarser sand sediments than group 7 sites. Group 8 was biologically characterized by absence of dominant species and the presence of low tide terrace species (Figure 4A-10).

Sites in composite group 1-2-3-4, group 5 and group 6 were all very close or partially overlapping in the Axis 1-2 discriminant space. They were characterized by various density combinations of the Emerita and Hemipodus populations. The sites had coarser sand sediments than those in groups 7 and 8, particularly those sites with Hemipodus at high relative density (groups 3 and 6). Site patterns in relation to beach width, slope, and level were not consistant. The population centers of both Emerita and Hemipodus were concentrated at sites typified by medium, coarse, and very coarse sands, and skewed grain size distribution.

Except in February, the factors most important in explaining biological distribution patterns were the beach configuration and sediment characteristics. Intertidal organisms seemed particularly responsive to variations in the proportions of the various sand classes, and to the slope of the lower beach.

PHYSICAL CHANGES AT SONGS AND THEIR BIOLOGICAL EFFECTS.

The annual cycle of natural beach erosion and accretion resulting from longshore sand transport and seasonal oceanographic changes accounted for the majority of beach variability at SONGS. Unusual or anomalous physical conditions in the intertidal zone were restricted to: 1) partial interruption of long shore sand transport by the construction lay-down pad; 2) stability along Transect BB in both beach form, beach width, and grain size distributions resulting from sand impoundment by the pad; 3) instability along Transect CC resulting from upcoast sand impoundment and intermittant disposal of dredge spoil; and 4) presence of an unbalanced sand facies at MLLW of Transect DD in August, presumably a result of spoil disposal.

The biological effects of the above physical modifications did not appear pronounced. Along Transect BB the steeper slope at lower tide levels which persisted throughout the year and the lack of the typical summer grain size shifts towards finer sand sediments at low levels depressed community diversity. Since the groin has filled and should remain filled barring heavy storm activity accompanied by south swell, the present depressed community diversity along Transect BB should persist.

The instability along Transects CC and DD (Figure 2D-6) did not reduce the diversity of the community. To the contrary, Transects CC and DD were more species rich on the average than either of the transects (AA and EE) which were farthest removed from the lay-down pad (Table 4A-1). The decrease in average community density along a downcoast gradient (Figure 4A-2) seemed to reflect vagaries in Emerita recruitment rather than response to beach structures.

The presence of anomalously high proportions of coarse sand in the sediments at MLLW of Transect DD in August was presumed to represent some of the almost 27,000 m^3 of dredge spoil deposited just downcoast of the pier in shallow water during June and July (Table 2D-1). The biotic responses were: 1) high species richness; 2) relatively high density of community members other than Emerita; and 3) absence of Emerita. Since Emerita occurred in over 80% of the August replicates, was found at all other sampling levels along Transect DD, and occurred at MLLW at the four other transects, it is highly probable that sampling error was not involved.

The biota at MLLW of Transect CC in August was also species rich, and community members other than Emerita were relatively dense. No anomalies were found in the statistical properties of the sediments, however. The density and species richness found in August at MLLW on both transects had largely disappeared by December, as had the sediment anomaly at Transect DD.

Although there is little indication of lasting damage to the biota caused by SONGS-induced modifications of sandy beaches, the continued decline in the density of the population is of concern. It is quite possible that the observed decline is but one phase of multiannual cyclic phenomena connected with long term oceanographic trends. It is also possible that the decline may be a result (at least in part) of the presence of the construction support structures on the beach at SONGS, and the sediment transport modifications they cause. The higher than average density decline at the three transects (BB,CC and DD) which appear influenced by the lay-down pad in 1979 supports the latter interpretation.

The annual site classification was used as a summarization of available biotic data. Transects BB, CC, and DD (affected by beach structures) and Transects AA and EE (unaffected by beach structures) were not separated in the cluster analysis. Transects AA and EE were represented in all groups defined by the first three dichotomies. Thus, although SONGS effects were detected along three transects, the community there was still basically the same as that found along unaffected transects nearby.

SUMMARY

The results of the intertidal sand monitoring in 1979 may be summarized as follows:

1. All sites at SONGS, despite considerable variation over time, contained a single sandy intertidal community.

2. Classification analysis revealed the underlying similarity of the biota along all five occupied transects.

3. 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.

4. 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 presence of Pisione remota and Excirolana kincaidi as characteristic community members.

5. Weighted multivariate discriminant analysis indicated that beach shape and grain size parameters were the abiotic factors most closely associated with biotic distributional differences.

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

7. Species richness was depressed immediately upcoast of onshore structures and enhanced within 500 m downcoast.

8. Intertidal community density has declined throughout the area since 1977, and at a more rapid rate within 500 m of the construction lay-down pad since 1978.

9. Changes in the intertidal community seem associated with construction activities, although no mechanism is apparent.

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

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CHAPTER 4B

INTERTIDAL COBBLE

INTRODUCTION

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 the results and analysis of 1979 data are presented. The 1979 results are compared to results of previous SONGS intertidal studies and discussed in relation to possible effects of SONGS operation. The 1979 biological data used in this Analysis Report are contained in the Annual Operating Report, San Onofre Nuclear Generating Station, Volume III, Biological Data 1979 (SCE 1980c).

APPROACH

Qualitative intertidal data were collected in the vicinity of the SONGS discharge and a representative reference area outside the area of probable discharge influence. Data analysis is directed at determining temporal trends and comparing study and reference areas. Field observations include photographic records, abundance estimates for the two most abundant taxa, estimates of percent sand composition of each quadrat, and qualitative observations.

BACKGROUND

The intertidal cobble habitat in the vicinity of SONGS is limited to relatively small rocky areas interspersed among the larger areas of sand beaches. The areas at Stations 1 and 2, upcoast of SONGS (Figure 4B-1), have generally exhibited the largest expanses of cobble during past studies. The cobble habitats immediately upcoast of SONGS (Station 3) and downcoast of SONGS (Stations 4 and 5) exhibit smaller expanses of cobble than Stations 1 and 2. These downcoast habitats have steeper beaches and generally have a mixture of cobbles and boulders thinly covering a bedrock base.

The cobble habitats upcoast of SONGS (Stations 1, 2, and 3) are subject to periodic exposure to fresh water and detritus/sediment burdened runoff from San Mateo and San Onofre Creeks. The entire coastal intertidal area under consideration is subject to moderate to heavy surf and shifting of cobble occurs constantly due to natural phenomena and human activities. Sand moved by longshore drift often partially or totally covers the cobble areas for varying lengths of time. In general, the intertidal cobble environment is highly unstable, subject to extensive substrata shifting, sand inundation, considerable natural temperature variation, desiccation, and salinity changes.

Studies of intertidal sand and cobble biota have been conducted in the vicinity of SONGS since 1963. Results of early qualitative studies conducted from 1963 through 1972 were summarized and reviewed by Parr (1973) and Given (1973). Parr (1973) stated that biological differences in the major cobble areas reflect differences in substratum quality, exposure, and wave action. Given (1973) concluded that there had been no long-term effect on cobble beach biota as a result of the construction or operation of SONGS Unit 1.

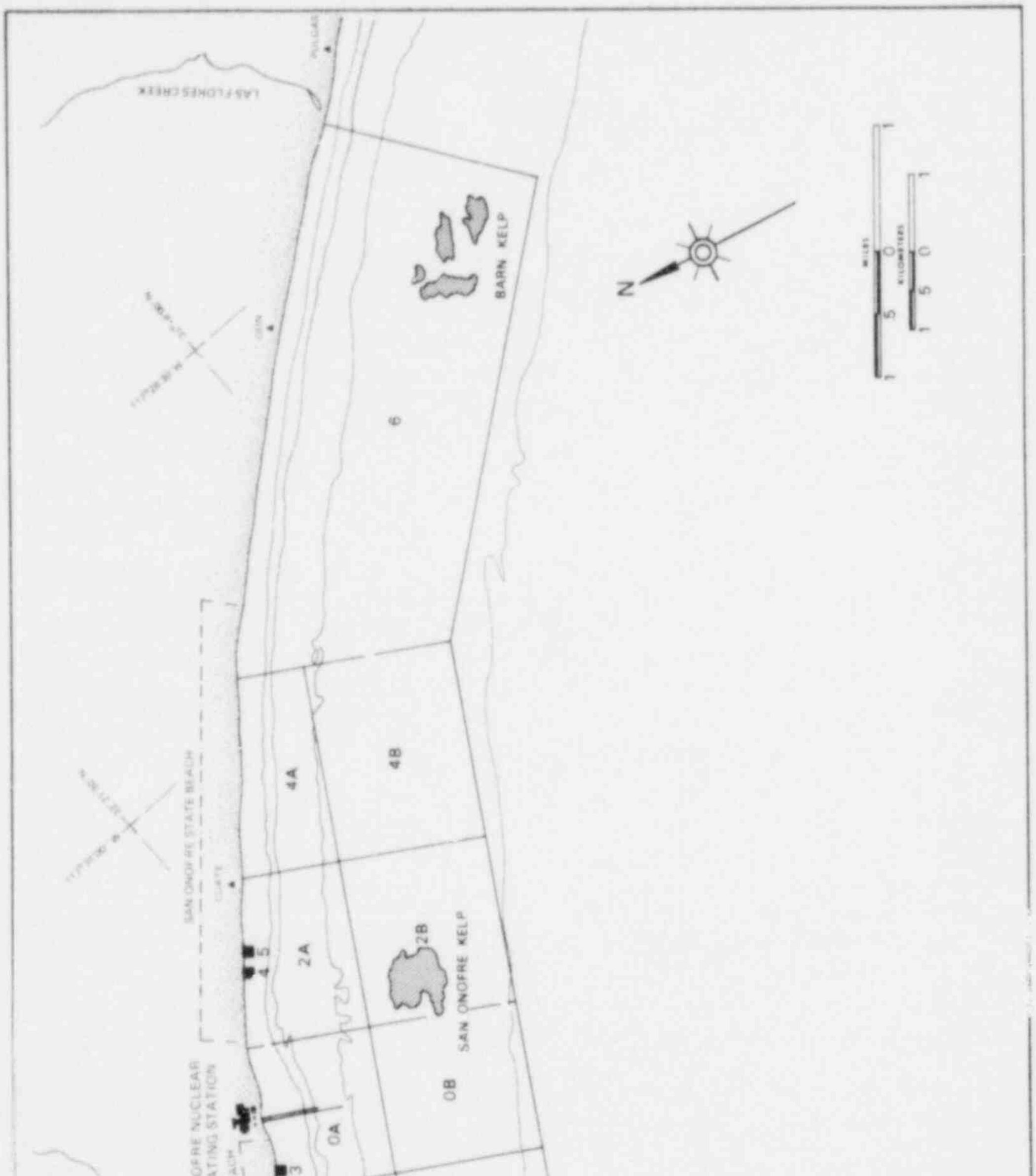

Figure 4B-1. ETS intertidal station locations at San Onofre Nuclear Generating Station.

Studies continued from 1973 to 1975 in compliance with California Regional Water Quality Control Board, San Diego Region requirements for the SONGS Unit 1 Marine Environmental Monitoring (LCMR 1974b, 1974c, 1975f) and SONGS Units 2 and 3 Sand Disposal Study (LCMR 1974a, 1975a, b, c, d, e, 1976a, 1976b). In November 1974, coordination of environmental monitoring programs resulted in formation of the SONGS Unit 1 Environmental Technical Specifications (ETS) Program that fulfilled both California Regional Water Quality Control Board and Nuclear Regulatory Commission (NRC) requirements as described in the ETS, Docket No. 50-206.

The ETS intertidal field program began in February 1975 when a preliminary survey was conducted to establish five permanent intertidal stations in cobble areas. Station locations were based on (1) available similar substrata and habitat types, (2) historical extent of the surface water thermal field of the SONGS Unit 1 cooling water discharge, (3) similar flora and fauna, and (4) proximity to previously established intertidal stations studied during past surveys. Surveys were conducted quarterly, tides permitting, until mid-1977.

Human activity (e.g., tide pooling, clam digging, walking in the intertidal, and surfing) has substantially increased in the study area since the opening of San Onofre State Beach in 1971. Due to ease of access, some intertidal station areas are much more susceptible to human activities than others (LCMR 1976d). Thus, it is extremely difficult to separate the effect of human intervention from any effect which may be caused by the operation of SONGS Unit 1. This, in conjunction with the conclusions of previous studies that there were no detectable effects resulting from the operation of SONGS Unit 1, resulted in an SCE request that the comprehensive intertidal sampling program be deleted from the ETS. This request was approved by the Nuclear Regulatory Commission on 22 September 1977. A program of reduced scope, which is described below, was implemented to continue monitoring of the intertidal cobble areas at San Onofre. The reduced program maintains continuity with station locations used during the ETS study.

METHODS

FIELD

A detailed description of intertidal cobble survey methods and station location data is presented in the combined ETS and PMP procedures (SCE R&D/LCMR Procedure EMP 46-5-5).

Station locations are shown in Figure 4B-1. Station 1, 3.1 km upcoast of the SONGS 1 discharge line, is outside the 1°F isotherm based on the predicted maximum upcoast-downcoast extent of the offshore thermal plume and is considered to be a reference station; whereas Stations 2, 3, 4, and 5, located within the potential influence of the 1°F isotherm, are considered to be test stations. Three equidistantly spaced 0.25-m^2 quadrats, located within ecological Zone 4 (Ricketts and Calvin 1971), have been permanently established along a line parallel to shore at each station.

Nondestructive sampling techniques are employed to survey the dominant macroorganisms living on the surface of the substrata at each station. Biologists visually estimate the percent cover of the two most abundant taxa, and the percent cover of sand in each 0.25-m^2 quadrat. General observations of the area are recorded, such as uninhabited cobble substrata and disturbances of the habitat (e.g., excavations left by clam diggers) which may have affected the biota within the fixed quadrats. Photographs (35-mm slides) of each fixed quadrat are taken during each survey using natural light. All field work is conducted in daylight during low tides of at least -0. 3 m MLLW.

During 1979, surveys were conducted on 26 February, 13 June, and 3 and 19 December. There were no daylight low tides suitable for sampling during the third calendar quarter.

RESULTS

A qualitative description of the 1979 biological and physical data is presented for each station.

INTERTIDAL COBBLE STATION 1 - REFERENCE STATION

Observations recorded during the three 1979 surveys revealed that the major human activity in the area was surfing. During 1979 surveys, no excavations were noted near the fixed quadrats and no clammers were observed in the area. Tidepooling activity resulted in limited habitat disturbance (e.g., turning over cobbles) in the intertidal cobble areas.

Sand coverage in the fixed quadrats ranged from 5 to 40% during the February and December 1979 surveys, and varied from 1 to 10% during the June survey. The sand and cobble contact line was shoreward of the fixed quadrats during all 1979 sampling but closer to fixed quadrat 2 during the December (35 m) than the June survey (47 m).

Based on percent cover, the following taxa were the most abundant in the fixed quadrats during 1979: erect coralline algae (Corallina/Haliptylon complex and Jania spp.) and a turf complex of small algae, Parvosilvosa (Neushul and Dahl 1967). During each of the three surveys, a chlorophyte alga such as Enteromorpha spp. was abundant in one quadrat. Zonaria farlowii and unidentified crustose coralline algae were abundant during the June and December surveys. Egregia laevigata and Sargassum muticum were recorded only during the December survey.

INTERTIDAL COBBLE STATION 2

During the 1979 surveys, no excavations were noted in the vicinity of the fixed quadrats, but clammers were noted in the area during the February and December surveys. Tidepooling activity was also noted. The mean percent sand cover was low during all surveys, with individual quadrats exhibiting a range from 2 to 45% sand cover. During the February and December surveys, more bare cobble surface was exposed, apparently due to the overturning of smaller cobbles. The sand and cobble contact line was 30 m shoreward of fixed quadrat 2 in December, 9 m closer than during the June survey.

Zonaria farlowii and the algal turf complex Parvosilvosa were generally the most abundant algae in the quadrats during 1979. Crustose coralline algae was abundant in the June and December surveys. Erect coralline algae was also reported as abundant during February and December 1979 surveys. Entermorpha spp. and Sargassum spp. were reported only during the June survey.

INTERTIDAL COBBLE STATION 3

Clamming and tidepooling activities were observed in the cobble area during the December survey. Sand cover in the fixed quadrats varied from 10 to 92%

during the February and June 1979 surveys. The sand and cobble contact line was 4-m shoreward of fixed quadrat 2 and was within 1 m of quadrat 3 during the February and June survey. During the December survey, all quadrats were completely covered by sand approximately 30 cm deep as the sand and cobble contact line was about 40 m seaward of fixed quadrat 2.

The Corallina/Haliptylon complex and unidentified crustose coralline algae were usually the most abundant algae during the February and June surveys. The red alga Endocladia spp. and the chlorophyte algae Entermorpha spp. and Ulva spp. were among the most abundant algae during the June survey. Zonaria farlowii was one of the most abundant algae only in one quadrat in the February 1979 survey.

INTERTIDAL COBBLE STATION 4

No clammers were noted during the 1979 surveys, however, overturned boulders and cobble, and exposed bedrock were evident in fixed quadrats 2 and 3, possibly indicating that some clamming activity had occurred. During the 1979 surveys, sand cover in the quadrats varied from 10 to 60%. The sand and cobble contact line was about 2, 9, and 17 m shoreward of fixed quadrat 2 during the February, June, and December surveys, respectively.

The Corallina/Haliptylon complex and Parvosilvosa were usually the most abundant algae during all three surveys. Zonaria farlowii was also abundant in the June and December surveys. Endocladia spp. was recorded among the two most abundant taxa in one fixed quadrat during the June 1979 survey.

INTERTIDAL COBBLE STATION 5

No clamming activity or excavations were noted in the cobble area during the 1979 surveys. Surfing and tidepooling activities were observed in the vicinity of Station 5 during the December survey. The sand and cobble contact line was about 14 m shoreward of fixed quadrat 2 during the June and December surveys.

The most abundant taxa in each fixed quadrat at Station 5 remained the same during the 1979 surveys. The Corallina/Haliptylon complex was one of the two most abundant algae in all quadrats during all surveys, ranging from 11 to 25% cover. Parvosilvosa was abundant in fixed quadrats 2 and 3, covering from 6 to 16%. Phyllospadix spp. was abundant only in fixed quadrat 1, covering from 16 to 50%.

DISCUSSION

Changes in abundance of the abundant organisms observed during 1979 exhibited recognizable seasonal trends. Variations in the abundance of a species within a station in 1979 may be attributed to a variety of factors including natural seasonal differences in abundance of populations due to recruitment, long-term fluctuations in populations, and mortality.

The total number of abundant taxa within a survey for all stations combined was greatest in June, when a total of nine taxa were observed. The minimum number of abundant taxa observed during a survey was seven taxa in February. The number of different abundant taxa recorded during summer was greater due to the establishment of species such as the green algae Enteromorpha spp. and Ulva spp. on previously bare cobble surfaces. These species colonize in the spring when bare cobble becomes available (Emerson 1975). Sargassum spp. also is more abundant in the warmer season, with occasional survival of the stipe and lamellae into colder periods. Comparison of 1979 data with historical data from the SONGS intertidal area indicated that the abundant taxa were those that have been reported as common in the nearby geographical area and previously noted at the intertidal stations (LCMR 1975b).

Data for all stations during all surveys indicate that sand cover of fixed quadrats was higher during winter surveys and lower during summer surveys (Figure 4B-2). The high percentage of sand cover noted in February 1979 (Figure 4B-2) was probably a remnant from the severe storms and associated deposition of terrestrial sediments from stream runoff that occurred in the winter period from late 1978 to early 1979.

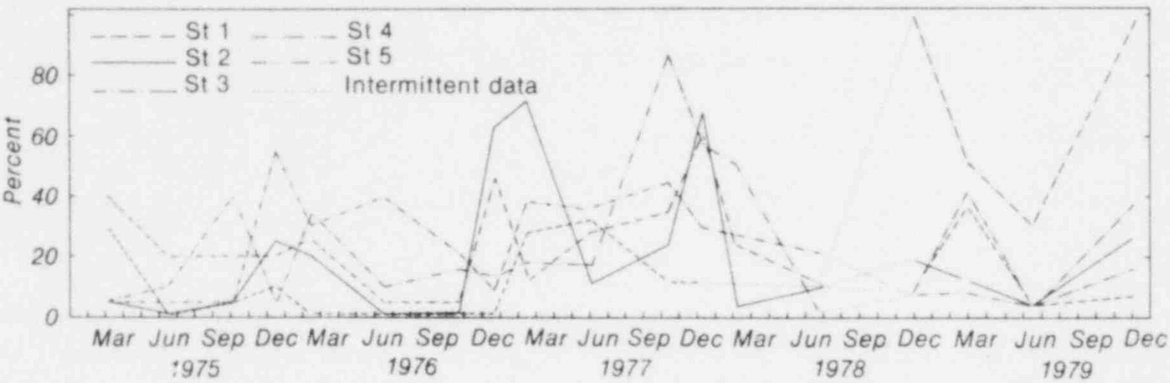

Figure 4B-2. Mean percent sand in three fixed 0.25-m^2 quadrats at ETS intertidal cobble stations in ecological Zone 4 from February 1975 to December 1979. Data from February 1975 to June 1976 obtained from photographs. All other data are field estimates. Intermittent data are indicated by the dotted line (······).

The extension of the intertidal sand areas over the cobble beds immediately upcoast of SONGS may be related to the large fluctuations of beach profiles noted at the Units 2 and 3 construction site near the laydown pad and the construction trestles (SCE 1979d). The sand accumulation upcoast of the pad is a consequence of a temporary structure obstructing normal longshore drift. This accumulation may be extending into the Station 3 area which increases the frequency that the fixed quadrats will be covered by sand.

Sand accretion and burial of intertidal cobble areas has frequently been noted in reports on the SONGS area since 1963. This process is probably significant in defining or limiting the populations of intertidal organisms (McKnight 1969, Connell 1972, SCE 1979b). Organisms such as erect and crustose coralline algae and Zonaria farlowii are resistant to factors such as sand accretion and disturbance of the substratum (Dahl 1971), whether by natural or human intervention, and are usually the most abundant in the study areas. Increasing accretion of sand in areas upcoast of SONGS (Station 3) is followed by decreasing abundance of macrobiota (MBC 1978). This phenomenon was obvious in the study area as reflected by the reduced percentage of biota in quadrats with sand cover.

As winter sands errode, new areas of cobble surface are exposed to settlement and growth of intertidal organisms during the spring and summer (Emerson 1975). Photographs of fixed quadrats taken during the February 1979 survey showed the presence of small cobble with uncolonized surfaces exposed. Less bare cobble surfaces were present during the June survey (Figure 4B-3), indicating that much of the area exposed by decreased sand cover and shifted cobble had been colonized, by species such as Ulva and Enteromorpha.

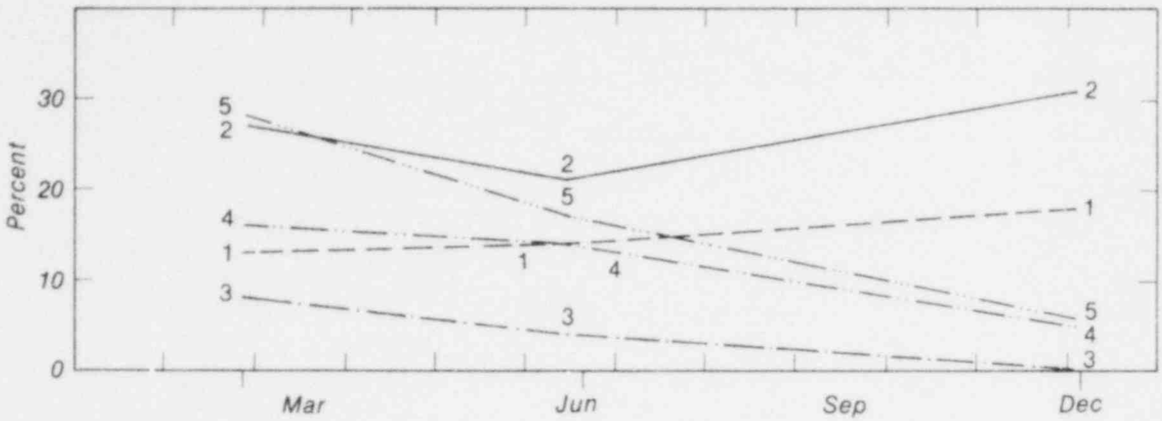

Figure 4B-3. Mean percent bare rock exposed at intertidal cobble station fixed quadrats from 27 February to 5 December 1979.

Substratum instability may also be a major process controlling intertidal biota. The high number of different abundant taxa observed between intertidal stations and seasonal changes within stations, coupled with the presence of bare cobbles during some surveys, indicates the possibility of mortality or disruption of populations due to abrasion associated with moving cobbles or burial by overturning the cobbles. Similar results have been observed in other studies (Osman 1977, 1978) which indicated that intermediate sized cobble of 1 to 10 dm are stable enough to establish a community, but not stable long enough to allow a few taxa to establish dominance. This seemed to be the situation near SONGS except at Station 5 which showed a persistence of the same taxa during the 1979 surveys.

The clamming or digging activity observed during 1979 was considerably reduced when compared with activity noted in previous years (Parr 1973, LCMR 1977b, SCE 1979d). Severe local storms and associated terrestrial runoff during the last two years have been implicated in reduced clam populations in the SONGS area (Williams 1979), and are probably responsible for the reduced clamming activity. However, human intervention and excavation activity was noted during February and June, resulting in considerable disturbance of the habitat and associated biota in some areas. Recolonization of biota in the disturbed areas seemed almost complete by the December survey, when compared to surrounding areas. Other human intervention such as tidepooling, people walking in the station areas, and surfing was frequently noted at all stations (SCE 1980c).

The upcoast reference area was apparently within the +1°F isotherm from the SONGS Unit 1 discharge on three of seven temperature surveys in 1979. The other four stations were frequently within the +1°F isotherm. Biotic changes at test and reference stations were similar. This is in agreement with conclusions of previous studies (SCE 1979d).

Since the thermal plume was observed to impinge on the shore, it is possible that any changes in offshore water quality parameters such as pH, dissolved oxygen, turbidity, and heavy metals could affect intertidal biota, since they could be contained in the water mass represented by the thermal plume. Water quality in the area offshore SONGS as indicated by ocean water pH and dissolved oxygen concentration were not significantly affected by the SONGS Unit 1 discharge (SCE 1979d). Analysis of water and sediment samples from the SONGS area for heavy metals over the four year period ending in 1978 revealed no apparent spatial or temporal patterns in the distribution of metals in the water or sediment (SCE 1979a,d). Nearshore turbidity was higher within the influence of the SONGS Unit 1 discharge (SCE 1979d) and the Units 2 and 3 dredging activities, but high natural nearshore turbidity exists due to suspension of sediments generated by rip currents and wave action (SCE 1979a). Thus, any possible effect of turbidity associated with SONGS related activities was obscured by natural variability.

There is no evidence that the operation of SONGS Unit 1 influenced the intertidal cobble biota sigificantly, which is in agreement with previous findings. SONGS Units 2 and 3 construction activities temporarily increased the frequency of total sand cover of cobble habitats immediately upcoast of the laydown pad.

SUMMARY

A qualitative analysis of the 1979 data and a comparison with previous intertidal studies in the area indicated the following.

1. Comparison of data collected at all cobble stations in 1979 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 number 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. Clamming activity was reduced at all stations during the 1979 surveys, compared to previous years.

4. New areas of cobble surface were exposed to settlement of organisms, during both winter and summer periods at all 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 upcoast reference area was apparently within the +1°F influence of SONGS Unit 1 discharge during three of seven temperature surveys during 1979. The four test stations were frequently within the 1°F isotherm. 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 winter-summer beach processes and winter storms.

6. Construction of SONGS Units 2 and 3 caused some temporary changes in biota of cobble communities immediately upcoast of the laydown pad, due to a greater tendency for the area to be inundated by sand.

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

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CHAPTER 5

SUBTIDAL

INTRODUCTION

The sea floor off SONGS is composed of a mosaic of sediments ranging in size from microscopic clay particles to boulders several meters in diameter. The sediments are predominantly sandy, with some admixture of silts and clays. Fields of cobble or cobble/boulder mixtures are interspersed with the softer sediments throughout the SONGS offshore area. In consequence, the subtidal biota is composed of both species adopted to live between sediment particles (the infaunal community), and species adapted to life on rocks (the epibiota of cobble and kelp beds). The requirements of the two divisions of the subtidal benthic habitat are quite different, as are their biotas. They are discussed separately.

CHAPTER 5A

SEDIMENT INFAUNAL HABITAT

INTRODUCTION

The San Onofre sublittoral zone is composed of both rocky and sandy benthic habitats. The sandy soft bottom environment is extensive and supports a highly diverse community (MBC 1978, Diener and Parr 1977). The community is composed primarily of invertebrate species from the phyla Mollusca, Annelida, and Arthropoda. Not only do these species exhibit individual and population characteristics, but they also serve an important functional role in the trophic structure and flow of energy through the marine ecosystem. Soft bottom benthic organisms live in or on the bottom sediments and are intimately dependent on the physical-chemical nature of this habitat for food and living space (Rhoads 1974). Several authors have reported benthic organisms to be selective of the grain size of sediments they live in or consume (Gray 1974, Johnson 1971, Lie and Kisker 1970). McCave (1974) also suggests that sediment grain size is the most important factor regulating the distribution of benthic organisms; however, he also indicated that sediment porosity, permeability, and oxygen content (all related to grain size) may also be important factors 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 the composition and distribution of benthic communities (Oliver and Slattery 1973, Rhoads and Young 1970).

POTENTIAL IMPACTS AND REGULATORY REQUIREMENTS

The construction of Units 2 and 3 and the placement of intake and diffuser lines offshore may represent potential sources of impact to the benthic infaunal community. In addition, dredging and resulting sediment suspension related to conduit installation, as well as disruption of longshore sediment transport by construction trestles, impact the benthic habitat to some degree. The primary goal of the Construction Monitoring Program (CMP) 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 caused by 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.

This study investigates and quantitatively documents the environmental impact of dredging and construction activities associated with SONGS Units 2 and 3 on the benthic infaunal community. This study also fulfills all requirements set forth by the California Regional Water Quality Control Board-San Diego Region Monitoring and Report Program No. 71-6 for Construction of SONGS Units and 3, including Technical Change Orders No. 1, 2, and 3. Further, the investigation satisfies Nuclear Regulatory Commission (NRC) requirements.

QUESTIONS ADDRESSED

Environmental effects associated with construction of Units 2 and 3 and/or with operation of Unit 1 may be indicated by population or community characteristics which differ markedly from the "normal" characteristics exhibited by benthic organisms in reference areas. The data gathered during this investigation were subjected to scrutiny at various levels of complexity to determine the effects of construction activities. The questions addressed were:

1. Are construction activities related to Units 2 and 3 or operation of Unit 1 causing:

   a. differences in community compositional characteristics, including taxonomic composition, biomass, feeding types, species diversity, or numbers of individuals between treatment and reference stations?

   b. changes in benthic infaunal community distribution patterns normally associated with the area offshore of SONGS?

2. a. What physical/chemical factors are associated with observed biological differences?

   b. Have these factors been modified by SONGS construction and/or operation?

   c. What is the magnitude of any impact attributed to SONGS construction or operation relative to natural phenomena?

PREVIOUS STUDIES

Marine Environmental Monitoring (MEM) of the soft bottom benthos in the vicinity of SONGS Unit 1 began in 1963 and continued until 1975. In 1974 a program designed to investigate the effect of sand disposal (Sand Disposal Monitoring Program) from construction of Units 2 and 3 on the benthic infauna was initiated. This study, part of the Construction Monitoring Program (CMP) continued with revised methods in 1976 to examine the effects of offshore dredging for Units 2 and 3 intake and diffuser lines. Reports detailing the results of the CMP programs were released by Marine Biological Consultants, Inc. (MBC) in 1978 and 1979 (MBC 1978, SCE 1979).

MATERIAL AND METHODS

Data were collected quarterly during February, May, August, and November 1979. Biological collections were made at stations located along 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 5A-1). Selection of treatment (B, C, D, and E) and reference (A and F) transects 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 could be subject to perturbation during some portion of the construction period. Transects B and C flanked the intake and discharge ports of operating Unit 1. The upcoast (A) and downcoast (F) reference transects were well outside this area of potential construction influence. Comparisons between reference and treatment areas were the basis for determining construction related impacts.

BIOLOGICAL SAMPLING

At each station replicate 1ℓ sediment samples (10 cm x 10 cm x 10 cm) were removed by biologist-divers. Samples were collected adjacent to a permanent monument using a hand-operated box core (Figure 5A-2).

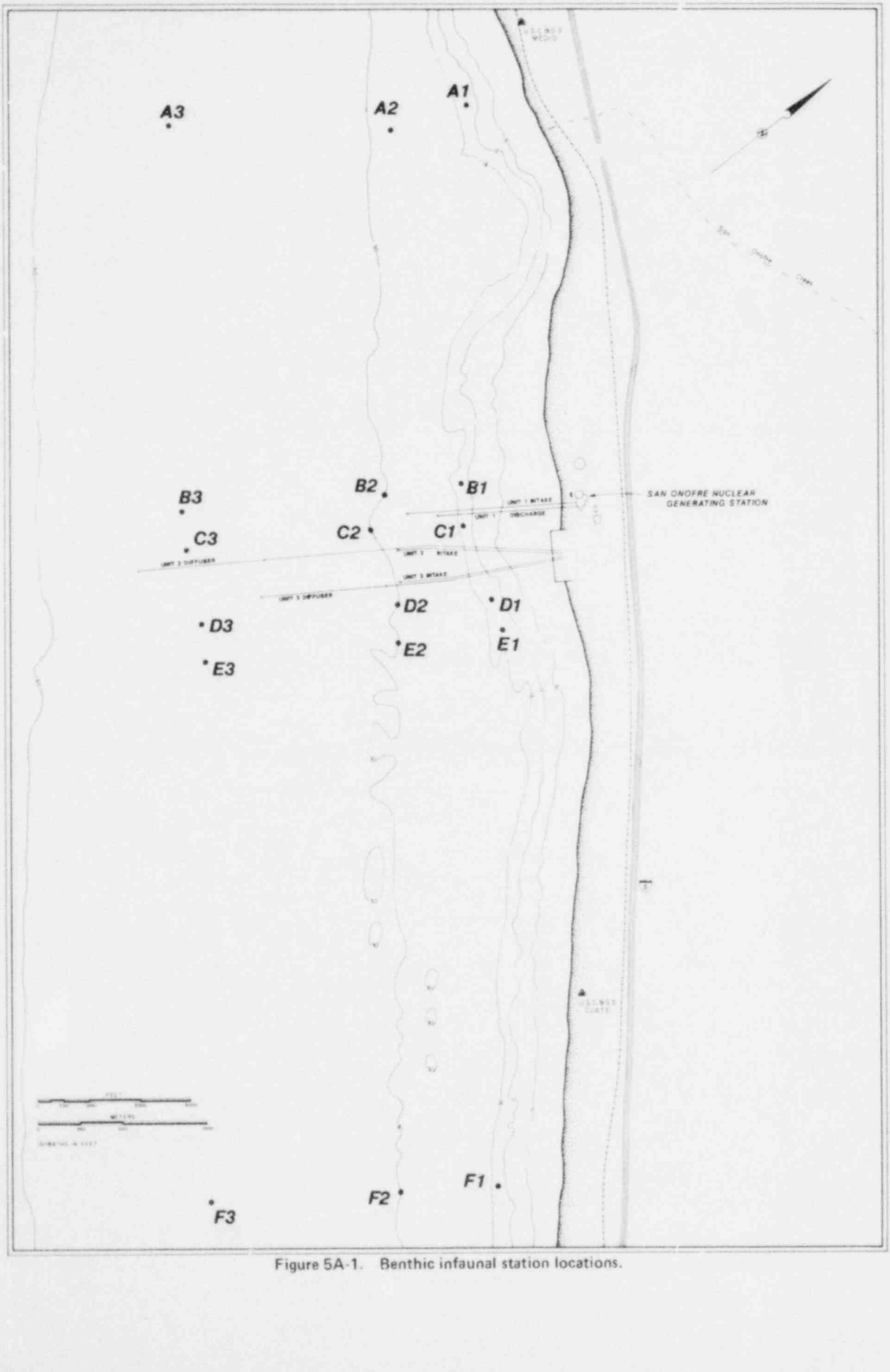

Figure 5A-1. Benthic infaunal station locations.

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 (special study results presented in Statement of Work for CMP). Optimum levels of effort and information were determined to be 5 replicates/station along the 6 m isobath (A1, B1, C1, D1, E1, and F1), and 12 replicates /station along the 9 m and 15 m isobaths (A2, B2 ... F2 and A3, B3 ... F3). Each sample was screened through a 0.5 mm screen in the field, and the retained fraction preserved in 10% formalin. In the laboratory, samples were sorted and the species identified and enumerated. All biological data collected by the above techniques was presented in Section III of Voume II, Construction Monitoring Program Annual Operating Report (SCE 1980).

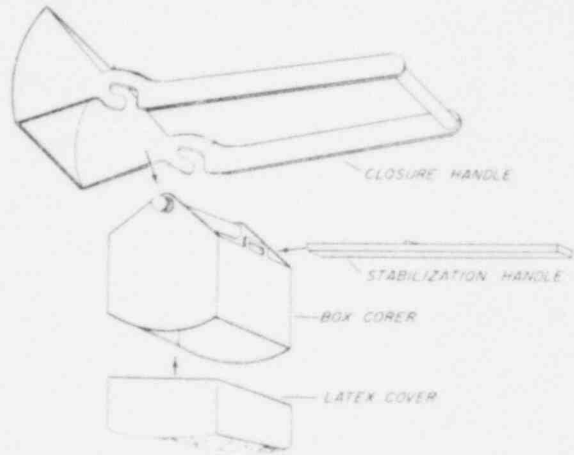

Figure 5A-2. Diver-operated box corer.

Biomass

Biomass was determined and used as a summary value to characterize the total amount of living material at a station and was expressed as total wet weight of whole organisms in grams/*. Whole organism weights included the weight of the inorganic portions of the shells, tests, and carapaces of mollusks, echinoderms, and arthropods. One should note that the preser . of a single large organism may cause extreme deviations in the values.

Physical Measurements and Sediment Characteristic

At each station, sediment stake heights (vertical distance from substrate to top of a permanent monument) were measured and were used to detect changes in bottom height between surveys. The sediment flux which reflected monthly deposition rates, was calculated from sediment trap collections. Sediment traps at each station were positioned on top of the permanent monuments and were replaced monthly. The contents were returned to the laboratory, oven dried at 100°C for 24 hours, and their dry weight recorded (see Chapter 2D, Sedimentology).

Sediment samples for total organic carbon determinations and grain size analysis were collected adjacent to the biological samples at each station. Sample replication necessary to adequately characterize a station was previously determined with a special study. At stations located along the 6 m isobath, three core samples were collected for both sediment size and organic carbon analyses. For stations located along the 9 and 15 m isobaths, four core samples were collected for sediment size analysis and eight samples collected for organic carbon analyses. Total organic carbon content was determined for each sample using a LECO gasometric carbon analyzer (Bandy and Kolpack 1963). Grain size was determined by automatic settling tube analyses of sand sized fractions (combined with sieving for gravel when necessary) (Gibbs 1974). Silt-clay fractions were analyzed using standard hydrometric techniques (Folk 1968). Calculations for mean phi, skewness, kurtosis, and other sediment descriptive characteristics followed standard formulae based on moment measures (see Chapter 2D, Sedimentology).

Bottom water temperature and Secchi disc readings (measuring water clarity) were recorded at all stations during each quarterly survey.

All physical and chemical data collected by the above techniques was presented in Volume I. Oceanography (SCE 1980).

DATA ANALYSIS

Analytical Rationale

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.

Univariate Techniques

Analysis of Variance. One-way analyses of variance (ANOVA) were performed on replicate biological data collected quarterly from all stations located on a particular isobath. The analyses considered station differences separately in terms of the number of species, and the number of individuals. Since statistical assumptions of normality were met by the data, the more robust parametric ANOVA was utilized rather than a non-parametric counterpart (Steele and Torrie 1960). When the ANOVA revealed significant differences between stations, in the number of species and/or individuals, the Duncan multiple range test (Steele and Torrie 1960) was used to determine which pairs of stations were significantly different.

Multivariate Techniques. Classification Analysis of Biological Data. Classificatory procedures (Clifford and Stephenson 1975) were employed in the analysis of subtidal benthic infaunal data. Species presence and abundance defined habitat areas. The operative assumption was that optimal areas for a given species within an 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.

Two classification analyses were performed in which entities were grouped by specific joint attributes. The sampling stations (entities) were classified by the similarity of their species composition (attributes). This is termed "normal" analysis by Clifford and Stephenson (1975). The "inverse" analysis classified the species (entities) with respect to their distribution among the sampling stations (attributes). Both analyses utilized all species that occurred at more than two stations in a survey (quarter sampling) and/or with a mean abundance greater than one individual.

Classification analysis involves three basic procedures. The first is 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, clusters the entities into a hierarchial a dendrogram. In this study, the "step-across" procedure proposed by Williamson (1978) and modified by Smith (in preparation) to be compatible with quantitative data was applied. This procedure was selected in preference to other methods since it compensated for the loss of sensitivity by large ecological distances (Beals 1973). Dendrograms from both the normal and inverse analyses were 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 then entered into the body of the two-way table, which displayed patterns of species occurrences that were subsequently interpreted.

Prior to any analysis, all data were square root transformed and standardized by the species maximum to reduce the excessive influence of abundant species (Smith 1976).

Principal Components Analysis. The composition of sediments at SONGS was complex (SCE 1978) and ranged from coarse sand-sized to clay-sized particles. Synoptic measures such as mean grain size may not truly represent the sediment features to which animals respond and, therefore, may not reflect physical differences between stations. 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) and, therefore, it was more informative to examine these features in addition to synoptic measures.

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).

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 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.

A reduction of sediment variables into sediment factors streamlines data handling and interpretation while eliminating certain problems inherent in analyzing many potentially redundant variables.

The PCA with varimax 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 sediment factors (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.

Weighted Multiple Discriminant Analyses. Variables representing relevant abiotic characteristics of the subtidal benthic habitat were measured at all infaunal stations. These measurements reflect differences in the physical-chemical nature of the benthic habitat, the input from Unit 1 operation, and Units 2 and 3 dredging and construction related materials. These parameters included:

- Substrate Depth
- Sediment Organic Carbon
- Bottom Temperature (Sediment and Water Temperature)
- Water Clarity
- Sediment Flux (Depositional Rate)
- Change in Sediment Height (Sea bed Elevation)
- Sediment Factors (Sediment Size and Size Distribution Characteristics)

Weighted multiple discriminant analysis (Smith 1976 and 1978; see also Hope 1969, Cooley and Lohnes 1971, Green 1971) was employed to determine which abiotic features were associated with biotic community differences. Weighted analysis utilized more biological information contained in the distance matrix since each site in each group was weighted in proportion to its average biological similarity to other group members (Smith 1978). Discriminant analysis requires the predefinicion of groups, and these groups were defined by the normal classification analysis of stations. Discriminant analysis produces a linear combination of measured variables which maximize the differences between groups (i.e. abiotic variables which maximize between group variance and minimize within group variance). The linear combination of variables define a new discriminant axis which is composed of the original variables. The proportion of each original variables contribution to the discriminant axis is indicated by the absolute value of the coefficient of separate determination (Hope 1969, Smith 1976) and is expressed as percent of the axis total. The higher the coefficient of separate determination, the greater influence the variable has on the formation of the discriminant axis.

RESULTS

BENTHIC INFAUNAL COMMUNITY COMPOSITION

The infaunal communities surveyed during this program were highly variable among stations in terms of species composition and abundance (SCE 1980). Over 31,000 infaunal organisms were collected during the year including 486 taxa representing 16 phyla (Table 5A-1). The total number of individuals from all stations ranged from a low of 5,371 in March to a high of 10,358 in August (Table 5A-2). The total number of taxa recorded by survey followed a similar trend and increased from a low of 247 in March to a high of 316 in August. Although the majority of taxa were identified to species, many taxa could only be identified to higher levels of classification. 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

Table 5A-1. Phyletic composition of the benthic infaunal community.

Phylum	Number of Taxa	Percent
Annelida	175	36.01
Arthropoda	155	31.89
Mollusca	105	21.60
Echinodermata	13	2.67
Cnidaria	9	1.85
Nemertea	9	1.85
Sipunculoidea	7	1.44
Ectoprocta	3	0.62
Chordata	2	0.41
Phoronida	2	0.41
Brachiopoda	1	0.21
Chaetognatha	1	0.21
Hemichordata	1	0.21
Nematoda	1	0.21
Platyhelminthes	1	0.21
Sarcodina	1	0.21
Total Taxa	486	
Total Phyla	16	
Total percent		*100

Table 5A-2. Total number of taxa and individuals by quarter.

Station	Isobaths 6 m	9 m	15 m	Total
February				
Total Taxa 247				
A	82	246	348	676
B	108	304	516	928
C	175	311	544	1030
D	229	259	354	842
E	141	349	369	859
F	112	354	570	1036
Total	847	1823	2701	5371
May				
Total Taxa 283				
A	0	443	495	938
B	120	437	1229	1786
C	195	418	1139	1752
D	197	482	435	1114
E	175	391	286	852
F	175	495	696	1366
Total	862	2666	4280	7806
August				
Total Taxa 316				
A	413	683	592	1688
B	328	998	652	1978
C	251	777	758	1786
D	421	855	476	1852
E	370	774	508	1652
F	412	669	521	1602
Total	2195	4756	3607	10558
November				
Total Taxa 297				
A	186	314	794	1294
B	131	779	323	1233
C	44	498	585	1127
D	243	342	376	961
E	332	374	424	1130
F	209	761	574	1544
Total	1145	3068	3076	7289
Grand Total Number of Individuals				31026

fragmentation during sampling which results in overestimation through introduction of "artificial" taxa (e.g. Tellina sp.). These small clams were probably juveniles of T. modesta that had not developed the 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 90% of all the taxa collected (Table 5A-1). These taxa 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

The number of species reported per station represented the cumulative number for all replicate 1ℓ samples collected at that station. Since the optimal sample size was previously determined, the cumulative species diversity value reflected the total diversity at a station.

In this section, only taxa which were identified to species level were used in diversity calculations (a conservative approach). The only exceptions were in cases of morphologically distinct taxa, representing undescribed species. These taxa were assigned a morphotype designation, e.g. Ogyrides sp. A, and were included in the species counts.

The number of species found per station during each survey are listed in Table 5A-3 and are graphically presented in Figures 5A-3 and 5A-4. The number of species generally increased with increasing depth. The mean number of species at all stations increased through the survey year. The 6 m isobath stations contained the greatest number of species in May, while the maximum number of species at the 9 m and 15 m isobath stations were recorded during August (Figure 5A-3).

The mean number of species collected at 6 m reference stations ranged from a low of 17.5 during February to a high of 33.0 species in May (Table 5A-3). The absence of sandy substrate at Station A1 during May prevented sampling. Apparently erosional processes had removed all sediment covering the subsurface cobble substrate. The mean number of species at 6 m treatment stations ranged from a low of 21.8 in February to a high of 34.8 in May. The mean number of species at 9 m reference stations ranged from 45.5 in February

Table 5A-3. Number of benthic infauna species collected at each station during all sampling periods.

Isobath	Station	Survey Feb	May	Aug	Nov	Mean for Year
6 m	A	10	0*	31	22	21.00
	F	25	33	30	31	19.75
Reference $\bar{X}$		17.50	33.00	30.50	26.50	25.38**
	B	17	30	30	23	25.00
	C	25	35	30	21	27.75
	D	22	34	29	30	28.75
	E	23	40	27	25	28.75
Treatment $\bar{X}$		21.75	34.75	29.00	24.75	27.56
9 m	A	47	64	70	48	57.25
	F	44	56	54	62	54.00
Reference $\bar{X}$		45.50	60.00	62.00	55.00	55.63
	B	48	62	71	62	60.75
	C	37	60	78	63	59.50
	D	44	55	61	56	54.00
	E	48	63	66	58	58.75
Treatment $\bar{X}$		44.25	60.00	69.00	59.75	58.75
15 m	A	62	82	85	78	76.75
	F	69	70	90	90	79.75
Reference $\bar{X}$		65.50	76.00	87.50	84.00	78.25
	B	62	72	91	71	74.00
	C	63	78	95	79	78.75
	D	61	72	82	62	69.25
	E	43	52	64	70	57.25
Treatment $\bar{X}$		57.25	68.50	83.00	70.50	69.81

* No samples May A1 because rock substrate was exposed, therefore, no benthic infauna were present.
** This mean was calculated using the vertical column.

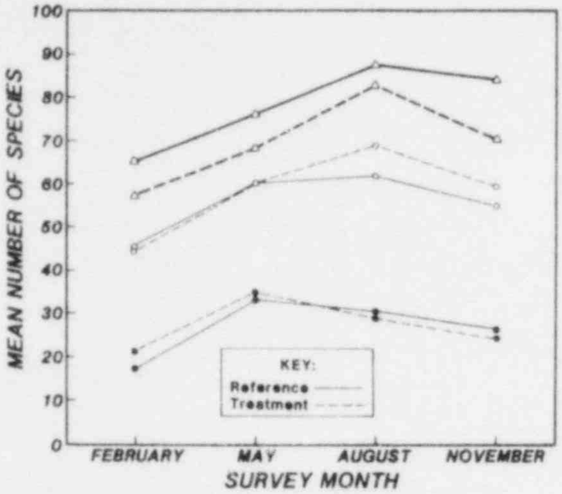

Figure 5A-3. Mean number of benthic infaunal species found at reference and treatment stations throughout the year.

to 62.0 in August, while 9 m treatment station means ranged from 44.2 in February to 69.0 in August. The mean number of species recorded for the 15 m treatment stations ranged from 57.2 in February to 83.0 in August.

Annual mean number of species for all reference stations located on the 6 m isobath was 25.4, while the annual mean at treatment stations was 27.7 (Table 5A-3). The annual mean number of species found at 9 m isobath reference stations was 55.6 and that for treatment stations was 58.8. At the 15 m isobath reference stations, the annual mean number of species was 78.0, while the treatment stations on the same isobath had a mean of 70.0.

NUMBER OF INDIVIDUALS

The mean number of individuals/ℓ at a station generally increased through the survey year. Lowest levels occurred in February, while peak levels were found in August at treatment and reference stations (Table 5A-4, Figures 5A-5 and 5A-6). When annual isobath means for reference and treatment areas are considered, the mean number of individuals/ℓ decreased with increasing depth offshore. The annual mean values at the reference stations were highest (42.4 individuals/ℓ) at the 6 m station and dropped to 37.0 and

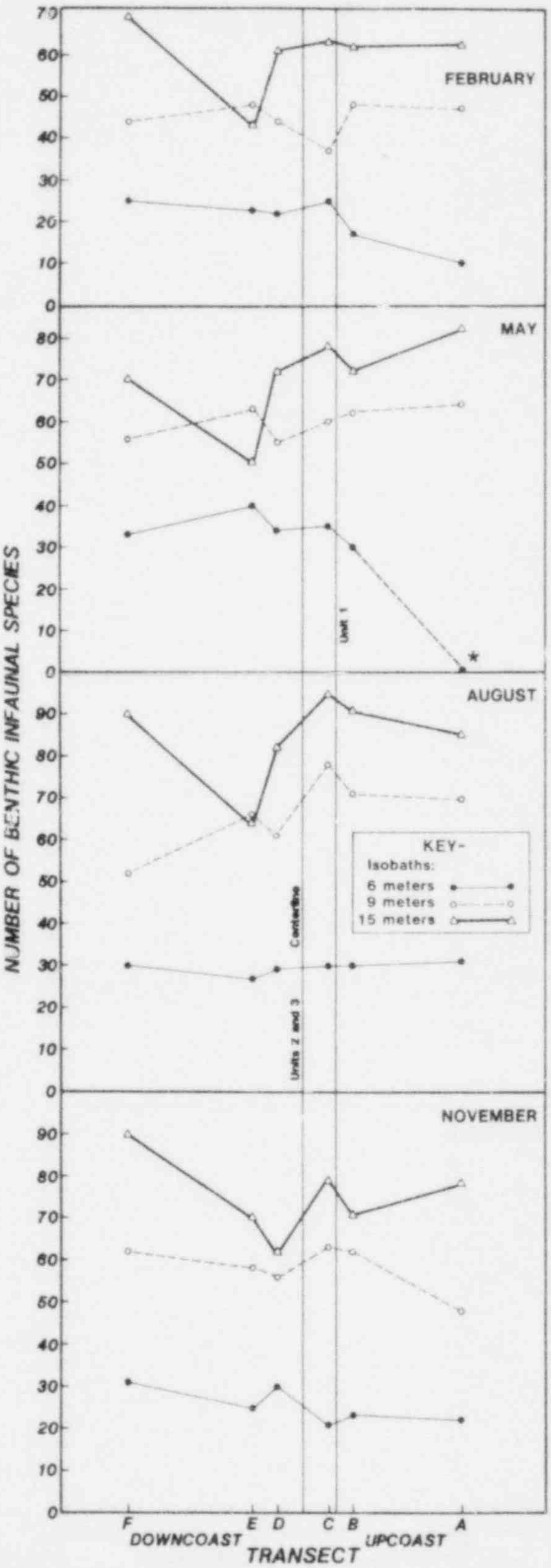

Figure 5-4. Number of benthic infaunal species found at each station during each survey period. No samples were collected at * because of rock substrate.

Table 5A-4. Mean number of benthic infauna individuals/ℓ at reference and treatment stations by survey.

Isobath	Station	Feb	May	Aug	Nov	Mean for Year
6 m	A	14	0*	81	34	43.00
	F	20	31	79	37	41.75
Reference X̄		17.00	15.50*	80.00	35.50	42.38**
	B	23	23	63	25	33.50
	C	30	37	47	7	30.25
	D	40	36	81	47	51.00
	E	24	34	73	64	48.25
Treatment X̄		29.25	32.50	66.00	35.75	40.88
9 m	A	18	33	53	24	32.[illegible]
	F	19	38	52	59	4[illegible]
Reference X̄		18.50	35.50	52.50	41.50	37.00
	B	23	33	78	62	49.00
	C	23	30	60	40	38.25
	D	19	37	68	26	37.50
	E	19	30	62	29	35.00
Treatment X̄		21.00	32.50	67.00	39.25	39.94
15 m	A	25	37	45	26	33.25
	F	41	51	36	43	42.75
Reference X̄		33.00	44.00	40.50	34.50	38.00
	B	38	53	41	21	38.25
	C	41	47	53	44	46.25
	D	48	31	43	25	36.75
	E	27	21	34	31	28.25
Treatment X̄		38.50	38.00	42.75	30.25	37.38

* No samples collected May 6 m isobath because rock substrate exposed; therefore, no benthic infauna was present.

** This mean calculated using vertical column.

38.0, respectively, for the 9 and 15 m stations. The annual mean number of individuals/ℓ at the treatment stations ranged from 40.9 at the 6 m stations to 37.4 at the 15 m stations.

The mean number of individuals/ℓ at the 6 m reference stations ranged

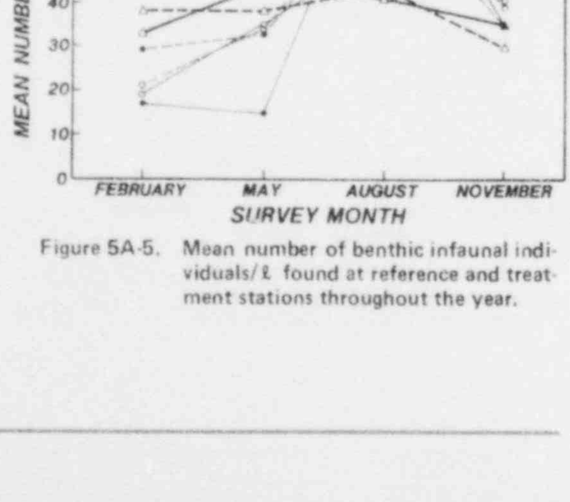

Figure 5A-5. Mean number of benthic infaunal individuals/ℓ found at reference and treatment stations throughout the year.

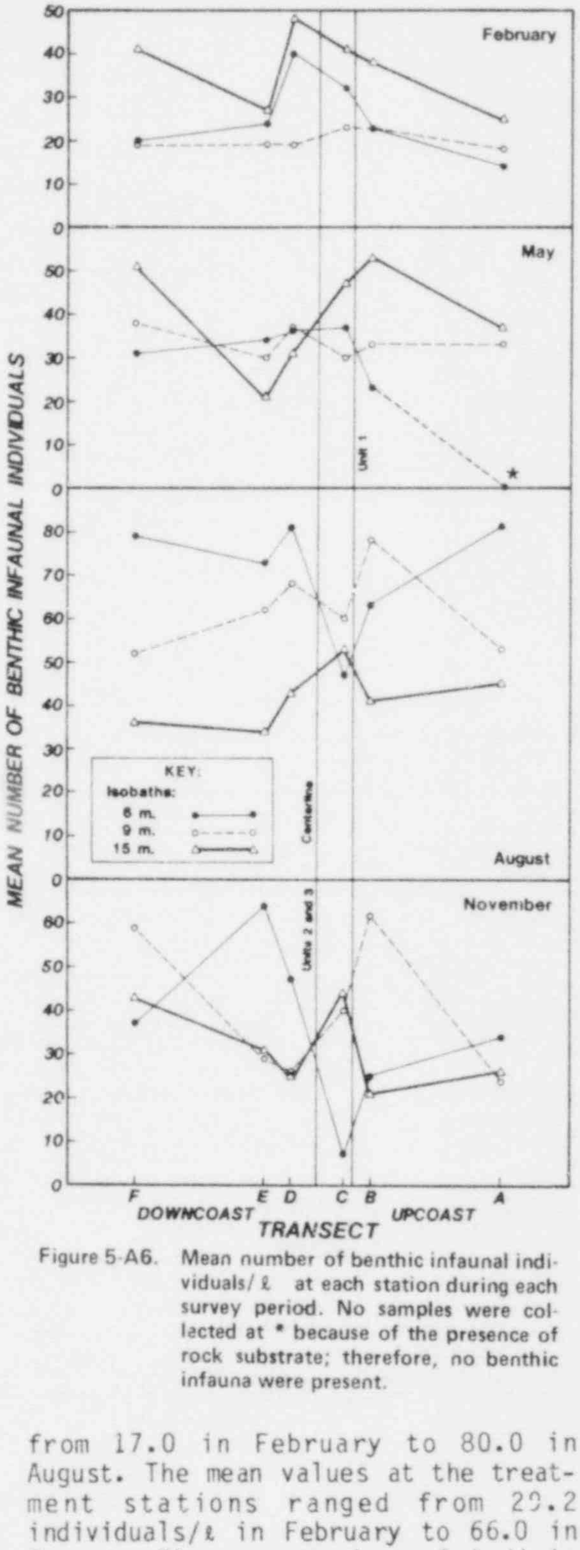

Figure 5-A6. Mean number of benthic infaunal individuals/ℓ at each station during each survey period. No samples were collected at * because of the presence of rock substrate; therefore, no benthic infauna were present.

from 17.0 in February to 80.0 in August. The mean values at the treatment stations ranged from 29.2 individuals/ℓ in February to 66.0 in August. The mean number of individuals/ℓ found at the 9 m reference stations ranged from 18.5 in February to 67.0 in August. Reference stations from the 15 m isobath contained mean numbers of individuals/ℓ in February of 33.0 and high values of 44.0 individuals/ℓ in May. The treatment station values ranged from 30.2 in November to 42.8 in August.

Table 5A-5. ANOVA test results for between stations vs. within station differences in the number of species and the number of individuals. Probability of lesser F value level of significance PR >F.

Isobath Characteristics	Survey Month Feb	May	Aug	Nov
6 m				
Number of Species	0.0732[a]	0.2589[a]	0.1484[a]	0.0001[b]
Number of Individuals	0.0611[a]	0.1909[a]	0.1955[a]	0.0016[b]
9 m				
Number of Species	0.0258[b]	0.0395[b]	0.0001[c]	0.0211[b]
Number of Individuals	0.6106[a]	0.6874[a]	0.1218[a]	0.0005[c]
15 m				
Number of Species	0.0001[c]	0.0001[c]	0.0001[c]	0.0054[b]
Number of Individuals	0.0034[b]	0.0001[c]	0.0498[b]	0.0121[b]

a = not significant
b = significant
c = highly significant

ANOVA AND DUNCAN MULTIPLE RANGE TEST RESULTS

The results of ANOVA's comparing the number of species and the number of individuals found at 6 m isobath stations for the February, May, and August surveys indicated that no significant differences existed between stations (Table 5A-5). However, significant differences in both the number of species and individuals existed when November data were compared. Duncan multiple range tests of November data revealed that Stations C and E were significantly different from most other stations, although other pair differences did exist (Table 5A-6).

Comparisons of the number of species and the number of individuals from 9 m isobath stations by ANOVA indicated that while significant differences between stations existed in the number of species during all survey periods, only the results from November for the number of individuals were significant (Table 5A-5). Duncan multiple range pair comparison showed that significant differences existed in treatment and reference stations as well as between reference and treatment station pairs (Table 5A-6).

Tests for the differences in the number of species and the number of individuals at 15 m isobath stations by ANOVA's revealed that significant differences existed between stations for these parameters during all survey periods (Table 5A-5). Pair comparisons by the Duncan multiple range test showed that Station E was significantly different from most other stations during all survey periods (Table 5A-6). In addition, several reference, treatment, and treatment/reference station comparisons were significant.

Table 5A-6. Duncan multiple range test results for significant differences between station pairs with regards to number of species and number of individuals.

Isobath Characteristic	Survey Months February	May	August	November
	Station Pairs			
6 m				
Number of Species	None	None	None	C-A, C-B, C-D, C-E C-F, A-F
Number of Individuals	None	None	None	C-A, C-D, C-E, C-F E-A, E-B, E-F
9 m				
Number of Species	C-B, F-B	F-A, F-B	A-F, B-D, B-E, B-F C-D, C-E, C-F	A-B, A-C
Number of Individuals	None	None	None	B-A, B-D, B-E, F-A, F-D, F-E
15 m				
Number of Species	E-A, E-B, E-C, E-D E-F	E-A, E-B, E-C, E-D E-F	E-A, E-B, E-C, E-D E-F	C-B, C-D, C-E, F-D F-E, F-B
Number of Individuals	A-C, A-D, A-F, E-C E-D, E-F	E-A, E-B, E-F, B-A B-D, D-C, D-F	C-E, C-F	C-A, C-B, C-D, F-B F-D, F-A

Table 5A-7. Benthic infaunal biomas (g/ℓ) by station and survey.

Isobath	Station	Feb	May	Aug	Nov	Mean for Year
6 m	A	0.08	0*	0.07	0.14	0.10
	F	0.25	0.22	0.33	0.16	0.24
Reference $\bar{X}$		0.17	0.11*	0.20	0.15	0.17**
	B	0.16	0.15	0.18	0.05	0.14
	C	0.21	0.29	0.16	0.04	0.18
	D	0.08	0.28	0.18	0.06	0.15
	E	0.10	0.16	0.09	0.05	0.10
Treatment $\bar{X}$		0.14	0.22	0.15	0.05	0.14
9 m	A	0.15	0.32	0.25	0.12	0.21
	F	0.20	0.30	0.08	0.17	0.19
Reference $\bar{X}$		0.18	0.31	0.17	0.15	0.20
	B	0.20	0.29	0.38	0.08	0.24
	C	0.21	0.23	0.21	0.21	0.22
	D	0.07	0.18	0.18	0.10	0.13
	E	0.10	0.25	0.19	0.44	0.25
Treatment $\bar{X}$		0.15	0.24	0.24	0.21	0.21
15 m	A	0.42	0.46	0.54	0.21	0.41
	F	0.40	0.46	0.38	0.78	0.51
Reference $\bar{X}$		0.41	0.46	0.46	0.50	0.46
	B	0.44	0.51	0.87	0.65	0.62
	C	0.18	0.16	0.38	0.38	0.28
	D	0.22	0.33	0.32	0.14	0.25
	E	0.18	0.36	0.30	0.48	0.33
Treatment $\bar{X}$		0.26	0.34	0.47	0.41	0.37

* No samples taken at 6m A transect in May because rock substrate exposed; therefore, no benthic infauna was present.

** This mean calculated from vertical column.

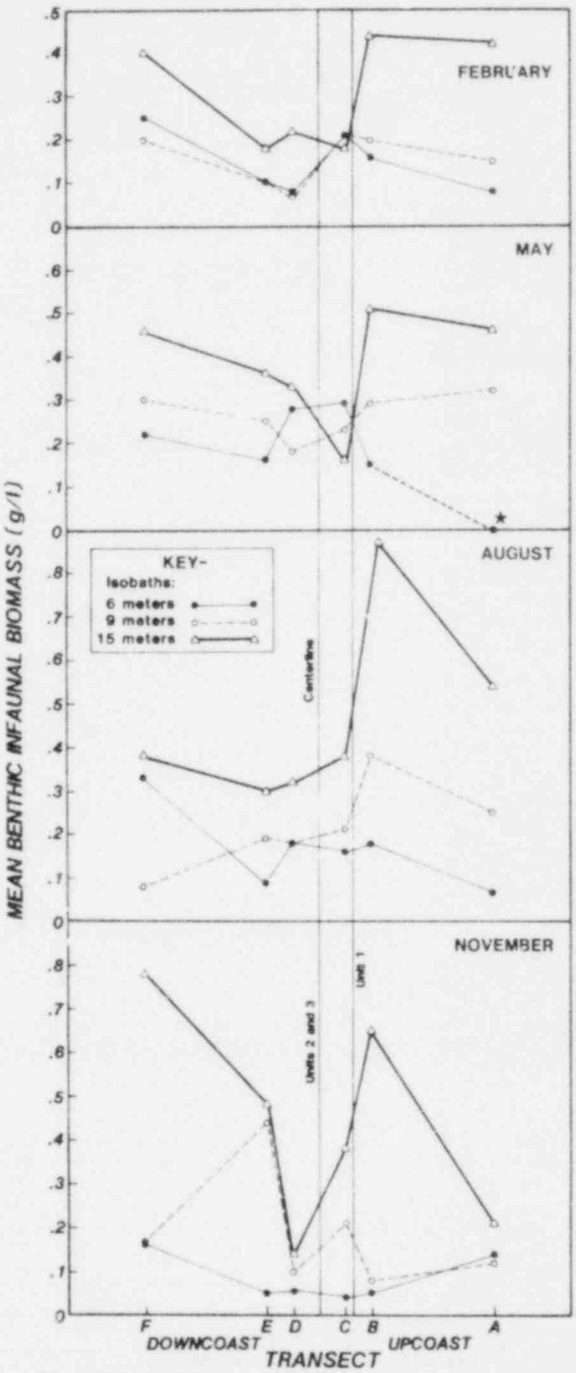

Figure 5A-7. Mean benthic infaunal biomass (g/ℓ) by station for each survey. No samples were collected at * because of the presence of rock substrate; therefore, no benthic infauna were present.

BIOMASS

During all seasons, biomass values increased with increasing depth (Table 5A-7, Figure 5A-7). Annual mean biomass values for reference and treatment stations were comparable. The annual mean biomass for the 6 m reference stations was 0.17 g/ℓ and 0.14 g/ℓ for the treatment stations. The annual mean biomass for the 9 m reference stations was 0.20 g/ℓ and 0.21 g/ℓ for treatment areas. The annual mean biomass for the 15 m reference stations was 0.46 g/ℓ and 0.37 g/ℓ for treatment stations.

Quarterly survey mean biomass values for 6 m reference stations ranged from 0.11 g/ℓ in May to 0.20 g/ℓ in August. Biomass values at 6 m treatment stations ranged from 0.05 g/ℓ in November to 0.22 g/ℓ in May. Survey mean biomass values at 9 m reference stations ranged from 0.15 g/ℓ in November to 0.31 g/ℓ in May. Biomass values for treatment stations at that isobath ranged from 0.15 g/ℓ in February to 0.24 g/ℓ in both May and August. The quarterly mean biomass values from the 15 m reference stations ranged from 0.41 g/ℓ in February to 0.50 g/ℓ in November. Values for treatment stations at 15 m ranged from 0.26 g/ℓ in February to 0.47 g/ℓ in August.

COMMUNITY TROPHIC STRUCTURE

Species collected during the four surveys were categorized according to feeding mode and food source. These categories included: 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 V).

The number of species in each feeding category increased with depth (Table 5A-8). This pattern persisted throughout the year (Figure 5A-8). With few exceptions the maximum number of species/station within each feeding category were recorded from the August collections while the lowest numbers of species were recorded in February. The mean number/station of filter feeders for the year found at the 6, 9, and 15 m isobath stations was 7.0, 13.9 and 17.0 species, respectively. The annual mean number of carnivores/station was 6.4, 15.7, and 17.7 at the 6, 9, and 15 m isobath stations, respectively. Mean annual numbers of omnivores/station were 3.0, 6.6, and 5.9 at the 6, 9, and 15 m, respectively. The annual mean number of deposit feeders/station found at the 6, 9, and 15 m isobath stations was 18.2, 36.8 and 48.9, respectively.

Table 5A-8. Annual mean number/station of benthic infaunal species by isobath and feeding mode.

Level (m)	Survey	Filter Feeder	Total Carnivore	Omnivore	Deposit Feeder
6	1 Feb.	5.33	4.00	2.33	14.83
	*2 May.	7.80	8.80	4.00	22.80
	3 Aug.	8.83	6.33	3.33	18.33
	4 Nov.	6.17	6.50	2.33	17.17
$\bar{X}$		7.03	6.41	3.00	18.28
9	1 Feb.	12.00	11.50	4.50	28.67
	2 May	14.33	17.67	5.83	38.50
	3 Aug.	15.67	18.83	9.00	41.17
	4 Nov.	13.50	14.67	7.00	38.83
$\bar{X}$		13.88	15.67	6.58	36.79
15	1 Feb.	13.00	14.00	4.83	41.00
	2 May	18.00	18.67	4.83	47.33
	3 Aug.	19.00	20.00	7.17	57.17
	4 Nov.	18.00	18.00	6.67	50.17
$\bar{X}$		17.00	17.67	5.88	48.92

*No sample taken May at A1 because of exposed rock substrate.

PATTERNS IN BENTHIC INFAUNAL COMMUNITY DISTRIBUTION

Intercommunity similarity analyses were performed separately for each survey period using classificatory techniques (Clifford and Stephenson, 1975). 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 cluster localities based on similarity of faunal composition. The inverse dendrograms cluster species with

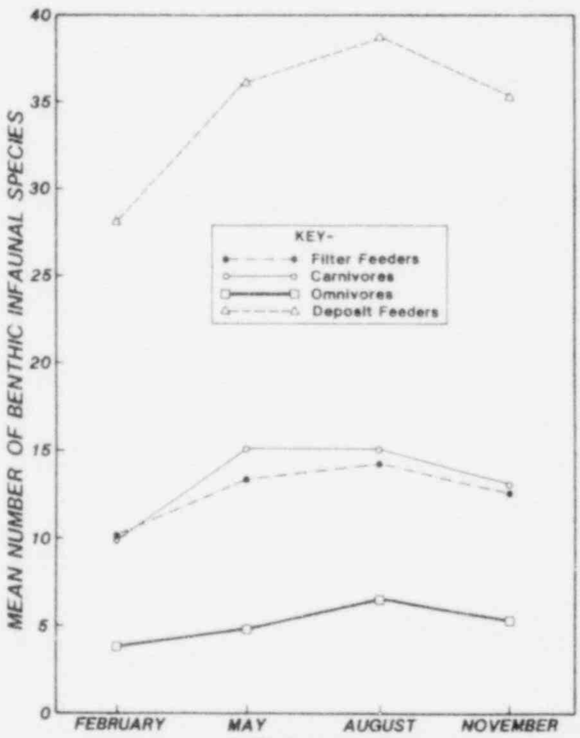

Figure 5A-8. Mean number of benthic infaunal species of each feeding type at reference and treatment stations throughout the year.

similar distribution patterns among stations. The two-way coincidence tables summarize faunal distributions with symbols (Table 5A-9) representing relative abundances based on the maximum abundance for each species.

Table 5A-9. 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 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 5A-9 through 5A-12). Species groups are similarly labeled with letters. In order to interpret the species composition of a specific group, it is necessary to refer directly to the two-way table (Figures 5A-9 through 5A-12). To find the phylum of a particular species one must reference the data report master species list (SCE 1980).

Winter Classification

The normal classification dendrogram from February contained one primary and one secondary division resulting in three groups of stations (Figure 5A-9). The primary division separated Groups 1 and 2 from Group 3. The secondary division in turn separated Groups 1 and 2 from each other. The three station groups corresponded primarily to the three isobaths sampled. Station Group 1 was composed exclusively of 15 m stations from Transects A, B, C, D, and F. Station Group 2 included all 9 m isobath stations A through F plus the 15 m isobath station from Transect E. Station Group 3 contained all 6 m isobath stations from Transects A through F.

The inverse analysis from February produced six species groups (A through F, Figure 5A-9). Species of Group A occurred at most 15 m isobath stations in high relative abundance. Some members of this group, including Sthenelais verruculosa and Eteone alba, were patchily represented at other stations in very low to high relative abundances. Species in Group B had a distribution similar to those in Group A. These species, including Nephtys cornuta franciscana, Spiochaetopterus costarum, and Hemilamprops californica, were found in medium to high abundances at most 15 m isobath stations. Low (or medium) numbers of species in Group B were inconsistently found at other stations. Species in Group E characterized the 15 m stations of Group 1 with medium to high abundances and the intermediate depth (9 m) stations in low to very low abundances. Among the species in this group were Lumbrineris tetraura, Mediomastus acutus, and Goniada littorea. Species in Group D were found primarily at the 9 m and 15 m stations of Groups 1 and 2, but were not consistently found at all stations. The relative abundance of these species varied, but was usually medium to high. Species from Group C were ubiquitous, and of variable relative abundance. These species included Rhepoxynius epistomus, Amastigos acutus, and Tellina modesta. The shallow (6 m) stations were characterized by high abundances of species from Group F, including Eohaustorius washingtonianus and Rhepoxynius bicuspidatus.

Spring Classification

The normal classification dendrogram from May exhibited one primary and one secondary division resulting in three groups of stations. The primary dendrogram division separated Groups 1 and 2 from 3. The secondary division in turn separated Groups 1 and 2 (Figure 5A-10). The station groups corresponded primarily to the isobaths sampled. A tertiary group split has been indicated within Group 2 because of the uniqueness of Station E3. Station Group 1 was composed primarily of 15 m isobath stations from Transects A, B, C, D, and F, however, the 9 m isobath station from Transect A was also included. Station Group 2 contained

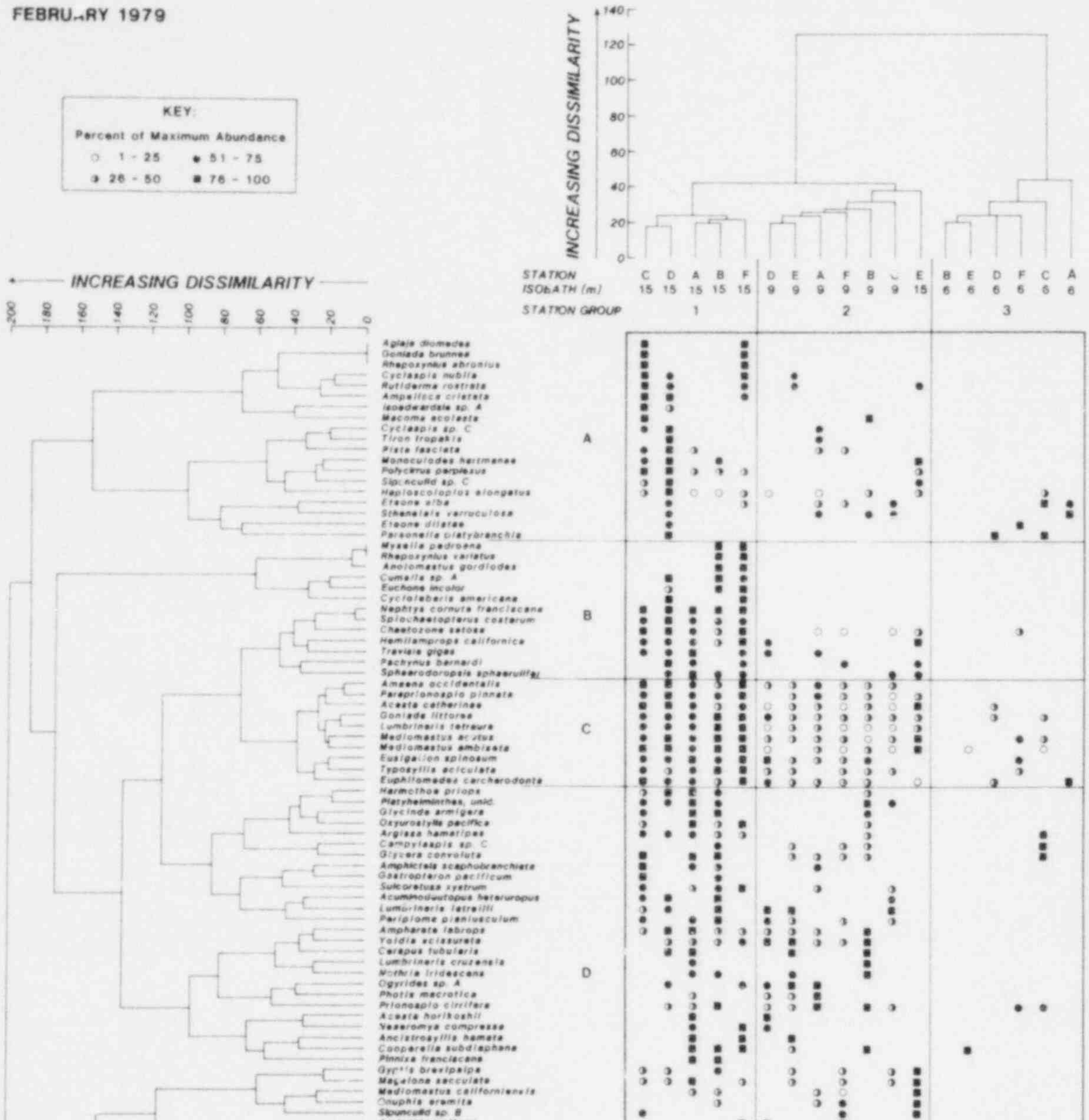

Figure 5A-9. February classification results. Normal and inverse dendrograms with resultant two-way table.

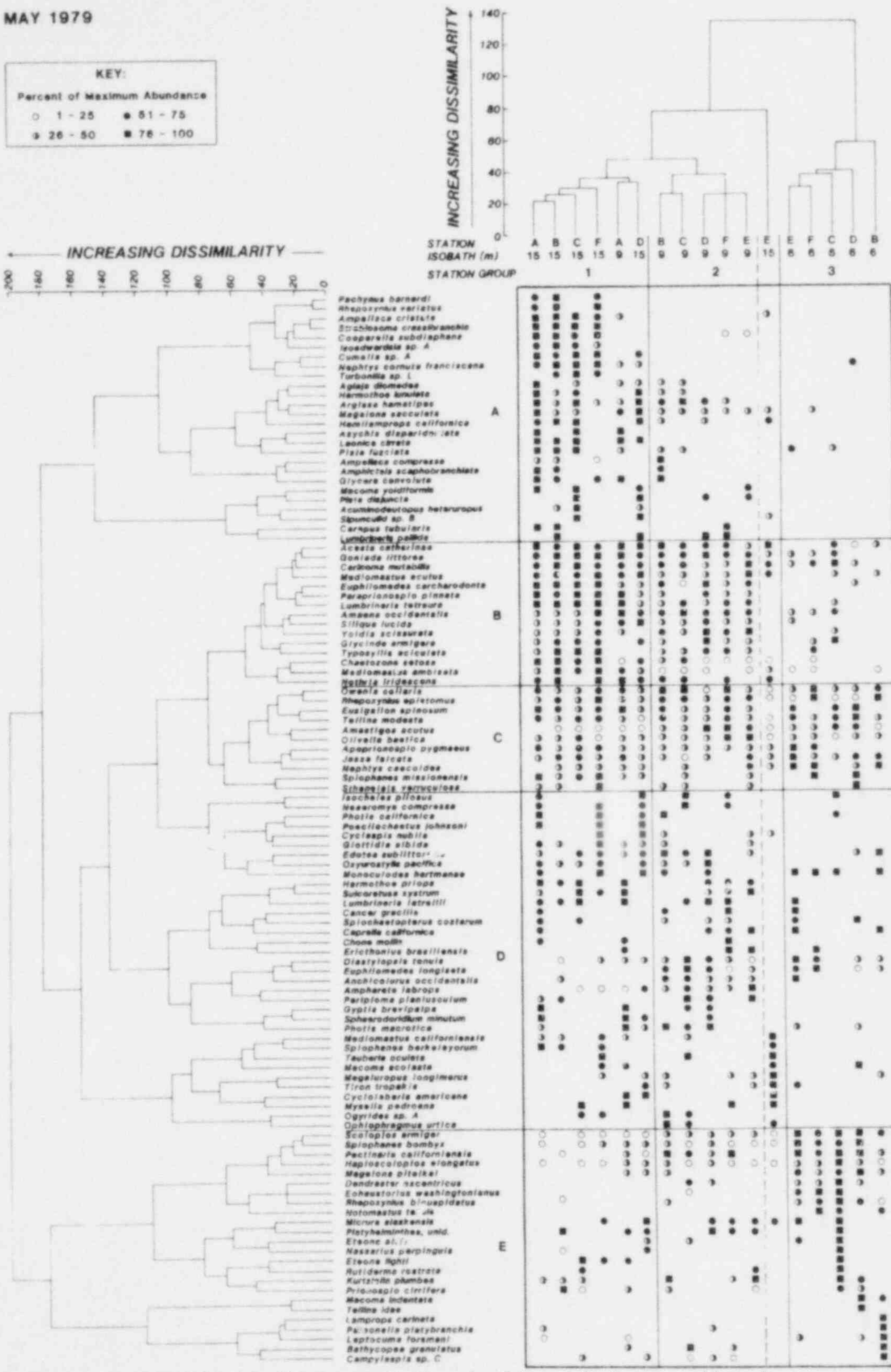

Figure 5A-10. May classification results. Normal and inverse dendrograms with resultant two-way table.

the 9 m isobath stations from Transects B, C, D, E, and F, and also the 15 m station from Transect E. Station Group 3 was composed exclusively of the 6 m isobath stations from Transects B, C, D, E, and F. Station A from this depth contour was not sampled during May because of the presence of exposed rock substrate.

The May inverse analysis contained five species groups (A through E in Figure 5A-10). A relatively high abundance of species Group A characterized station Group 1. Although a few species such as Argissa hamitipes and Mage'ona sacculata occurred at other stations, Group A species were primarily restricted to the deeper (15 m) isobath areas. Species in Group B were primarily found in relatively high abundances at stations in Groups 1 and 2. Species such as Paraprionospio pinnata, Euphilomedes carcharodonta, and Lumbrineris tetraura occurred in higher abundances at the 15 m stations than at the 9 m stations of Group 2. Some species in this group including Goniada littorea, were found at the shallower (6 m) stations, but only at low abundance. Species in Group C were found at all stations, and their relative abundance was similar at all depths. Species of this group included Tellina modesta, Amastigos acutus, and Rhepoxynius epistomus. Species of Group D were scattered among all the sites with slightly more occurrences at the 9 m and 15 m stations, however, no well-defined pattern was apparent. Site Group 3 was characterized by the high abundance of species from Group E, including Rhepoxyn: s bicuspidatus and Eohaustorius washingtonianus. Several of the species from this group also appeared at other depths, but only in low or very low abundance.

Summer Classification

The normal classification of August data resulted in the formation of three station groups conforming to the three isobaths sampled (Figure 5A-11). Station Groups 1 and 2 were separated from Group 3 by the primary dendrogram division, while Groups 1 and 2 were separated by the secondary split. Station Group 1 was composed of the 15 m isobath stations A through F. The 9 m isobath stations A through F comprised station Group 2. The shallow 6 m isobath stations A through F formed Group 3. It should be noted that Station A from the 6 m isobath was unique and split off from the remainder of Group 3 by a tertiary division.

Inverse analysis of the August data resulted in the formation of seven species groups (A through G, Figure 5A-11). Species from Group A characterized the 15 m isobath stations of Group 1, and occurred in medium to high relative abundance. Among the species from this group were Acuminodeutopus heteruropus and Euchone incolor. Species from Group B also characterized the 15 m isobath stations in relatively high abundance, but many of the species including Pista fasciata and Chaetozone setosa, were found at 9 m isobath stations of Group 2 (in lower relative abundances). Group C species were found at most 9 m and 15 m isobath stations in low to high abundance. Although a few of these species were found at the shallow 6 m stations, several species such as Mediomastus acutus and Lumbrineris tetraura were only recorded from the 9 m and 15 m stations. Although less dense and consistent at 9 m and 15 m stations, species from Group D exhibited a distributional pattern similar to those of Group C. Species from Group E were found at all stations, and included Rhepoxynius epistomus and Tellina modesta. Group F species were found in their highest relative abundance at shallow (6 m) isobath stations, although some species such as Apoprionospio pygmaeus were found at all stations. Species Group F included Eohaustorius washingtonianus and Leptocuma forsmani. Species from Group G were scattered primarily among the 9 m and 15 m isobath stations. Their inconsistent representation among the stations at any particular isobath probably accounted for their assignment to this group.

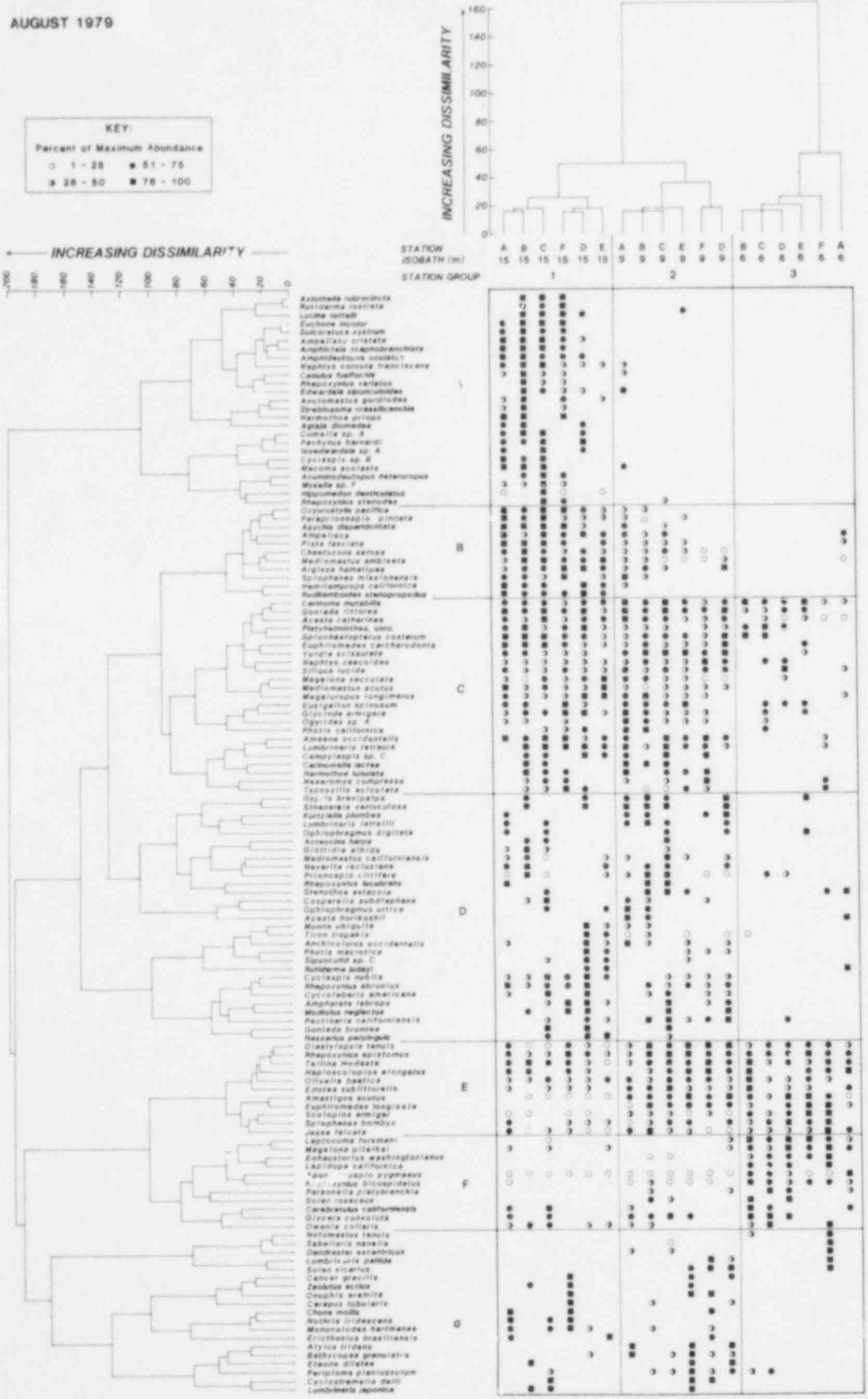

Figure 5A-11. August classification results. Normal and inverse dendrograms with resultant two-way table.

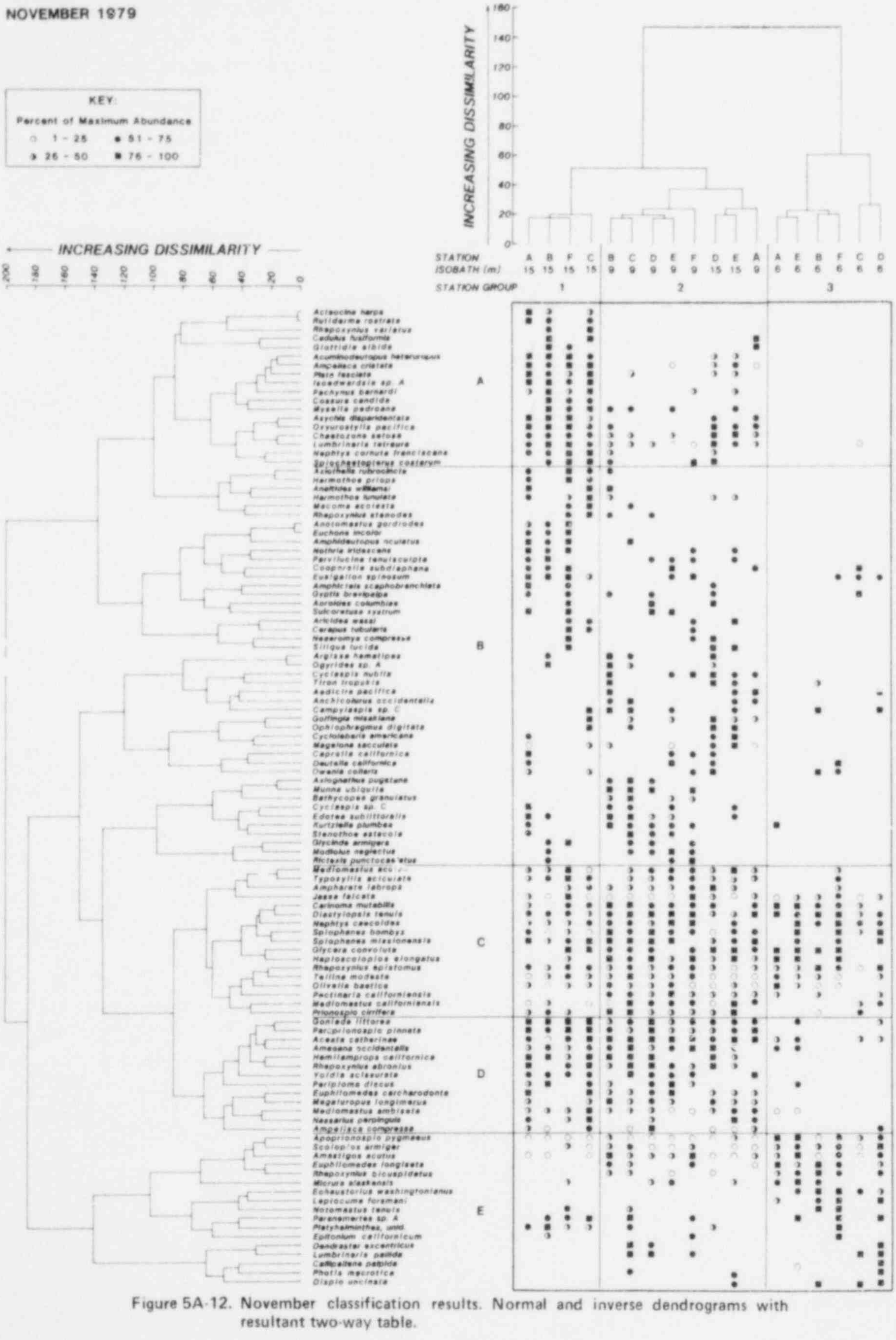

Figure 5A-12. November classification results. Normal and inverse dendrograms with resultant two-way table.

Fall Classification

The normal classification dendrogram for November exhibited one primary and one secondary division resulting in three groups of stations (Figure 5A-12). The primary division separated Groups 1 and 2 from 3. The secondary division in turn separated Group 1 from 2. Station Group 1 was composed exclusively of 15 m isobath stations including those from Transects A, B, C, and F. Station Group 2 contained all the 9 m isobath stations A through F plus the 15 m stations from Transects D and E. The 6 m isobath stations from Transects A through F were all in station Group 3.

The inverse analysis of November data produced five species groups (A through E, Figure 5A-12). Species in Group A including Acuminodeutopus heteruropus and Oxyurostylis pacifica occurred in high abundance and characterized the 15 m isobath stations of Group 1. Some species from this group were found at Group 2 stations, including the two 15 m isobath stations from Transects D and E. Species from Group B were usually found at the 9 m and 15 m isobath stations of Groups 1 and 2. Although the relative abundance of these species was medium to high, they were not consistently found at all stations within an isobath. Species from Group C were found at all stations in widely varying abundances. Included in this group were Rhepoxynius epistomus, Mediomastus acutus, and Tellina modesta. Species from Group D were primarily found at 9 m and 15 m isobath stations in medium to high relative abundance. Species included in this group were Mediomastus ambiseta and Goniada littorea. The shallow 6 m isobath stations of Group 3 were characterized by medium to high relative abundances of species from Group E. These species, including Eohaustorius washingtonianus and Rhepoxynius bicuspidatus, were found at other stations, particularly those from the 9 m isobath, but in lower relative abundance.

RELATIONSHIP BETWEEN BENTHIC INFAUNAL COMMUNITY DISTRIBUTION PATTERNS AND THE PHYSICAL-CHEMICAL ENVIRONMENT

Weighted multiple discriminant analysis was employed to identify the most important abiotic features associated with biotic distributional patterns. The variables examined in the analyses and their abbreviations are listed in Table 5A-10.

The variables considered in the discriminant analysis provided separately or in combination, food and habitat resources for the infaunal community. Single variables may have supplied combinations of resources for selected species. For example, sediment constitutes both habitat and food for deposit feeding polychaetes. The discriminant analysis produced linear combinations of abiotic variables (axes) which best separated the station groups predefined by the classification analysis. The relative importance of a variable in the formation of a discriminant axis was indicated by the magnitude of its coefficient of separate determination (Table 5A-11). The most important variables are indicated on the discriminant axes which depict group separations (Figures 5A-13a through d).

A vector diagram is presented on each discriminant figure (Figure 5A-13a through d). The vectors indicate the direction of increase for the important abiotic variables. The

Table 5A-10. Variables (and abbreviations) considered in the multiple discriminant analyses.

Variable	Abbreviation
Number of Species	H
Depth	D
Sediment Organic Carbon	TOC
Sediment Calcium Carbonate Carbon	CC
Sediment Temperature	ST
Water Clarity	WC
Sediment Flux	SF
Sediment Height	SH
Change in Sediment Height	ΔH
Sediment Factor 1	SF1
Sediment Factor 2	SF2
Sediment Factor 3	SF3
Sediment Factor 4	SF4

Table 5A-11. Coefficients of separate determination.

Abiotic Variables	Axis 1	Axis 2	Abiotic Variables	Axis 1	Axis 2
	February			August	
Sediment Factor 1	25.1	36.8	Sediment Factor 1	26.8	3.3
Sediment Factor 2	7.6	4.9	Sediment Factor 2	0.8	12.4
Sediment Factor 3	1.1	2.4	Sediment Factor 3	1.9	2.5
Sediment Factor 4	0.6	11.3	Sediment Organic Carbon	4.5	0.1
Sediment Organic Carbon	0.4	2.2	Sediment Carbonate Carbon	1.8	0.6
Sediment Calcium Carbonate Carbon	1.9	5.8	Sediment temperature	20.0	65.2
Sediment Temperature	0.6	4.0	Depth	29.5	1.3
Depth	52.9	21.4	Water clarity	1.9	8.3
Water Clarity	7.1	1.5	Sedimentation flux	12.2	0.4
Sedimentation Flux	1.3	4.4	Sediment height	0.1	0.2
Sediment Height	0.2	4.3	Change in sediment height	0.4	5.5
Change in Sediment Height	1.1	1.0			
	May			November	
Sediment Factor 1	4.8	44.7	Sediment Factor 1	5.2	5.6
Sediment Factor 2	9.4	4.3	Sediment Factor 2	1.3	7.6
Sediment Factor 4	1.9	0.2	Sediment Factor 3	0.5	21.1
Sediment Organic Carbon	4.8	21.6	Sediment Organic Carbon	3.5	3.6
Sediment Calcium Carbonate	2.2	4.9	Sediment Carbonate Carbon	6.9	5.9
Sediment Temperature	2.4	9.7	Sediment temperature	2.8	0.0
Depth	44.0	2.3	Depth	39.4	16.1
Water Clarity	19.1	3.0	Water clarity	12.7	17.2
Sedimentation Flux	11.3	7.2	Sedimentation flux	22.0	7.1
Sediment Height	0.0	0.6	Sediment height	3.6	2.0
Change in Sediment Height	0.0	1.4	Change in sediment height	2.1	13.7

correlation of sediment textural features with the sediment factor variables considered in the discriminant analyses are listed in the Factor Matrix (Table 5A-12). 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 arrow 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 structure and species distributional differences.

Two discriminant axes adequately separated the four station groups from the classification of February data (Figure 5A-13a). Axis 1 accounted for 82.1% of the between groups separation while Axis 2 accounted for 8.6% for a cumulative value of 90.7% (Table 5A-13). The dominant variables on the first axis were Sediment Factor 1 and water depth (Table 5A-11). Coarse silt, medium silt, coarse clay, fine clay, and very fine clay were all positively correlated with Sediment Factor 1, while very fine sand was negatively correlated (Table 5A-12). The dominant variables on Axis 2 were Sediment Factor 1, Sediment Factor 4 and water depth. The sediment distribution characteristics of skewness and kurtosis were highly correlated with Sediment Factor 4. Station A1 was unique during this quarter because of the large quantities of fine silts and clays located there compared to other 6 m stations. The faunal differences reflected in the station groupings were in part explained by the differences in the dominant physical/chemical factors. The vector diagram on Figure 5A-13a illustrates that the number of species increased with increasing depth, with the quantity of finer sediments (silts and clays), and with the degree of skewness, leptokurtosis of the sediments (finer sediments dominating). The opposite of these patterns was noted at the 6 m isobath stations (Group 3) with fine sands becoming important in the shallower water. The 9 m isobath stations were in an intermediate position on this gradient of abiotic variables.

Two discriminant axes separated the three station groups from the classification analysis of May data (Figure 5A-13b). Axis 1 accounted for 69.2% of the between group separation variance while Axis 2 accounted for an additional 16.6% for a cumulative total of 85.8% (Table 5A-13). The dominant abiotic features on

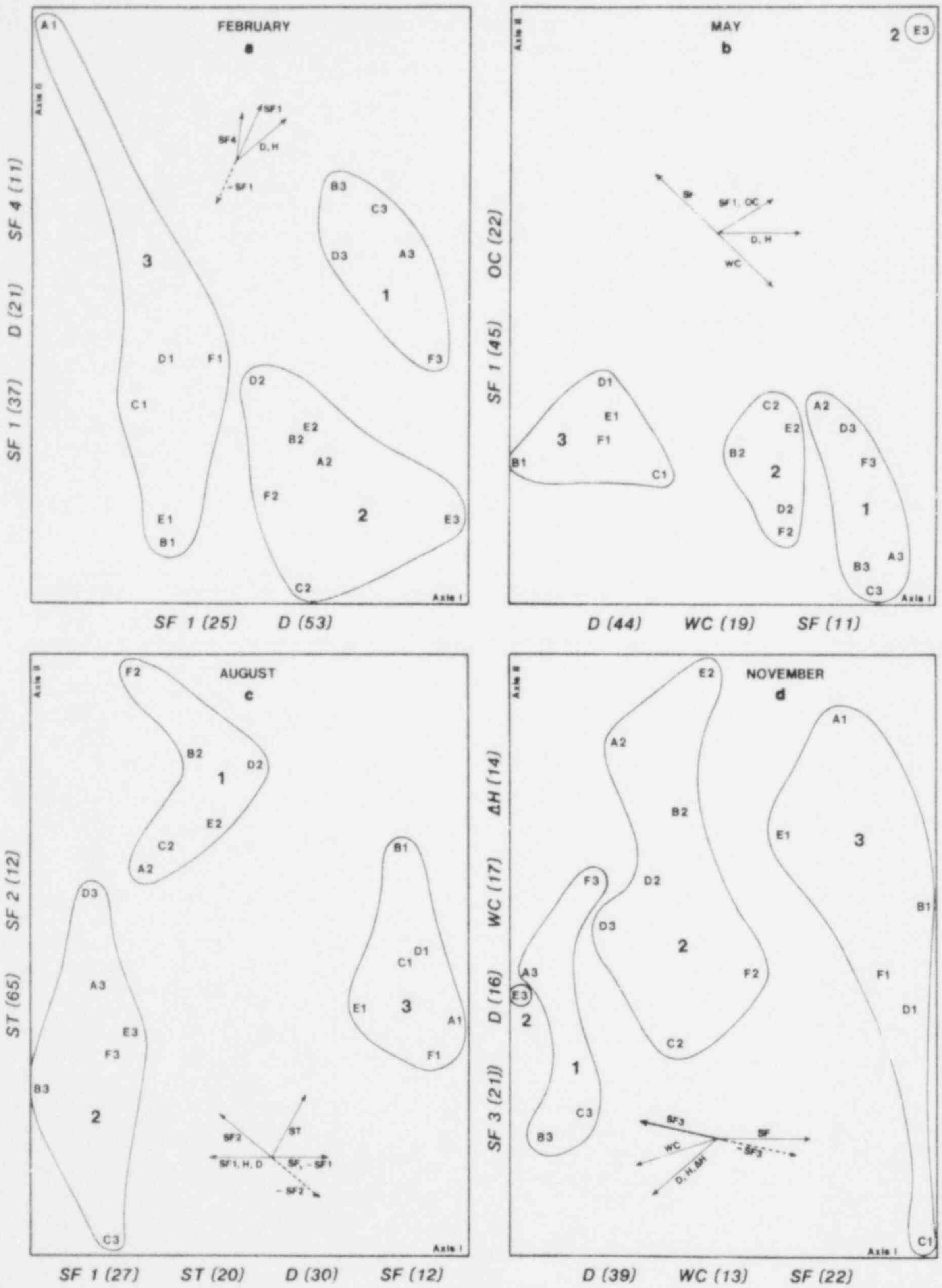

Figure 5A-13. Discriminant analysis axes illustrating station group separation and relationship to physical/chemical environment of features. (See results text Relationship Between Benthic Infaunal Community Distribution Patterns and the Physical-Chemical Environment, and Table 5A-8.)

Table 5A-12. Sediment factors derived from principal components analysis with varimax rotation. Underlined values represent high correlations with the sediment factor.

Sediment Characteristics	Phi Size	Sediment Factors 1	2	3	4	Sediment Characteristics	Phi Size	Sediment Factors 1	2	3	4
		February						August			
Very coarse sand	-1< 0	0.14	0.97	-0.06	-0.07	Very coarse sand	-1< 0	-0.05	0.43	0.05	
Coa-se sand	0< 1	0.14	0.96	-0.03	-0.15	Coarse sand	0< 1	0.58	0.50	0.42	
Medium sand	1< 2	0.17	0.71	-0.02	-0.58	Medium sand	1< 2	0.49	0.75	0.33	
Fine sand	2< 3	-0.20	0.04	-0.01	-0.23	Fine sand	2< 3	-0.54	0.56	0.16	
Very fine sand	3< 4	-0.84	-0.35	-0.07	0.19	Very fine sand	3< 4	-0.85	-0.16	0.32	
Coarse silt	4< 5	0.77	-0.05	0.07	0.07	Coarse silt	4< 5	0.84	-0.20	-0.41	
Medium silt	5< 6	0.82	0.19	0.08	0.18	Medium silt	5< 6	0.79	-0.21	-0.44	
Fine silt	6< 7	0.39	0.68	0.24	0.01	Fine silt	6< 7	0.47	-0.08	-0.20	
Very fine silt	7< 8	-0.09	0.03	0.96	0.06	Very fine silt	7< 8	0.57	-0.34	-0.23	
Coarse clay	8< 9	0.75	0.44	0.14	0.10	Coarse clay	8< 9	0.05	-0.67	0.23	
Medium clay	9<10	0.17	-0.02	0.26	-0.01	Medium clay	9<10	0.73	-0.26	0.09	
Fine clay	10<11	0.83	0.10	-0.19	0.22	Fine clay	10<11	0.15	-0.70	0.29	
Very fine clay	11<12	0.46	-0.08	-0.02	0.27	Very fine clay	11<12	0.69	-0.01	0.48	
Very fine clay	12<13	0.80	0.06	-0.29	0.31	Very fine clay	12<13	0.30	-0.43	0.45	
Very fine clay	13<14	0.49	-0.01	-0.23	0.33	Very fine clay	13<14	0.40	-0.01	0.61	
Very fine clay	14<15	0.74	0.13	-0.32	0.34	Very fine clay	14<15	0.37	-0.35	0.53	
Sediment Mean phi	-	0.59	-0.40	0.06	0.38	Sediment Mean phi	-	0.73	-0.54	-0.37	
Sediment sorting	-	0.78	0.43	-0.02	-0.07	Sediment sorting	-	0.82	-0.00	0.31	
Sediment skewness	-	0.27	-0.08	0.01	0.90	Sediment skewness	-	-0.52	-0.75	0.14	
Sediment kurtosis	-	0.14	-0.15	0.06	0.92	Sediment kurtosis	-	-0.58	-0.69	0.18	
Sharp & Fan sorting	-	-0.63	-0.38	-0.05	+0.56	Sharp & Fan sorting	-	-0.85	-0.35	-0.05	
		May						November			
Very coarse sand	-1< 0	0.97	-0.05	-0.21	-0.04						
Coarse sand	0< 1	0.94	0.07	-0.26	-0.01	Coarse sand	0< 1	0.49	0.07	-0.23	-0.22
Medium sand	1< 2	0.80	0.19	-0.42	-0.02	Medium sanu	1< 2	0.55	0.08	-0.63	-0.34
Fine sand	2< 3	0.01	0.84	-0.27	-0.06	Fine sand	2< 3	0.26	0.12	-0.89	0.11
Very fine sand	3< 4	-0.50	0.51	0.40	-0.11	Very fine sand	3< 4	-0.60	-0.10	0.09	0.21
Coar:e silt	4< 5	0.07	-0.95	-0.12	0.11	Coarse silt	4< 5	0.23	0.06	0.66	-0.14
Medium silt	5< 6	0.75	-0.37	-0.22	0.37	Medium silt	5< 6	0.70	-0.27	0.49	-0.25
Fine silt	6< 7	0.76	-0.29	0.07	-0.42	Fine silt	6< 7	0.09	0.23	0.05	0.85
Very fine silt	7< 8	0.29	-0.41	-0.04	0.77	Very fine silt	7< 8	0.61	0.24	0.26	-0.67
Coarse clay	8< 9	0.86	-0.18	0.16	-0.28	Coarse clay	8< 9	-0.13	-0.01	-0.05	0.28
Medium clay	9<10	-0.28	-0.15	0.27	0.89	Medium clay	9<10	0.44	0.07	0.20	-0.84
Fine clay	10<11	0.98	-0.04	-0.10	-0.08	Fine clay	10<11	-0.17	-0.81	0.08	-0.06
Very fine clay	11<12	0.80	-0.12	-0.07	0.54	Very fine clay	11<12	0.20	-0.21	0.02	-0.90
Very fine clay	12<13	0.97	-0.05	-0.22	-0.02	Very fine clay	12<13	-0.01	-0.97	0.10	-0.13
Very fine clay	13<14	0.92	-0.08	-0.18	0.29	Very fine clay	13<14	0.08	-0.73	0.08	-0.58
Very fine clay	14<15	0.97	-0.05	-0.21	-0.04	Very fine clay	14<15	0.01	-0.96	0.07	0.04
Sediment Mean phi	-	0.03	-0.97	0.11	0.21	Sediment Mean phi	-	-0.03	-0.12	0.99	-0.06
Sediment sorting	-	0.90	0.03	-0.14	0.23	Sediment sorting	-	0.67	-0.17	-0.28	-0.59
Sediment skewness	-	-0.16	-0.08	0.96	0.13	Sediment skewness	-	-0.92	-0.07	0.10	0.03
Sediment kurtosis	-	-0.25	-0.05	-0.75	0.02	Sediment kurtosis	-	-0.98	-0.00	0.09	0.09
Sharp & Fan sorting	-	-0.62	-0.18	0.45	-0.28	Sharp & Fan sorting	-	-0.84	-0.07	0.23	0.25

the first axis were water depth, water clarity, and sediment flux (Table 5A-11). Axis 2 was dominated by Sediment Factor 1 and sediment organic carbon content. Sediment Factor 1 primarily reflects the highly correlated sediment size variables of medium and fine silt, coarse clay, fine and very fine clay, as well as very coarse, coarse, and medium sand. The bimodality of Sediment Factor 1 was principally influenced by Station E3 which apparently had a fine layer of clays relict deposits containing coarse sands. The vector diagram showed that the number of species increased with increased water depth, greater water clarity, increased sediment organic carbon, and finer sediments. Lower sedimentation in terms of sediment flux was also associated with higher species numbers.

Two discriminant axes separated the three station groups derived from the classification analysis of August data (Figure 5A-13c). Axis 1 acccunted for 86.1% of the between group separation while Axis 2 added another 6.10% for a total of 92.2% of the variance (Table 5A-13). The most important variables on the first axis were Sediment Factor 1, sediment temperature, and sedimentation flux. Sediment Factor 1 represented the highly correlated variables of coarse silt, medium silt, coarse, fine, and very fine clay (Table 5A-12). Fine sand was negatively correlated with Sediment Factor 1. Sediments at stations with high

Table 5A-13. Amount of between group separation accounted for by each discriminant axis.

Survey	Axis	Cumulative Percent of Variance
February	1	82.1
	2	90.7
May	1	69.2
	2	85.C
August	1	86.1
	2	92.2
November	1	76.2
	2	85.3

values of sediment Factor 1 were also usually poorly sorted (i.e. contained a wide range of sediment sizes). Axis 2 was dominated by the abiotic variables of Sediment Factor 2 plus sediment temperature. Sediment Factor 2 represented the highly correlated sediment feature of medium sand and the negatively correlated characteristics of coarse and fine clay, skewness, and kurtosis. The vector diagram illustrates that increased numbers of species are associated with increased water depth, skewed leptokurtotic sediment regimes containing greater quantities of fine sediments (particularly silts and clays), and lower sediment temperatures. These features are all associated with the deeper 9 m and 15 m isobath stations. Lower numbers of species were associated with the sandier, warmer sediments of the inshore 6 m stations.

Two discriminant axes adequately separated the three major station groups defined by the classification of the November survey data (Figure 5A-13d). Axis 1 accounted for 76.2% of the between group separation while Axis 2 added another 9.1% for a total of 85.3% (Table 5A-13). It should be noted that Station E3 from the 15 m isobath closely resemble. the remainder of the 15 m stations with respect to the dominant environmental variables of Axes 1 and 2 and, therefore, clustered close to these stations in discriminant space. However, biologically the community at Station E3 more closely resembled those 9 m isobath stations grouped in station Group 2 (Figure 5A-12). The most important environmental variables of the first axis were water depth, water clarity, and sedimentation flux. Axis 2 was dominated by Sediment Factor 3, depth, water clarity, and change in sediment height (Table 5A-11). Mean phi was positively correlated with Sediment Factor 3 while medium sand was negatively correlated with this factor (Table 5A-10). The vector diagram (Figure 5A-13d) illustrates that greater numbers of species were associated with deeper water, increased water clarity, and sediments which were finer (indicated by high mean phi). The shallower 6 m isobath stations of Group 3 supported lower species numbers. These stations had decreased water clarity, coarser sediments (including a predominance of medium sand) and greater sedimentation flux.

DISCUSSION

NUMBER OF SPECIES, INDIVIDUALS, AND BIOMASS OF THE BENTHIC INFAUNAL COMMUNITY

The number of species, number of individuals, and biomass are interrelated community parameters. These features were examined at SONGS quarterly on a station by station basis during 1979. (See Table 5A-14 for station depth abbreviations). The survey grid encompassed both reference and treatment areas and provided a framework within which construction and/or operation induced changes in these features could be assessed.

The number of species was used in assessing diversity, in preference to an index (e.g. Shannon-Weiner index), since it does not imply ecological importance based on species abundance and can incorporate encrusting and colonial organisms (Cody 1974, Hurlbert 1971, Pianka 1966). The species numbers provided a biologically meaningful basis for interpreting diversity differences between areas since the presence of a species implied its occupation of a multidimensional

Table 5A-14. Station depth abbreviations.

Depth	Transects					
6 m	A1	B1	C1	D1	E1	F1
9 m	A2	B2	C2	D2	E2	F2
15 m	A3	B3	C3	D3	E3	F3

niche (Hutchinson 1957). An area with greater species diversity reflected more efficient use of available niches and/or an area with a greater number of niche resources.

The dominant biotic pattern, which was not modified by construction of Units 2 and 3 or operation of Unit 1, was the increase in the number of species with depth. This pattern was evident throughout 1979 (Figures 5A-3 and 5A-4), and followed the results of 1978 (SCE 1979). This pattern is characteristic of exposed open coast environments such as SONGS (Lie and Kisker 1970, Diener and Parr 1977).

The mean number of species at reference and treatment stations was very similar throughout the year (Figure 5A-3). However, there were two notable exceptions to this general trend. Station A1 in May supported no infauna. The absence of suitable soft substrate was responsible for this, since substantial erosion at this station prior to the May survey resulted in the exposure of underlying cobble. This change was assumed to be a result of natural forces, since Transect A is removed from SONGS influences. Total elimination and recovery of the infaunal community within a six-month period emphasized both the high natural variability of the habitat, and the ability of the community to rapidly recover after massive perturbation.

A second departure from generalities occurred at Station, E3. Throughout 1979 this station supported lower numbers of species than other 15 m station. This could not be attributed directly to construction or operation effects, and there is evidence (discussed in detail in Relationship of Community Patterns to Physical/ Chemical Environment) that natural substrate alterations influenced the observed biological changes.

A pronounced seasonal pattern of change in the number of species was apparent at all depths (Figure 5A-3). The greatest number of species was found at the 6 m stations during May following seasonal lows in February. These results were similar to those of 1978 (SCE 1979), however, the magnitude of seasonal variation noted during 1978 was small. Seasonal highs in the number of species found at the 9 and 15 m isobaths occurred in August, with values declining slightly in November. Although a similar pattern was noted in 1978 (SCE 1979:) species numbers remained fairly high through November of that year.

The number of species are displayed by station in Figure 5A-4. Patterns of species diversity revealed by each quarterly survey were well defined by a summary graph for the entire year (Figure 5A-14b). The increase in species diversity with depth was again illustrated by these data. The patterns of enhancement and depression of species numbers upcoast and downcoast of Units 2 and 3 and the discharge of Unit 1 recorded during 1978 (SCE 1979) were still evident, though less distinct. The 6 m treatment stations displayed slightly elevated annual mean species numbers. The number of species at Station C1 was elevated as in 1978, but Station D1, which in 1978 supported depressed numbers of species, exceeded the reference stations in species numbers during 1979.

The elevated numbers of species in 1978 at Station C2 (SCE 1979) did not recur in 1979, although the depressed count at Station D2 did. Slightly elevated species numbers were noted for Station C3, while depressed species numbers were noted at Stations D3 and E3. (Explanations for these observations are advanced in subsequent paragraphs.)

The mean number of individuals/ℓ recorded by depth during the quarterly surveys is shown in in Figure 5A-5. As with the patterns noted for species diversity, trends in the annual mean number of individuals/ℓ were fairly consistent between stations on the same isobath. Reference and treatment stations generally contained similar annual mean numbers of individuals/ℓ, suggesting limited effects from construction or operation. Peak seasonal abundance occurred in August, and was particularly evident at the 6 and 9 m isobath stations. In the month of peak abundance, August, high numbers of individuals/ℓ were recorded at the 6 m stations, while the lowest numbers of individuals/ℓ were found at the 15 m stations.

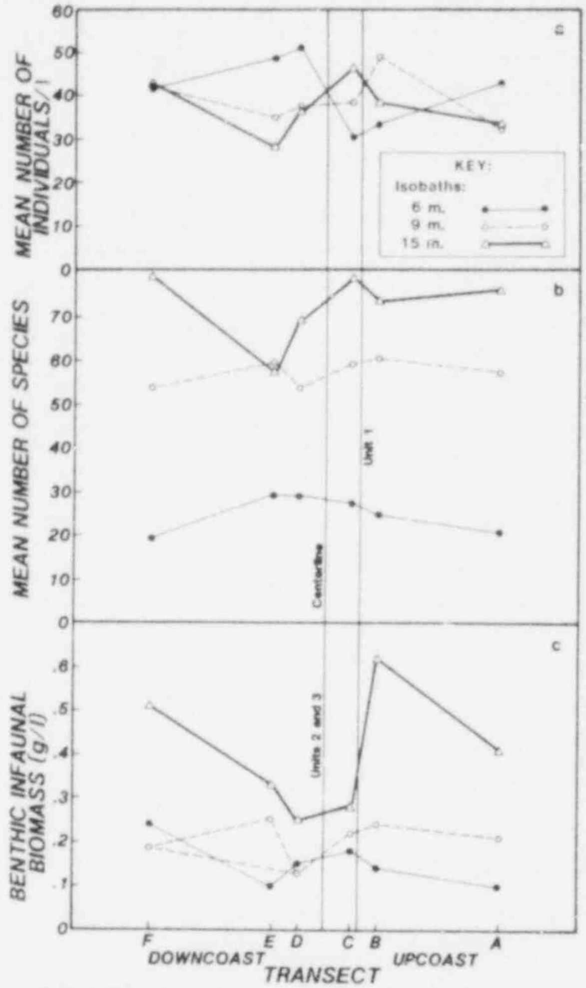

Figure 5A-14. Summary graphs for entire year illustrating a) number of individuals, b) number of species, and c) biomass of benthic infaunal species from each station.

Annual mean number of individuals/ℓ for each station (Figure 5A-14a) reflected a pattern of enhancement and depression similar to that observed for numbers of species. Treatment stations on the 9 and 15 m isobaths upcoast of the dredgeline supported elevated numbers of individuals/ℓ compared to reference stations, while lower values were noted downcoast of the centerline of Units 2 and 3. This pattern was reversed at the 6 m treatment stations.

Station differences in the number of species and the number of individuals, which produced the enhancement /depression patterns illustrated in Figure 5A-14, were tested for statistical significance. Not all station pair comparisons were statistically different, however, many pair comparisons for selected depths and survey periods were (Table 5A-5 and 5A-6). The pairwise comparison results suggest that the observed patterns of enhancement/depression of species numbers and individuals are real and not sampling artifacts.

Total benthic infaunal biomass (g/ℓ) at each station was plotted by survey (Figure 5A-7) and presented graphically for the entire year in Figure 5A-14c. These patterns depicted paralleled those shown for species diversity. Biomass increased with depth, and a similar pattern of elevation and depression upcoast and downcoast of the dredgeline was evident.

The three community parameters discussed above are interdependent and strong similarities in their distributional patterns were expected. There was a strong relationship between biotic patterns and sediment patterns (see Chapter 2D, Sedimentology). Biotically correlated environmental features were; change in sea floor elevation, sediment flux, and sediment organic carbon content (Appendix V). Natural longshore sediment transport processes appear to have been modified by the presence of the construction related laydown pad and trestles, and the pipeline emplacement. The result was net accretion of sediments upcoast and adjacent to the construction activities, and erosion with inhibited replacement downcoast of this area. Thus, the enhancement and depression patterns previously noted, resulted from substrate modification associated with construction activities. It is anticipated that these effects will not persist after the barriers to normal longshore transport have been removed. The slightly elevated level of organic carbon in the sediments at treatment stations upcoast of the dredgeline and near the Unit 1 discharge appear to be related to Unit 1 operation. They may have resulted from the expulsion of debris following heat treatment as suggested by Diener and Parr (1977), or come from the deposition of other debris carried by the thermal discharge plume of Unit 1.

The patterns reflected by the number of individuals/ℓ may in part represent species life history adaptations to the environment off SONGS. Dynamic environments of low predictability generally favor species with opportunistic life history attributes (Grassle and Grassle 1974). Such attributes typically include rapid growth and colonization rate, high reproductive and mortality rates, high population density and production, small individual size and biomass, and low standing crop (Grassle and Grassle 1974, Pianka 1970, Sameoto 1968). Such species have populations whose density is subject to rapid fluctuation, and which often suffer local extinction. The majority of the species occupying the inshore (6 m) stations (which exhibited high substrate dynamism) would be considered opportunists. This may account for the increased numbers of individuals/ℓ without corresponding biomass changes and the decrease in numbers proceeding offshore to more stable substrate conditions.

Additional factors associated with substrate stability can influence observed biotic patterns by affecting larval recruitment. Many species colonize from meroplanktonic recruits transported into the SONGS area by currents and water masses. Substrate selection by recruits is dependent on many factors including sediment texture (Crisp and Ryland 1960), substrate surface contour (Crisp and Barnes 1954), and current strength and turbulence near the substrate (Crisp 1955, Crisp and Meadows 1963). All of these factors were influenced by the construction-modified local patterns of accretion and erosion as well as operation of Unit 1.

COMMUNITY TROPHIC STRUCTURE

Benthic infaunal communities depend on a variety of energy sources including plankton, sediment organics, suspended terrestrial and aquatic detritus, and localized detrital drift. Although none of the species collected during the subtidal infaunal sampling directly utilized the sun as an energy source (primary production), all were ultimately dependent on the organic materials manufactured by primary producers.

Species diversity increased through the year reaching maximum levels in August (Figure 5A-3). This pattern of increase was reflected in the numbers of species in each feeding type, with the exception of carnivores whose maximum numbers were observed in May (Figure 5A-8). The deposit feeding species exhibited the largest numerical increase (10 species); a rise of 36% (Appendix V). Carnivorous and filter feeding species each increased by 5 species, or 50% above their lowest mean numbers. The largest percentage increase within a trophic group occurred with omnivorous species which increased 75% from a mean low of 3.9 species/ℓ in February to 6.5 species/ℓ in August. These results suggest that the community underwent a seasonal growth cycle similar to that noted in 1978 (SCE 1979). The differing rates of change between trophic types indicated a community trophic shift. This shift may be a response to changes in the availability of food resources during the year, or simply reflect the change in community composition resulting from habitat modification by hydrographic seasons (i.e. the relative calm of summer conditions versus winter storms).

The mean number of deposit feeding species increased with depth (Figure 5A-15). 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 organic food sources, in deeper water sediments (Newell 1972). The enhancement/depression pattern described earlier for the total species number was only pronounced for deposit feeders at the 15m treatment stations. However, a slight depression in species number was also noted at Station D2. The elevated number of species found at Station C3 could be related to elevated organic levels observed at this station, and presumed to have originated at the Unit 1 discharge. Depressed species numbers at both 9 and 15 m stations downcoast of the dredgeline appear to be related to modification of sediment regimes by construction structures rather than discharge of dredge spoil.

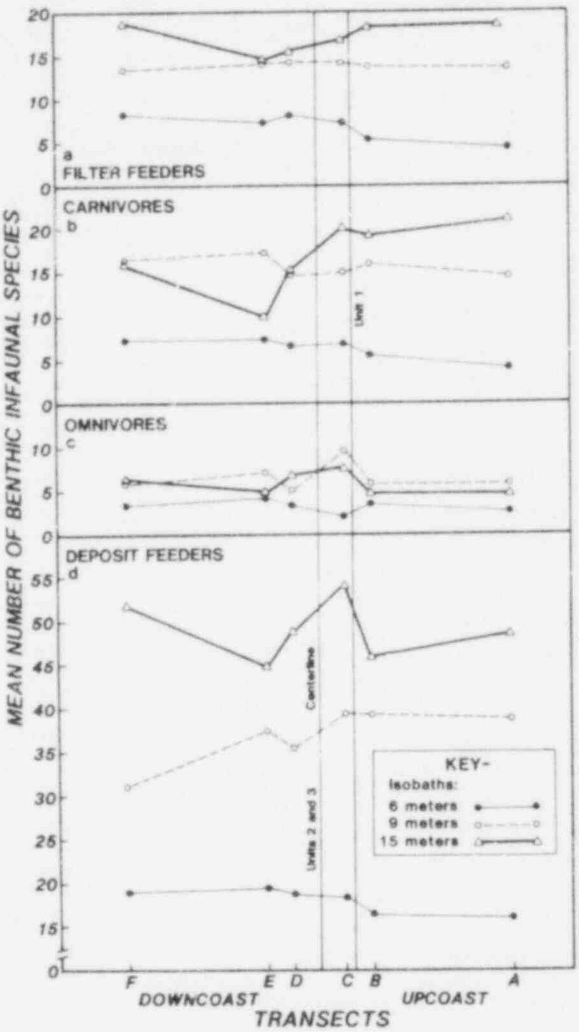

Figure 5A-15. Summary for entire year by station of the number of benthic species of each feeding type.

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 5A-15a). The consistency of this pattern between years suggests that this pattern is characteristic of the SONGS area and contrasts to that found on the east coast of the United States. Filter feeding species as a group have been described as characteristic of sandy substrates (Sanders 1968; Rhoads and Young 1970). However, the number of species found in offshore silt-clay dominated sediments near SONGS exceeded those found in the inshore sandy sediments. The number of filter feeding species exhibited little evidence of the enhancement/depression pattern observed for the number of species occurring upcoast and downcoast of the dredgeline. (A slight depression in the number of species at stations downcoast of the dredgeline in 15m of water was apparent (Figure 5A-15a). Since filter feeding species depend on the substrate solely for habitat and not food, these results support the hypothesis advanced to explain the elevated numbers of deposit feeders at Stations C2 and C3. That is, increased species numbers occurred in response to elevated food resources supplied by detrital outfall from the Unit 1 discharge.

The mean number of carnivorous species found at each station increased with depth (Figure 5A-6). A notable exception was Station E3 which yielded significantly lower numbers of carnivorous species. No simple explanation for this is apparent; however, Station E3 differed greatly from all others in community composition during several seasonal surveys. Its uniqueness, along with possible explanations, are discussed in the next two sections (Patterns in Benthic Infaunal Community Distribution, Relationship Between Community

Distribution Patterns and the Physical/ Chemical Environment). The pattern of enhancement/depression of species numbers was not well defined with respect to numbers of carnivorous species.

Few omnivorous species occurred in the benthic infaunal samples (Figure 5A-15c). The pattern of enhancement/depression of species numbers upcoast and downcoast of the Units 2 and 3 construction activities and Unit 1 operation was evident in the distributional patterns of omnivores. This was particularly true at the 9 m treatment stations, which displayed a well defined pattern.

Patterns in Benthic Infaunal Community Distribution

Classification analysis of benthic infaunal data revealed several types of community distributional patterns. They were: 1) clusters of stations whose communities varied along a depth gradient, 2) individual stations within the 9 and 15 m isobaths which clustered with stations from other depths due to faunal differences, 3) groups of species whose distribution and highest abundance characterized specific isobaths, and 4) presence of several ubiquitous species. All patterns (except 2) persisted throughout the year and were similar to the results from 1978 (SCE 1979).

Normal analyses of data from all four surveys revealed a distinct onshore-offshore pattern of station similarity which corresponded to the depth gradient (Figures 5A-9 through 5A-12). The results indicated that most stations on an isobath (both reference and treatment stations) had similar faunal assemblages throughout the year.

Communities at the 9 and 15 m stations were more similar to each other than either was to the inshore 6 m station biota. This was apparent from the dendrogram which showed a primary dichotomy betwen the 6 m stations and the 9 and 15 m stations. Further, the secondary dichotomy between 9 and 15 m station groups occurred at a much lower level of dissimilarity than the primary dichotomy (Figures 5A-9 through 5A-12).

An important feature of the station classification dendrograms was the high internal consistency within a station group, (i.e. close similarity of the stations with respect to community composition). Also, there was a 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 above. These results suggest that communities within an isobath, while varying occasionally, displayed a high degree of internal consistency in the presence and abundance of dominant community members.

No benthic infaunal samples were collected from Station A1 (Table 5A-14) during the May survey since only rock substrate remained after storm erosion of the sediments. In August, when Station A1 was revisited, a new community had developed which was similar to others found at the 6 m depth. However, as suggested by the tertiary division in the classification analysis (Figure 5A-11) the community still differed somewhat from others at the 6 m isobath. Total species numbers were very close but composition and abundance differences set Station A1 apart. In particular, the high abundance of the polychates Notomastus tenuis, Sabellaria nanella, and Lumbrineris pallida, the razor clam Solen sicarius and the sand dollar Dendraster excentricus were responsible for the observed differences since no other 6 m stations supported these species. This species assemblage may represent a successional community stage, since the species composition at Station A1 had apparently equilibrated by the November survey (Figure 5A-12), and appeared very similar to that of other 6 m stations.

Although the normal classification analysis generally grouped stations by depth, occasionally a station would be grouped outside of its respective depth group (e.g. Stations E3 and D3 in station Group 2 of the February survey, Station E3 in station Group 2 and A2 in station Group 1 in the May survey). Since station groups represent stations with similar species composition, a shift in species makeup must have occurred in which the faunal composition of the outlier station resembled stations from a different isobath. An examination of the two-way table revealed the changes in species composition which occurred (Figures 5A-9 through 5A-12). This phenomenon was apparently short-lived, since stations which shifted group affinities returned to their depth group in subsequent surveys. The exception to this pattern was Station E3 which grouped with the 9 m isobath stations during three surveys. The February and May classification results (Figures 5A-9 and 5A-10) show that Station E3 clustered with station Group 2 (9 m stations) primarily because of the absence of species in Groups A and B which characterize 15 m isobath stations. In November (Figure 5A-12) following return to the "proper" station group with a full compliment of species, Station E3 along with D3, clustered with the 9 m station Group 2. Similar to the February and May results, many of the characteristic species from the 15 m stations (Group A) are absent or in reduced abundances at these stations. Major substrate differences in sediment size and grain size distribution were highly correlated with the observed biological differences. The biological differences probably represent responses to habitat modification and are discussed in greater detail in the following section (Relationship Between Benthic Infaunal Community Distribution Patterns and The Physical-Chemical Environment).

The species groups determined from the inverse classification had abundance patterns characterizing the various stations which persisted through the year. However, as some species additions and disappearances occurred between surveys the communities were modified slightly through the year. Since a large number of species was included in these analyses, subsequent discussions will treat only a few of the species which displayed a particular pattern. Species patterns can be ascertained by examination of the two-way tables (Figures 5A-9 through 5A-12).

The inshore 6 m isobath stations were characterized by species groups with few species. Many of these species also occurred at the same stations in 1978 (SCE 1979). The species listed below either were found exclusively at the 6m stations during most seasons or exhibited their greatest relative abundance at these stations. These species included: the polychaetes Scoloplos armiger, Spiophanes bombyx, Magelona pitelkae, and Dispio uncinata; the amphipods Rhepoxynius bicuspidatas and Euhaustorius washingtonianus; and the cumacean Leptocuma forsmani.

Species which were restricted to the 9 m isobath stations during most seasons or which occurred in their highest relative abundances at these stations included: the polychaetes Scoloplos armiger (February), Amastigos acutus, and Owenia collaris; the mollusks Neverita recluziana, Periploma planiusculum and Yoldia scissurata; the amphipod Photis macrotica and the ophiuroid Ophiophragmus digitata.

Species unique to the 15 m isobath or which occurred in highest abundance at these stations included: the polychaetes Mediomastus ambiseta, Mediomastus acutus, Nephtys cornuta franciscana, Chaetozone setosa, and Eusigalion spinosum; the ostracod Euphilomedes carcharodonta; the cumacean Oxyurostylis pacifica; and the amphipod Monoculodes hartmanae.

Most of the species encountered in the quarterly subtidal benthic collections displayed a definite distributional pattern and occured in assemblages which characterized distinct depth intervals. Some species, however, were ubiquitous in the study area, although they may have occurred in high abundance at only one depth. Among these speci - were: the polychaetes Spiophanes bombyx, Amastigos acutas, and Spiophanes m. ..ionensis; the mollusk Tellina modesta; the isopod Edotea sublittoralis; the amphipod Rhepoxyniu: epistomus and the cumacean Diastylopsis tenuis.

The restricted patterns of distribution exhibited by many of the species discussed above was not coincidental. Physiological, food and habitat requirements define the area where an organism can live. Once a suitable environment has been invaded, other factors such as interspecific and intraspecific competition for limited resources become the key factors influencing localized patterns of distribution (Connell 1972, Dayton 1971).

RELATIONSHIP BETWEEN COMMUNITY DISTRIBUTION PATTERNS AND THE PHYSICAL-CHEMICAL ENVIRONMENT

Weighted multiple discriminant analysis (Smith 1976 and 1978) was employed to determine which abiotic features were associated with community distribution patterns. Many physical-chemical features varied between survey periods, but the dominant features persisted through the year (Figure 5A-13a-d). These included: 1) the importance of depth in community distribution; 2) the importance of fine silt and clay sediments to communities at the 9 and 15 m isobath stations; 3) the association of a bimodal (coarse and very fine) sediment distribution at Stations D3 and E3 during certain surveys; 4) the association of fine sands with stations on the 6 m isobath; and 5) the correlation of sediment temperature, sediment flux, and water clarity to species distribution patterns.

Depth was the dominant environmental factor associated with community distribution patterns. As mentioned previously, this feature was the only one remaining unchanged between surveys and during Units 2 and 3 construction activities and Unit 1 operation. Depth exerts its influence on community composition and abundance both directly and indirectly. As a habitat variable, depth translates into a pressure factor to which organisms must be adapted (Hoar 1966). Depth indirectly influences many other niche dimensions in the benthic environment. In open coastal areas, there is an inverse relationship between water movement and depth (Shepard 1963). Substrate stability also follows this pattern, as does the increase in species numbers, an observation documented by several authors (Gage and Geekie 1973, Rhoads and Young 1970, Lie and Kisker 1970). Deeper, less turbulent waters provide a more stable and predictable environment, particularly on sedimentary bottoms. Thus, deep water (e.g. 9 and 15 m isobaths) favors K selected species (Pianka 1974) and permits a higher equilibrium species density. In contrast with offshore stations, the habitat represented by the 6 m stations favors r selected or opportunistic species. These species, although few in number allocate a large amount of energy into many small (energetically inexpensive) offspring resulting in high settlement as observed at the 6 m stations.

The effects of sediment grain size are of fundamental importance in explaining observed community differences, since both food and habitat resources are provided by the sediments. The turbulence continuum related to depth (described above) provides the sedimentation environment which controls sediment grain size characteristics in the subtidal areas. Deeper stations (9 and 15 m) and their associated communities were characterized by finer sediments (i.e. coarse silt, fine silt, coarse, medium, and fine clays). These finer sediments were deposited because of reduced water movement in deeper water. Communities in deeper water had more deposit feeding species than those in shallow water (Table 5A-8 and Figure 5A-15). Nichols (1970) and Sanders (1968) describe similar benthic assemblages in habitats dominated by clay and silt-clay sediments.

Stations E3 and D3 supported faunal assemblages resembling the 9 m stations during February, May and November (Discussed in the preceeding section: Patterns in Infaunal Community Distribution). Discriminant analyses revealed that all 15 m stations were dominated by silt and clay-sized sediments. However, Stations E3 and D3 additionally contained high proportions of very coarse, coarse, and medium sands accounting in part for observed faunal differences in response to this feature (see Chapter 2D, Sedimentology). This coarse material apparently originated from the underlying relict San Mateo formation and was exposed by surge or current scouring. Similar results were observed at Stations C3, D3, and E3 in 1978 (SCE 1979). Since natural longshore current patterns were apparently disrupted by the construction activities, replenishment of scoured sediments at these stations may have been impeded, thus resulting in the exposure of relict sediments.

The sand component characterized the inshore (6 m) sediment regime. Relatively greater water movement at this depth apparently removed the finer silts and clays, leaving behind a well-sorted sediment regime of fine and very fine sand. Reduced silt and clay components probably accounted for reduced numbers of deposit feeders found within the 6 m isobath (Nichols, 1970) rather than the presence of sand. The association between high energy inshore sand regimes and certain biological communities has 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 5A-8 and Figure 5A-15). Moreover, the diversity of filter feeders was always less than that of deposit feeders, particularly at the inshore stations.

Sedimentation flux (monthly sedimentation rate) was an important variable associated with community differences during the May, August, and November surveys. The highest sedimentation occurred at the 6 m stations. The origin of this sediment was: 1) sediment transported from the sea bed and nearby rivers by waves, surge, and currents; and 2) suspended sediments released by dredging activities (Figure 2D-1). It is probable that stations downcoast of the dredgeline received larger quantities of dredge-originated sediments than upcoast stations since: 1) the predominant longshore movement is downcoast; and 2) there exist structural impediments to upcoast transport, particularly inshore near the laydown pad and trestles. Reference to Figure 2D-1 and Table 2D-1, indicates that large quantities of dredged material were suspended, used for backfill, and released during the periods prior to each survey. The total displaced material exceeded 318,000 m^2, and approximately two-thirds of this material was redistributed in waters of less than 9 m depth. This quantity of material probably contributed substantially to inshore sedimentation. Increased sedimentation may affect the community by favoring selected opportunists as discussed previously. Mobile forms and species with respiratory and feeding structures that are not easily fouled would also be favored.

Water clarity was also associated with community distribution patterns. Although water clarity, as measured by Secchi disc, generally agrees with the turbidity measurements (Chapter 2C, Water Quality), these data should be viewed with caution, since the observations were limited to single measurements quarterly. Furthermore, the Secchi disc readings measured water above the substrate and not at the sediment water interface. Community diversity was highest at stations with the highest water clarity. 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) with increasing distance offshore and depth water clarity increased. This pattern as with sedimentation, was influenced by natural as well as construction-related inputs. Water clarity was depressed near the area of highest dredge discharge; however, (SCE 1979, Chapter 2B, Turbidity), this area corresponded to different isobaths during each survey (Figure 2D-1).

Other factors such as organic carbon content and sediment temperature, were important environmental factors in the May and August surveys, respectively. Sediment temperature was highest at the 6 m isobath stations and lowest at the 15 m isobath stations. This pattern is consistent with other coastal marine environments where colder water occurs at greater depths. No other distinct patterns of temperature and community distribution were recorded. The temperature measurements used in these analyses were limited, yet they agree with the general trends presented in Chapter 2A, Temperature.

Organic carbon content of the sediment during the May survey period was highest at deep stations and was associated with differences in infaunal community structure. Higher levels of organic carbon offshore corresponded to the period of highest infaunal density (Figure 5A-5). The organic carbon levels may have contributed to this increased density by providing additional food for deposit feeding species. The origin of these organics is unknown, however, both natural sources and discharge from Unit 1 probably contributed to the input.

In general, community composition and distributional patterns were influenced by depth, sediment composition, water clarity, sedimentation, sediment temperature and the organic carbon content of the sediments. Depth was the only factor which was not influenced by SONGS construction and operation. The remaining environmental variables, however, were affected by SONGS Units 1, 2, and 3. The community analysis indicated that the distributional patterns of characteristic benthic species were not significantly altered by SONGS construction and operation activities. However, community parameters such as diversity, number of individuals, and biomass, were modified at stations immediately adjacent (within 236 m) upcoast and downcoast of the SONGS Units 2 and 3 construction compared with reference stations. The effects presumably were caused by the impediment of longshore sediment transport patterns. Effects of construction activities on the benthic infauna are not expected to persist after construction-related trestles and other structural impediments are removed.

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 analyses revealed:

1. Stations upcoast and immediately adjacent to the construction activities for Units 2 and 3 and operational Unit 1 supported elevated numbers of species, individuals, and biomass compared to reference areas. These patterns appear related to SONGS operation and construction.

2. Stations downcoast and immediately adjacent to the construction areas of Units 2 and 3 discharge and intake structures supported fewer numbers of species, individuals, and lower biomass than reference areas. These patterns appear related to construction activities, particularly structural impediments to longshore transport.

3. Increased species numbers proceeding offshore from the 6 m to the 15 m isobath stations. This pattern 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 trophic categories of: deposit feeders, filter feeders, carnivores, and omnivores which generally parallelled those patterns described for species numbers (1 and 2 above).

6. A general increase in the number of species at all trophic levels through the survey year, reaching their highest levels in August. This is part of a multi-year cycle.

7. Community composition changrs at the 15 m isobath stations corresponding to sediment substrate modifications.

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 5B

SUBTIDAL COBBLE

INTRODUCTION

The hard benthos habitat offshore the San Onofre Nuclear Generating Station (SONGS) is currently under investigation to address three objectives: (1) to provide baseline data for future 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 macroorganisms associated with cobble habitats; (2) to assess the environmental effects of sediment dispersal on the near-field cobble habitats within the San Onofre Kelp Bed during construction and dredging operations for the Units 2 and 3 intake and diffuser-discharge conduit systems; and (3) to determine the operational effect(s) of Unit 1 on near-field benthic marine resources. This study meets the regulatory requirements for the Environmental Technical Specifications (ETS) program, the Construction Monitoring Program (CMP), and the Preoperational Monitoring Program (PMP).

The purpose of this chapter is to present analyses and interpret the 1979 hard benthos data with respect to each of the study elements and objectives. The 1979 biological data used in this analysis report were presented in the Annual Operating Report, San Onofre Nuclear Generating Station, Volumes II (SCE 1980b) and III (SCE 1980c). The 1979 physical oceanographic data utilized in this report were presented in Volume I (SCE 1980a). The tabular data in these reports included all the qualitative and quantitative biological and physical oceanographic data collected at benthic sampling stations during 1979. Additional data collected for each study element during previous years was used to identify general temporal patterns or trends.

APPROACH

The hard benthos program consists of several elements (ETS, CMP, PMP) that were originated at different times for separate regulatory requirements and objectives. Consequently, there are differences in design and methodology among the three study elements. In order to address the objectives of this study, data from all elements are considered.

Data analyses for this report were oriented to identify the dominant benthic organisms associated with the inshore cobble, offshore cobble, and offshore kelp habitats in the vicinity of San Onofre. The abundances and distributions of these organisms are interpreted with respect to the functional adaptations and roles they exhibit in response to their habitats. The hypothesis that community structure is strongly influenced by the physical instability of the substrata in the area immediately offshore of SONGS is examined by comparison of community structure and abundance patterns of dominant organisms from areas of demonstrated greater stability.

The following definitions are presented with respect to the benthic program. Benthic marine resources are defined as all subtidal macroorganisms occupying hard substrata to a depth of approximately 14-m. A list of local subtidal macroorganisms and their relative importance with respect to the San Onofre area was presented and discussed in the Final Environmental Statement for SONGS 2 and 3 (AEC 1973). The near-field vicinity of the Unit 1 discharge is defined as a rectangular area centered on the Unit 1 discharge, and extending approximately 1 km upcoast and downcoast, and 0.5 km inshore and offshore of the discharge. This rectangle includes ETS Benthic Stations 1, 2, 3, and 4 (Figure 5B-1). The near-field vicinity of the Units 2 and 3 discharges 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 (Figure 5B-1). The upcoast-downcoast boundaries were determined by the predicted areal extent of the thermal plume (Koh et al. 1974) and potential turbidity effects. During the summer of 1978 the area acceptable for station locations within the onshore and offshore boundaries was 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 for Unit 2 an 3.

Collectively, all sampling stations have been assigned to one of three groups. These groups include stations located on the nearshore isobath 10-12 m), stations on the offshore isobath (12-14 m) within areas of previously or presently existing giant kelp canopies, and stations on the offshore isobath without kelp canopies.

The collection and documentation of physical oceanographic data is an essential component of any complete benthic sampling program because physical and biological factors are interrelated and operate together to define the structure of the benthic community. To acquire synoptic physical data, a Benthic Sensing Package (BSP) was designed and installed during August 1979 to collect continuous data on sediment and organic detrital accumulation or movement, ambient bottom water temperature, and photosynthetically active radiation reaching the benthos near each pair of stations located on the offshore isobath.

BACKGROUND

In order to place the present hard benthos program and objectives into perspective with regard to previous benthic studies at San Onofre, a brief description of the subtidal environment offshore SONGS is presented below, as well as 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 (Chapter 2D, 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 hard substrata by sand or silt can limit and define associated biological populations (Connell 1972, Given 1973, Valentine 1973). The greatest proportion of hard 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 (from 5 km upcoast to 10 km 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 region 5 km upcoast of SONGS consists of relatively stable cobble and boulder substratum from the 18-m isobath to the shoreline (Figure I-3, LCMR 1978c). In contrast, the Don Light area 8 km downcoast from SONGS is largely sand with isolated patches of cobble occurring at the 10 to 12-m isobath (IRC 1978; Figure I-5, LCMR 1978c). The area directly offshore of SONGS is a mixture of all three substrata components (IRC 1978; MBC 1978; Figure 5B-1).

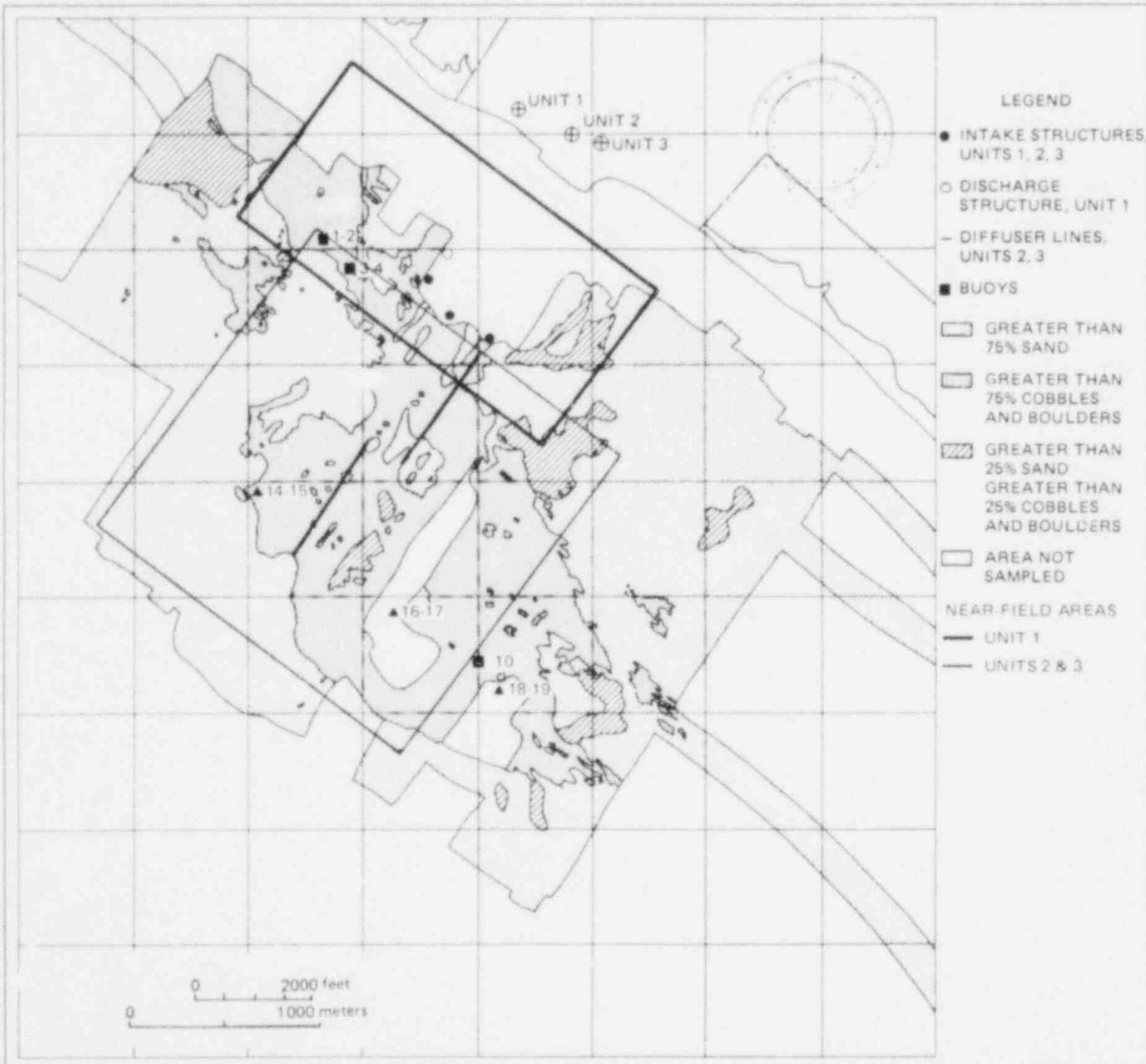

Figure 5B-1. Distribution of substrata types in the vicinity of the San Onofre Nuclear Generating Station (after IRC 1978).

Benthic biological studies of the marine environment at San Onofre began in 1963 and consisted of periodic monitoring programs. 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 was 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 the generating station began operation. Further, it was suggested that turbidity in the immediate proximity of the discharge reduced available light levels and inhibited algal growth (Given 1973).

In a more recent study, Osman (1978) reported a relative increase in benthic invertebrate larval settlement on artificial hard substrata within 50 m of the Unit 1 discharge. This increased larval settlement on hard substrata was attributed to alteration of natural current conditions near the discharge (within 50 m) resulting from the hydrodynamic entrainment of surrounding water. This entrainment exposed the near-field hard substrata to greater densities and subsequently greater settlement of merozooplankton than would normally be expected under natural conditions (Osman 1978).

Semiquantitative data were collected from 1963 until March 1975 when the existing Environmental Technical Specifications program was initiated. 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 include giant kelp mapping using an electronic positioning and side scan sonar system and studies of kelp plant condition (general appearance, nitrogen content). 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 element was not designed to identify expected biological effects immediately adjacent to the Unit 1 discharge (very near-field effects), 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 5B-1). Therefore, no ETS stations occur closer than 500 m from the Unit 1 discharge, no CMP stations occur within 900 m of the Units 2 and 3 discharges, and no PMP stations occur within 300 m of the Units 2 and 3 discharges. The results, analyses, and interpretation of yearly benthic survey data from 1975 to 1978 (LCMR 1976b, 1977b, 1978c, SCE 1979d) 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 nine quaterly surveys conducted from December 1976 to December 1978 (MBC 1978, SCE 1979d) did not identify any biological effects on the San Onofre kelp bed macrobiota that could be associated with diffuser-discharge conduit construction for SONGS Units 2 and 3.

METHODS

QUARTERLY DATA COLLECTION

A total of 23 subtidal stations are sampled quaterly by the ETS, CMP, and PMP benthic elements. A map detailing the position of all stations with respect to SONGS 1, 2 and 3 is presented in Figure 5B-2.

The ETS sampling design includes eight cobble stations located on the nearshore (10-m) isobath and three kelp beds on the offshore (14-m) isobath. These eleven permanent benthic stations, marked with surface buoys, were originally established in areas of comparable substrata in February 1975 (LCMR 1975g). 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 original 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 Unit 1 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, near the Unit 1 discharge, and Stations 5 through 8 are located in the far-field reference area, Zone 6 (Figure 5B-2). Similarly, the ETS offshore kelp stations are numbered 9, 10, and 11 and are located in the San Mateo, San Onofre, and Barn Kelp beds, respectively. The CMP benthic study added two stations within the San Onofre Kelp bed in 1977 (MBC 1978), which are located a short distance upcoast and downcoast of Station 10 (Figure 5B-2). For this report the two CMP stations are referred to as Stations 22 and 23 (previously labeled SOK-U and SOK-D, respectively; MBC 1978).

Organisms for all benthic elements presented in this chapter are defined as those organisms living on the exposed portions of the hard substrata. Organisms are identified in the field and are surveyed quarterly at each station using nondestructive sampling techniques. Each permanent benthic station for the ETS and CMP studies consists of a band transect 10 m long and 1 m wide, divided into ten, 1-m^2 quadrats. 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 ten quadrats at each station. In order to maintain consistency in data recording among biologists, the type of data (i.e., enumeration or percent cover) to be reported for each organism is standardized and indicated on preprinted plastic data sheets. Conspicuous organisms which cannot be field identified are collected outside the sampling area and returned to the laboratory for positive identification. Other organisms that are less common or that cannot be specifically identified in the field are classified into higher taxonomic groups, such as unidentified hydroids or ectoprocts. Descriptive as well as functional 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 of turf on hard substrata (Neushul and Dahl 1967). The substratum characteristics and relief of each quadrat are described. Measurements of surface and bottom water temperatures, and observations of visibility and surge conditions are recorded. Additionally, the following information is collected on kelp (Macrocystis) sporophytes within the band transects at the kelp stations: (1) number of stipes on each individual kelp plant, 2 m

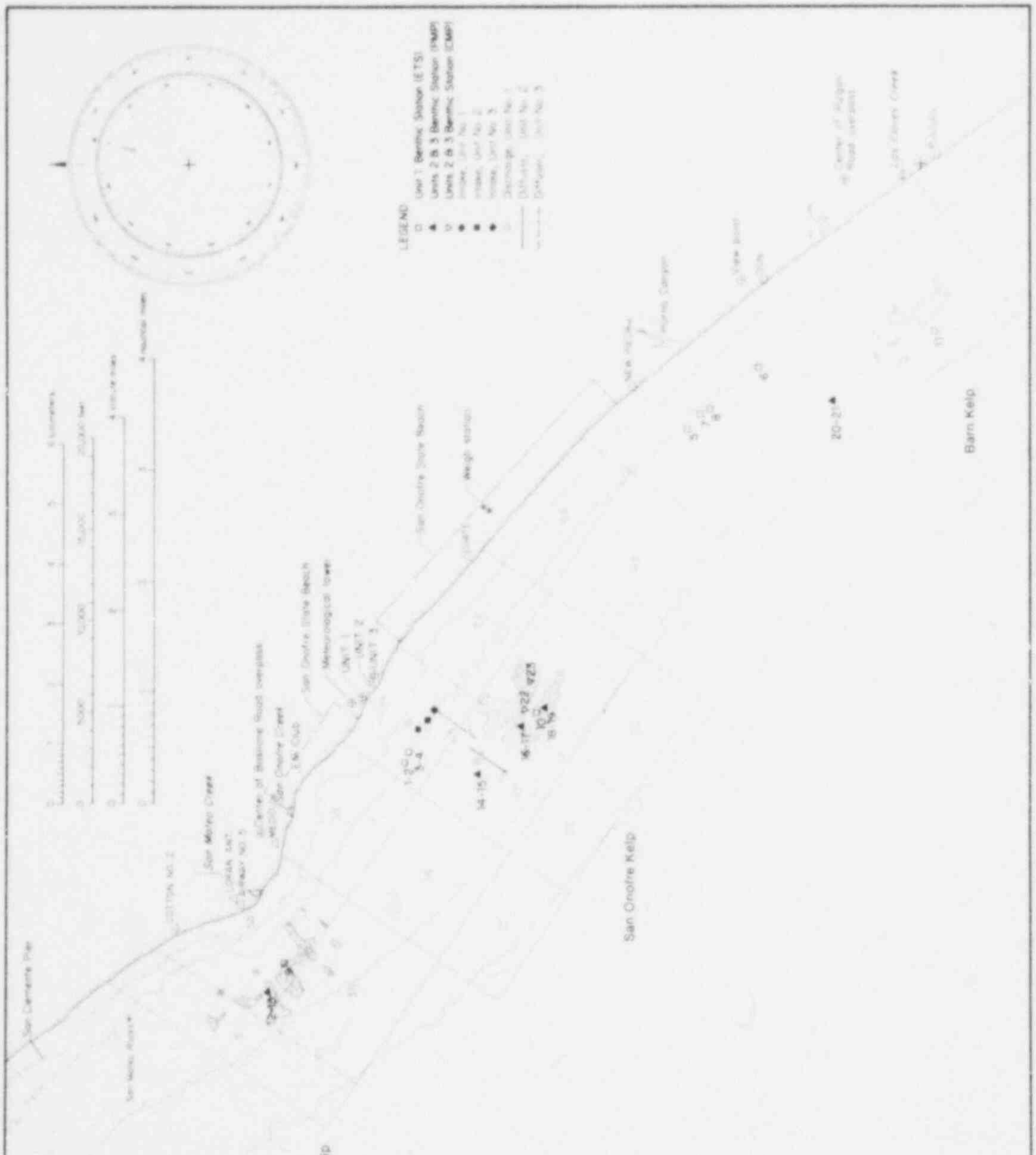

Figure 5B-2. ETS, CMP, and PMP benthic station locations and surveillance zones (e.g., OA, 6) at San Onofre Nuclear Generation Station. Shaded areas represent the areal extent of the kelp canopies sampled in December 1978.

above the bottom, (2) general condition of the kelp plants (e.g., tattered fronds), and (3) kelp growth (e.g., small new fronds with no fouling).

Quarterly ETS surveys were conducted during 1979 on 7-10 February, 12-24 April, 31 July -16 August, and 18 October - 1 November. ETS Stations 3, 4, and 7 were completely covered with sand during the first quarter survey period and no biological data were collected at these stations. All ETS stations were sampled during each remaining quarterly survey period. The two CMP stations located in San Onofre Kelp were sampled during 1979 on 14-15 February, 23 May, 10-12 August, and 1 November.

The PMP benthic element is designed to collect baseline data on cobble community biota located on the 14-m isobath offshore of the ETS kelp stations. 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 surveys and sampling investigations were conducted on cobble substratum 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 1977) between San Mateo Point and Barn Kelp bed along 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 analysis of preliminary data, a program was designed to collect baseline data to characterize the biota of offshore cobble habitats in the vicinity of the Units 2 and 3 diffuser-discharges. The sampling design includes a total of five station-pairs (10 stations) distributed within and outside of the possible region of impact (Figures 5B-1 and 2). This design is oriented at evaluating natural or artifically induced changes associated with the cobble benthic community prior to and after operation of Units 2 and 3. 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 (Figure 5B-1). Station-pair 18-19 is located downcoast of Station-pair 16-17 within San Onofre Kelp. Station-pair 20-21 is located approximately 9 km downcoast in the Don Light reference area (Figure 5B-2).

Each permanent PMP benthic station is a rectangle measuring 2 m x 3 m. Station-pairs are permanently marked with a surface buoy attached to a 907-kg anchor block. Each 6.0-m^2 station is sampled by a point contact technique similar to methods utilized in terrestrial vegetation studies (Goodall 1952, Winkworth 1955, Greig-Smith 1957). 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 organism level (Dayton 1975, Foster 1975a); and (4) the derivation of a statistical confidence interval which may be applied to the estimated abundance of each taxon or substratum type encountered.

Benthic organisms at each offshore station are sampled by two methods to collect data on temporal abundance patterns and spatial dispersion. To collect these data, diving biologists utilize two reference (stationary) lines and one movable sampling line to sample each 6.0-m^2 station with 300 evenly distributed points (Figure 5B-3). Data collected at each point include the identification of

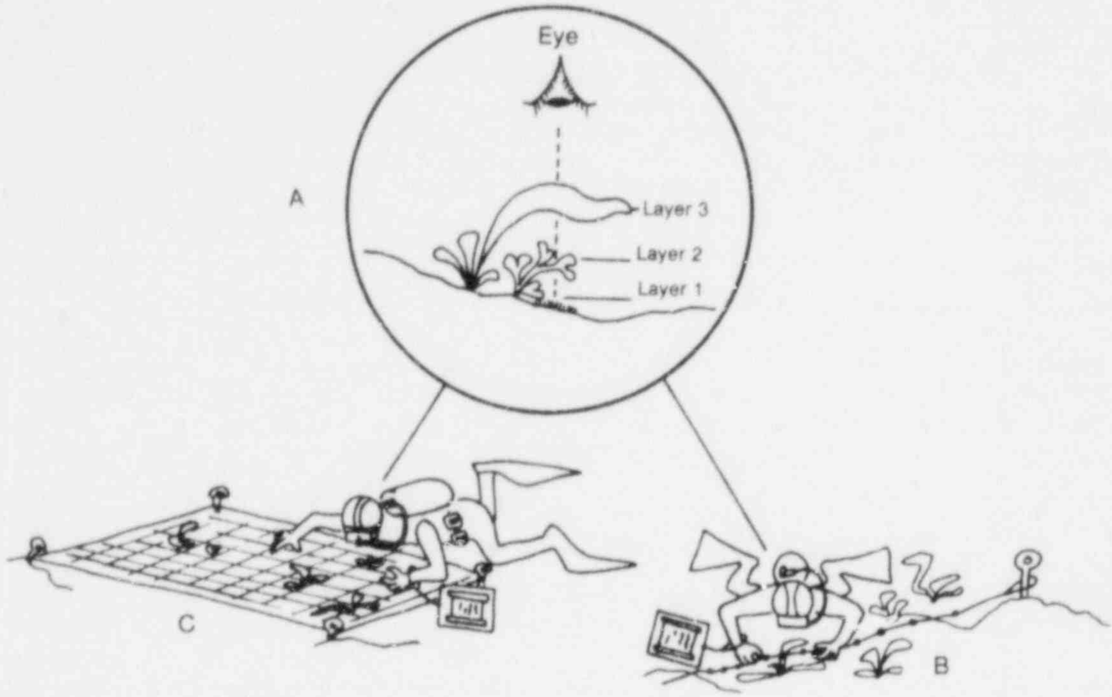

Figure 5B-3. An illustration of multiple layering sampled at a single point (a) with examples of divers sampling evenly distributed points on a line (b) and within a quadrat (c) (after Carter et al., 1979).

substratum type and macroorganisms present. Up to three organism levels, indicating layering in the community, are recorded. Organism Levels 1, 2, and 3 refer to organisms attached to the substratum (OL1), occurring over other organisms (OL2), and forming a canopy over the sampling area (OL3), respectively. Additionally, four 0.125-m^2 square quadrats are randomly located within the 6.0-m^2 station area and are sampled with 60 evenly distributed points to examine small, cryptic, clumped, or patchily distributed organisms. Data for both sampling elements (6.0-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 identification. Surface and bottom water temperature, visibility, and surge conditions are recorded.

To effectively document the changing composition of substrata near the stations, a wide area reconnaissance is 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 definitions of substratum are employed for boulder and cobble. Boulder is defined as hard substratum which is immovable by natural current conditions and/or which measures 26 cm or greater in greatest linear dimension. Cobble is defined as hard 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 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.

The sampling frequency of the PMP benthic element is also quarterly. Surveys were conducted during 6-13 February, 19-24 April, 17 July - 5 August, and 18-25 October. The steel reinforcing bar marking Station 14 was destroyed during February 1979. This occurred when an anchor system securing the position of the dredging barge used for installation of the Units 2 and 3 diffuser-discharge system was dragged over the sampling area. Station 14 was re-established within 4 m of the original location and sampled that same month.

CONTINUOUS PHYSICAL DATA COLLECTION

Benthic Sensing Packages (BSP)

Field. One Benthic Sensing Package (BSP) is located at each of the five offshore cobble station-pairs (PMP station-pairs, Figures 5B-2, 4). BSP instrumentation consists of a sediment trap array, an Endeco Type 109 recording thermograph, and a LiCor Li-192S Underwater Quantum Sensor whose output is processed and recorded by a Campbell CR-21 Micrologger and magnetic tape recorder (Figure 5B-4).

Each sediment trap (Figure 5B-4) consists of a 2.5-cm inside diameter polyvinyl chloride tube, 27.3 cm long, terminating in a 1-liter Nalgene plastic bottle filled with dense modified Lugol's solution to fix organic detrital material and discourage organisms from entering the collection bottles. The trap is capable of collecting and retaining sediment over a one month period, where total sedimentation rates approach 7 cm /cm^2/day. The 10 to 1 ratio of length to diameter of the sediment trap collection tube allows acceptable sediment retention (Hargrave and Burns 1979). Each sediment trap array consists of three tube systems which take three replicate samples from points in the water column varying from 0.6 m to 1.0 m above the substratum. Mean sedimentation rate is calculated from the dry weight and cross sectional area of the collection tube.

The Endeco type 109 recording thermograph collects data by photographing a calibrated thermometer traceable to the National Bureau of Standards. Temperature readings are taken at hourly intervals, with resolution $> \pm 0.1$°C and accuracy to ± 0.3°C. Temperature readings are also recorded by the CR-21 micrologger and tape recorder combination from an an internally mounted temperature sensor. Resolution is also $> \pm 0.1$°C and accuracy is to ± 0.1°C.

The Li-Cor Li-192S Underwater Quantum Sensor is sensitive to photosynthetically active radiation in the 400 to 700-nm band width. The Li-192S sensor has a reported accuracy of ± 5% and resolution of ± 1.81 microeinsteins µE/m^2/s. The system's microprocessor records station identification, date, time, temperature, and light data onto a magnetic tape cassette recorder with about a six week data storage capacity. Light data taken every minute are averaged, recorded, and stored as hourly data points in µE from one hour after sunrise to one hour before sunset.

All instrumentation is securely attached to a protective frame constructed of stainless steel. The frame is 50-cm high and anchored in a 112 x 112 x 30.5-cm concrete block with an underwater weight of about 500 kg (Figure 5B-4). The BSP system at Station-pair 12-13 is located under a *Macrocystis* canopy on cobble

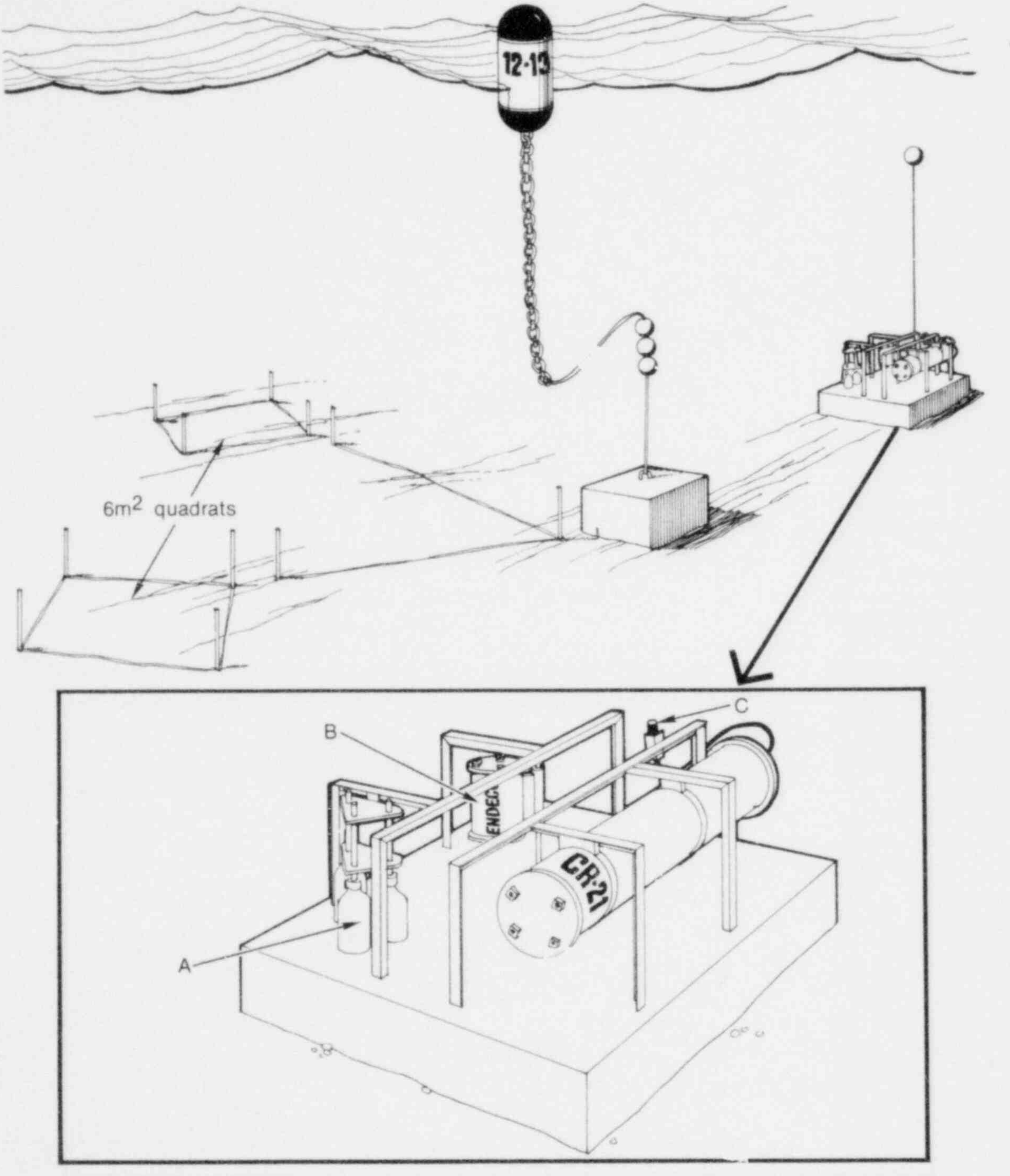

Figure 5B-4. Diagram of Preoperational Monitoring Program benthic station pair and Benthic Sensing Package instrument array (a — sedimentation chambers; b — Endeco thermograph; c — Li-Cor underwater quatum sensor).

substrata with little sand present. The BSP array at Station-pair 14-15 is located on cobble substrata slightly outside a scattered Macrocystis kelp canopy. The BSP system at Station-pair 16-17 is located on coarse sand and cobble substrata with Laminaria spp. and Pterygophora californica representing the dominant kelp plants in the area. The array at Station-pair 18-19 is located on cobble substrata under a scattered Macrocystis canopy. The BSP array at Station-pair 20-21 is located on an extensive area of fine sand. Scattered cobble and coarse sand are nearby at the offshore cobble benthic Station-pair 20-21.

Each benthic sensing package is inspected and cleaned by divers on a biweekly basis. Light, sediment, and temperature data are retrieved on approximately a 30-day sampling interval.

Laboratory. Laboratory processing of temperature and light data are described in Chapter 2. Sediment analysis is described below.

After the sediment samples are returned from the field, they are poured into graduated cylinders through a 1-mm mesh screen to remove small invertebrates and large detrital material. Volume is measured to the nearest milliliter and recorded after settling for a 24-h period. Samples are then suction-filtered through glass fiber filter paper which has been heated at 450° for 4 h, cooled overnight in a dessicator, and weighed to the nearest thousandth of a gram. The sediment is dried at 80°C for 48 h, cooled in a dessicator overnight, and weighed to the nearest thousandth of a gram. Subtraction of the filter paper weight gives the actual weight of the sediment in grams.

Samples are then prepared for organic carbon (OC) analysis by grinding with a mortar and pestle to obtain sediment particles of a small uniform size. Three aliquots of each sample of the prepared sediment are then analyzed for OC. Each aliquot is placed in a glass ampule, treated with acid to remove inorganic carbon, and burned to liberate all carbon dioxide from the organic fraction of the sediments. The amount of carbon dioxide evolved is quantified with a non-dispersive infra-red analyzer. The amount of OC is recorded as a fraction or percent by weight of the sediment aliquot analyzed.

DATA ANALYSIS

Data collected during the 1979 sampling period were analyzed using nonparametric and parametric techniques. Generally, abundance estimates of organisms or individuals of organisms were compared spatially using analysis of variance (ANOVA) or a nonparametric counterpart (Sokal and Rhulf 1969, Conover 1971). Associations between organisms were compared using Pearson's product-moment (r) and Spearman's rho (p) parametric and nonparametric correlation coefficients, respectively.

Community relationships among the offshore cobble stations were examined using normal and inverse classification analysis (Clifford and Stephenson 1975). Data were first classified according to organism composition and abundance. Second, species were classified according to their abundance and distribution recorded at each station from August 1978 to October 1979. Flexible sorting and square root transformations were used to generate dendrograms from a Bray-Curtis dissimilarity matrix and reduce the effect of excessively dominant organisms, respectively (Boesch 1977). Station and species dendrogram classifications results are combined with a two-way table showing station and species groups or clusters.

RESULTS

The results of the 1979 hard substrata benthos program presented below are grouped into four categories based on sampling techniques and types of data collected. These categories include oceanographic and meteorological observations, qualitative field observations, analysis of the inshore cobble and sand and offshore kelp stations, and analysis of data collected at the offshore cobble habitats. An overall review of all the information collected indicated that the best understanding of the physical and biological environment in the study area is obtained by presenting the results in this manner rather than by study element (i.e, ETS, CMP, PMP).

OCEANOGRAPHIC AND METEOROLOGICAL OBSERVATIONS

Oceanographic data consisting of bottom temperatures, bottom transmissivity measurements, and water column Secchi disc extinction depths were collected on a bimonthly basis at oceanographic stations near benthic stations in the SONGS area (SCE 1980a, p 3-1 to 4-1). Bottom temperatures were generally highest during the months of July and September and lowest during March. Temperatures varied little between stations on the 10-m isobath within sampling periods, with the exception of notable differences in temperatures recorded at oceanographic stations 610 m upcoast (14.4°C) and 6,710 m downcoast (18.2°C) of the SONGS 1 discharge during the July 1979 sampling period.

Bottom transmissivity ranged from 0 to 5% transmittance at most stations throughout the year-long sampling period. Two stations on the 10-m isobath exhibited substantially greater percent transmittance levels; 24% was recorded 610 m upcoast and 21% transmittance was recorded 6,710 m downcoast of the SONGS 1 discharge during the November survey. Secchi disc readings on the 10-m isobath appeared to be greater at stations downcoast of SONGS (6,710 - 7,320 m) than at those near SONGS (610 m upcoast). The greatest overall vertical water clarity was observed during November 1979.

Results of continuous light measurements recorded during the period from 27 August to 31 December 1979 appear in Table 5B-1. During this period mean light

Table 5B-1. Mean diurnal light* ($\mu E/m^2/sec$) recorded during 1979 at Benthic Sensing Packages located near offshore benthic station-pairs.

Survey Period	Station-pairs				
	12-13	14-15	16-17	18-19	20-21
27 Aug - 11 Sep	**	43.2	**	**	61.7
11 Sep - 25 Sep	17.6	13.3	**	18.1	12.7
25 Sep - 9 Oct	21.5	39.4	**	38.8	5.1
9 Oct - 23 Oct	**	26.2	**	30.6	16.6
23 Oct - 6 Nov	**	**	[illegible].6	39.5	**
6 Nov - 20 Nov	13.8	**	42.6	25.2	43.4
20 Nov - 4 Dec	12.3	**	48.7	[illegible]	41.6
4 Dec - 18 Dec	10.5	52.4	51.5	**	31.8
18 Dec - 31 Dec	6.5	**	27.8	18.4	**

* Light was recorded from one hour after sunrise to one hour before sunset each day.

** No usable data collected.

values were greatest at Station-pairs 14-15 and 16-17, averaging 38.7 μE/m²/s. Similar intermediate means were recorded at Station-pairs 18-19 and 20-21 which averaged 29.5 μE/m²/s. Minimum mean light was recorded at Station-pair 12-13 (13.7 μE/m²/s).

Station-pair 12-13 exhibited low sedimentation rates and high organic carbon values compared to other offshore cobble stations throughout the 1979 sampling period (Table 5B-2). In contrast, Station-pair 20-21 exhibited consistently high sedimentation rates and low organic carbon values. Intermediate sedimentation rates and organic carbon levels were recorded at Station-pairs 14-15, 16-17, and 18-19.

Table 5B-2. Mean sediment collection rate (S) in g/cm²/day and mean percent organic carbon levels (C) in sediment collected during 1979 at Benthic Sensing Packages (BSP's) located near offshore benthic station-pairs.

		Station-pairs				
Survey Period		12-13	14-15	16-17	18-19	20-21
8 Aug - 25 Sep	S	0.031	0.078	0.120	0.077	0.112
	C	1.370	0.840	0.960	0.980	0.530
25 Sep - 25 Oct	S	0.029	0.040	0.104	0.048	0.082
	C	*	*	*	*	*
25 Oct - 20 Nov	S	0.033	0.066	0.106	0.060	0.105
	C	1.380	0.830	0.810	0.870	0.400
20 Nov - 18 Dec	S	0.023	0.034	0.044	0.025	0.046
	C	1.020	0.750	0.560	1.090	0.360

* Samples were destroyed due to an equipment malfunction.

Precipitation measured in the southern California area during 1979 did not approach levels recorded in 1978. The Oceanside Harbor area, 21 km downcoast of SONGS, received a total of 24 cm of rain during the first three months of 1979 (U.S. National Weather Service, San Diego, CA) while 53 cm were recorded during the first three months of 1978 (SCE 1979d).

QUALITATIVE FIELD OBSERVATIONS

Physical disturbance (movement of cobble and small boulders) was evident at offshore cobble Stations 12 and 13 during the July and October 1979 surveys. This disturbance may have occurred during periods of severe surge generated by the large swells and storms during the early part of the year. Moderate surge conditions were recorded during the actual 1979 surveys (SCE 1980a, Table 6-98).

Diver observations indicate that cobble and small boulders attached to kelp plants may easily be displaced under strong surge conditions. Several young *Pterygophora californica* plants were observed at Station 14 on small cobbles which had been displaced. The same dynamic bottom conditions probably exist at offshore cobble Stations 12, 13, 14, and 15 due to similar bottom characteristics and the presence of adult or developing *Pterygophora* and *Macrocystis* spp. plants attached to movable hard substrata.

Recruitment of algae and invertebrate species occurred at offshore cobble stations during 1978. Station-pair 12-13 exhibited recruitment of *Macrocystis* spp. while the presence of juvenile *Styela montereyensis* was noted at Station 14 during August 1978. A dominant algal overstory composed of Desmarestia spp. and the Cryptonemia/Halymenia/Schizymenia complex existed at Station-pair 14-15 during the August 1978 survey. In subsequent sampling periods, these algal species were either absent or far less abundant. Inshore cobble stations exhibited recruitment of Muricea spp. juveniles during all sampling periods with the exception of the April-May survey. Recruitment of juvenile Macrocystis spp. occurred at various kelp stations throughout the May, July, and October 1978 and all 1979 surveys with the exception of April. Juvenile Chelyosoma productum and Styela spp. were also observed at San Mateo, San Onofre and Barn Kelp, respectively.

In comparison to previous percent cover estimates of Parvosilvosa, low estimates were recorded during the July survey at Station 9 (San Mateo Kelp, SCE 1980c). A dense kelp canopy also existed during this survey. This co-occurrence suggests that the algal community composed of Parvosilvosa was reduced due to limited light penetration to the benthic community.

INSHORE COBBLE AND SAND, AND OFFSHORE KELP STATIONS

Substrata Composition

Substrata (cobble, boulder, and sand) abundance estimates recorded at inshore cobble and sand stations during the 1979 sampling period are presented in Table 5B-3. Hard substrata (cobble and boulder) abundances at cobble stations in Zone

Table 5B-3. Substrata composition at inshore cobble and sand stations sampled during 1979. Estimates are based upon 20 m^2 of sampling area unless otherwise noted.

Cobble Stations

	Stations 1 and 2				Stations 6 and 8			
Substrata	Feb	Apr	Jul	Oct	Feb	Apr	Jul	Oct
Boulder	10.8	16.1	12.9	16.0	36.3	37.0	41.0	42.0
Cobble	71.0	54.1	54.5	39.2	15.6	14.2	9.5	13.8
Sand	18.2	29.8	32.6	44.8	48.1	48.8	49.5	44.2
Percent hard substratum	81.8	70.2	67.4	55.2	51.9	51.2	50.5	55.8
Percent sand substratum	18.2	29.8	32.6	44.8	48.1	48.8	49.5	44.2

Sand Stations

	Stations 3 and 4				Stations 5 and 7			
Substrata	Feb*	Apr	Jul	Oct	Feb**	APR	JUL	OCT
Boulder		6.7	0.0	0.0	11.5	2.0	8.8	8.1
Cobble		2.0	0.0	0.2	0.0	1.8	2.2	1.8
Sand		91.3	100.0	99.8	88.5	96.2	89.0	89.1
Percent hard substratum		8.7	0.0	0.2	11.5	3.8	11.0	10.9
Percent sand substratum		91.3	100.0	99.8	88.5	96.2	89.0	89.1

* Stations 3 and 4 were not sampled during the February 1979 survey.

** Station 7 was not sampled during the February 1979 survey, therefore, values are based upon 10 m^2 of sampling area.

0A (Stations 1 and 2) near the Unit 1 discharge and the Zone 6 far-field area (Stations 6 and 8) were most similar between stations within zones. Comparison of substrata estimates between Zones 0A and 6 indicates a greater abundance of hard substrata present in Zone 0A, however, the difference between zones is not statistically significant (Mann-Whitney test, $P > 0.05$). Substrata composition at predominantly sand stations located in Zone 0A (Stations 3 and 4) and Zone 6 (Stations 6 and 8) was similar between zones with slightly more exposed hard substrata occurring at stations located in Zone 6.

Substrata abundance estimates at kelp stations sampled during 1979 appear in Table 5B-4. Hard substrata was most abundant at Stations 9 (San Mateo Kelp) and 23 (San Onofre Kelp) averaging 93.4 and 85.3% cobble and boulder during the four surveys of 1979, respectively. Similar mean abundance estimates of hard substrata were noted at Stations 10 (San Onofre Kelp, 65.8%) and 11 (Barn Kelp, 69.8%). Lowest estimates of hard substrata were consistently recorded at Station 22 (San Onofre Kelp) during each survey and averaged 42.3% during the 1979 sampling period. Statistical comparison of hard substrata abundance estimates among kelp stations during 1979 revealed a significant difference with highest estimates at Stations 9 and 23 (median test, $P \leq 0.05$).

Number of Taxa

The number of taxa or taxonomic assemblages identified during each 1979 survey period at the inshore cobble and sand stations appears in Table 5B-5. The majority of the taxa sampled at all stations were sessile organisms. Differences in the number of taxa sampled within zones and among surveys at the respective stations is more closely associated with the presence and absence of the same species and does not reflect major changes in species composition. Similar numbers of taxa were identified at cobble stations in Zones 0A and 6. The greatest mean numbers of taxa observed in each zone were associated with Station 1 (45.0, Zone 0A) and Station 8 (38.5, Zone 6) during all surveys. Comparison of the total number of taxa recorded at cobble stations in Zones 0A and 6 during 1979 revealed no statistically significant difference (Mann-Whitney test, $P > 0.05$).

The number of taxa identified at sand stations was similar among Stations 3 and 4, located in Zone 0A, and Station 7, located in Zone 6. Greater numbers of taxa were consistently recorded at Station 5 during each 1979 survey (Table 5B-5). The greater number of taxa observed at Station 5 is probably associated with the greater amount of hard substrata recorded at that station during each survey. The substrata sampled at Station 7 was composed of 100% sand during all 1979 quarterly surveys (SCE 1980c).

The number of taxa or taxonomic assemblages of organisms identified at the offshore kelp stations during 1979 appears in Table 5B-6. The mean number of taxa identified during 1979 was greatest at Station 9 (61.3). The lowest mean number of taxa was identified at Station 10 (43) with similar mean numbers of taxa at Stations 11 (59), 22 (59), and 23 (56). Temporal comparison of the mean number of taxa identified at kelp stations during each 1979 survey revealed no significant differences among kelp stations (median test, $P > 0.05$).

Trophic Structure

Organisms observed during the benthic studies were assigned to trophic types defined in the glossary. In instances where an organism occupies more than one trophic type, the method by which it processes the majority of its food is designated as the trophic type. The trophic types and the methods of designating the type for each species are identical to those previously used (LCMR 1978c).

Table 5B-4. Substrata composition at kelp stations sampled during 1979. Estimates are based upon 10 m^2 of sampling area at each station.

	Station 9				Station 10			
Substrata	Feb	Apr	Jul	Oct	Feb	Apr	Jul	Oct
Boulder	38.5	46.5	44.5	64.2	48.0	50.0	42.5	47.5
Cobble	52.9	45.0	50.5	31.3	23.0	31.0	11.0	10.5
Sand	8.6	8.5	5.0	4.5	29.0	19.0	46.5	42.0
Percent hard substratum	91.4	91.5	95.0	95.5	71.0	81.0	53.5	58.0
Percent sand substratum	8.6	8.5	5.0	4.5	29.0	19.0	46.5	42.0

	Station 11			
Substrata	Feb	Apr	Jul	Oct
Boulder	59.5	54.5	55.7	53.5
Cobble	10.9	13.5	18.4	13.0
Sand	29.6	32.0	25.9	33.5
Percent hard substratum	70.4	68.0	74.1	66.5
Percent sand substratum	29.6	32.0	25.9	33.5

	Station 22				Station 23			
Substrata	Feb	May	Jul	Oct	Feb	May	Jul	Oct
Boulder	49.9	44.5	1.5	1.7	85.5	78.0	75.9	59.5
Cobble	*	*	37.9	34.5	*	*	13.1	29.0
Sand	50.1	55.5	60.6	63.8	14.5	22.0	11.0	11.5
Percent hard substratum	49.1	44.5	39.4	36.2	85.5	78.0	89.0	88.5
Percent sand substratum	50.1	55.5	60.6	63.8	14.5	22.0	11.0	11.5

* No differentiation was made between the cobble and boulder components of the hard substratum during the February and May surveys.

Table 5B-5. Number of benthic taxa sampled at the inshore cobble and sand substratum stations during 1979.

Survey	Cobble Stations 1	2	6	8	Sand Stations 3	4	5	7
Feb	42	31	43	39	*	*	23	*
Apr	25	17	28	30	9	6	9	3
Jul	53	35	41	44	3	4	25	4
Oct	60	42	45	41	5	3	23	7

* Station covered with sand, no biological data collected.

Table 5B-6. Number of benthic taxa sampled at offshore Station 9 (San Mateo Kelp), Stations 10, 22 and 23 (San Onofre Kelp), and Station 11 (Barn Kelp) during 1979.

Survey	Station 9	10	11	22	23
Feb	70	37	51	54	45
Apr	50	42	52	*	*
May	*	*	*	65	54
Jul	54	47	60	52	55
Oct	71	45	71	64	71

* During the second quarterly survey of 1979, Stations 9, 10, and 11 were sampled during April while Stations 22 and 23 were sampled during May.

The trophic composition at the inshore cobble and sand stations, and the kelp stations during the 1979 sampling period is presented in Tables 5B-7 and 5B-8, respectively. Primary producers and suspension feeders were the dominant trophic types at inshore cobble stations in both Zones 0A and 6. Sand substratum stations generally supported lower numbers of all trophic types in contrast to numbers observed at cobble stations (Table 5B-7).

Primary producer taxa were abundant at both the offshore kelp stations and the inshore cobble stations. Suspension feeding taxa were the most numerous trophic types recorded at offshore kelp stations with the exception of Station 10 (Table 5B-8). The annual mean abundances of primary producer and suspension feeding taxa enumerated at offshore kelp stations were consistently less than abundances observed at inshore cobble stations (Tables 5B-7, 8). The lowest annual mean number of each trophic type, with the exception of grazing taxa, was recorded at Station 10 (Table 5B-8). The same was true in 1978.

Abundant Taxa

The five most abundant enumerated and percent cover taxa and/or taxa assemblages observed at the inshore cobble stations during each 1979 sampling period are presented in Tables 5B-9 and 5B-10. These taxa are defined as the abundant organisms. They are generally non-motile, and are considered to represent both the numerically dominant and functionally important organisms associated with the inshore cobble habitat.

Table 5B-7. Trophic composition as represented by the number of taxa of each trophic type sampled at the inshore cobble and sand substratum stations during 1979.

Trophic Type	Cobble Stations		Sand Stations	
Survey	1 and 2	6 and 8	3 and 4	5 and 7
Primary Producers				
Feb	28	36	*	7
Apr	19	26	6	5
Jul	39	32	0	10
Oct	41	29	2	4
Mean Number of Taxa/20 m^2	31.8	30.8	2.7	6.5
Suspension Feeders				
Feb	30	33	*	13
Apr	19	24	6	4
Jul	36	40	1	13
Oct	40	40	1	17
Mean Number of Taxa/20 m^2	31.3	34.3	2.7	11.8
Grazers				
Feb	2	1	*	*
Apr	1	0	0	0
Jul	2	1	0	0
Oct	5	3	0	0
Mean Number of Taxa/20 m^2	2.5	1.3	0.0	0.0
Scavengers				
Feb	9	7	*	3
Apr	1	5	2	3
Jul	7	6	5	4
Oct	8	8	5	6
Mean Number of Taxa/20 m^2	6.3	6.5	4.0	4.0
Predators				
Feb	4	3	*	0
Apr	1	3	1	0
Jul	3	5	0	1
Oct	7	5	0	3
Mean Number of Taxa/20 m^2	3.8	4.0	0.3	1.0

* Stations 3, 4, and 7 were covered with sand, no biological observations were made.

Table 5B-8. Trophic composition as represented by the number of taxa of each trophic type sampled at the offshore kelp stations during 1979.

Trophic Type / Survey	Station 9	10	11	22	23
Primary Producers					
Feb	19	13	16	15	15
Apr	17	16	16	14	14
Jul	12	12	17	18	18
Oct	14	18	19	22	20
Mean Number of Taxa/10 m^2	15.5	14.8	17.0	17.3	16.8
Suspension Feeders					
Feb	34	12	25	19	19
Apr	26	14	26	30	24
Jul	29	16	27	20	24
Oct	31	18	30	21	27
Mean Number of Taxa/10 m^2	30.0	15.0	27.0	22.5	23.5
Grazers					
Feb	3	2	0	8	4
Apr	2	2	0	6	5
Jul	4	5	2	5	5
Oct	7	4	4	5	6
Mean Number of Taxa/10 m^2	4.0	3.3	1.5	6.0	5.0
Scavengers					
Feb	5	5	6	7	6
Apr	2	7	5	11	6
Jul	7	7	9	6	5
Oct	8	2	9	9	9
Mean Number of Taxa/10 m^2	5.5	5.3	7.3	8.3	6.5
Predators					
Feb	8	3	4	5	1
Apr	1	3	4	4	5
Jul	2	6	5	3	3
Oct	10	3	9	7	9
Mean Number of Taxa/10 m^2	5.3	3.8	5.5	4.8	4.5

Table 5B-9. Density (number/m^2) and rank order of abundance (value in parentheses) of the five most abundant taxa enumerated at inshore cobble substratum stations during 1979.

	Stations 1 and 2				Stations 6 and 8			
Abundant Taxa	Feb	Apr	Jul	Oct	Feb	Apr	Jul	Oct
Cystoseira/Halidrys	0.3	1.2 (1)	1.4 (5)	1.8 (5)	3.7 (1)	2.1 (2)	2.2 (3.5)	3.4 (3)
Muricea californica	1.2 (3)	0.4 (3)	1.9 (4)	1.7	1.8 (3)	2.2 (1)	14.8 (2)	11.5 (1)
Diopatra ornata	1.6 (2)	0.2 (4)	3.2 (3)	2.1 (4)	1.5 (4)	1.6 (3)	2.2 (3.5)	3.6 (2)
Diopatra splendissima	0.0	0.0	0.0	0.1	0.3	0.2 (4)	0.1	0.0
Spiochaetopterus costarum	0.6 (5)	0.1	0.1	0.5	1.9 (2)	0.1 (5)	0.2	0.2
Crepipatella lingulata	0.0	0.0	0.0	3.0 (3)	0.0	0.0	0.0	0.2
Mitrella carinata	2.0 (1)	0.2 (5)	0.1	0.5	0.5 (5)	0.0	0.1	0.4
Pelecypods, unident.	0.0	0.0	0.0	0.1	0.1	0.0	0.0	1.8 (4)
Chelyosoma productum	0.0	0.0	96.5 (1)	43.6 (1)	0.0	0.0	19.9 (1)	1.5 (5)
Styela montereyensis	0.6 (4)	0.6 (2)	4.6 (2)	5.0 (2)	0.0	0.1	2.0 (5)	1.0
Total number of individuals*	172	56	2196	1264	230	154	906	536
Total individuals, abundant taxa**	120	52	2152	1110	188	124	822	436
Percent†	69.8	92.8	98.0	87.8	81.7	80.5	90.7	81.3

* Estimates based on 20 m^2 of sampling area.
** Total numbers of individuals contributed by the five most abundant taxa.
† Percent represented by the five most abundant taxa.

Table 5B-10. Mean percent cover (%/m^2) and rank order of abundance (value in parentheses) of the five most abundant taxa sampled at the inshore cobble substratum stations during 1979.

	Stations 1 and 2				Stations 6 and 8			
Abundant Taxa	Feb	Apr	Jul	Oct	Feb	Apr	Jul	Oct
Bryopsis hypnoides	0.0	0.0	0.0	0.0	4.1 (3)	1.9	7.2 (4)	5.6 (2)
Acrosorium uncinatum	1.0	0.6	3.2 (5)	8.2 (2)	0.2	0.0	0.6	0.4
Corallina/Haliptylon	0.5	0.3	0.4	0.6	10.0 (1)	3.2 (3)	5.0 (5)	3.4 (3)
Hildenbrandia prototypus	2.5 (4)	0.6	1.0	0.8	0.7	0.3	0.2	0.5
Platythamnion spp.	0.0	0.0	0.0	2.0 (5)	0.0	0.0	0.0	0.1
Crustose corallines, unident.	9.8 (1)	1.5 (4)	12.8 (3)	1.1	3.6 (4)	0.6	1.1	0.9
Parjosilvosa	7.4 (2)	4.5 (1)	23.8 (2)	8.6 (1)	9.4 (2)	5.3 (1)	10.1 (2)	2.8 (4)
Rhodophytes, unident.	1.3	0.8	0.7	1.3	3.3 (5)	1.0	1.5	1.0
White crustose corallines	1.4 (5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leucilla nuttingi	0.3	0.0	0.9	0.6	0.9	1.7	0.7	2.3 (5)
Hydroids, unident.	0.6	2.4 (2)	2.8	2.8 (4)	0.8	0.8	1.0	0.9
Balanus spp.	0.2	0.7	1.8	0.6	0.9	2.0 (5)	1.0	0.9
Ectoprocts, unident. (erect)	0.7	1.0 (5)	4.0 (4)	3.1 (3)	1.8	3.3 (2)	9.1 (3)	7.6 (1)
Ectoprocts, unident. (encr.)	4.0 (3)	2.2 (3)	33.0 (1)	1.9	0.8	1.5	21.6 (1)	0.9
Euherdmania claviformis	0.6	0.6	0.7	0.6	2.3	2.8 (4)	1.3	0.9
Total Biological cover*	34.2	18.3	93.4	39.4	45.4	28.6	69.7	34.6
Cover, abundant taxa**	25.1	11.6	76.8	24.7	30.4	16.6	53.0	21.7
Percent (%)†	73.4	63.4	82.2	62.7	67.0	58.0	76.0	62.7

* Estimates based on 20 m^2 of sampling area.
** Total percent cover contributed by the five most abundant taxa.
† Percent of the biological cover accounted for by the five most abundant taxa.

Abundant enumerated taxa at all inshore cobble stations included one alga and nine invertebrates (Table 5B-9), which accounted for a mean of 85% of all individuals enumerated. Minimum and maximum numbers of individuals of these abundant taxa in both zones were observed during the April and July surveys, respectively. These surveys were conducted during or after periods of major (April) and minor (July) nearshore disturbances from storms. High numbers of individuals were also sampled during the late fall (October) when swell was reduced. Comparison of the total number of individuals of abundant taxa recorded in each zone indicated a statistically significant difference between zones with greater numbers recorded in Zone 0A (Mann-Whitney test, $P \leq 0.05$).

Both zones exhibited substantial increases in the abundance of the solitary plate tunicate, *Chelyosoma productum*, during the July survey. These increases may represent recruitment as evidenced by the high numbers of small individuals observed. Similarly, the sea fan, *Muricea californica* exhibited a considerable numerical increase in Zone 6 during the July survey period. *Muricea* is a long-lived soft coral (Grigg 1975) and the appearance of numerous juveniles during this survey may be considered evidence of recruitment to uninhabited hard substrata (Table 5B-9).

No enumerated taxa in either zone were consistently ranked first or second during 1979. Only the ornate polychaete, Diopatra ornata, was ranked among the five most abundant organisms, occurring during all surveys in both zones (Table 5B-9).

Abundant percent cover taxa sampled at inshore cobble stations in Zones 0A and 6 during each 1979 sampling period included nine algae or algal assemblages and six invertebrates (Table 5B-10). These taxa accounted for an average of 68% of the total biological cover at cobble stations within Zones 0A and 6. Similar to abundance estimates of enumerated organisms, the lowest total percent biological cover was observed during the April survey and the highest during the July survey in both zones.

Four taxa, unidentified crustose coralline algae, the algal assemblage Parvosilvosa, and unidentified encrusting and erect ectoprocts, were considered abundant in both zones (Table 5B-10). Maximum percent cover abundance estimates of these groups were recorded during the July survey in both zones. Minimum percent cover estimates for these organisms in Zone 0A were observed during the April survey. Similar minimum estimates of unidentified erect ectoprocts and Parvosilvosa were recorded in Zone 6 during April and October, respectively.

Abundant taxa or taxa assemblages observed at the inshore sand stations in Zone 0A and Zone 6 during the 1979 sampling period included 13 invertebrates represented by 10 sessile and 3 motile species. These abundant organisms accounted for an average of 99% of all individuals sampled at the inshore sand stations during the 1979 survey period (Table 5B-11).

Table 5B-11. Density (number/m^2) and rank order of abundance (value in parentheses) of the five most abundant taxa enumerated at inshore sand substratum stations during 1979.

	Stations 3 and 4				Stations 5 and 7			
Abundant Taxa	Feb*	Apr	Jul	Oct	Feb*	Apr	Jul	Oct
Muricea californica		0.2 (2)	0.05 (4)	0.1 (3)	1.7 (2)	1.3 (2)	1.8 (3)	1.6 (3)
Diopatra ornata		0.8 (1)	1.4 ([illegible])	0.5 (2)	4.5 (1)	0.0	1.9 (2)	4.6 (2)
Diopatra splendissima		0.0	0.0	0.8 (1)	0.0	8.2 (1)	6.4 (1)	4.7 (1)
Spiochaetopterus costarum		0.0	0.0	0.0	0.4 (4)	0.0	0.0	0.1
Onuphid, unident.		0.0	0.2 (2)	0.05 (4)	0.2 (5)	0.0	0.2	0.5 (4)
Sabellariid, unident.		0.0	0.0	0.0	0.0	0.0	0.0	0.2 (5.5)
Loxorhynchus spp.		0.0	0.05 (4)	0.0	0.0	0.0	0.0	0.0
Kelletia kelletii		0.0	0.0	0.0	0.0	0.05 (3)	0.0	0.0
Patiria miniata		0.05 (3)	0.0	0.0	0.0	0.0	0.0	0.1
Chelyosoma productum		0.0	0.0	0.0	0.0	0.0	0.4 (4)	0.0
Clavelina huntsmani		0.0	0.0	0.0	0.7 (3)	0.0	0.0	0.0
Styela montereyensis		0.0	0.0	0.0	0.0	0.0	0.2 (5)	0.2 (5.5)
Invertebrate eggs, unident.		0.0	0.05 (4)	0.0	0.0	0.0	0.0	0.0
Total number of individuals*		20	35	29	78	190	220	245
Total individuals, abundant taxa**		20	35	29	75	190	214	236
Percent (%)†		100	100	100	96.2	100	97.3	96.3

* Stations 3 and 4 in Zone 0A and 7 in Zone 6 were covered with sand during the February survey and no biological data were collected; therefore, these data are based upon 10 m^2 of sampling area.
** Total numbers of individuals contributed by the five most abundant taxa.
† Percent represented by the five most abundant taxa.

Only one organism, Muricea californica, was considered abundant in both zones during all survey periods. Two congeners of the polychaete Diopatra were also observed in both zones and were consistently ranked first or second during surveys when they were present. The maximum number of Diopatra was found during the July survey period. With the exception of an unidentified onuphid polychaete, the remaining abundant organisms sampled at the inshore sand stations occurred in low densities and were recorded in only one of the two zones (Table 5B-11).

The five most abundant enumerated and percent cover taxa and/or taxa assemblages observed at the kelp stations during the 1979 sampling period are presented in Tables 5B-12 and 5B-13, respectively. These taxa are defined as abundant, are generally non-motile, and appear to represent the dominant and functionally important organisms associated with the kelp forest habitat.

Table 5B-12. Density (number/m^2) and rank order of abundance (value in parentheses) of the five most abundant taxa enumerated at each kelp station during 1979.

Abundant Taxa	Station 9 Feb	Station 9 Apr	Station 9 Jul	Station 9 Oct	Station 10 Feb	Station 10 Apr	Station 10 Jul	Station 10 Oct	Station 11 Feb	Station 11 Apr	Station 11 Jul	Station 11 Oct
Macrocystis spp.	2.0(4)	1.2(4)	0.4	0.3	0.0	0.0	0.0	0.0	2.6(3)	1.6(4)	1.6	1.5
Muricea californica	1.1	1.0(5)	1.3	3.1(5)	0.1	0.0	0.0	0.0	1.9(5)	2.0(3)	2.1	2.5(5)
Zaolutus actius	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0(4)
Anemone, unident.	0.0	0.2	0.1	0.8	0.4	0.5	0.2	0.0	2.2(4)	1.1	2.8(5)	0.0
Diopatra ornata	1.7(5)	1.5(2)	2.7(5)	2.1	2.2(2)	1.1(3.5)	0.6	0.2	3.5(2)	2.9(2)	5.0(3)	6.4(2)
Phragmatopoma californica	0.6	0.0	7.0(3)	0.0	0.4	0.0	1.5	0.0	0.4	0.0	0.6	0.0
Spiochaetopterus costarum	1.3	0.2	1.6	0.0	1.4(3.5)	0.2	3.5(3)	4.7(2)	0.4	0.1	3.2(4)	0.6
Onuphid, unident.	0.0	0.0	0.0	0.0	0.2	0.1	0.0	1.0(5)	0.0	0.0	0.0	0.0
Balanus spp. (moribund)	0.0	0.0	0.0	0.0	0.0	0.0	3.6(2)	0.0	0.0	0.0	0.0	0.0
Tetraclita spp.	0.0	0.0	0.0	0.0	0.0	0.0	2.7(4)	0.0	0.0	0.0	0.1	0.0
Pagurids, unident.	7.3(2)	0.0	0.1	3.3(4)	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.3
Mitrella carinata	12.0(1)	0.4	1.2	30.2(2)	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.6
Kelletia kelletii	0.6	0.4	0.6	1.5	0.9(5)	0.8(5)	0.8	0.0	1.3	0.3	0.2	0.7
Patiria miniata	0.0	0.0	0.0	0.0	1.4(3.5)	1.3(2)	1.0	0.9	0.0	0.0	0.0	0.0
Lytechinus spp.	0.0	0.0	0.5	3.7(3)	2.8(1)	4.1(1)	2.4(5)	3.1(3)	0.0	0.0	0.3	0.2
Strongylocentrotus purpuratus	1.2	0.0	0.3	0.1	0.4	1.1(3.5)	0.9	0.5	0.0	0.0	0.0	0.0
Strongylocentrotus franciscanus	1.0(3)	2.5(1)	1.3	7.8	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.4
Chelyosoma productum	1.3	1.4(3)	31.5(1)	32.6(1)	0.0	0.0	15.4(1)	8.2(1)	0.0	0.5	5.1(2)	11.6(1)
Distaplia occidentalis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3(5)	0.0	0.0
Molgula spp.	0.1	0.0	11.4(2)	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Pyura haustor	0.3	0.4	2.9(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0
Styela montereyensis	0.1	0.2	1.8	2.4	0.0	0.2	0.8	1.1(4)	4.7(1)	3.6(1)	5.8(1)	6.1(3)
Total number of individuals*	381	115	673	950	108	108	367	218	211	161	327	442
Total individuals, top 5 taxa**	260	76	555	729	87	84	276	181	149	114	219	306
Percent (%)†	68.2	66.1	2.5	6.7	80.6	77.8	75.2	83.0	70.6	70.8	67.0	69.2

Abundant Taxa	Station 22 Feb	Station 22 May	Station 22 Jul	Station 22 Oct	Station 23 Feb	Station 23 May	Station 23 Jul	Station 23 Oct
Pterygophora californica	2.2(3)	2.2(5)	2.8(2)	4.5(2)	22.5(2)	27.7(2)	27.6(2)	20.8(2)
Laminoid, unident.	0.0	0.0	0.2	0.0	0.0	0.0	15.5(4)	0.0
Muricea californica	0.6	0.7	1.0(5.5)	0.4	0.2	0.3	0.3	0.5
Epiactis prolifera	0.8	2.4(3.5)	0.2	0.0	0.0	0.0	0.0	0.0
Diopatra ornata	0.6	0.7	1.1(4)	1.2	2.3(5)	2.2(6)	7.3(5)	8.8(4)
Sabellaria cementarium	1.3(4)	3.6(2)	0.0	0.0	0.3	2.2(6)	0.0	0.0
Paguristes, spp.	0.9	3.6	1.8(3)	0.1	0.3	0.0	0.0	0.1
Pagurids, unident.	3.6(1)	0.3	0.9	4.3(3)	0.0	0.0	2.4	5.2(5)
Mitrella carinata	1.1	2.4(3.5)	0.2	1.1	6.4(4)	5.2(4)	0.3	2.0
Kelletia kelletii	0.6	1.2	0.3	0.8	1.7	2.2(6)	1.0	0.5
Lytechinus spp.	0.5	0.2	1.0(5.5)	0.5	0.4	0.3	0.0	0.3
Strongylocentrotus franciscanus	1.2(5)	1.2	0.8	1.4(5)	0.0	0.1	0.0	0.0
Chelyosoma productum	2.8(2)	6.5(1)	12.2(1)	9.4(1)	109.7(1)	123.6(1)	125.2(1)	73.0(1)
Styela montereyensis	0.4	1.4	0.7	1.5(4)	8.6(3)	10.8(3)	21.8(3)	16.6(3)
Total number of individuals*	237	335	277	324	156	181	210	145
Total individuals, top 5 taxa**	111	171	199	211	150	174	197	125
Percent (%)†	46.8	51.0	71.8	65.1	95.8	95.9	94.2	85.6

* Estimates based on 10m^2 of sampling area.
** Total number of individuals accounted for by the five most abundant taxa.
† Percent represented by the five most abundant taxa.

The abundant enumerated organisms sampled at the five kelp stations included 27 taxa consisting of three algal and 23 invertebrate taxa and a single secondary substrata group (Balanus spp., moribund, Table 5B-12). These abundant organisms accounted for a mean of 75% of the total number of individuals observed at each kelp station during the 1979 sampling period. The mean of the total number of individuals observed at each kelp station during 1979, calculated by averaging the total number of individuals sampled during each survey, ranged from 530 at Station 9 (San Mateo Kelp) to 173 at Station 23 (San Onofre Kelp). Mean total number of individuals at Stations 22 (San Onofre Kelp) and 11 (Barn Kelp) were 293 and 285, respectively. Low total number of individuals were recorded during the April survey period at Stations 9, 10, and 11. Low numbers of individuals were also observed during the February and October surveys at Stations 22 and 23, respectively. Comparison of the total number of individuals observed at each kelp station during each survey period revealed a statistically significant difference among kelp stations, with Station 9 averaging the greatest number of individuals throughout the year (median test, $P \leq 0.05$).

No enumerated taxon was considered abundant at all kelp stations during the 1979 sampling period. The majority of abundant enumerated taxa usually occurred infrequently throughout 1979. Five organisms including Lytechinus spp. at Station 10, Diopatra ornata and Styela montereyensis at Stations 11 and 23, and Pterygophora californica and Chelyosoma productum at Stations 22 and 23 were abundant during each survey (Table 5B-12). Mean densities of these organisms were calculated by averaging the number of individuals counted in each of the ten 1-m^2 quadrats. The urchin Lytechinus was usually the most numerous organism observed at Station 10, occurring in mean densities ranging from 2.8 to 4.1/m^2 during 1979. Lytechinus was also found at Stations 9 (3.7/m^2) and 22 (1.0/m^2) during the October and July survey periods, respectively. The polychaete Diopatra ornata occurred in mean densities ranging from 2.9 to 6.4/m^2 and 2.2 to 8.8/m^2 at Stations 11 and 23 during 1979, respectively. Although Diopatra was observed during at least one survey at all other kelp stations, mean densities were less than 2.0/m^2. The tunicate Styela montereyensis was observed in mean densities ranging from 3.6 to 6.1/m^2 and 8.6 to 21.8/m^2 at Stations 11 and 23, respectively. In contrast, Styela density in October at Station 22 was 1.5/m^2. These animals may represent new recruits. The presence of juvenile Styela spp. has been noted at several inshore and offshore cobble stations during 1979.

Table 5B-13. Mean percent cover (%/m^2) and rank order of abundance (value in parentheses) of the five most abundant taxa sampled at each kelp station during 1979.

Abundant Taxa	Station 9 Feb	Apr	Jul	Oct	Station 10 Feb	Apr	Jul	Oct	Station 11 Feb	Apr	Jul	Oct
Bossiella spp.	1.1	0.4	0.1	0.4	0.0	0.0	0.0	0.0	2.6	1.9(5.5)	1.4(5.5)	1.5
Corallina/Haliptylon	5.2	2.7	1.8	1.1	0.2	0.1	0.1	0.0	3.1(4)	0.9	1.4(5.5)	0.1
Hildenbrandia prototypus	0.9	0.4	0.1	0.9	8.3(3)	2.5(4)	2.5(3)	1.1	0.6	1.1	0.0	0.8
Pterocladia/Gelidium	10.2(3)	7.4(5)	5.7(4)	4.2(5)	0.0	0.0	0.0	0.0	1.7	0.9	1.0	1.1
Rhodymenia spp.	8.2(5)	12.[illegible](4)	1.3	3.3	0.4	0.5	0.8	0.0	7.7(2)	4.1(3)	10.4(1)	8.7(2)
Crustose corallines, unident.	11.0(2)	14.5(3)	26.2(1)	11.8(1)	42.7(1)	35.0(1)	33.0(1)	47.5(1)	2.3	1.0	0.5	1.7
Parvosilvosa	17.8(1)	21.5(1)	2.7(5)	6.8(2)	16.9(2)	16.5(2)	23.2(2)	37.0(2)	7.9(1)	5.4(2)	5.3(3)	17.5(1)
White coralline crust	0.3	0.0	0.0	0.0	1.3(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leucilla nuttingi	1.8	2.6	0.7	2.0	0.5	0.1	0.0	0.2	0.9	0.5	0.4	3.0(5)
Hydroids, unident.	2.5	15.0(2)	1.0	4.5(4)	0.5	1.4	0.9	2.6(4)	0.5	1.9(5.5)	1.0	4.3(4)
Astrangia spp.	3.5	2.1	1.9	1.0	6.3(4)	3.0(3)	2.4(4)	3.5(3)	0.5	0.4	0.5	0.6
Balanus spp.	0.3	0.0	0.0	0.0	0.4	2.0(5)	0.0	0.3	0.0	0.2	0.0	0.0
Ectoprocts, unident. (encr)	9.8(4)	4.[illegible]	9.4(2)	1.2	0.6	1.4	0.5	2.5(5)	7.3(3)	2.9(4)	1.9(4)	1.1
Ectoprocts, unident. (erect)	2.6	7.3	6.9(3)	5.0(3)	0.0	0.2	0.0	0.0	2.7(5)	7.2(1)	6.8(2)	5.2(3)
Trididemnum/Didemnum	0.8	0.3	1.2	1.5	0.8	0.3	1.0(5)	0.4	0.2	0.1	0.1	1.0
Total biological cover*	84.8	104.2	68.5	53.3	81.3	67.0	67.6	106.9	45.8	36.3	40.1	57.9
Cover, abundant taxa**	57.0	70.9	50.4	32.1	75.5	59.0	62.6	93.1	28.7	23.3	27.2	39.2
Percent (%)†	67.2	68.0	73.6	60.1	92.9	88.0	92.6	87.1	62.7	64.2	67.8	67.7

Abundant Taxa	Station 22 Feb	May	Jul	Oct	Station 23 Feb	May	Jul	Oct
Bossiella spp.	1.4	0.8	2.1	1.6(4.5)	0.1	0.1	0.1	0.2
Corallina/Haliptylon	1.2	1.4	2.8(5)	1.6(4.5)	0.6	0.7	0.4	0.8
Pterocladia/Gelidium	1.3	0.9	1.9	1.4	4.9(4)	4.4(5)	7.8	3.5(4)
Rhodymenia spp.	10.2(3)	8.4(3)	6.3(3)	5.7(3)	20.5(3)	18.6(3)	11.1(4)	10.0(3)
Crustose corallines, unident.	33.6(1)	37.1(1)	37.6(1)	11.1(2)	48.5(1)	58.5(1)	33.8(1)	32.7(1)
Parvosilvosa	12.2(2)	21.6(2)	24.1(2)	11.7(1)	29.5(2)	30.5(2)	22.3(2)	29.2(2)
Hydroids, unident.	0.7	1.7	0.8	0.9	0.9	2.9	8.5(5)	3.0
Astrangia spp.	1.8(5)	1.4	0.[illegible]	0.9	0.7	0.7	1.2	1.0
Balanus spp.	1.0	3.5(5)	3.[illegible]	1.2	1.3	0.7	0.0	0.1
Ectoprocts, unident. (erect)	0.0	0.0	2.0	1.0	0.0	0.0	19.7(3)	3.1(5)
Ectoprocts, unident.	3.4(4)	4.1(4)	1.4	[illegible].0	3.5(5)	5.4(4)	1.6	1.1
Total biological cover*	70.0	85.0	90.2	45.3	113.2	129.6	118.7	96.5
Cover, abundant taxa**	61.2	74.7	74.2	31.7	106.9	117.4	95.4	78.5
Percent (%)†	87.4	87.9	62.3	70.0	94.4	90.6	80.4	81.3

* Estimates based on 10 m^2 of sampling area.
** Total percent cover contributed by the five most abundant taxa.
† Percent of the total biological cover accounted for by the five most abundant taxa.

Mean densities of the kelp Pterygophora californica and the tunicate Chelyosoma productum ranged from 2.2 to 4.5/m^2 and 2.8 to 12.2/m^2 at Station 22, and from 20.8 to 27.7/m^2 and 73.0 to 125.2/m^2 at Station 23, respectively. Pterygophora was not recorded as an abundant enumerated organism at the other offshore kelp stations. Chelyosoma was considered an abundant organism at Stations 10 and 11 during the July and October surveys and at Station 9 during April, July and October surveys. Mean densities of Chelyosoma during these survey periods at Stations 9, 10, and 11 were 18.5, 11.8, and 8.4/m^2, respectively.

Abundant percent cover organisms observed at offshore kelp stations during 1979 include 16 taxa or taxa assemblages representing eight algae and eight invertebrate taxa (Table 5B-13). The abundant percent cover organisms accounted for an average of 78.3% of the total biological cover observed at the offshore kelp stations during the 1979 sampling period.

Total biological cover was greatest at Station 23 which averaged 114.5% during 1979. Biological cover was similar among Stations 10, 22, and 9 during 1979 averaging 80.7, 72.6, and 77.8%, respectively (Table 5B-13). Statistical comparison of the total percent biological cover observed at each kelp station during 1979 revealed no significant differences among stations (median test, $P \leq 0.05$).

Parvosilvosa was the only abundant percent cover taxa which occurred at each kelp station during all surveys (Table 5B-13). Mean percent cover estimates were greatest at Stations 23 and 10 where 27.8 and 23.5% cover was observed, respectively. Estimates of Parvosilvosa were similar at Stations 9 and 22 averaging 12.2 and 17.4%, respectively. The minimum mean estimate of Parvosilvosa (9.0%) was recorded at Station 11 during 1979. Statistical comparison of percent cover estimates of Parvosilvosa sampled at each kelp station during the 1979 sampling period revealed no significant differences among stations (median test, $P > 0.05$). Percent cover estimates of Parvosilvosa at Station 9, however, decreased significantly during the July and October surveys in comparison to the February and April survey periods (t-test, $P \leq 0.05$).

Unidentified crustose coralline algae were considered abundant at all stations except Station 11 and was generally the most abundant percent cover organism sampled. Highest mean percent cover of this taxon was recorded at Station 23 (43.4%). High levels were also found at Stations 10 (39.6%) and 22 (29.8%). Percent cover estimates were usually lowest during each survey at Station 9 which averaged 15.9% during the year. Temporal comparison of percent cover estimates of unidentified encrusting coralline algae recorded at Stations 9, 10, 22, and 23 detected a significant difference in abundance patterns among kelp stations (median test, $P \leq 0.05$).

The alga *Rhodymenia* spp. ranked as an abundant organism at Stations 11, 22, and 23 during all survey periods and averaged 7.7, 7.7, and 10.0% cover, respectively. It occurred at Station 9 averaging 10.4% cover during the February and April surveys (Table 5B-13).

OFFSHORE COBBLE STATIONS

The sampling design for the offshore cobble stations uses two sampling strategies to generate data describing the benthic communities associated with cobble habitats. These strategies include abundance estimates of the dominant flora and fauna by the sampling of a 2 x 3-m (6.0-m^2) station area with 300 evenly distributed points. The second strategy subsamples the same 6.0-m^2 station area with four randomly placed 0.125-m^2 quadrats to generate dispersion data (*in sensu* Elliott 1971) on the numerically dominant as well as the less conspicuous organisms. These two sampling methods produce different data types and are presented independently in this section. The results of both will be considered collectively in the discussion of all the 1979 benthic data.

Wide Area Substrata Reconnaissance

Estimates of substrata composition at offshore cobble stations were presented in SCE 1980a (Tables 6-91 through 6-94). A definite distinction exists between groups of station-pairs in regard to substrata composition. Station-pairs 12-13, 14-15, 16-17, and 18-19 are characterized by a predominance of dynamic cobble and boulder habitats. Although the composition of cobble and boulder is variable, the total composition of hard substrata is relatively stable. Station-pair 20-21, historically surrounded by an extensive sand plain, is the only station-pair dominated by sand.

Total Number of Taxa, Percent Hard Substrata, and Percent Biological Cover

Observations on the total number of taxa, total percent hard substrata, and total percent biological cover collected using the 6.0-m^2 sampling technique at each offshore cobble station from August 1978 through October 1979 are summarized in Table 5B-14.

Table 5B-14. Total number of taxa (T), total percent hard substrata (S), and total percent biological cover (B) sampled at each offshore 6.0 m^2 cobble station from August 1978 through October 1979.

		1978		1979					Std
		Aug	Oct	Feb	Apr	Jul	Oct	Mean	Error
Station 12	T	27	22	22	30	30	22	25.5	1.6
	S	89.3	87.7	91.0	95.7	96.3	96.0	92.7	1.6
	B	191.7	157.3	147.3	159.3	168.3	150.0	162.3	6.6
Station 13	T	36	24	24	28	31	27	28.3	1.9
	S	89.7	91.0	90.3	95.7	98.3	94.7	93.3	1.4
	B	165.7	173.0	150.7	167.0	195.7	163.7	169.3	6.1
Station 14	T	31	32	25	31	29	29	29.5	1.0
	S	94.0	81.3	82.7	86.0	90.0	89.3	87.2	2.0
	B	177.7	133.3	124.7	178.3	181.3	178.0	162.2	10.6
Station 15	T	33	27	25	28	29	29	28.5	1.1
	S	90.3	92.3	82.7	90.0	90.7	86.0	88.7	1.5
	B	202.3	171.0	134.7	142.0	185.7	171.3	167.8	10.5
Station 16	T	20	18	23	19	25	15	20.0	1.5
	S	63.3	69.3	59.3	68.0	64.3	66.7	65.2	1.5
	B	121.0	149.0	122.3	121.0	143.0	118.7	129.2	5.4
Station 17	T	21	20	18	20	26	21	21.0	1.1
	S	68.0	74.7	68.7	71.7	61.7	63.3	68.0	2.0
	B	175.0	175.0	182.0	183.0	177.3	184.0	179.4	1.7
Station 18	T	23	19	17	17	20	21	19.5	1.0
	S	90.0	91.0	86.0	91.7	89.7	93.0	90.2	1.0
	B	119.3	131.0	121.3	115.7	142.3	143.3	128.8	4.9
Station 19	T	22	19	18	23	21	22	20.8	0.8
	S	88.3	92.0	88.7	92.7	92.0	85.0	89.8	1.2
	B	118.7	117.7	118.3	122.3	117.3	113.0	117.9	1.2
Station 20	T	28	22	24	25	24	29	25.3	1.1
	S	50.7	58.0	50.7	67.3	59.0	62.0	58.0	2.7
	B	60.0	72.0	85.7	98.0	87.3	89.7	82.1	5.6
Station 21	T	26	19	21	20	22	24	22.0	1.1
	S	57.0	68.3	66.3	76.3	64.3	65.3	66.3	2.6
	B	72.7	91.7	90.0	98.0	98.0	106.0	92.7	4.6

The offshore cobble stations may be separated into three groups based on station location and similar mean estimates of the total number of taxa, percent hard substrata, and percent biological cover (Figure 5B-2, Table 5B-14). These groups are Station-pairs 12-13 and 14-15, Station-pairs 16-17 and 18-19, and Station-pair 20-21. The highest mean estimates of total number of taxa, percent hard substrata, and percent biological cover (with the exception of Station 17) occurred at Station-pairs 12-13 and 14-15 located near San Mateo Kelp and approximately 600 m upcoast of the Unit 2 diffuser, respectively (Figure 5B-2, Table 5B-14). The lowest mean number of taxa and intermediate estimates of percent biological cover were recorded at Station-pairs 16-17 and 18-19 which are located approximately 800 m and 2 km downcoast of the Unit 3 diffuser near the offshore center of San Onofre Kelp, respectively (Figure 5B-2, Table 5B-14). Percent hard substrata estimates were intermediate at Station-pair 18-19 and low at Station-pair 16-17. An intermediate estimate of the mean number of taxa, and low estimates of percent hard substrata and percent biological cover were recorded at Station-pair 20-21 located approximately 8 km downcoast of San Onofre Kelp on a small cobble area surrounded by sand (Figure 5B-2, Table 5B-14). Statistical comparisons of the total number of taxa, percent hard substrata, and percent biological cover revealed a significant difference among station groups with highest mean estimates recorded at Station-pairs 12-13 and 14-15 (ANOVA, $P \leq 0.001$).

Temporal changes associated with number of taxa were not apparent during the 1978-1979 sampling period, however, percent hard substrata and biological cover varied moderately through time at some stations (Table 5B-14). Hard substrata estimates exhibited little variation (standard errors ≤ 2.0) among surveys at Stations 12 through 19 (Table 5B-12). In contrast, hard substrata estimates recorded at Station-pair 20-21 increased 9.8% between the August 1978 and October 1979. Temporal variation associated with total biological cover was greatest at Station-pair 14-15 where maximum estimates were generally recorded during the summer sampling periods in both 1978 and 1979, and minimum estimates were recorded during the February 1979 survey. Moderate temporal variation in percent biological cover was recorded at Station-pair 20-21 which exhibited a mean increase of 31.5% between August 1978 and October 1979 (Table 5B-14). A significant positive correlation (Spearman rho, $P < 0.05$) was found between the estimates of hard substrata and biological cover for the six sampling periods.

Community Composition

Distinct similarities exist among the offshore cobble station-pairs with regard to percent cover of primary producing algae and sessile invertebrates (Table 5B-15). Station-pairs 12-13 and 20-21 exhibited a greater mean percent cover of sessile invertebrates than primary producers. Data for individual surveys reveal that relative abundances of algae and sessile invertebrates reversed patterns of dominance between the October 1978 and February 1979 surveys at Station 12. Station 13 has had a higher percent cover of sessile invertebrates than primary producers during all surveys. The distance between Stations 12 and 13 may account for these differences. The kelp canopy over Station 13 has, in the past, been more prevalent because of neighboring adult *Macrocystis* plants. Therefore, ambient light reaching the underlying benthic community probably was less than at Station 12 until the kelp canopy extended over both stations. The reverse relationship is apparent at Station-pairs 14-15, 16-17, and 18-19 where primary producer percent cover was always substantially greater than invertebrate cover. The only exception to this occurred at Station 18 during August 1978 where sessile invertebrate cover slightly exceeded primary producer cover and at Station 12 which had greater primary producer cover through the October 1978 survey.

Table 5B-15. Biological cover (%/6 m^2) of primary producers (PP) and sessile invertebrates (SI) observed at offshore cobble stations from August 1978 through October 1979.

Station	PP/SI	1978 Aug	1978 Oct	1979 Feb	1979 Apr	1979 Jul	1979 Oct	Mean	Standard Error
12	PP	138	83	59	49	35	33	66.2	16.2
	SI	50	65	72	91	94	86	76.3	7.0
13	PP	59	51	34	27	40	35	41.0	4.9
	SI	94	107	102	125	151	104	113.8	8.5
14	PP	138	100	87	137	138	131	121.8	9.2
	SI	19	17	12	25	21	21	19.2	1.8
15	PP	174	139	83	112	152	141	133.5	13.0
	SI	18	18	13	14	18	13	15.7	1.1
16	PP	77	114	101	93	112	103	100.0	5.6
	SI	10	6	5	4	10	2	6.2	1.3
17	PP	121	145	146	151	150	154	144.5	4.9
	SI	14	7	5	9	15	7	9.5	1.7
18	PP	42	88	55	69	104	109	77.8	11.0
	SI	46	17	17	12	8	12	18.7	5.6
19	PP	61	68	65	65	70	74	67.2	1.9
	SI	28	18	13	20	12	11	17.0	2.6
20	PP	17	17	38	25	22	35	25.7	3.7
	SI	39	50	46	69	63	53	53.3	4.5
21	PP	21	37	28	28	25	32	28.5	2.3
	SI	47	52	48	66	72	72	59.5	4.8

Three Dimensional Layering of Organisms

Three distinct levels of biological cover ranging from organisms attached to the substratum to those which form a canopy over the substratum were recorded using the point contact sampling technique. Percent biological cover estimates recorded for Organism Level 1 (OL1), Organism Level 2 (OL2), and Organism Level 3 (OL3) at each offshore cobble station during the study period appear in Table 5B-16.

Inspection of these data reveals that OL1, the basement story, always included the major portion of the total biological cover reported for each station. High levels of mean percent biological cover observed at OL1 during the 1978-1979 sampling period were recorded at Stations 12, 13, 14, 15, and 17 with an average of 95.5%. Low levels of mean biological cover at the basement story were noted at Stations 16, 20, and 21 averaging 69.4%. The second story level, OL2, varied considerably among stations ranging from a mean of 18.0% cover at Station 20 to a mean of 62.7% cover at Station 17. The lowest proportion of biological cover always occurred in OL3, the overstory, ranging from a mean of 1.3% at Station 19 to 22.0% at Station 17 (Table 5B-16).

Table 5B-16. Biological cover (%/6 m^2) recorded at Organism Levels 1 (OL1), 2 (OL2), and 3 (OL3) from August 1978 to October 1979.

Station	Organism Level	1978 Aug	1978 Oct	1979 Feb	1979 Apr	1979 Jul	1979 Oct	Mean	Standard Error
12	OL3	18	9	7	8	13	9	10.7	1.7
	OL2	75	53	48	55	59	45	55.8	4.3
	OL1	98	95	92	96	97	97	95.8	0.9
13	OL3	9	10	4	13	15	11	10.3	1.5
	OL2	59	66	50	57	82	57	61.8	4.5
	OL1	98	97	97	96	99	96	97.2	0.5
14	OL3	17	6	4	14	20	18	13.2	2.7
	OL2	63	36	34	67	63	64	54.5	6.2
	OL1	97	92	87	98	99	96	94.8	1.9
15	OL3	28	14	5	5	20	14	14.3	3.6
	OL2	75	60	41	43	70	60	58.2	5.6
	OL1	99	97	89	94	96	97	95.3	1.4
16	OL3	7	18	12	6	12	5	10.0	2.0
	OL2	39	50	38	39	48	38	42.0	2.2
	OL1	75	81	72	76	84	76	77.3	1.8
17	OL3	30	18	25	17	22	20	22.0	2.0
	OL2	60	64	60	67	59	66	62.7	1.4
	OL1	85	93	97	98	96	98	94.5	2.0
18	OL3	2	2	1	1	7	8	3.5	1.3
	OL2	30	39	31	20	41	41	33.7	3.4
	OL1	88	90	89	95	95	95	92.0	1.4
19	OL3	2	1	2	0	1	2	1.3	0.3
	OL2	28	28	27	26	27	24	26.7	0.6
	OL1	89	89	91	96	89	87	90.2	1.3
20	OL3	1	2	2	3	5	2	2.5	0.6
	OL2	8	13	20	23	22	22	18.0	2.5
	OL1	52	57	69	72	61	66	62.8	3.1
21	OL3	1	3	3	1	3	2	2.2	0.4
	OL2	16	24	22	19	24	27	22.0	1.6
	OL1	57	65	61	78	71	76	68.0	3.4

The stations may be separated into three groups according to mean estimates of biological cover at each organism level (Table 5B-16). Similar high levels of biological cover in OL1 were found at Stations 12, 13, 14, 15, 18, 19, and 17 with a mean of 94.3% cover. Comparatively low mean levels of biological cover in OL1 were exhibited by Stations 16, 20, and 21. High estimates of mean biological cover in OL2 occurred at Stations 12, 13, 14, 15, and 17 with a mean of 58.6%. Intermediate mean estimates of biological cover in OL2 were associated with Stations 16, 18, and 19. Stations 12 through 17 had high mean estimates of biological cover at OL3 ranging from 10 to 22% while Stations 18 through 21 had low mean estimates varying from 1.3 to 3.5%. Similar to OL1, no stations had intermediate estimates of biological cover at OL3.

Descriptive Taxa

Descriptive organisms, in addition to elucidating temporal and spatial patterns of variation, may be indicative of subtle, specialized habitats, and provide insight to localized environmental influences. Descriptive organisms are defined the numerically abundant organisms (i.e., the five most abundant organisms per survey) as well as those organisms which, by means of their abundance patterns or functional adaptations, may be indicative of the local habitat types (e.g. stable cobble, sand scour areas).

The percent biological cover estimates for descriptive organisms sampled at Station-pair 12-13 during each survey period appear in Table 5B-17. Sessile invertebrates represented the majority of the mean biological cover at each station. The red alga *Rhodymenia* spp. and two sessile invertebrates, unidentified hydroids and *Muricea californica*, were the three most abundant organisms based on mean percent cover during the 1978-1979 sampling period at Station 12. *Rhodymenia* and the sessile invertebrates, *Muricea californica* and unidentified erect ectoprocts, were usually ranked 1, 2, or 3 during the same sampling periods at Station 13. Mean percent cover estimates of unidentified crustose corallines, unidentified hydroids, encrusting ectoprocts, Parvosilvosa, and *Rhodymenia* were similar between stations. Abundances of encrusting ectoprocts observed at Station 12 exhibited an increasing trend through time with maximum percent cover recorded during the July 1979 survey while no discernible temporal variation was present at Station 13. Differences in sessile invertebrate abundances between Stations 12 and 13 were also observed. *Muricea californica* was observed in greater abundances at Station 13 than at Station 12 during each survey, however, temporal variation at either station was not apparent. Unidentified erect

Table 5B-17. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at the offshore cobble Station-pair 12/13.

	Station 12						
	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	3 (8)	7 (7.5)	11 (5.5)	9 (7)	6 (7)	11 (6)	7.8
Rhodymenia spp.	49 (2)	39 (1)	35 (1)	26 (2)	28 (2)	22 (2.5)	33.2
Parvosilvosa	25 (3)	14 (5)	8 (7)	6 (8)	17 (4)	6 (7)	12.7
Macrocystis spp.	53 (1)	25 (2)	11 (5.5)	10 (6)	1 (8)	0 (8)	16.7
Hydroids, unident.	8 (5.5)	20 (4)	25 (2)	33 (1)	15 (5.5)	22 (2.5)	20.5
Muricea californica	23 (4)	22 (3)	21 (3)	19 (4)	15 (5.5)	16 (5)	19.3
Ectoprocts, unident. (encr.)	8 (5.5)	12 (6)	13 (4)	20 (3)	26 (3)	24 (1)	17.2
Ectoprocts, unident. (erect)	5 (7)	7 (7.5)	10 (6)	13 (5)	29 (1)	19 (4)	13.8
Total biological cover (%)	191.7	157.3	147.3	159.3	168.3	150.0	
Cover, descriptive taxa (%)*	174.0	146.0	134.0	136.0	137.0	120.0	
Percent (%)**	90.8	92.8	91.0	85.4	81.4	80.0	

	Station 13						
	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	8 (7)	13 (6)	8 (6.5)	7 (6.5)	7 (7)	12 (6)	9.2
Rhodymenia spp.	29 (2)	29 (2)	21 (2.5)	15 (4)	27 (3)	21 (3)	23.7
Parvosilvosa	11 (6)	15 (5)	8 (6.5)	7 (6.5)	9 (6)	8 (7)	9.7
Macrocystis spp.	4 (8)	3 (8)	1 (8)	0 (8)	1 (8)	0 (8)	1.5
Hydroids, unident.	16 (3)	12 (7)	16 (4)	31 (2)	16 (5)	14 (5)	17.5
Muricea californica	37 (1)	42 (1)	41 (1)	40 (1)	36 (2)	36 (1)	38.7
Ectoprocts, unident. (encr.)	12 (5)	17 (4)	11 (5)	13 (5)	17 (4)	17 (4)	14.5
Ectoprocts, unident. (erect)	14 (4)	21 (3)	21 (2.5)	26 (3)	38 (1)	24 (2)	24.0
Total biological cover (%)	165.7	173.0	150.7	167.0	195.7	163.7	
Cover, descriptive taxa (%)*	131.0	152.0	127.0	139.0	151.0	132.0	
Percent (%)**	79.1	87.9	84.3	83.2	77.2	80.6	

* Total percent cover contributed by the descriptive taxa.
** Percent of the total biological cover accounted for by the descriptive taxa.

ectoprocts occurred in greater abundances at Station 13 during each survey with maximum percent cover recorded during the July 1979 sampling period at both stations. Individuals of subadult Macrocystis spp. were considerably more abundant at Station 12 until the July 1979 survey when they decreased to abundance levels similar to those found at Station 13 throughout all surveys.

The descriptive taxa at Station-pair 14-15 during the 1978-1979 sampling period were represented mostly by algae (Table 5B-18). The four most abundant organisms based upon mean percent cover and rank during each sampling period at this station-pair include Parvosilvosa, Rhodymenia, unidentified crustose corallines, and Pterygophora californica. Temporal variation of the algal complex of Cryptonemia/Halymenia/Schizymenia, the brown alga Desmarestia spp., and Pterygophora californica at Station-pair 14-15 was evident. Percent cover estimates of Cryptonemia/Halymenia/Schizymenia were greatest during the August 1978 sampling periods when these organisms were dominant at both stations. Desmarestia also exhibited maximum abundance at Station 15 during August 1978. Percent cover estimates recorded during subsequent surveys revealed that abundances of these organisms had decreased substantially. Only Desmarestia exhibited comparatively high abundance at Station 14 during the April 1979 survey. Abundance estimates of Pterygophora were lowest during the initial three surveys at both stations. Significantly greater abundances were recorded during subsequent surveys at both stations (t-test, $P \leq 0.01$). This suggests that either successful recruitment had occurred or plants attached to small cobble had been transported to the area. Two other kelp species, Macrocystis spp. and Laminaria spp., were also noted at Station-pair 14-15 and showed no discernable temporal pattern.

Table 5B-18. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at the offshore cobble Station-pair 14/15.

	Station 14						
	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	15 (3)	12 (2)	16 (2)	11 (4.5)	11 (4)	19 (3)	14.0
Cryptomenia/Halymenia/Schizymenia	33 (2)	0 (9.5)	0 (9.5)	1 (8.5)	3 (6.5)	2 (7)	6.5
Rhodymenia spp.	13 (4)	11 (3)	7 (4)	11 (4.5)	15 (3)	17 (4)	12.3
Parvosilvosa	67 (1)	63 (1)	59 (1)	60 (1)	61 (1)	53 (1)	60.5
Desmarestia spp.	8 (5)	6 (4.5)	0 (9.5)	25 (3)	1 (9)	0 (9.5)	6.7
Laminaria spp.	0 (10)	5 (6)	10 (3)	0 (10)	0 (10)	0 (9.5)	2.5
Macrocystis spp.	2 (7.5)	6 (4.5)	6 (5)	8 (6)	8 (5)	10 (5)	6.7
Pterygophora californica	2 (7.5)	0 (9.5)	1 (7.5)	28 (2)	44 (2)	40 (2)	19.2
Ectoprocts, unident. (encr.)	5 (6)	3 (7)	4 (6)	1 (8.5)	3 (6.5)	1 (8)	2.8
Ectoprocts, unident. (erect)	1 (9)	1 (8)	1 (7.5)	3 (7)	2 (8)	4 (6)	2.0
Total biological cover (%)	177.7	133.3	124.7	178.3	181.3	178.0	
Cover, descriptive taxa (%)*	146.0	107.0	107.0	148.0	148.0	146.0	
Percent (%)**	82.1	80.2	85.8	83.0	81.6	82.0	

	Station 15						
	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	7 (4.5)	11 (4)	16 (2)	12 (3)	11 (5)	16 (3)	12.2
Cryptomenia/Halymenia/Schizymenia	31 (3)	0 (10)	0 (10)	2 (7)	12 (3.5)	1 (7.5)	7.7
Rhodymenia spp.	6 (6)	16 (3)	9 (3)	8 (5)	12 (3.5)	13 (4)	10.7
Parvosilvosa	62 (1)	70 (1)	52 (1)	69 (1)	70 (1)	58 (2)	63.5
Desmarestia spp.	46 (2)	27 (2)	7 (5)	1 (9)	1 (9.5)	1 (7.5)	13.8
Laminaria spp.	3 (7)	5 (7)	3 (8)	3 (6)	1 (8.5)	0 (9)	2.5
Macrocystis spp.	1 (9.5)	10 (5)	4 (7)	9 (4)	5 (6)	4 (5)	5.5
Pterygophora californica	7 (4.5)	5 (7)	8 (4)	16 (2)	41 (2)	60 (1)	22.8
Ectoprocts, unident. (encr.)	2 (8)	5 (7)	5 (6)	1 (9)	3 (7.5)	1 (7.5)	2.8
Ectoprocts, unident. (erect)	1 (9.5)	2 (9)	2 (9)	1 (9)	3 (7.5)	1 (7.5)	1.7
Total biological cover (%)	202.3	171.0	134.7	142.0	185.7	171.3	
Cover, descriptive taxa (%)*	169.0	151.0	114.0	123.0	159.0	155.0	
Percent (%)**	83.5	88.3	84.6	86.6	85.6	90.4	

* Total percent cover contributed by the descriptive taxa.
** Percent of the total biological cover accounted for by the descriptive taxa.

Table 5B-19. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at the offshore cobble Station-pair 16/17.

Station 16	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	32 (2)	24 (3)	12 (4)	20 (4)	15 (4)	12 (4)	19.2
Hildenbrandia prototypus	1 (7)	3 (5.5)	1 (7.5)	1 (7)	1 (8)	1 (6.5)	1.3
Pterocladia/Gelidium	1 (7)	2 (7)	5 (5)	2 (5)	4 (5)	4 (5)	3.0
Rhodymenia spp.	8 (4)	19 (4)	26 (2)	21 (3)	28 (3)	25 (3)	21.2
Parvosilvosa	33 (1)	50 (1)	43 (1)	42 (1)	35 (2)	40 (1)	40.5
Pterygophora californica	31 (3)	39 (2)	23 (3)	25 (2)	38 (1)	28 (2)	30.7
Hydroids, unident.	4 (5)	0 (9)	1 (7.5)	1 (7)	1 (8)	1 (6.5)	1.3
Ectoprocts, unident. (encr.)	1 (7)	3 (5.5)	1 (7.5)	0 (9)	2 (6)	0 (8.5)	1.8
Ectoprocts, unident. (erect)	0 (9)	1 (8)	1 (7.5)	1 (7)	1 (8)	0 (8.5)	0.7
Total biological cover (%)	121.0	149.0	122.3	121.0	143.0	118.7	
Cover, descriptive taxa (%)*	111.0	141.0	113.0	113.0	125.0	111.0	
Percent (%)**	91.7	94.6	92.4	93.4	87.4	93.5	

Station 17	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	33 (2)	16 (3)	23 (3)	18 (3)	9 (4)	17 (3)	19.3
Hildenbrandia prototypus	6 (5)	6 (5)	7 (5)	5 (5)	2 (8)	4 (5.5)	5.0
Pterocladia/Gelidium	3 (7.5)	3 (6)	3 (6)	3 (6)	4 (6)	4 (5.5)	3.3
Rhodymenia spp.	10 (4)	13 (4)	13 (4)	11 (4)	19 (3)	19 (4)	14.2
Parvosilvosa	32 (3)	43 (2)	40 (2)	39 (2)	30 (2)	29 (2)	35.5
Pterygophora californica	72 (1)	82 (1)	85 (1)	93 (1)	90 (1)	95 (1)	86.2
Hydroids, unident.	3 (7.5)	1 (8.5)	2 (7)	2 (7)	3 (7)	0 (8)	1.8
Ectoprocts, unident. (encr.)	4 (6)	2 (7)	1 (8.5)	0 (9)	1 (9)	0 (8)	1.3
Ectoprocts, unident. (erect)	2 (9)	1 (8.5)	1 (8.5)	1 (8)	5 (5)	0 (8)	1.7
Total biological cover (%)	175.0	175.0	182.0	183.0	177.3	184.0	
Cover, descriptive taxa (%)*	165.0	167.0	175.0	172.0	163.0	168.0	
Percent (%)**	94.3	95.4	96.2	94.0	91.9	91.3	

* Total percent cover contributed by the descriptive taxa.
** Percent of the total biological cover accounted for by the descriptive taxa.

Table 5B-20. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at the offshore cobble Station-pair 18/19.

Station 18	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	26 (3)	24 (2)	42 (2)	33 (2)	29 (2)	21 (2)	29.2
Coeloseira/Champia	4 (4.5)	3 (5.5)	1 (8)	3 (4.5)	1 (6.5)	2 (6.5)	2.3
Rhodymenia spp.	3 (7)	7 (4)	2 (6.5)	1 (7.5)	3 (4)	7 (3)	3.8
Parvosilvosa	33 (1)	77 (1)	52 (1)	63 (1)	70 (1)	76 (1)	61.8
Astrangia spp.	3 (7)	9 (3)	5 (3.5)	5 (3)	1 (6.5)	4 (4.5)	4.5
Hydroids, unident.	27 (2)	1 (7.5)	2 (6.5)	3 (4.5)	1 (6.5)	4 (4.5)	6.3
Muricea californica	1 (8)	1 (7.5)	3 (5)	2 (6)	4 (3)	2 (6.5)	2.2
Ectoprocts, unident. (encr.)	3 (7)	3 (5.5)	5 (3.5)	1 (7.5)	1 (6.5)	1 (8)	2.3
Ectoprocts, unident. (erect)	4 (4.5)	0 (9)	0 (9)	0 (9)	0 (9)	0 (9)	0.7
Total biological cover (%)	119.3	131.0	121.3	115.7	142.3	143.3	
Cover, descriptive taxa (%)*	104.0	125.0	112.0	111.0	110.0	117.0	
Percent (%)**	87.2	95.4	92.3	95.9	77.3	81.6	

Station 19	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	28 (2)	29 (2)	35 (2)	32 (2)	30 (2)	25 (2)	29.8
Coeloseira/Champia	1 (7.5)	1 (7.5)	1 (7.5)	1 (7)	1 (7.5)	2 (6.5)	1.2
Rhodymenia spp.	1 (7.5)	1 (7.5)	1 (7.5)	1 (7)	3 (5)	5 (3)	2.0
Parvosilvosa	54 (1)	64 (1)	61 (1)	60 (1)	61 (1)	62 (1)	60.3
Astrangia spp.	4 (5)	6 (3)	4 (4)	3 (4.5)	1 (7.5)	3 (5)	3.5
Hydroids, unident.	14 (3)	2 (5.5)	2 (6)	11 (3)	4 (4)	2 (6.5)	5.8
Muricea californica	4 (5)	2 (5.5)	4 (4)	3 (4.5)	5 (3)	4 (4)	3.7
Ectoprocts, unident. (encr.)	4 (5)	5 (4)	4 (4)	1 (7)	2 (6)	1 (8)	2.8
Ectoprocts, unident. (erect)	0 (9)	1 (9)	0 (9)	0 (9)	0 (9)	0 (9)	0.2
Total biological cover (%)	118.7	117.7	118.3	122.3	117.3	113.0	
Cover, descriptive taxa (%)*	110.0	111.0	112.0	112.0	107.0	104.0	
Percent (%)**	92.7	94.3	94.7	91.6	91.2	92.0	

* Total percent cover contributed by the descriptive taxa.
** Percent of the total biological cover accounted for by the descriptive taxa.

Abundance estimates of descriptive taxa observed at Station-pair 16-17 appear in Table 5B-19. As noted at Station-pair 14-15, algae were dominant with the same abundant taxa including Parvosilvosa, Rhodymenia, unidentified crustose corallines, and Pterygophora. Pterygophora exhibited little temporal variation and accounted for an average of 40 and 85% of the total biological cover recorded at Stations 16 and 17, respectively. The overstory of Pterygophora at Station 17 may affect other organisms by shading a large portion of the sampling area. Low percent cover estimates and lack of temporal variation characterized the encrusting red alga Hildenbrandia prototypus, the algal complex Pterocladia/Gelidium, unidentified hydroids, and encrusting and erect ectoprocts were observed at Station-pair 16-17. The presence of Hildenbrandia and Pterocladia/Gelidium at Station-pair 16-17 may be indicative of the relatively high relief consisting of stable boulders interspersed with pockets of sand characteristic of these two stations.

Descriptive organisms at Station-pair 18-19 exhibited remarkably similar mean percent cover abundance estimates (Table 5B-20). Parvosilvosa was the dominant taxon in terms of percent cover at both stations during all surveys. With the exception of comparatively low abundance estimates of Parvosilvosa during the August 1978 sampling period at both stations, no temporal variation of biological cover was discernible for any descriptive organism at Station 18 or 19. Although the number of descriptive invertebrate taxa was larger than the number of algal taxa, percent biological cover contributed by sessile invertebrates was considerably less.

Abundance estimates of the descriptive organisms sampled at Station-pair 20-21 during the 1978-1979 sampling period are presented in Table 5B-21. The mean percent cover of each descriptive taxon was similar between stations

Table 5B-21. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at the offshore cobble Station-pair 20/21.

Station 20	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	1 (7.5)	3 (7)	1 (7)	1 (7.5)	2 (7)	1 (7.5)	1.5
Rhodymenia spp.	5 (5.5)	4 (6)	8 (4)	2 (6)	5 (6)	8 (4)	5.3
Parvosilvosa	6 (4)	7 (5)	26 (1)	15 (3)	12 (2)	18 (2)	14.0
Hydroids, unident.	10 (1)	18 (1)	11 (3)	24 (1)	21 (1)	24 (1)	18.0
Muricea californica	5 (5.5)	8 (3.5)	18 (2)	11 (4)	8 (4)	10 (3)	10.0
Balanus spp.	1 (7.5)	1 (8)	0 (8)	19 (2)	1 (8)	1 (7.5)	3.8
Ectoprocts, unident. (encr.)	7 (3)	8 (3.5)	6 (6)	1 (7.5)	6 (5)	5 (6)	5.5
Ectoprocts, unident. (erect)	9 (2)	9 (2)	7 (5)	8 (5)	11 (3)	6 (5)	8.3
Total biological cover (%)	60.0	72.0	85.7	98.0	87.3	89.7	
Cover, descriptive taxa (%)*	44.0	58.0	77.0	81.0	66.0	73.0	
Percent (%)**	73.3	80.6	89.8	82.7	75.6	81.4	

Station 21	1978		1979				
Descriptive Taxa	Aug	Oct	Feb	Apr	Jul	Oct	Mean Cover (%)
Crustose corallines, unident.	2 (7)	1 (7.5)	3 (7)	0 (8)	1 (8)	0 (7.5)	1.2
Rhodymenia spp.	4 (6)	6 (6)	4 (6)	3 (7)	9 (5.5)	5 (5.5)	5.2
Parvosilvosa	10 (3)	23 (1)	17 (1.5)	20 (2)	13 (3)	15 (3)	14.7
Hydroids, unident.	9 (4)	15 (2.5)	17 (1.5)	21 (1)	19 (1)	35 (1)	19.3
Muricea californica	13 (1)	15 (2.5)	11 (3)	16 (3)	16 (2)	16 (2)	14.5
Balanus spp.	0 (8)	1 (7.5)	1 (8)	9 (5)	2 (7)	0 (7.5)	2.2
Ectoprocts, unident. (encr.)	12 (2)	10 (4)	6 (5)	5 (6)	9 (5.5)	5 (5.5)	6.2
Ectoprocts, unident. (erect)	8 (5)	9 (5)	9 (4)	11 (4)	12 (4)	11 (4)	10.0
Total biological cover (%)	72.7	91.7	90.0	98.0	98.0	106.0	
Cover, descriptive taxa (%)*	58.0	80.0	68.0	85.0	81.0	87.0	
Percent (%)**	79.8	87.2	75.6	86.7	82.7	82.1	

* Total percent cover contributed by the descriptive taxa.

** Percent of the total biological cover accounted for by the descriptive taxa.

suggesting a relatively homogeneous area. In contrast to the other station-pairs except Station-pair 12-13, sessile invertebrates accounted for over twice as much mean biological cover as did algal taxa. The numerically dominant organisms at both stations included Parvosilvosa, Muricea californica, and unidentified hydroids. Distinct temporal variation of estimates of percent biological cover at Station-pair 20-21 was not evident for most of the descriptive taxa.

Dominant Organisms

The presentation of distribution and abundance data of dominant organisms sampled by the 0.125 m^2 sampling technique was restricted to six organisms for the following reasons: (1) these six organisms occurred at every station during every survey, and (2) rigorous statistical comparison of the abundance patterns of these organisms provides an effective method to evaluate habitat variability as a function of spatial differences within the San Onofre area.

Three algal assemblages, Rhodymenia spp., Parvosilvosa, and unidentified crustose coralline algae, and three sessile invertebrate groups, unidentified erect and encrusting ectoprocts, and unidentified hydroids, were the dominant organisms. No dominant organisms showed significant temporal variation with regard to percent cover estimates. In addition, all station-pairs exhibited less within station-pair variability than between station-pair variability.

The mean percent cover estimates of Rhodymenia spp. at each offshore cobble station is presented in Figure 5B-5a. Maximum percent cover was observed at Station-pair 12-13 (33.8) with significantly lower estimates noted at the other offshore cobble station-pairs (ANOVA, $P \leq 0.001$). Percent cover of Rhodymenia at Station-pair 16-17 (14.9) was greater than at neighboring station-pairs as well as at Station-pair 20-21.

Abundance estimates of Parvosilvosa demonstrated distinct spatial differences among station-pairs (Figure 5B-5b). Similar mean percent cover estimates of Parvosilvosa were observed at Station-pairs 14-15 (58.8), 16-17 (38.3), and 18-19 (56.8). These were significantly greater (ANOVA, $P \leq 0.001$) than the mean values at Station-pairs 12-13 (12.8) and 20-21 (17.1). The lower mean percent cover estimates at Station-pair 16-17 compared to neighboring stations may be associated with the Pterygophora overstory at Station 17.

Mean percent cover of unidentified crustose coralline algae recorded at each station-pair during the 1978-1979 sampling period appears in Figure 5B-5c. A distinct increasing gradient is apparent from Station-pair 12-13 (15.7%) to Station-pair 18-19 (44.9%) where the maximum mean cover of unidentified crustose coralline algae was recorded. Statistical comparison of percent cover estimates of crustose coralline algae among all station-pairs revealed a significant difference with the lowest estimates recorded at Station-pairs 12-13 and 20-21 (ANOVA, $P \leq 0.001$).

Unidentified encrusting and erect ectoprocts exhibited different abundance patterns among groups of station-pairs (Figures 5B-5d and e). Greatest mean percent cover of encrusting and erect ectoprocts were always recorded at Station-pairs 12-13 and 20-21. Within the San Onofre Kelp area, comparatively low percent cover estimates of encrusting and erect ectoprocts were observed at Station-pairs 16-17 and 18-19, respectively. Independent statistical comparisons of percent cover estimates of encrusting and erect ectoprocts revealed that the abundance patterns of each taxon were significantly different among groups of station-pairs (ANOVA, $P \leq 0.001$).

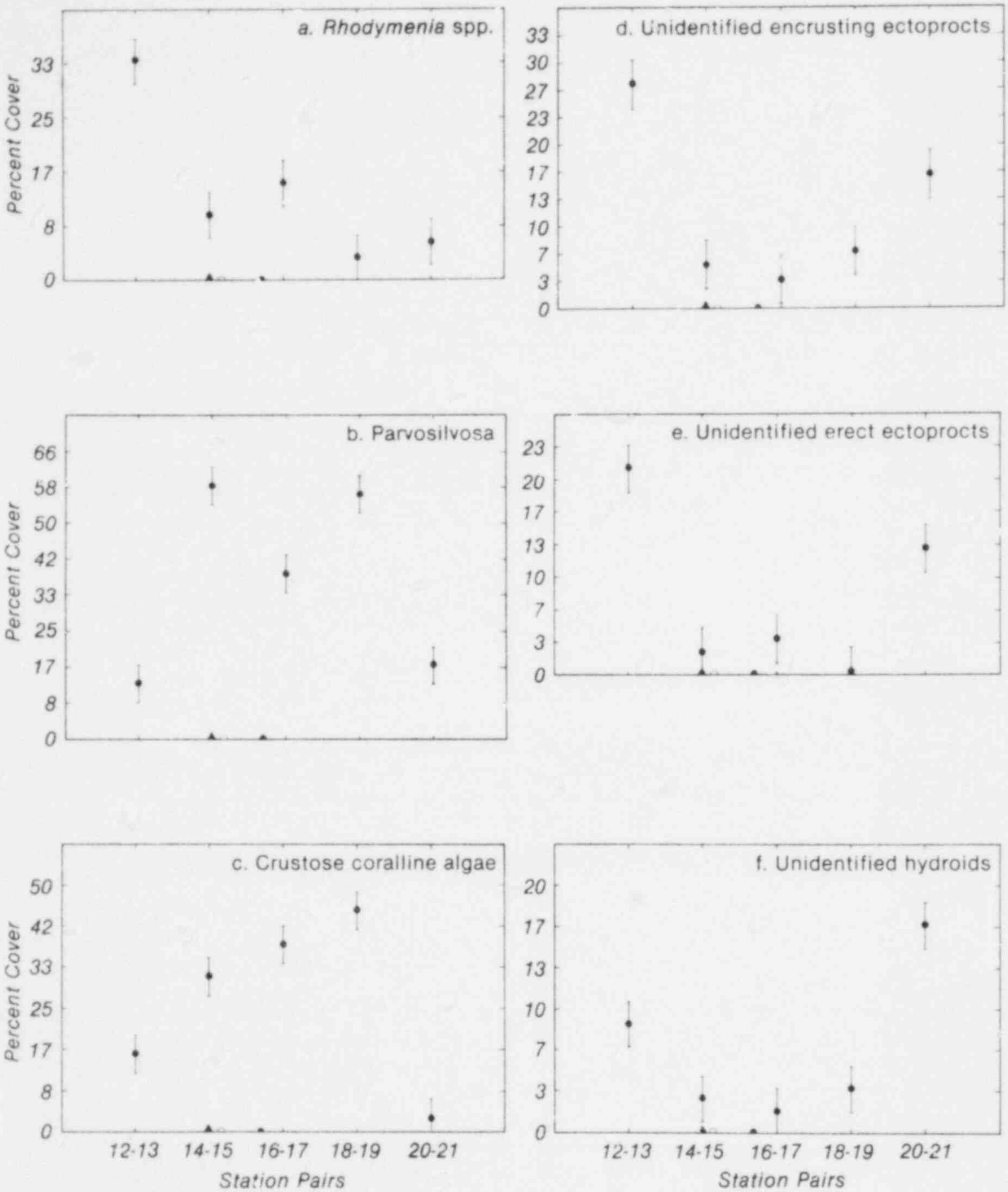

Figure 5B-5a-f. Mean percent cover estimates and 95% confidence intervals of abundant organisms (a - f), sampled at each offshore cobble station-pair during the 1978-1979 sampling period. Each data point represents 48 observations using the 0.125 m^2 sampling strategy. Triangle and hemispheres on station axes indicate location of SONGS Units 1, 2, and 3, respectively.

Mean percent cover estimates of unidentified hydroids are presented in Figure 5B-5f. Abundance patterns of this taxon were similar to unidentified ectoprocts (Figure 5B-5d and e). Maximum percent cover of hydroids was recorded at Station-pair 20-21 (18.0) in contrast to Station-pair 12-13 where maximum cover of encrusting and erect ectoprocts was observed. Percent hydroid cover was low at Station-pair 12-13 (8.8) with lesser abundances of hydroids recorded at Station-pairs 14-15, 16-17, and 18-19. Statistical comparison of percent cover estimates of unidentified hydroids revealed a significant difference among stations with highest mean values observed at Station-pairs 12-13 and 20-21 (ANOVA, $P \leq 0.001$).

In general, sessile invertebrate cover was consistently highest at Station-pairs 12-13 and 20-21 where the lowest mean estimates of crustose coralline algae and Parvosilvosa were consistently recorded. Rhodymenia did not exhibit a spatial abundance pattern consistent with any of the other dominant organisms.

Classification Analysis

Inverse and normal classification tables were generated to identify organisms or groups (clusters) of organisms associated with specific stations and/or surveys using data collected by the 6.0-m^2 sampling technique. Station-pairs always clustered together and formed five distinct groups, independent of surveys, which demonstrated no well defined temporal variation (Figure 5B-6). Station-pairs 14-15 and 18-19, located upcoast and downcoast of the diffuser lines, formed Groups D and C, respectively. These were the most similar groups of stations clustering at an intermediate similarity level. Station Group B consisting of Station-pair 12-13 was linked to Station Groups C and D at a lower level of similarity. Station-pairs 16-17 and 20-21 formed Groups A and E, respectively, which exhibited low similarity compared to all other groups.

The organisms sampled at each station group exhibited less distinctive clustering. Five taxa groups were formed which showed both strong and weak affinity with the five station groups (Figure 5B-6). Taxa Groups 1 and 2 formed the most ubiquitous taxa assemblages at most stations during the 1978-1979 sampling period. These taxa included eight and one, and three and seven algal and invertebrate species, respectively. Station Group A corresponded with Taxa Group 1 which consisted of Pterygophora californica, Bossiella spp., Pterocladia/Gelidium, and Chelyosoma productum. Station Group B showed a similar affinity with Taxa Group 2 which was characterized by dominant sessile invertebrates including unidentified hydroids and ectoprocts, and Muricea californica. Unidentified hydroids were also dominant at Station Group E as was the solitary coral Astrangia spp. at Station Group C. The distinctive lack of association of organisms in Taxa Group 5 with Station Group A may be partially associated with the sweeping motion of Pterygophora blades.

Organisms in Taxa Groups 3 and 4 exhibited comparatively low or no affinity with most station groups. Macrocystis spp. and Laminaria spp. occurred with greater frequency and abundance at Station Group D. Pterygophora was associated with Taxa Group 1 and Station Group D. Taxa Group 5 consisted of 10 taxa including seven motile invertebrates and three algae which exhibited comparatively strong and weak affinities for Station Groups B and E, respectively. Unidentified poriferans exhibited a limited distribution as they were only observed in notable abundances at Station Groups B and D. Strongylocentrotus franciscanus exhibited a limited distribution restricted to Station Groups B, C, and D.

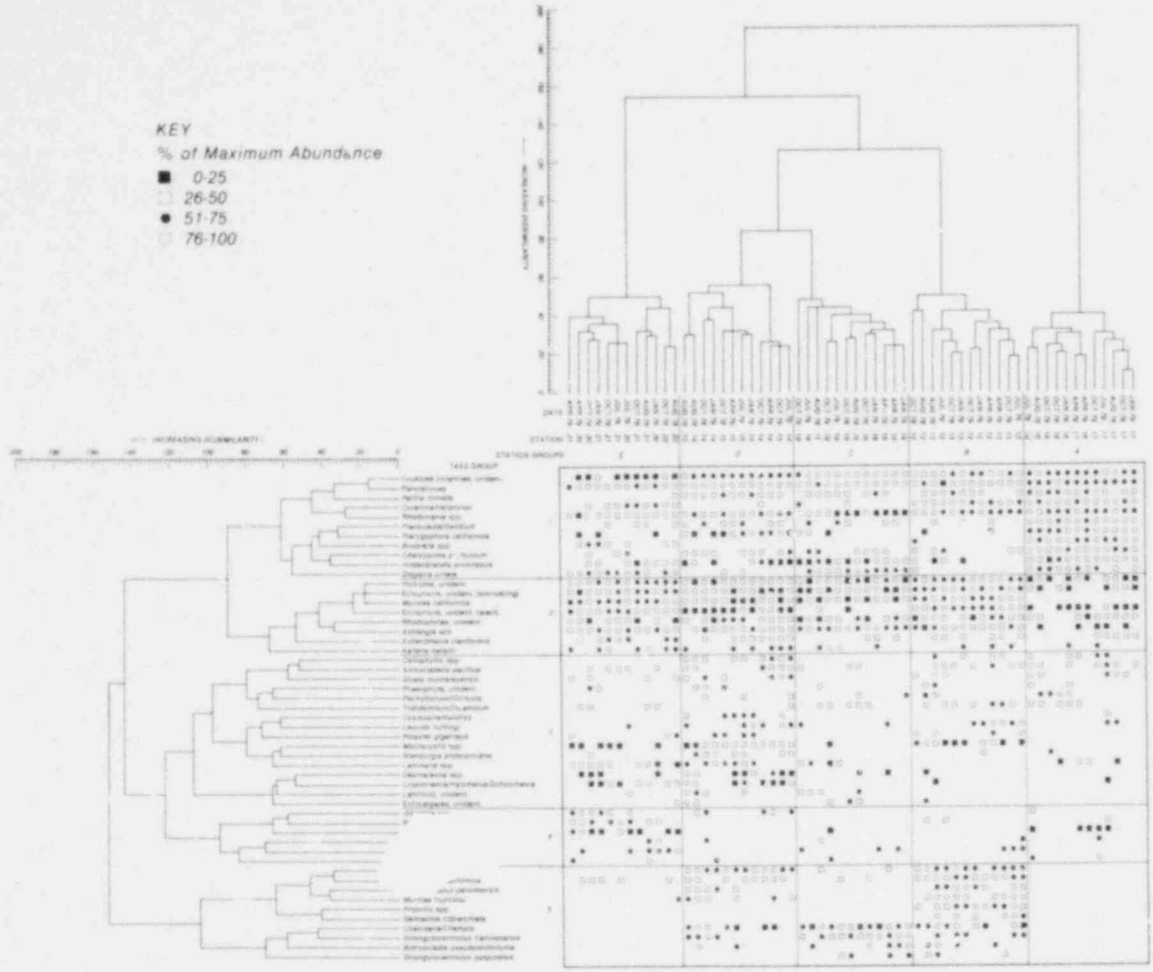

Figure 5B-6. Normal and inverse classification and resultant two-way table of the 1978-1979 data collected at each offshore cobble station using the 6.0-m^2 sampling strategy.

DISCUSSION

The studies of the biological communities living on hard substrata offshore the San Onofre Nuclear Generating Station are designed to develop baseline data 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 of all hard benthos studies are oriented to examine the general hypothesis that there is no significant 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 effect" is defined as any physical or biological change(s) attributable to SONGS activities which alters the factors under investigation to an extent that may be considered ecologically undesirable.

Analysis of all ETS, PMP, and CMP subtidal data collected from 1975 to 1978 revealed that no significant environmental effects could be associated with the operation of Unit 1 or the construction of Units 2 and 3 (SCE 1979d). Moreover, detailed interpretation of this continuous monitoring data suggested that the subtidal benthic community in the vicinity of the San Onofre Nuclear Generating Station is strongly influenced by physical factors related to natural nearshore dynamics. To examine these processes and their influence on the hard substrata benthos, this section is divided into two major components. First, the direct effect of the physical factors including substrata stability and light on community structure are discussed. Next, biological interactions with these factors as well as organism interactions and community structure are discussed. These components are then summarized.

PHYSICAL FACTORS

Substrata stability

The weather during the 1979 sampling period was relatively mild in comparison to 1978. Nearshore storm activity, abnormally high rainfall, and significant terrestrial drainage during the first three months of 1978 resulted in a significant impact on the nearshore cobble habitat. These impacts include the rapid and extensive burial of large expanses of cobble substratum near the Unit 1 discharge and approximately 8 km downcoast of the generating station (SCE 1979d). This burial resulted in the local extinction of a dominant red alga, *Rhodymenia* spp., at two stations (3 and 4) through the 1979 sampling period (Table 5B-10), and resulted in the mass mortality of the chestnut cowry, *Cypraea spadicea*, at Barn Kelp forest (SCE 1979d, 1980c).

The lack of intense nearshore meteorological disturbances during 1979 provides a qualitative comparison of the effects of the significant physical disturbance on the subtidal cobble habitats noted during 1978. Generally, those inshore sampling areas which were covered with sand during early 1978 are still predominantly sand (Table 5B-3). Although slight erosion of sand may have occurred during 1979, significant erosion was not detected at the inshore cobble stations which were covered with sand during 1978 (SCE 1980c). A review of five years of substrata composition data for the eight stations initially located and sampled on the inshore 10-m isobath between 1975 and 1978 (LCMR 1975g, SCE 1979a) indicated that during early 1978 at least six of these original inshore cobble stations were covered with sand (SCE 1979d). These stations were re-established at new locations on similar substrata and included two reference stations in Zone 6 and the kelp station at Barn Kelp. During the third and fourth quarterly sampling periods of 1978 all stations were sampled; however, no biological data were collected at three stations (3, 4, and 7) because of extensive sand accretion (SCE 1979d). Considering the 1979 substrata composition data in addition to the 1978 observations, it may be concluded that sand accretion due to unusually adverse meteorological or oceanographic conditions may occur rapidly while natural erosion of sand to the original substrata takes at least two years and probably longer (SCE 1980c).

Comparison of the data collected at the offshore kelp stations reveals the presence of a relatively heterogenous assemblage of benthic communities. The structure of these communities appears to be primarily a function of substrata composition and stability, and secondarily a function of competitive interactions among organisms. Substrata composition is most consistent at Station 9 where hard substrata estimates are the highest and vary less than 5% among annual survey periods (Table 5B-4, SCE 1979d). The composition and stability of the substrata may contribute to the greater mean diversity (number of taxa) and maximum number of individuals observed in comparison to the other offshore kelp stations during 1979 (Tables 5B-6, 12).

Instability of the cobble substratum in the San Onofre Kelp area has been strongly suggested by comparison of the ages of Muricea colonies near Barn Kelp, San Onofre Kelp, and San Mateo Kelp (SCE 1979d). Areas which are inhabited by young and sparse colonies in comparison to areas with dense aggregations of older colonies are probably characterized by an environment of greater physical instability (Grigg 1975). Although some areas in the San Onofre vicinity demonstrate long term stability, the sampling areas surrounding the offshore San Onofre Kelp stations and the offshore cobble stations exhibit varying degrees of substrata instability (SCE 1979d).

All offshore stations located in the vicinity of the San Onofre Kelp forest have exhibited in the past, and continue to be characterized by high abundance estimates of crustose coralline algae and Parvosilvosa (Table 5B-13, Figure 5B-5b,c, SCE 1979d). The relative dominance of crustose coralline algae and Parvosilvosa in the San Onofre Kelp forest vicinity may represent a functional adaptation to unstable areas which periodically are subjected to sand scour and/or burial. For example, encrusting coralline algae may undergo burial for three to four months and still exhibit a pinkish color indicative of health (SCE 1979d). If hard substrata are available after substantial sand scouring, crustose algae may act as rapid colonizers (Johansen and Austin 1970). In some instances encrusting coralline algae have been observed to grow faster and over colonies of encrusting ectoprocts at the sand-rock margin of boulders (Gordon 1972). In general, it would appear that areas which are characteristically dominated by crustose coralline algae have been exposed to a continuing disturbance. Although the nature of the disturbance appears to be sand scour or burial, the presence of hidden or cryptic sea urchins not counted during sampling periods may also be a contributing factor.

These characteristic patterns of crustose coralline algae abundance have been reported in other studies, however, the predominant abundance patterns were related to intensive biological disturbance by sea urchins (Paine and Vadas 1969, Lubchenco 1978, Pearse and Hines 1979, Vance 1979). Observations and data collected from the offshore kelp stations located in San Onofre Kelp tend to support the hypothesis that comparatively high abundance estimates of encrusting coralline algae are related to the general physical instability of the San Onofre area. In fact similar observations regarding frequent sand scouring and an associated understory consisting mainly of encrusting coralline algae have been made at the Del Mar Kelp forest located approximately 50 km downcoast of San Onofre Kelp bed (Rosenthal, Clarke, and Dayton 1974, Grigg 1975).

The conspicuous absence or low abundance of kelp plants at the offshore San Onofre Kelp stations during the 1979 sampling period may also be related to instability of the substrata (SCE 1980c). The presence of sediment can alter the chemical and physical microenvironment of settling Macrocystis spores and prevent development (Devinny and Volse 1978). Additionally, development of spores may be interrupted by attachment to sand grains, burial, or, if attached to substrata, may be damaged by scouring action (Devinny and Volse 1978). Because Station 10 and Station-pair 18-19 have been found to be subject to more sand scour than other kelp stations, it is hypothesized that recruitment of Macrocystis has been inhibited by the physical microenvironment (sand scour). Dredging activity conducted during 1978 and 1979 may have contributed to sedimentation resulting in reduced Macrocystis recruitment at San Onofre Kelp (Chapter 7, this volume). However, abundance estimates of sand cover at San Onofre Kelp during 1978 and 1979 have not demonstrated an increase in sand substratum (SCE 1979d, SCE 1980b,c). Reduced Macrocystis recruitment at San Onofre Kelp may therefore have resulted from the scouring action of suspended sediment due to dredging activities and not from burial of hard substrata.

The instability of small cobble may also result in mortality of juvenile Macrocystis plants. As developing plants become larger, they exert a greater upward lift due to pneumatocysts filled with gas. Once the combination of currents and upward lift overcome the weight and inertia of the substratum, the attached plant may drift in the water column and be lost to the kelp forest, tangled with other kelp plants, or be damaged by abrasion with other cobbles (Rosenthal, Clarke, and Dayton 1974). Sand scour as well as physical burial can cause juvenile plant mortality. This was noted at the Del Mar Kelp forest south of the San Onofre area (Rosenthal, Clarke, and Dayton 1974). Factors including sand scour, alteration of the microenvironment around developing spores and cobble abrasion may be partially responsible for the lack of development and persistence of adult Macrocystis plants in, and in the vicinity of San Onofre Kelp forest offshore of SONGS.

Light

Expansion of the Macrocystis canopy over San Mateo Kelp stations occurred between the February and July 1979 sampling periods. This provided an opportunity to evaluate the effect of shading on a hard bottom community when a substantial portion of sunlight is obscured by a kelp canopy. The most obvious effect was the significant reduction in abundances of Parvosilvosa, Rhodymenia, and to a lesser extent, Pterocladia/Gelidium during later surveys at San Mateo Kelp (Table 5B-13, 17). Similar observations have been made by investigators in other kelp forests. The reduction of light by overstory Macrocystis has been found to inhibit the growth of understory plants resulting in the bottom flora appearing "conspicuously sparse" (Neushul 1971). Additionally, controlled field experiments in a Macrocystis forest in southern California demonstrated that light reduction may have a greater effect on basement story algae than does competition for available hard substrata with sessile invertebrates (Foster 1975b).

Reduction of a substantial portion of light reaching the bottom has a dramatic effect on algal growth. As noted above, because of significant shading, areas under dense Macrocystis surface canopies are not conducive to the development of most algae (Anderson and North 1966, Neushul 1971, Pearse and Hines 1979). Similar shading effects may also be associated with kelp which grow to heights of one to two meters above the bottom. Pterygophora californica and Laminaria spp. are two kelps that may grow to these heights and shade portions of the bottom.

The redistribution of naturally turbid bottom by the operation of SONGS Unit 1 and dredging activities associated with construction of SONGS Units 2 and 3 also increased turbidity over a localized area (SCE 1980a). Biological effects of a reduction in light reaching the bottom due to this increased turbidity were, however, not demonstrable at any of the benthic sampling stations during the 1979 sampling period.

BIOLOGICAL INTERACTIONS

Macrocystis and Lytechinus Interaction

It is well established that urchins of the genus Strongylocentrotus can alter the standing crop as well as contribute significantly to the decline of Macrocystis forests (Leighton, Jones, and North 1965; North 1971, 1974; Mattison et al. 1977; Pearse and Hines 1979). Densities of Strongylocentrotus and the white urchin Lytechinus have been recorded at all kelp stations since 1975. Only Lytechinus has occurred in mean densities greater than 25 individuals/m during this time. Although feeding preference studies with Lytechinus (Lytechinus anamesus) have indicated a primary preference for red algae, the secondary choice was Macrocystis (Leighton 1966). When preferred food items become rare, food item selectivity may disappear (Leighton 1966). Foliose red algae including Rhodymenia and the Pterocladia/Gelidium complex were not abundant at Station 10 during the 1979 sampling period (Table 5B-13). The lack of abundant fleshy red algae at Station 10 and Station-pair 18-19 suggests that in addition to sand scour, intensive foraging by Lytechinus may also be partially responsible for the lack of Macrocystis recruitment and foliose red algae noted at all other offshore kelp and cobble stations (Table 5B-13, 17 through 21).

Temporal and Spatial Variation

Distinct temporal or seasonal variation in organism abundance or recruitment patterns has not been detected at any inshore or offshore sampling area since these studies began in 1975. The lack of identifiable temporal variation within or among calendar years and the ubiquitous nature of recruitment patterns observed during most sampling periods may be considered typical of the dominant components of the subtidal community. This is not to conclude that the subtidal environment in the study areas is static. The significant reduction in the surface area of the San Onofre kelp canopy between March and September of 1976 and the extensive burial of large expanses of cobble habitat during the first four months of 1978 are examples of significant changes which occurred over a relatively short period of time (LCMR 1977b, SCE 1979d). On a smaller scale, the effects of canopy shading on understory algae, although highly localized, have been immediately apparent at San Mateo Kelp where abundance estimates of several species or groups of red algae decreased significantly after the appearance of a dense kelp canopy (Table 5B-13, 17).

In contrast to the lack of identifiable temporal variation, spatial differences within the study area are both distinct and predictable. The magnitude of the spatial differences appears to be closely related to community stability as influenced by natural physical disturbances. For example, the inshore cobble stations are located in a dynamic area where they experience greater bottom turbulence, sand scour, cobble abrasion, and greater impacts from terrestrial drainage associated with storms than the offshore stations (SCE 1979d).

Although the cobble stations near the Unit 1 discharge and those located downcoast are separated by about 8 km, no significant difference in abundances of hard substrata or number of taxa was detected. This indicates that exposure to the dynamic physical environment along the inshore isobath resulted in greater community similarity. The offshore cobble communities are located in a more stable and less dynamic environment. Thus, with occasional disturbance that is variable in both space and time, these offshore areas appear to exhibit a more immediate and long term response to physical or biological disturbances. This is substantiated by the distinct differences among the offshore cobble stations discussed below.

All offshore cobble stations located in the San Onofre Kelp area exhibited significantly greater mean percent algal cover than sessile invertebrate cover (Table 5B-18 through 20, Figure 5B-5a-c). In contrast, offshore stations outside of the San Onofre Kelp area exhibited significantly greater mean sessile invertebrate cover (Table 5B-17 and 15, Figure 5B-5d-f). However, the dominance of sessile invertebrates at these stations appears to be related to different factors. Data collected at Station 12 during August 1978 revealed that algae were present in significantly greater abundance than were sessile invertebrates. The percent cover of sessile invertebrates increased through time until it was greater than algal cover (Tables 5B-16 and 17). The gradual expansion of the kelp canopy over the Station 12 sampling area appears to have reduced the quantity and quality of light sufficiently to give the sessile invertebrate populations a competitive advantage.

The abundance of sessile invertebrates at Station-pair 20-21, however, may be related to its position on a large expanse of sand. The fine sand surrounding this cobble habitat is easily suspended by ocean waves. This often results in a turbid layer of suspended sediment up to 3-m thick covering the bottom. The suspension of fine sand at these stations, however, does not appear to result in a clogging or scouring action as evidenced by the high abundances of erect ectoprocts and hydroids. Low percent cover of algae may be attributed to low light and the resultant inability to successfully compete with the established communities of erect and encrusting ectoprocts and hydroids which occupy a substantial portion of the hard substrata (Table 5B-21, Figures 5B-5d-f). Sessile invertebrates can grow over small developing algae, probably feed on algal spores, and at the very least, prevent spore settlement thus limiting benthic primary productivity (Foster 1975b). In addition, algal recruitment to this area from other hard substrata regions may be poor by virtue of the isolation of Station-pair 20-21. The nearest area of substantial hard substrata is Barn Kelp which is located approximately 1.5 km downcoast of Station-pair 20-21. The predominant direction of currents in this area flow past Station-pair 20-21 and towards Barn Kelp (Berry 1977). Motile fish predators including the "picker-type" fish (in sensu Bray and Ebeling 1975) are not common in the Station-pair 20-21 area, but, barred sand bass, Paralabrax nebulifer, are commonly observed. These fish forage mostly on smaller fish and motile invertebrates and not on sessile ectoprocts (Quast 1968). Thus, the general lack of fish predation on sessile invertebrates and the isolated location of Station-pair 20-21 probably contributes to the dominance of sessile invertebrate populations.

The community structure and algal abundance patterns observed at the stations offshore SONGS (Station-pairs 14-15, 16-17, 18-19) suggest that those factors which limit the abundance of sessile invertebrate populations are not the same at each station-pair. The abundance patterns of crustose coralline algae and Parvosilvosa at the stations immediately offshore of SONGS (Figure 5B-5b,c) appear to represent a gradient which integrates the effects of physical and biological perturbations. These patterns are similar to the dominance patterns of these organisms at the offshore San Onofre Kelp stations. It appears reasonable that sand scour, turbidity, shading, predation, and cobble abrasion are the factors controlling these patterns (Table 5B-18,19,20, SCE 1979d).

Light probably plays a significant role in structuring even small areas of benthic communities. The significantly lower estimates of Parvosilvosa at Station-pairs 14-15 and 18-19 are probably associated with the heavy overstory of Pterygophora which shades much of the sampling area (Figure 5B-5). The lower estimates of crustose coralline algae at Station-pair 14-15 suggest this area, in comparison to Station-pairs 16-17 and 18-19, is subject to substantially less sand scour. Additionally, many "picker-type" fish are observed in the general area during sampling efforts. Some of these fish species are probably associated with a nearby Macrocystis forest, foraging near interface areas of existing or developing kelp (Chapter 6B this volume, Love and Ebeling 1978). The presence of fish and other motile predators may function to reduce the kinds and numbers of sessile invertebrates.

Community Classification-Offshore Cobble Stations

The distinctive clustering of all offshore cobble station-pairs independent of time emphasizes the magnitude of community heterogeneity observed in the sampling areas (Figure 5B-6). The general stability of each area is also reflected in the abundances of specific organisms. The station groupings resulting from classification analysis suggest that Station-pairs 14-15 and 18-19 are most similar with regard to community structure (Figure 5B-6). These station-pairs are located in areas with unstable substrata and are subject to sand scour and cobble abrasion. Crustose coralline algae and Parvosilvosa are most abundant at these stations (Figure 5B-6). In contrast, Station-pairs 12-13, 16-17, and 20-21 exhibit less similarity while the abundance and distribution of organisms observed at these station-pairs suggest that the substrata at these stations are comparatively more stable. Several organisms occur more frequently at Stations 12 and 13 than at other stations. One of these organisms is the holothurian Parastichopus parvimensis that is found between boulders and cobbles. The habitat favored by Parastichopus includes areas where surge is minimized. The more frequent occurrence of Parastichopus at Station-pair 12-13 may be related to the greater stability of cobbles and boulders and moderated surge conditions associated with the San Mateo Kelp forest. The consistenly high abundance of Pterygophora californica at Station-pair 16-17 may be indicative of the stability of the hard substrata at this area. Numbers of individual adult plants at these stations during all surveys ranged from 3 to 9 and 17 to 24 at Stations 16 and 17, respectively (SCE 1980b). The variability associated with these ranges, as previously noted, is related to juvenile plants that are moved in and out of the sampling areas by water motion.

The community classification analysis using site and species co-occurrences suggests certain suites of organisms are closely related to the environmental statiblity of the sampling area. The rather distinct site-species groupings (Figure 5B-6) supports the general hypothesis, at least in part, that the San Onofre Kelp forest consists of a heterogenuous assemblage of communities as a result of differing substrata types and physical stability.

Summation

An evaluation of the quantitative data collected at all sampling locations strongly suggests four principal factors are responsible for the structure of benthic communities in the vicinity of the San Onofre Nuclear Generating Station. These factors, not necessarily in the order of importance are; depth, substrata stability, light intensity and quality and biological interactions. These factors are all related and exhibit various influences on community structure depending on localized stability of the area as well as the physical and biological heterogeneity of the environment. The integration of these factors as a function of depth on community structure is more predictable and more pronounced on the nearshore isobath. Biological parameters of communities at stations located in the offshore areas appear to represent gradients of variable physical and biological factors.

The physical factor of sand scour is most pronounced and probably the structuring factor at Station 10 and Station-pair 18-19. Cobble abrasion and shading by overstory perennial plants are significant factors influencing the community structure at Stations 22, 23, and Station-pair 16-17. This is supported by the abundance estimates of Pterygophora californica and other laminarians which exhibit temporal changes in density due to the movement of plants attached to small cobbles in and out of sampling areas. The area surrounding Station-pair 14-15 appears to be more influenced by biological factors, including the removal of sessile invertebrates by predators, which may result in the development of more foliose algae. At Station-pair 12-13 the reduction of light by the overstory kelp canopy appears to have been the factor which led to the preponderance of sessile invertebrate populations. In contrast, Station-pair 20-21 was also dominated by sessile invertebrates but apparently for a different reason (bottom turbidity, reduced light). The isolated position of the station-pair on a plain of sand probably resulted in poor recruitment of hard substrata inhabiting organisms from nearby areas. Additionally, the lack of predators on sessile invertebrates at this station may give sessile invertebrates a competitive advantage.

Generally, the area offshore of the generating station is controlled by the physical factors of sand movement and cobble abrasion. The other areas appear to be more influenced by biological interactions mediated by natural changes in light.

Similar to the findings of previous studies (SCE 1979d), analyses of the 1979 data suggest that none of the hypothesized controlling factors (i.e., light, biological interactions, sand scour) at the stations surveyed were influenced by the operation of Unit 1 or the construction of Units 2 and 3. No ecological effects associated with the operation of Unit 1 or the construction of Units 2 and 3 were discernible at these stations during the 1979 sampling period.

SUMMARY

A detailed analysis of the 1979 data and a comparison with data collected in 1975, 1976, 1977, 1978 indicated the following.

INSHORE 10-m COBBLE HABITAT

1. Comparison of substrata composition at the inshore cobble stations during five years of monitoring indicates that sand accretion due to unusually adverse meteorological or oceanographic conditions may occur rapidly during a short period of time (e.g., three months). Displacement of sand resulting in the exposure of the original cobble habitats will take at least two years and probably longer.

KELP FOREST COBBLE HABITAT AND OFFSHORE 14-m COBBLE HABITAT

1. The structure of the offshore kelp forest cobble communities appear to be primarily a function of substrata composition and stability, and secondarily a function of competitive interactions among organisms.

2. Expansion of the San Mateo Kelp canopy over biological stations occurred between February and July 1979. This provided a natural experiment to evaluate the effect of shading on hard bottom communities. The most obvious effect was the significant reduction in abundances of the algal assemblage Parvosilvosa and the red alga *Rhodymenia* spp.

3. San Onofre Kelp Stations (10 and 22), and offshore cobble in the vicinity of SONGS (Station-pairs 14-15, 16-17, and 18-19) appear to be continually disturbed by physical sand scour as evidenced by comparatively high abundance estimates of crustose coralline algae.

4. Instability of movable cobbles probably resulted in the mortality of juvenile *Macrocystis* plants in the vicinity of San Onofre Kelp (Stations 22 and 23) and offshore SONGS (Station-pairs 14-15 and 16-17).

5. In addition to intensive sand scour at San Onofre Kelp Station 10, intensive foraging by the small white urchin, *Lytechinus* spp., may also be partially responsible for the lack of *Macrocystis* recruitment and development of foliose red algae at this station.

6. All offshore cobble stations located in the San Onofre Kelp area (Stations 14 through 19) exhibited significantly greater mean percent algal cover than sessile invertebrate cover. In contrast, stations in the upcoast and downcoast reference areas (Station-pairs 12-13 and 20-21) both exhibited significantly greater mean sessile invertebrate cover.

7. The abundance patterns of crustose coralline algae and Parvosilvosa at offshore cobble stations in the vicinity of SONGS (Station-pairs 14-15, 16-17, and 18-19) appear to represent a gradient which integrates the effects of physical and biological perturbations. These patterns are similar to the dominance patterns of these organisms at some offshore San Onofre Kelp stations (10, 22, and 23). It appears reasonable that sand scour, turbidity, shading, predation, and cobble abrasion are the factors controlling these patterns.

GENERAL

1. An evaluation of the quantitative data collected at all sampling locations strongly suggest four principal factors are responsible for the structure of benthic communities in the vicinity of the San Onofre Nuclear Generating Station. These factors, not necessarily in the order of importance, are depth (which influences water motion and light), substrata stability, light intensity, and biological interactions.

2. Analyses of the data suggest that none of the hypothesized controlling factors (i.e., light, biological interactions, sand scour) were influenced by intakes. No long-term ecological effects associated with the operation of Unit 1 or the construction of Units 2 and 3 were discernible at the inshore cobble stations, the kelp stations or the offshore cobble stations during the 1979 sampling period.

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CHAPTER 6

FISH

INTRODUCTION

Observations and interpretation of nearshore fisheries investigations at the San Onofre Nuclear Generating Station include: a) nearshore and entrained ichthyoplankton at Unit 1; b) density and distribution of adult fishes in the receiving waters; c) estimates of fish impingement at Unit 1; and d) an examination of the sport-fishery resource near San Onofre. The integration of fishery data is designed to facilitate discussion of potential effects of San Onofre operation on the nearshore fish population structure.

CHAPTER 6A

ICHTHYOPLANKTON

INTRODUCTION

This was a special study of the Units 2 and 3 preoperational monitoring program. The objectives were to: 1) provide baseline data on the distribution and abundance of larval fishes near San Onofre; and 2) estimate larval fish entrainment at San Onofre Unit 1 to determine the relationship between larval concentrations in the nearshore San Onofre area and the operational Unit 1 intake. This relationship was examined to determine potential changes in nearshore ichthyoplankton populations induced by plant operation.

MATERIALS AND METHODS

NEARSHORE SAMPLING

Three depth strata of the water column were sampled for ichthyoplankton. Surface samples were taken with a Manta net (Brown, 1979) designed to sample the upper 14 cm of the water column (Figure 6A-1). The mouth was rectangular with an area of 0.13 m^2 (0.86 x 0.15 m). The filtering ratio, or filtering area to mouth area, was designed to meet the special requirements of each net employed in the study (Table 6A-1). For the Manta Net, a theoretical ratio, R, was calculated from a desired collection volume and the fixed mouth area. The theoretical R or filtering ratio was calculated as:

$$\log_{10} R = .38 \log_{10} \frac{V}{A} - .17$$

where V was volume filtered and A was mouth area. This equation, from Smith et al. (1968), was for nearshore or "green water", where clogging was more likely, as opposed to offshore "blue water", where clogging was less likely. Calculations were based on a porosity of 0.46 associated with 333 micron Nitex mesh. Since the actual R (filtering area/mouth area), equals the theoretical R, nearshore net clogging was rarely expected. The objective was 85% filtering efficiency. Based on 215 m^3, the theoretical R of the Manta Net was 11.30 (Table 6A-1). The actual R of the Manta Net was 13.48, with a total mesh area of 3.19 m^2. The cylinder and cone areas were 1.91 m^2 and 1.28 m^2, respectively. The Manta Net mouth was mounted with both General Oceanics (GO) and Tsurumi Seiki (TSK) flowmeters. The target volume for the Manta net was 100 m^3.

The midwater sampling device was a paired 0.6 m opening-closing Bongo net (McGowan and Brown 1966), with a combined mouth area of 0.57 m^2 (Figure 6A-1). The theoretical R, based on 260 m^3 for each net, was 9.04 (Table 6A-1). The actual R was 9.33, with 7.83 m^2 of total mesh area. The cylinder was 5.44 m^2 and the cone 2.39 m^2. A GO flowmeter was mounted in each Bongo Net. Net depth was monitored via a deck readout Hydroproducts Model 902 Bathykymograph mounted on the net frame. The combined target volume of the Bongo net was 400 m^3.

The epibenthic sampling device (Auriga; Mitchell unpublished) was designed to sample over rock or cobble terrain within 21 cm of the bottom (Figure 6A-1). The mouth was rectangular (2.0 x 0.5 m) with an area of 1 m^2. The theoretical R, based on 400 m^3, was 6.60 (Table 6A-1). Actual R was 6.70, with a total mesh area of 14.35 m^2. The cone area was 5.74 m^2 and the cylinder 8.61 m^2. Both GO and TSK flowmeters were mounted in the Auriga mouth. The target volume of the Auriga net was 400 m^3.

Towed net samples (Table 6A-2) were taken from three depth strata at three stations designated 12, 13, and 14 (Figure 6A-2). Station 12 initiated at the Unit 1 intake and continued upcoast (NW) along the intake isobath (8 m). Station 13 initiated offshore at the intersection of the projected line of the Unit 1 intake and the midpoint of the Unit 3 discharge conduit (10 m). Station 14 was located along the projected Unit 1 intake line at the midpoint of the Unit 2 discharge diffuser (14 m).

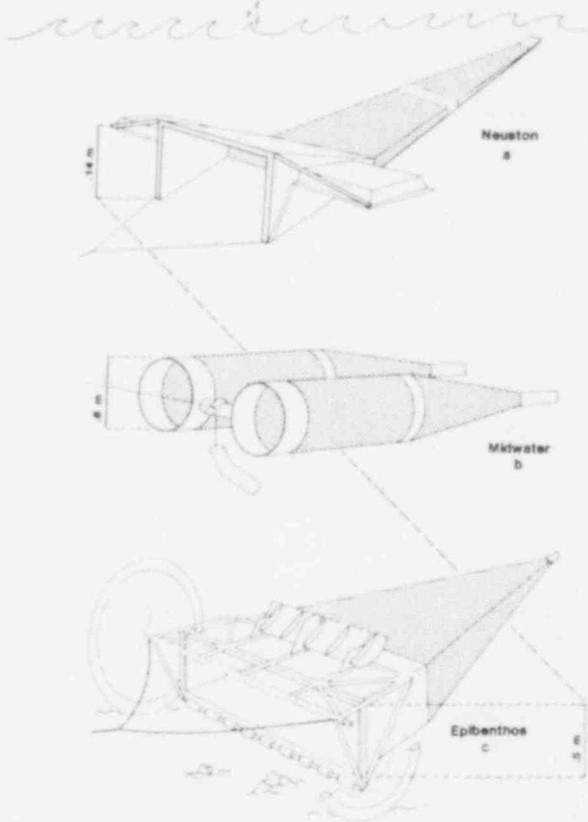

Figure 6A-1. Sampling gear employed for nearshore ichthyoplankton collections.

From August through December 1977 (Table 6A-2) one replicate with each sampling gear was taken at each station during day and night. The Bongo Net sampled at three depths (1, 3, and 6 m at Station 12; 1, 3, and 7 m at Station 13; and 1, 5, and 10 m at Station 14).

Stations 12 and 14 were sampled only at night in January 1978 (Table 6A-2). Five replicates of each gear type were collected at Station 12, and one replicate at Station 14. Station 13 was not sampled.

In February 1978 (Table 6A-2), four replicate samples were collected only at night at Stations 12 and 14.

In March 1978 (Table 6A-2) sampling protocol was finalized. Nearshore sampling transects were adopted that paralleled the Units 2 and 3 discharge diffuser conduit (Figure 6A-2). Two transects ranging from 8 to 11 m (Treatment 1) and 12 to 15 m (Treatment 2) in depth, and 762 m in length, were sampled. A reference area located beyond the projected region of influence of the generating station intake and discharge was established north of San Mateo Point (Figure 6A-2). The reference area (5.8 km upcoast) was similar to the nearshore area in the vicinity of the generating station in contour and bottom composition, and in the proximity of a kelp bed downcoast of the transects. Two transects 762 m in length (Reference 1 and 2, designated C-1 and C-2) were established in the reference area at the same depths as those sampled in the treatment area. Four replicate tows were collected with each gear type at each of the four stations.

Table 6A-1. Theoretical and actual filtering ratios and mouth areas of net types.

	Manta	Bongo	Auriga
R_T	11.30	9.04	6.60
R_A	13.48	9.33	6.70
Mouth Area (m^2)	0.13	0.57	1.00

All net collections were made with 333 micron mesh and preserved in 4% buffered Formalin-seawater.

Table 6A-2. Ichthyoplankton sampling regime.

Nearshore

Year	Month	Stations	Periods	Replicates /Track	Comments
1977	Aug-Dec	12, 13, 14	Day, Night	1	Longshore transects in treatment area
1978	Jan	12, 14	Night	5 @ 12 1 @ 14	Station 13 eliminated Day sampling eliminated
	Feb	12, 14	Night	4	
1978-79	Mar-Jul	T1 - T2 C1 - C2	Night	4	Nearshore transects in treatment and reference areas

Intake

Year	Month	Periods	Replicates /Period	Pumping Duration (min)	Comments
1977	Aug-Sep	Day, Night	4	60	1 m standpipe
	Oct	Day, Night	4	60	3 m standpipe
	Nov	Day, Night	8	30	Shorter pump duration resulted in less larval damage
1978	Jan	Day 1, Day 2 Night	8 day 8 night	30	Day period split
1978-79	Feb-Jul	2 Day, 2 Night Crepuscular	4	30	24 total samples in 6 periods

Beginning in March 1978, temperature and conductivity of the water column were measured using a Martek Mark II water quality profiler.

INTAKE SAMPLING

Samples of entrained ichthyoplankton were pumped from the intake riser of San Onofre Unit 1 (Figure 6A-2) using a centrifugal whorl Nielsen Model NCH Fish Pump rated at 227 m^3 hr^{-1} at 2 m head. The pump discharge was directed over the side of the vessel and was equipped with a Dacron sleeve that flared from 25.4 cm to 1 m diameter at the point of attachment to the filtering net. The net was 333 micron Nitex mesh and remained submerged during sampling. The actual R (filtering area/mouth area) of the Fish Pump Net was 4.26, with a total mesh area of 7.32 m^2. The cylinder and cone areas were 4.39 m^2 and 2.93 m^2, respectively.

Intake samples were initially collected via a 1 m metal standpipe projecting through a manhole in the velocity cap (Figure 6A-3). The standpipe was lengthened to 3 m in October 1977 to ensure effective sampling of incoming water.

From August through October 1977 (Table 6A-2) samples were continuously pumped for four hours during both day and night. To reduce physical damage to the collected larvae retained within the net, the four one-hour periods were modified to eight half-hour intervals in November 1977.

In January 1978 (Table 6A-2) the day sampling period was divided into two independent periods, and half-hour samples were pumped for two distinct two-hour periods. Half-hour night samples were pumped from 2100 to 0100 PST.

In February 1978 (Table 6A-2) the sampling regime was modified to include 24 half-hour pump samples with four morning and four afternoon samplings during the day, and four evening and four pre-dawn samplings at night. Four half-hour samples were collected during both the sunrise and sunset crepuscular periods. This sampling regime was interrupted only in March 1978 when the intake hose was temporarily unusable, and September 1978 when the generating station was not operational.

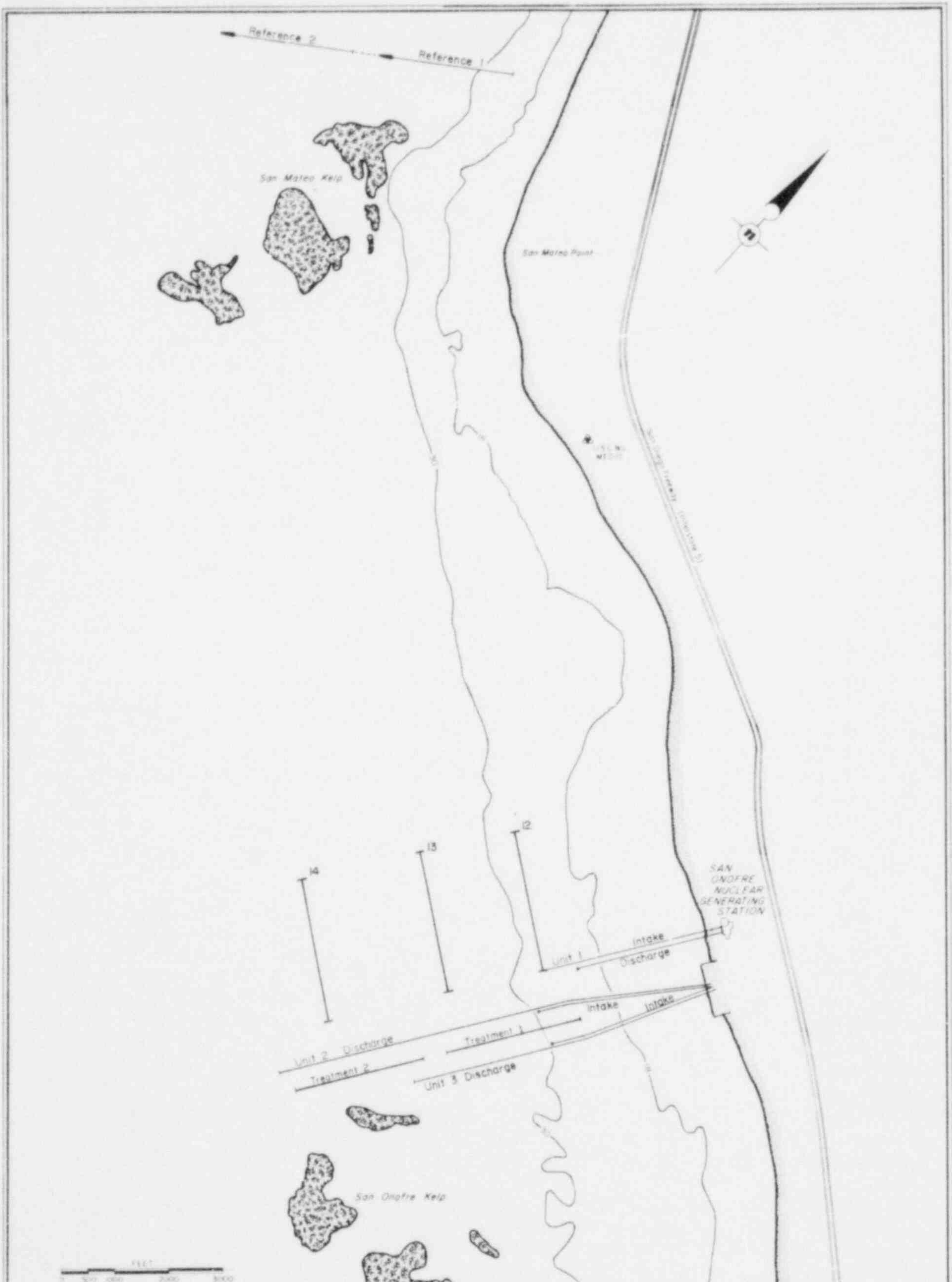

Figure 6A-2. Station locations for ichthyoplankton study.

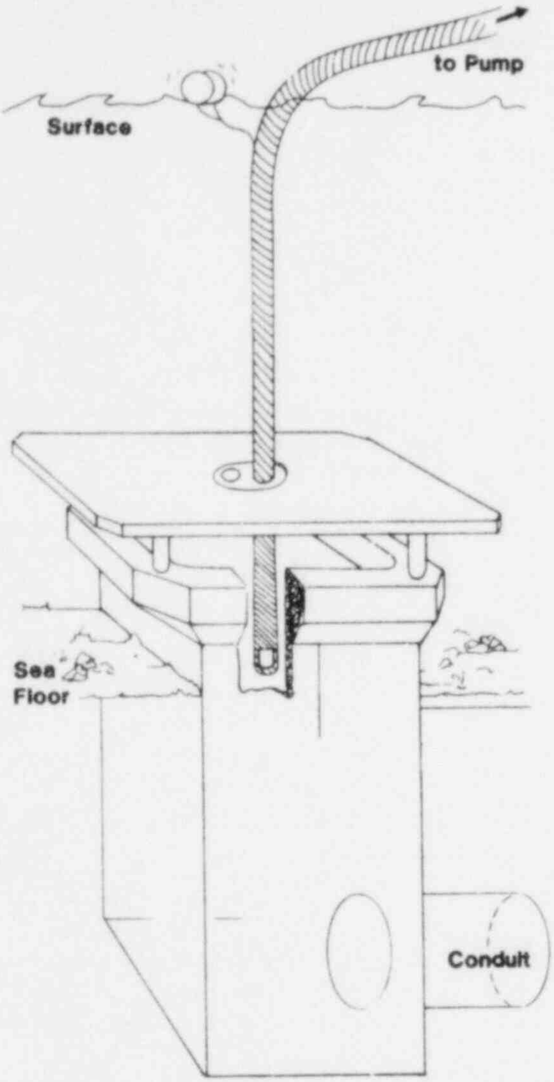

Figure 6A-3. Standpipe and velocity cap configuration.

Intake samples were filtered through a 333 micron mesh net and preserved with 4% buffered Formalin-seawater. Volumes of water pumped were determined by a GO Model 2030 flowmeter mounted in the intake hose.

REPRESENTATIVE INTAKE SAMPLING POSITION

A sampling point within the intake riser system which represented a completely mixed sample of all the water drawn into the intake was required. If an intake sample were biased by neuston, midwater, or epibenthic plankton components, then the interpretation of results would be erroneous. At San Onofre, it was demonstrated that water entering the intake may originate above the thermocline (Kinney 1977 unpublished); thus, influencing plankton withdrawal at the discontinuity layer.

In August 1977 a permanent standpipe extending into the vertical conduit was installed in the Unit 1 riser to sample entrained ichthyoplankton. This position was thought to provide a non-biased biologically representative sample. However, dye studies are required to determine the location of completely mixed intake waters before biological assumptions may be tested for validity. Preliminary dye studies at San Onofre Unit 1 (Kinney unpublished) indicated that the point of homogeneous mixing could be located as far as 10 to 15 m downstream in the horizontal conduit. The onshore screenwell and adjacent upstream conduit were shown not to be representative sampling sites (Barnett unpublished) because ichthyoplankton concentrations were substantially reduced at this point as compared to intake riser samples.

Once the point of homogeneous mixing was determined, simultaneous plankton samples from the standpipe and the completely mixed location were required to evaluate if biological differences are detectable. A comparison study (Schlotterbeck et al. 1979b) between the theoretical mixing point and the initial sampling position (3 m standpipe through the velocity cap) was conducted in August 1978 by placing two Nielsen Fish Pumps on a single vessel and pumping samples simultaneously from the standpipe and the projected mixing point (Kinney 1977 unpublished), 15 m within the horizontal intake conduit. The theoretical mixing point inside the intake conduit was sampled by a specially constructed Intake Unidirectional Diverter (IUD). The IUD was designed to reduce sampling bias associated with differential water velocity, turbulence, and conduit wall effect. Thirty-two replicates of 100 m^3 were collected over a 24 hr period to evaluate the effectiveness of both the IUD and existing standpipe. The standpipe was selected as the most biologically representative sampling device because it more effectively collected zooplankton and ichthyoplankton samples and was easier and safer to install and retrieve than the IUD while the generating station was in operation. A Wilcoxon matched pairs signed-ranks test applied to ten size classes of fish larvae (3 mm increments from 0 to 30 mm) indicated no statistical difference for black croaker and white croaker in the standpipe and IUD; however, the standpipe was significantly more effective in collecting northern anchovy and queenfish. The IUD was not as effective as the standpipe in collection of larvae smaller than 9 mm.

LABORATORY PROCESSING

Field samples were sorted in the laboratory with dissecting microscopes. Sample size reduction, where necessary, was accomplished by Folsom Splitter (McEwen et al. 1954). Auriga net samples were occasionally treated with a 1.2 x (H_2O) density $MgSO_4$ solution (Watson unpublished) to facilitate the separation of plant debris from the plankton portion of the sample.

Processing procedures generally followed those proposed by Smith and Richardson (1977), and permanent fixation followed Ahlstrom (1976). All larvae were sorted, identified, and enumerated. Eggs were sorted and enumerated as anchovy and other. A resort of all initially sorted samples resulted in a recovery rate greater than 99% for eggs and larvae.

TARGET SPECIES SELECTION

Certain fish species received substantially more analyses than others. These species were referred to as target species, and criteria established for their selection included: 1) importance in the local trophic structure (either as planktivorous, piscivorous, or benthic feeders; and, importance as a food source); 2) presence in the study area with at least minimal abundance during most periods of the year to lend statistical integrity to analyses; 3) subjectivity to high degrees of entrainment and impingement during most of their life history; and 4) utility as indicator species which, if adversely impacted, may demonstrate general communal effects. Based on these criteria, chosen target species were northern anchovy (Engraulis mordax), white croaker (Genyonemus lineatus) and queenfish (Seriphus politus).

RESULTS AND DISCUSSION

NEARSHORE LARVAL DISTRIBUTION

The species addressed below include the three target species northern anchovy, white croaker, and queenfish, and additional taxa, which were considered important because of their general abundance or value as commercial or sport fish. Ichthyoplankton raw data are presented in Volume II, Biological Data (SCE 1980).

Northern Anchovy

Larvae of the northern anchovy, the most abundant species collected, occurred during all months of the ichthyoplankton survey. Maximum abundance was recorded between February and April of 1978-79. Secondary peaks occurred during September 1977, December 1978, and July 1979 (Figures 6A-4, 5, and 6). Northern anchovy was least abundant in neuston samples, comprising only 9 to 10% of the total catch, and most abundant in epibenthic samples. During the major spawning periods (8 of the 24 months sampled) northern anchovy larvae were more abundant in oblique samples from the Bongo net (referred to hereafter as

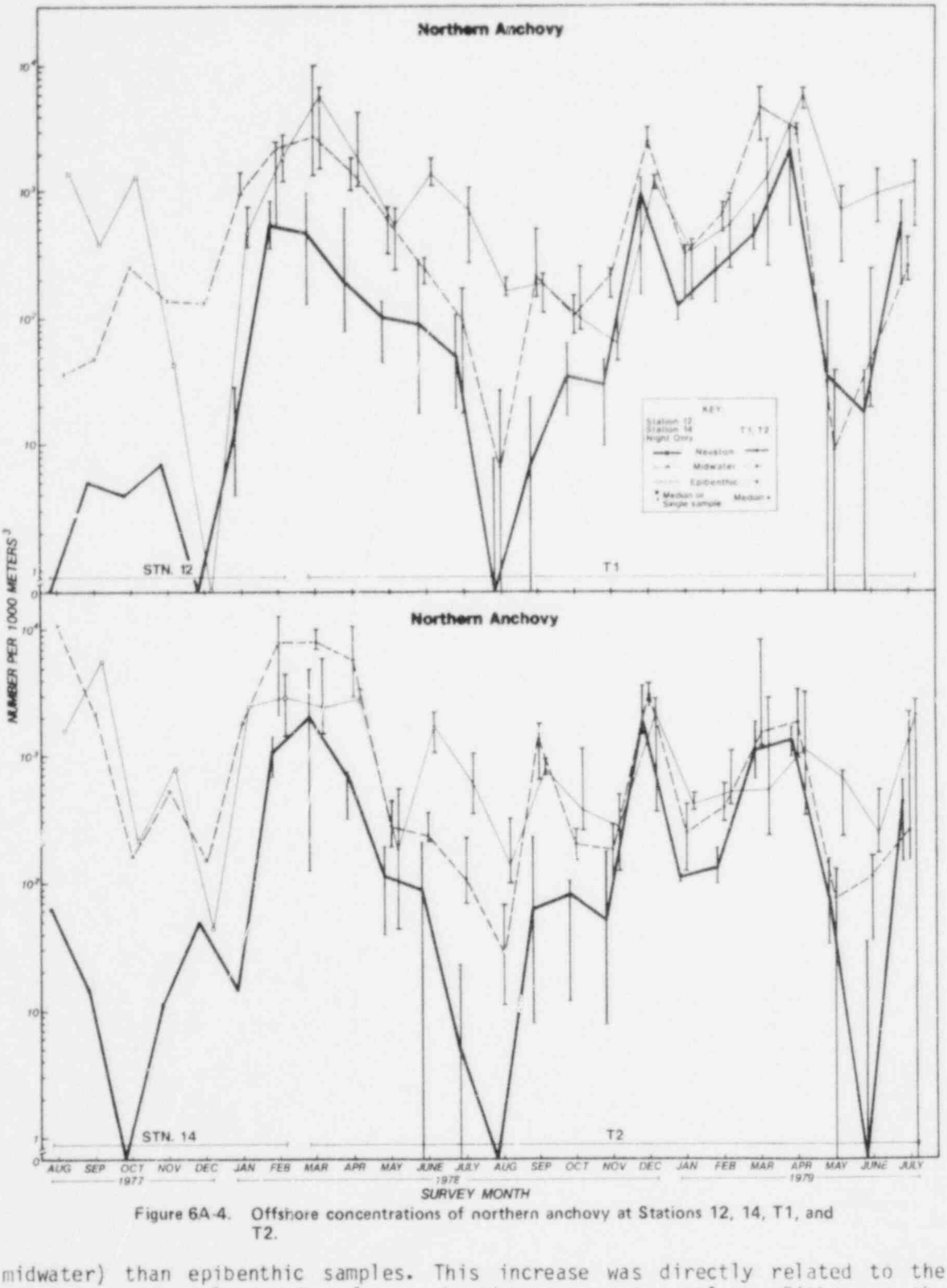

Figure 6A-4. Offshore concentrations of northern anchovy at Stations 12, 14, T1, and T2.

midwater) than epibenthic samples. This increase was directly related to the appearance of newly hatched larvae in the upper water column. Either as the result of sinking or migration, the cohort of newly hatched larvae was rapidly incorporated into the epibenthos resulting in a return to the "normal" vertical distribution of northern anchovy within the study area.

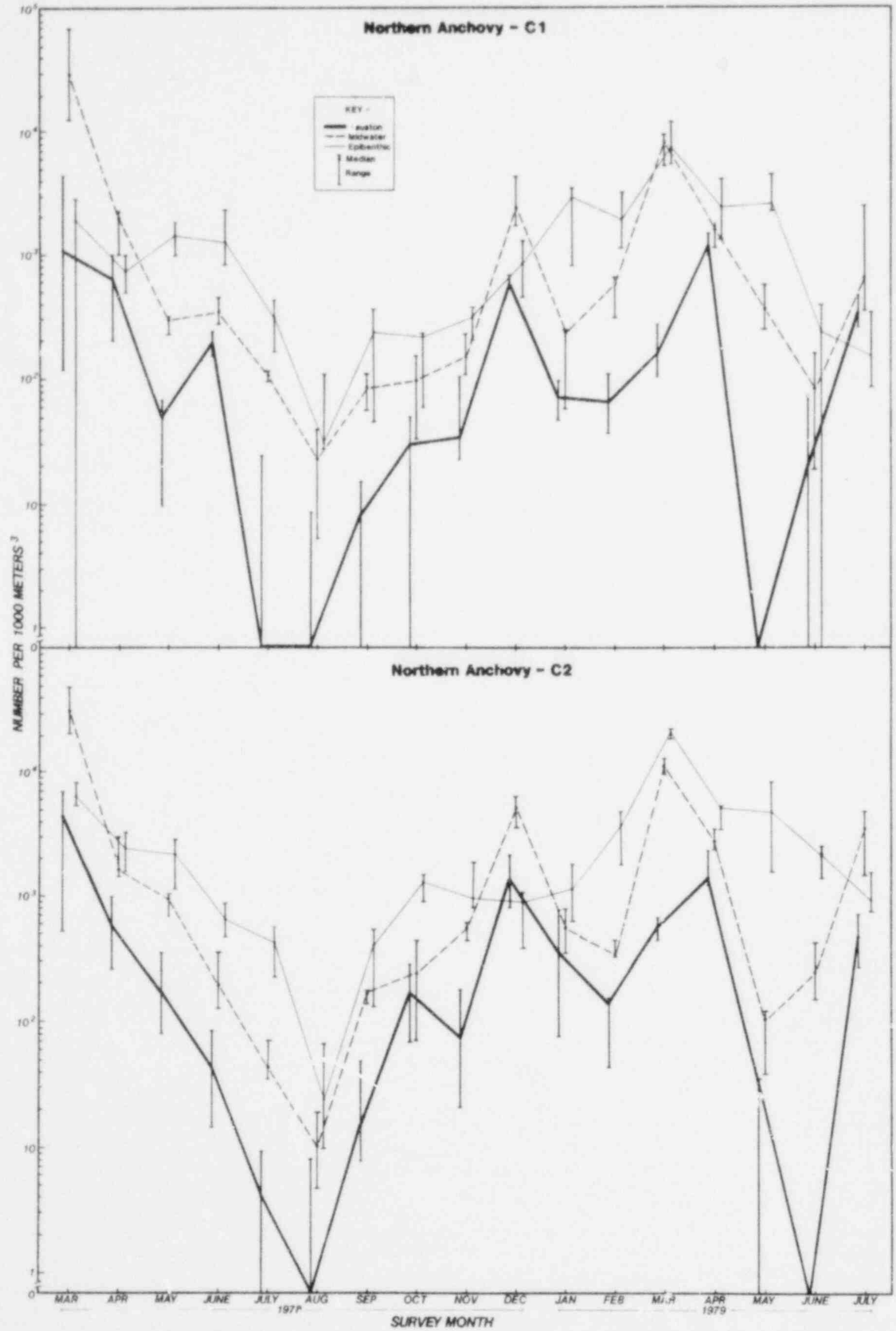

Figure 6A-5. Offshore concentrations of northern anchovy at Stations C1 and C2.

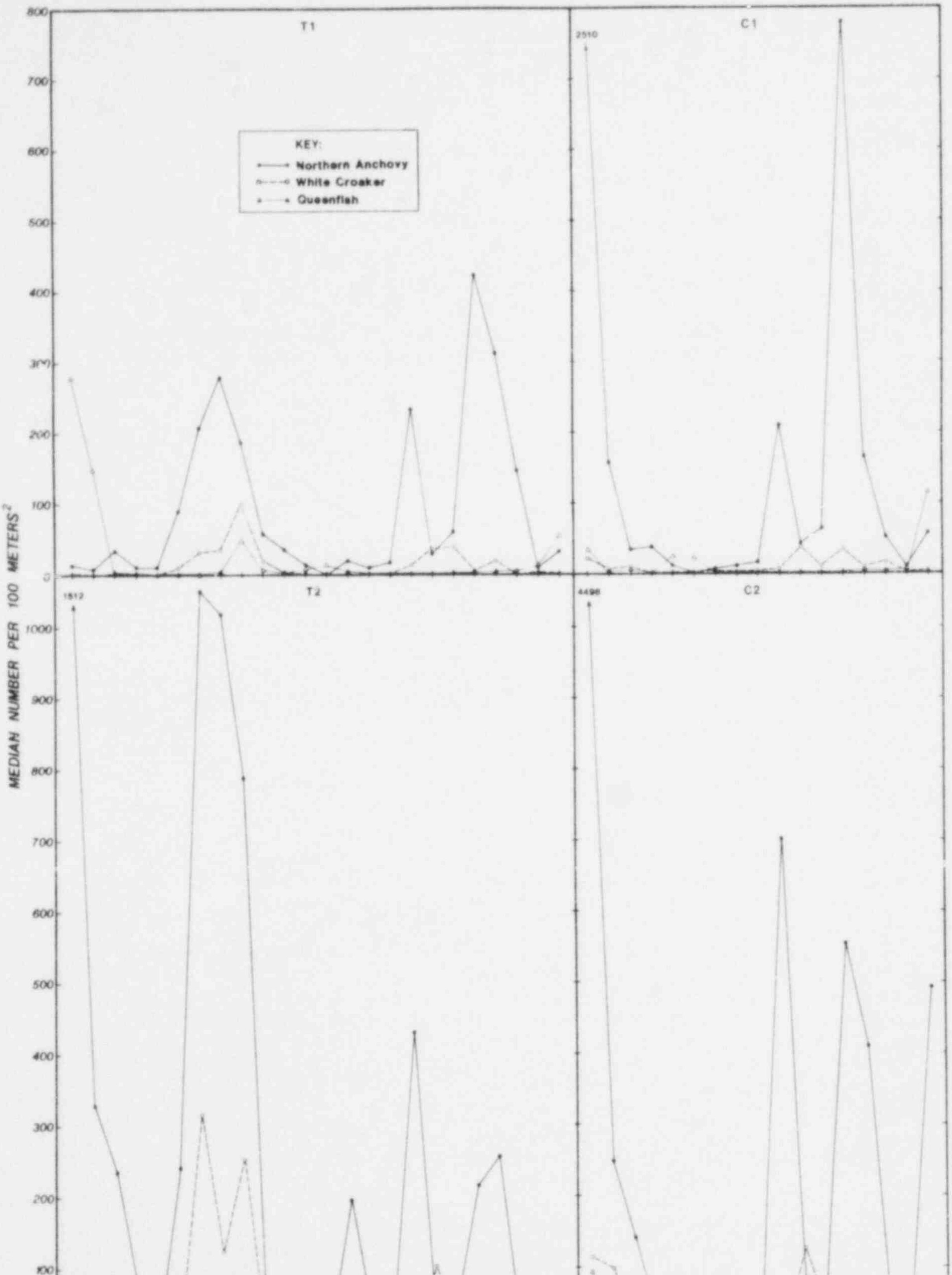

Figure 6A-6 Target species concentrations $100m^{-2}$ at Stations T1, T2, C1 and C2.

There was no consistent distributional pattern of northern anchovy larvae. However, the larvae were generally more abundant in the neuston at Station T1, whereas the midwater and epibenthic areas had maximum concentrations at Station C2.

An examination of an eight month summary of Southern California Bight data (Brewer et al. unpublished) indicated that northern anchovy larval concentrations in the San Onofre area were similar to that reported for the area from San Diego to Ventura. Northern anchovy densities increased from the inshore to offshore areas.

The median length class of northern anchovy in neuston samples fluctuated between 0-3 and 6-9 mm throughout the year, except during late spring and early summer of both 1978 and 1979, when an absence of small larvae resulted in medians near 24 mm. During these months, median lengths in neuston collections were larger than in midwater or epibenthic samples, which shared similar, though less dramatic increases during the same period. Median length classes in midwater samples were slightly larger than those observed in neuston collections during the latter part of the main spawning period. Median lengths in epibenthic samples were consistently in the 9 to 21 mm range, decreasing during winter in response to spawning.

The variability of the median length in neuston samples was highly dependent on spawning events, whereas variability in epibenthic samples was low, with median values changing gradually over the year. The median size class within the length-frequency distribution reflected spawning activity in that the lowest median lengths corresponded to high concentrations of small larvae taken from the neuston and midwater. Intermediate size classes (10 to 21 mm) of anchovy were collected in neuston samples only during winter or spring months of high larval abundance. Anchovy larvae appeared to migrate from the neuston to the epibenthos soon after hatching, but returned to the neuston after reaching lengths of approximately 20 mm (3 to 5 weeks).

White Croaker

White croaker were present in the plankton throughout most of the year, although the larvae generally were rare from June through October. Maximum concentrations were recorded from January through April in 1978 and from January through March in 1979 (Figures 6A-6, 7, and 8).

Larval white croaker were vertically stratified. Neuston samples contained approximately 4% of the larvae, whereas 83% of the larvae were collected from the epibenthic layer. Because a majority of the white croaker yolk sac larvae occurred in the neuston, and newly hatched yolk sac larvae often may not be taxonomically separated from other species, they were combined into a single group designated unidentified yolk sac larvae. This group was mainly comprised of white croaker and queenfish.

The affinity of white croaker larvae for the epibenthos was related to developmental strategy. The larvae hatch at or near the surface and begin to sink or migrate downward, a process completed during the early larval stage.

White croaker larvae were generally more abundant in the neuston at Stations T1 and C2. Larvae in the midwater were clearly more abundant at Stations T2 and C2, whereas in the epibenthic layer, larvae were more abundant at Stations T1 and C1. This distribution was related to the age of the larva. Size frequency data indicated that older white croaker larvae were collected in the epibenthos, whereas younger larvae were collected in the midwater. Once the larva reached the epibenthic layer, there was an apparent inshore migration.

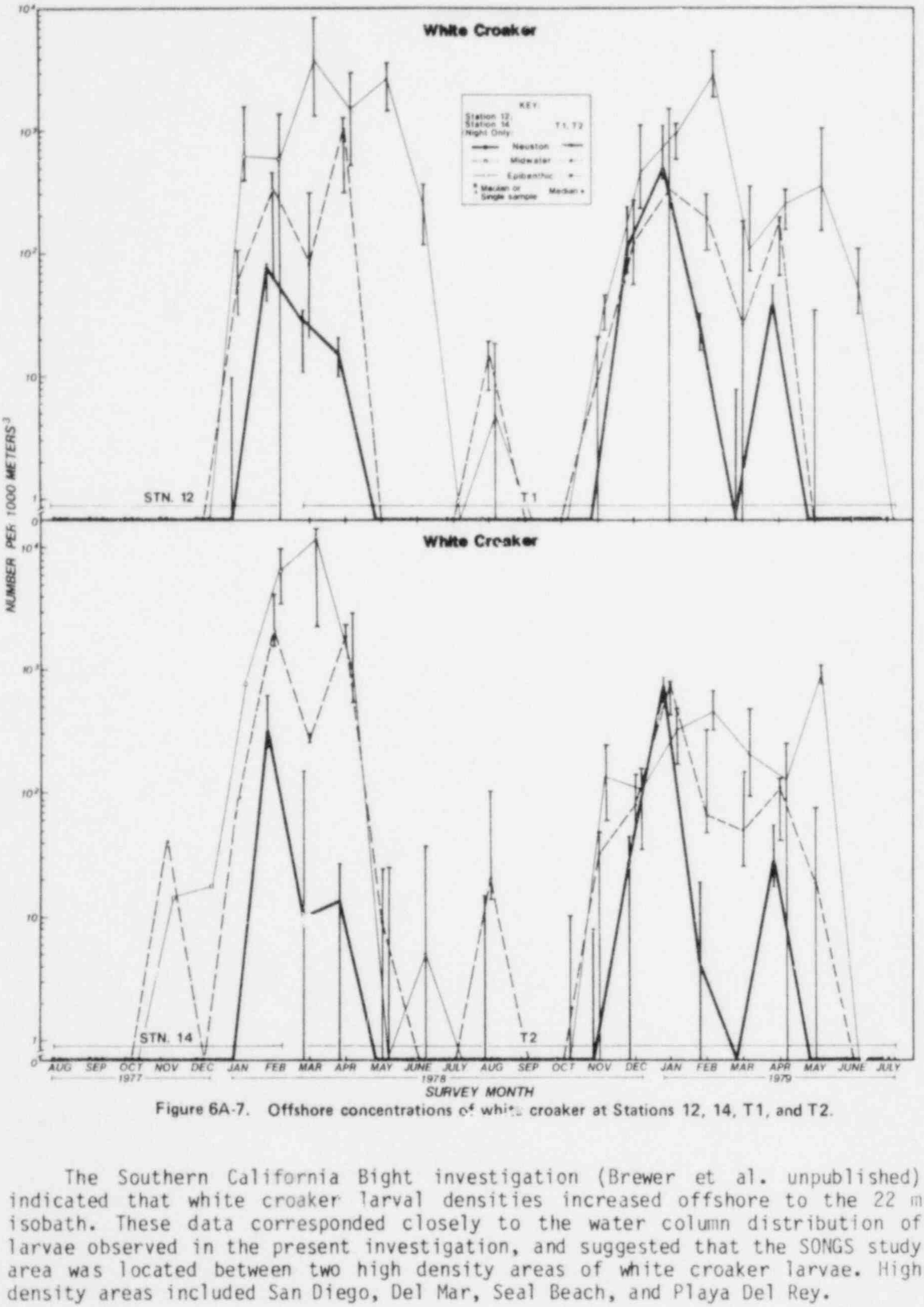

Figure 6A-7. Offshore concentrations of white croaker at Stations 12, 14, T1, and T2.

The Southern California Bight investigation (Brewer et al. unpublished) indicated that white croaker larval densities increased offshore to the 22 m isobath. These data corresponded closely to the water column distribution of larvae observed in the present investigation, and suggested that the SONGS study area was located between two high density areas of white croaker larvae. High density areas included San Diego, Del Mar, Seal Beach, and Playa Del Rey.

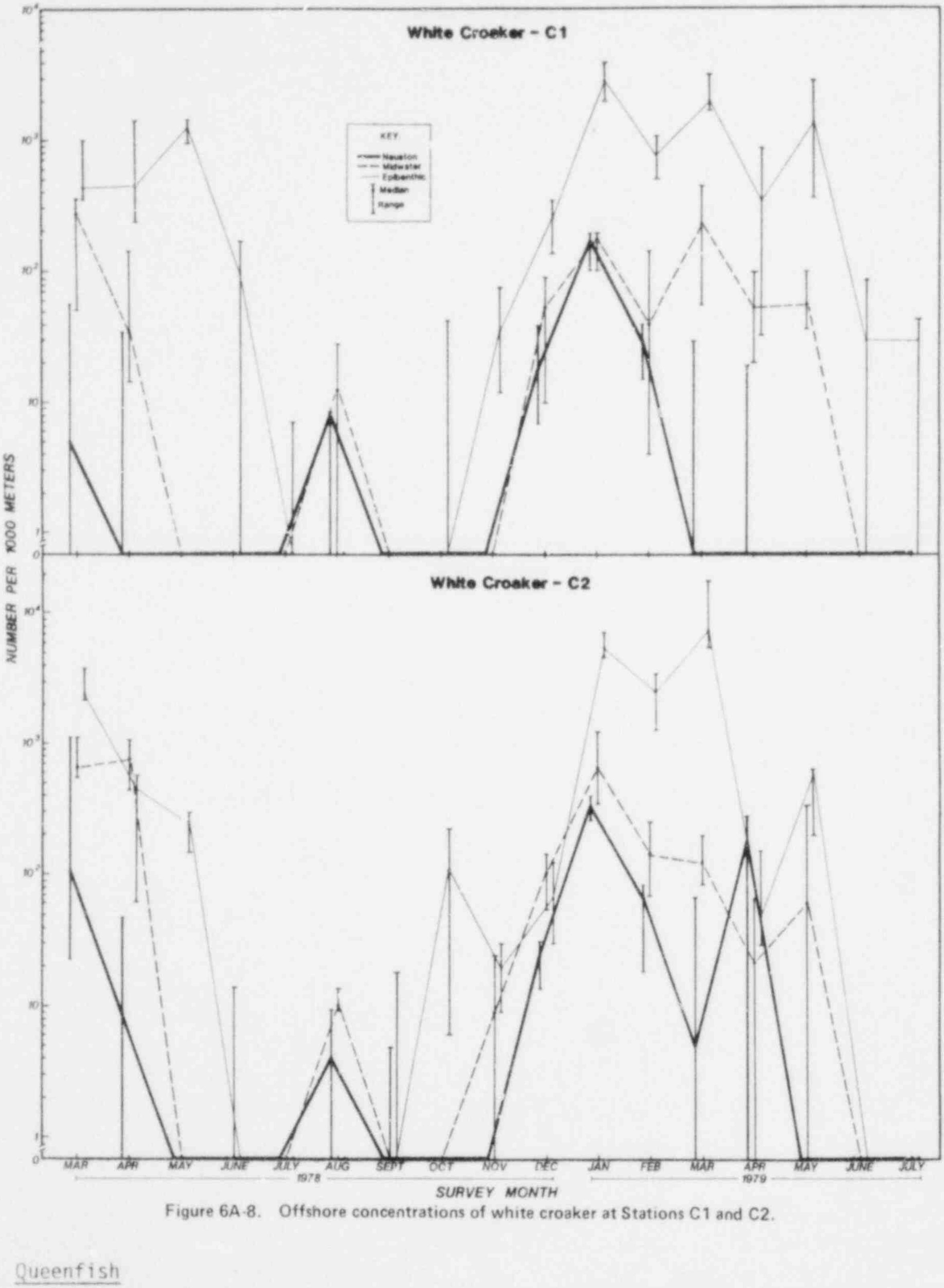

Figure 6A-8. Offshore concentrations of white croaker at Stations C1 and C2.

Queenfish

The third target species, queenfish (a croaker), was present in the plankton from February through December. Maximum concentrations occurred during July and August, with major density peaks in March and April 1978 (Figures 6A-6, 9, and 10).

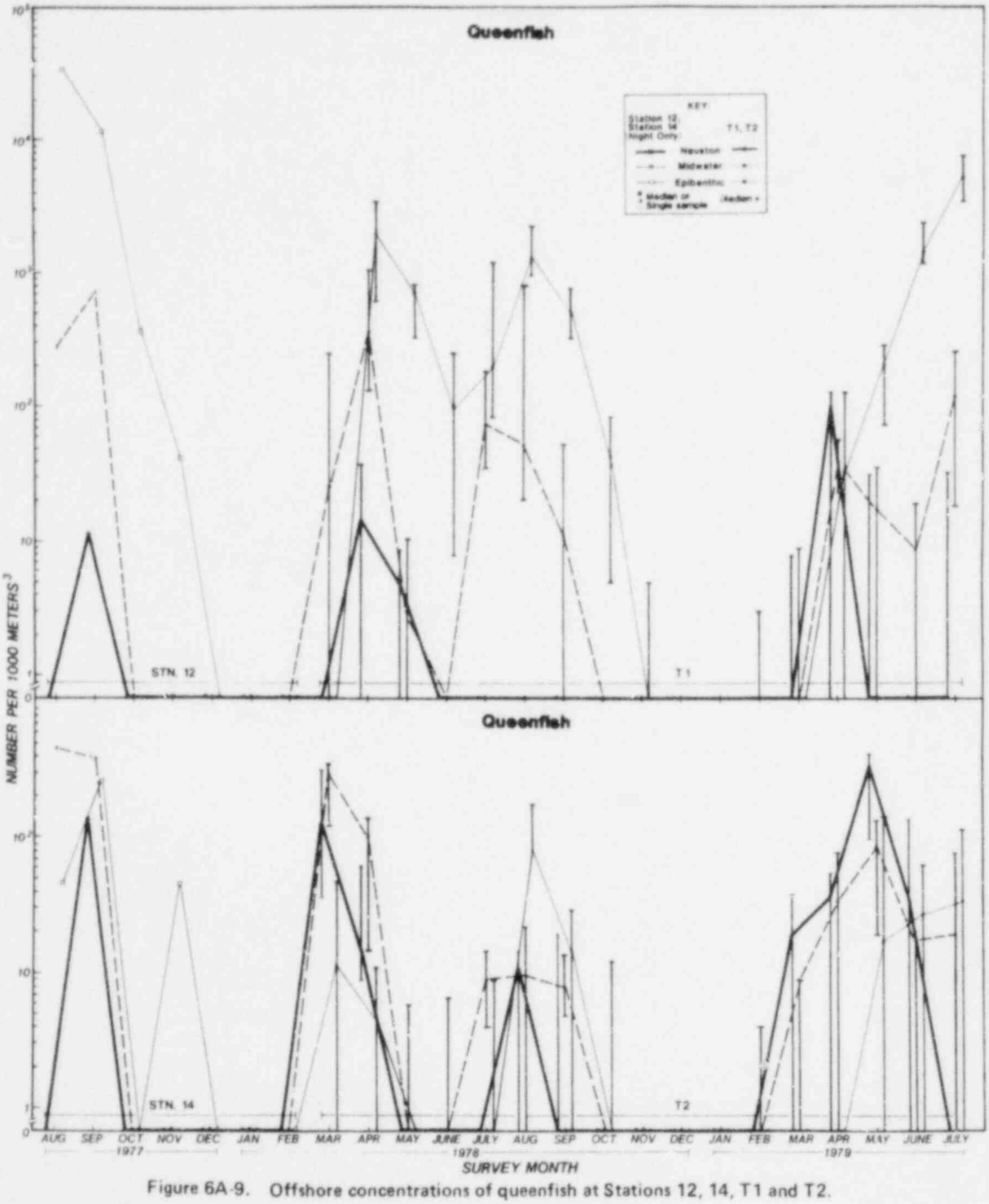

Figure 6A-9. Offshore concentrations of queenfish at Stations 12, 14, T1 and T2.

The vertical distribution of queenfish larvae in the midwater was similar to that reported for white croaker with an increase of larval densities with depth, which reflected the developmental strategy of the species.

Distributional data indicated an onshore and epibenthic movement of the larvae with age. In the neuston, larval density was highest at Stations T2 and C2. Density patterns in the midwater were not as pronounced as those in the neuston, although a general pattern of higher density at Stations T1 and C1 was present. Epibenthic densities were highest at Stations T1 and C1.

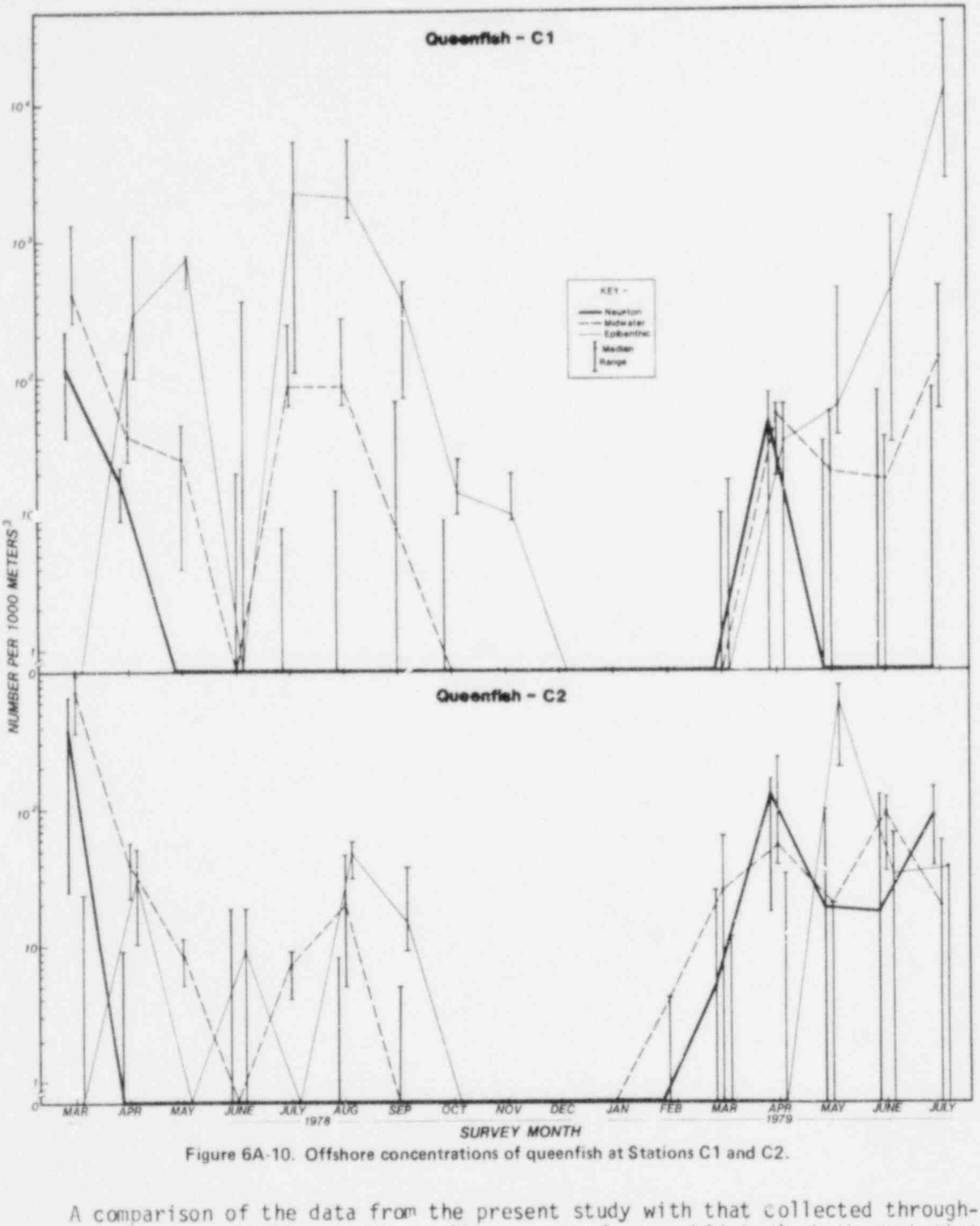

Figure 6A-10. Offshore concentrations of queenfish at Stations C1 and C2.

A comparison of the data from the present study with that collected throughout the Southern California Big t (Brewer et al. unpublished) indicated that queenfish larvae were generally concentrated along the 15 and 22 m contours, a pattern that differed with that observed at SONGS. Bight data suggested that SONGS was located in an area of reduced larval queenfish density as compared to areas north and south of SONGS.

Neuston collections of larval white croaker and queenfish were generally dominated by individuals of the two smallest size classes (0 to 3 and 3 to 6 mm). Distributions of these species in midwater samples followed the same trend. Median length frequency values in epibenthic samples were consistently the highest observed for these two species; however, values for each species fluctuated, exhibiting lowest medians during peak spawning periods, and highest medians near the end of the spawning season. Differences in the seasonal vertical distribution for the two species were noted in the upper water column. The absence of queenfish larvae in the neuston during the summer, and very low concentrations in the midwater compared to the epibenthos during the same period, may have been due to the formation of the thermocline restricting eggs from the upper water column prior to hatching. White croaker larvae were more abundant in the midwater during the winter, when the water column was well-mixed.

California Halibut

The California halibut, Paralichthys californicus, is a common member of the demersal ichthyofauna of southern California and an important sport and commercial fish. Taxonomic problems in separating preflection larvae of California halibut from those of fantail sole (Xystreurys liolepis), led to the formation of the combined taxon Paralichthys/Xystreurys. All postflection larvae collected in the SONGS investigation were California halibut.

California halibut larvae were present in the plankton throughout the year with maximum density recorded from November through March. The larvae were usually uncommon in the neuston samples. Preflection and early postflection larvae were normally more abundant in the water column, whereas the more advanced postflection larvae were concentrated in the epibenthos. The highest density of larvae occurred at Stations T2 and C2 in all vertical strata.

Bight-wide data (Brewer et al. unpublished) suggested that the SONGS study site was located on the northern perimeter of a major concentration of California halibut larvae, which was centered off San Diego. To the north was a second major high density region centered off Seal Beach. Both centers were located offshore of major harbo and bays that were suspected nursery grounds for the species (Haaker 1975).

Cheekspot Goby (Gobiidae Type A)

The family Gobiidae was one of the most speciose taxonomic groups collected during the study. Although not generally as abundant as the three target species, Ilypnus gilberti was common, especially between November and April, and was normally concentrated in the water column and epibenthic regions of the inshore stations.

Atherinidae

Atherinid larvae were a major ichthyoplankton component throughout the survey. All three species were combined because of the difficulties encountered in taxonomic separation during the first year of the program. The grunion, Leuresthes tenuis, was present in the plankton from February through November 1979, while the jacksmelt, Atherinopsis californiensis, occurred between October and June. The topsmelt, Atherinops affinis, occurred rarely, only during the summer months.

Approximately 90% of the atherinid population was collected from the neuston. The majority of the remaining larvae were taken in the midwater samples. Larvae from the epibenthic samples probably represented a contamination when the Auriga net was lowered from the surface.

Atherinid larvae were most abundant at Station T1, and least abundant at Stations C1 and C2. The surface layer distribution of atherinids may have been, in part, caused by construction activities in the San Onofre vicinity.

Field observations suggested that atherinid larvae were attracted to light during night. Illumination from the construction trestle and the SONGS Units 2 and 3 construction site may have artificially concentrated atherinid larvae near Station T1.

Blennies

Blenny larvae of the species *Hypsoblennius gentilis*, *H. gilberti*, and *H. jenkinsi* were taxonomically inseparable, and therefore were combined as *Hypsoblennius* spp. Larvae larger than 10 mm SL were primarily *H. jenkinsi*, suggesting that they also comprised the majority of larvae under 10 mm. Blenny larvae were a common component of the ichthyoplankton community during the summer and fall months, and were collected almost entirely from the neuston and water column. Larvae greater than 12 mm were not collected, suggesting that larger individuals have probably assumed the cryptic adult habitat.

In the neuston, larval blennies were most abundant at Stations C1 and C2, with maximum density at Station C2. No distinct distributional pattern was apparent in midwater samples, and maximum density was recorded at Stations C2 and T1.

California Corbina

The California corbina, *Menticirrhus undulatus*, ranked as the eighth most abundant larval species entrained by SONGS Unit 1, even though it was a minor component of the nearshore ichthyoplankton community. The species is important as a sport fish.

Corbina appeared in the plankton from August through November, with a single occurrence in March 1978. With the exception of the March sampling period, all corbina larvae were collected from the midwater. The species was not sufficiently abundant (except August 1978) to detect a vertical distribution pattern.

SEASONAL OCCURRENCE OF NEARSHORE LARVAE

A majority of the common taxa occurring off San Onofre were collected throughout most of the year. The taxa included northern anchovy and various members of the families Sciaenidae, Gobiidae, Atherinidae, Blenniidae, Bothidae, Clinidae, and Pleuronectidae.

Northern anchovy was the only species collected during all 24 monthly sampling periods, and one of the few species exhibiting major abundance peaks more than once during the year. The northern anchovy larval population increased substantially from February through April and again, one or more times, between July and December. Other taxa with a similar temporal distributional pattern included the cheekspot and the bay gobies. The peak occurrence of the remaining taxa was restricted to a one to three month period, even though they may have occurred sporadically throughout most of the year.

Sciaenids, one of the two major groups of larvae collected, displayed several temporal patterns. White croaker, one of two abundant sciaenids, was a cold water form reaching maximum density during January through March, while queenfish, the second major sciaenid larva, reached peak abundance during the warm water months of July through September. Two minor sciaenids in terms of abundance, black croaker and corbina, were generally most abundant in the spring or early summer months.

The peak occurrence of the two major species of larval atherinids, like sciaenids, appeared to be separated by time. Topsmelt reached peak densities in the winter months, while grunion reached peak densities during the spring and early summer months.

Clinids were present in the samples throughout most of the year with individual species attaining maximum population densities during the summer and fall months. The temporal distribution of the clinids, giant kelpfish and Neoclinus sp. A (equals Clinidae Type B), paralleled one another with maximum population density occurring in the summer months, while Gibbonsia sp. A (equals Clinidae sp. A) reached maximum density during the period September through November.

The seasonal distribution of blennies (Hypsoblennius spp.) and gobiesocids, specifically California clingfish, were parallel. Both groups were present in the samples throughout most of the year and reached maximum density during May and June. Minimum density for both groups was recorded from November through March.

Bothid and pleuronectid flatfish generally attained peak concentrations during the fall and winter months, while minimum concentrations occurred during the warmer water periods.

The two major species of flatfish larvae in the study area, California halibut (Bothidae) and diamond turbot (Pleuronectidae) both reached maximum density from November and December, while lower concentrations were recorded from May through July.

Several minor elements of the ichthyoplankton fauna were restricted in their occurrence to a relatively short period. Members of this group of larvae appear to be separable into two fractions: 1) cold water forms; and, 2) warm water forms. The cold water forms included the families Scorpaenidae and Cottidae. Though cottids were collected as early as August, they were most abundant from approximately November through March. Scorpaenid larvae first appeared in the samples during November and were collected through March.

Larvae considered as warm water forms were members of the families Exocoetidae, Serranidae, Pristipomatidae, Pomacentridae, and Labridae. Larvae representing most of these families were collected as early as May, though maximum densities did not occur until July or August.

ESTIMATE OF LARVAL ENTRAINMENT LOSS

Unit 1 Intake Loss

Empirical data from the Unit 1 intake were used to estimate the annual loss attributable to entrainment. Entrainment losses were estimated using four basic assumptions: 1) a representative sample was withdrawn from the intake; 2) the volume circulated per unit time was consistent and continuous over one year; 3) the density and composition of samples collected during the 16 month survey were representative of unsampled periods; and 4) entrainment mortality was 100%.

The daily loss, as numbers of individuals for each species was calculated as:

(1) Daily Loss = [Volume circulated/day] [(density_{day})(day hours/24 hrs)
+ $(\text{density}_{sunset})$ (sunset hours/24 hrs) + (density_{night}) (night hours/24 hrs
+ $(\text{density}_{sunrise})$ (sunrise hours/24 hrs)]/1000 m^3

where daily volume circulated = 1.911×10^6 m^3

density = mean number 1000 m^{-3} collected during a sample period day or night hours = proportion of time attributed to either period based on 24 hr day

sunset or sunrise hours = 2/24 = 0.08

The monthly loss, as numbers of individuals for each species was calculated as:

(2) Monthly loss = (Daily loss)(D_m)

daily loss = from equation (1)

D_m = 50% of the days until the subsequent survey + 50% of the days from the previous survey.

The monthly loss for March and September 1978 was based on an equal weighting of February and April, and August and October 1978, respectively.

The annual loss, as numbers of individuals for each species was calculated as:

(3) Annual Loss = [(monthly $loss_{Apr-Jul\ 78}$) + (monthly $loss_{Apr-Jul\ 79}$)/2] [4/12] + [(monthly $loss_{Aug\ 78-Mar\ 79}$)] [8/12]

monthly loss = from equation (2) for April-July 1978 and 1979; August 1978-March 1979

For months where two data sets were collected one year apart in time (February, March, April, May, June, and July), loss data were averaged. The estimated annual entrainment of 25 taxa at Unit 1 is presented in Table 6A-3.

COMPOSITION OF INTAKE LOSS

The annual estimate of the number of entrained larvae (based on mean and median) at the Unit 1 intake was calculated (Table 6A-3) as 8.75×10^8, based on mean, and 7.09×10^8, based on median. Six species and two groups (yolk sac

Table 6A-3. Annual estimated number of larvae entrained by San Onofre based on mean and median, with 95% confidence interval for target species.

Species	Common Name	Total from Mean ($\times 10^6$)	Rank	% Total	Total from Median ($\times 10^6$)	Rank	% Total
Total larvae		874.9		100.0	708.7		100.0
Engraulis mordax	northern anchovy	462.5±26.2	1	52.9	395.9	1	55.9
Genyonemus lineatus	white croaker	123.3±7.1	2	14.1	111.6	2	15.7
Seriphus politus	queenfish	50.8±33.4	3	5.8	43.4	3	6.1
unidentified larvae (fragments and mutilated)		46.3	4	5.3	36.7	4	5.1
yolk sac larvae		43.5	5	5.0	28.5	5	4.0
Hypsoblennius spp.		30.7	6	3.5	23.3	6	3.3
Ilypnus gilberti	cheekspot goby	23.0	7	2.6	19.1	7	2.7
Menticirrhus undulatus	corbina	21.5	8	2.5	12.9	8	1.8
Gibbonsia spp.		12.3	9	1.4	9.1	9	1.3
Cheilotrema saturnum	black croaker	9.0	10	1.0	4.1	11.5	0.6
Gobiesox rhessodon	California clingfish	8.3	11	0.9	5.1	10	0.7
Anisotremus davidsonii	sargo	7.4	12	0.8	0	23.5	0
Atherinidae, unid.		6.9	13	0.8	4.1	11.5	0.6
Heterostichus rostratus	giant kelpfish	5.8	14	0.7	2.3	14	0.3
Paralabrax clathratus	kelp bass	4.6	15	0.5	1.9	16	0.3
Paralichthys californicus/ Xystreurys liolepis	California halibut/ fantail sole	4.1	16	0.5	3.4	13	0.5
Typhlogobius californiensis	blind goby	3.7	17	0.4	2.0	15	0.3
Lepidogobius lepidus	bay goby	3.2	18	0.4	1.3	18	0.2
Hypsopsetta guttulata	diamond turbot	2.8	19	0.3	1.8	17	0.3
Citharichthys spp.		1.3	20	0.1	1.0	19.5	0.1
Leuresthes tenuis	California grunion	1.2	21	0.1	1.0	19.5	0.1
Paraclinus integripinnis	reef finspot	1.0	22	0.1	0	23.5	0
Trachurus symmetricus	jack mackerel	0.6	23.5	0.1	0	23.5	0
Peprilus simillimus	Pacific butterfish	0.6	23.5	0.1	0.2	21	0
Paralabrax nebulifer	barred sand bass	0.5	25	0.1	0	23.5	0

and unidentified larvae) represented 91.7 and 94.6% of the total annual entrainment loss as calculated by mean and median, respectively.

Northern anchovy was the most abundantly entrained species, representing over 50% of the total annual loss. Highest entrainment losses occurred in March, April, February, December, and January (Figures 6A-11 and 12). Nearly twice as many northern anchovy were collected at night than during day or either crepuscular period. Unidentified larvae, represented as either fragmented or mutilated larvae, were ranked fourth by mean (5.3%) and median (5.1%). This group was probably composed primarily of northern anchovy.

White croaker, the second most abundant larva entrained by Unit 1, represented 14.1% by mean and 15.7% by median of the annual loss. Maximum entrainment occurred between December and May and during August, with relatively few individuals collected from June, July, October, and November (Figures 6A-11 and 12). Comparable numbers of larval white croaker were entrained during the day and night, with fewer entrained at sunrise. The majority of larval white croaker were collected at sunset.

Queenfish, the third most abundant larva entrained by Unit 1, represented 5.8% by mean and 6.1% by median of the annual loss. Entrainment of larval queenfish occurred only between March and October, with maximum entrainment in July (Figures 6A-11 and 12). Nearly three times as many queenfish were entrained at night and during sunrise than during the day or sunset periods.

Yolk sac larva was ranked fifth in terms of annual entrainment loss based on mean (5.0%) and median (4.0%). Most larvae were entrained in August (mainly white croaker and some queenfish), January (mostly white croaker), and April (equal numbers of white croaker and queenfish).

The blenny complex was the sixth most abundantly entrained group (3.5% by mean and 3.3% by median). Highest entrainment losses occurred from April through October, corresponding to the reported spawning times for the three species (Stephens 1970). Entrainment losses occurred mainly during the day and night periods.

The cheekspot goby was the seventh most abundantly entrained larva at Unit 1 (2.6% by mean and 2.7% by median). Highest entrainment occurred in March and June with a nearly equal monthly entrainment loss over the remainder of the year. Entrainment was similar for all periods, except sunset which was lower.

California corbina was the eighth most abundantly entrained larva by mean (2.5%) and seventh by median (1.8%). All larval corbina were entrained during the August 1978 day and night sampling periods. However, data from September 1979 316(b) studies indicated substantial entrainment of larval corbina.

Factors Influencing Estimate of Larval Entrainment

There were several factors which influenced the estimate of entrainment effects: 1) the 100% mortality assumption; 2) the overestimate of intake larval loss at Unit 1 because circulation pumps did not operate throughout the entire study; 3) immigration and emmigration of larval populations and adult spawning aggregations; and 4) natural compensatory mechanisms.

If the transit mortality and subsequent delayed effects on ichthyoplankton were less than 100%, the current estimates need be adjusted to reflect actual loss. If mortality were 50 or 75%, then larval loss would be directly proportional and reduced by a factor of one-half to one-quarter, respectively. Since no estimates of through-plant mortality were available, we made the conservative estimate of 100% mortality.

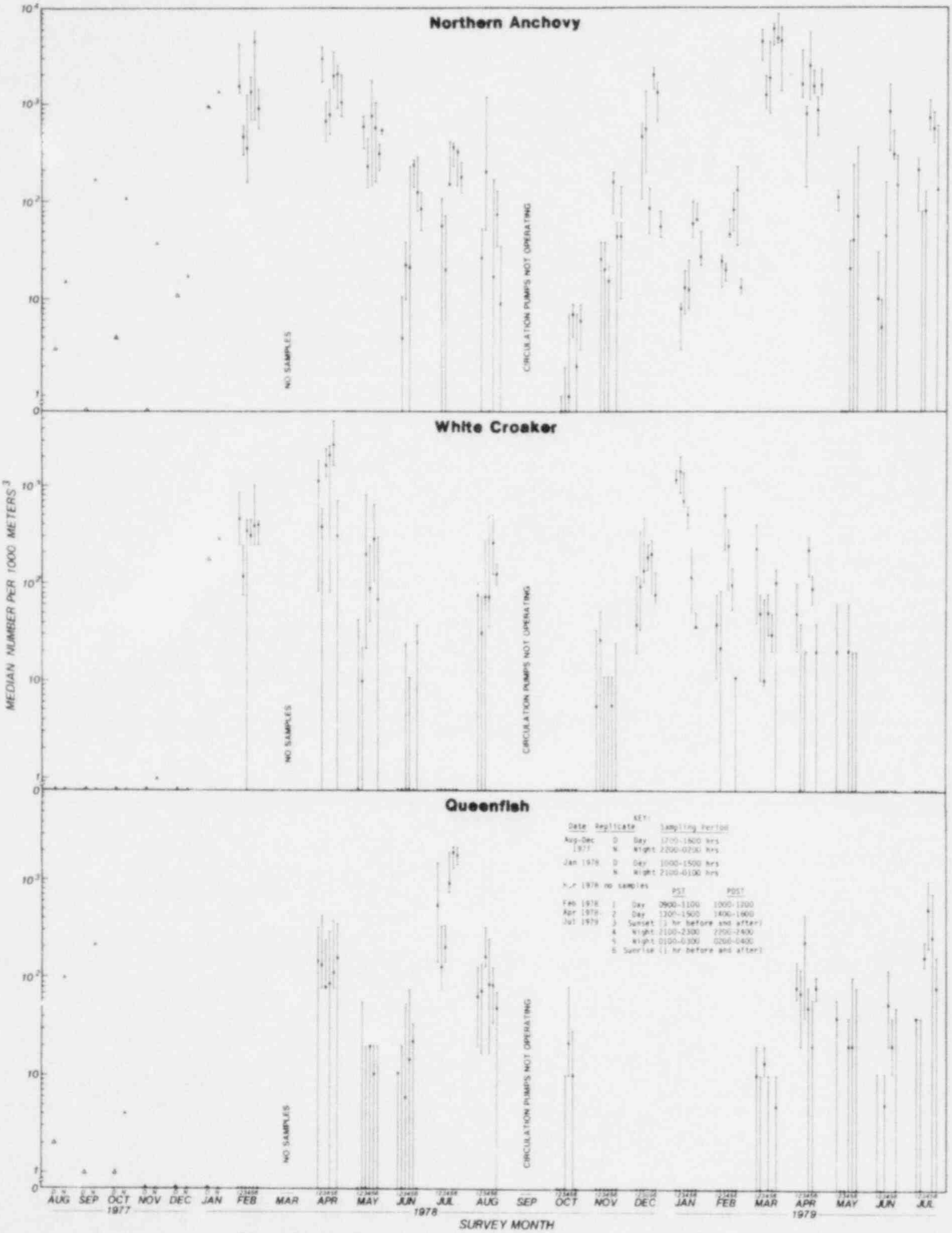

Figure 6A-11. Target species concentrations at the Unit 1 intake.

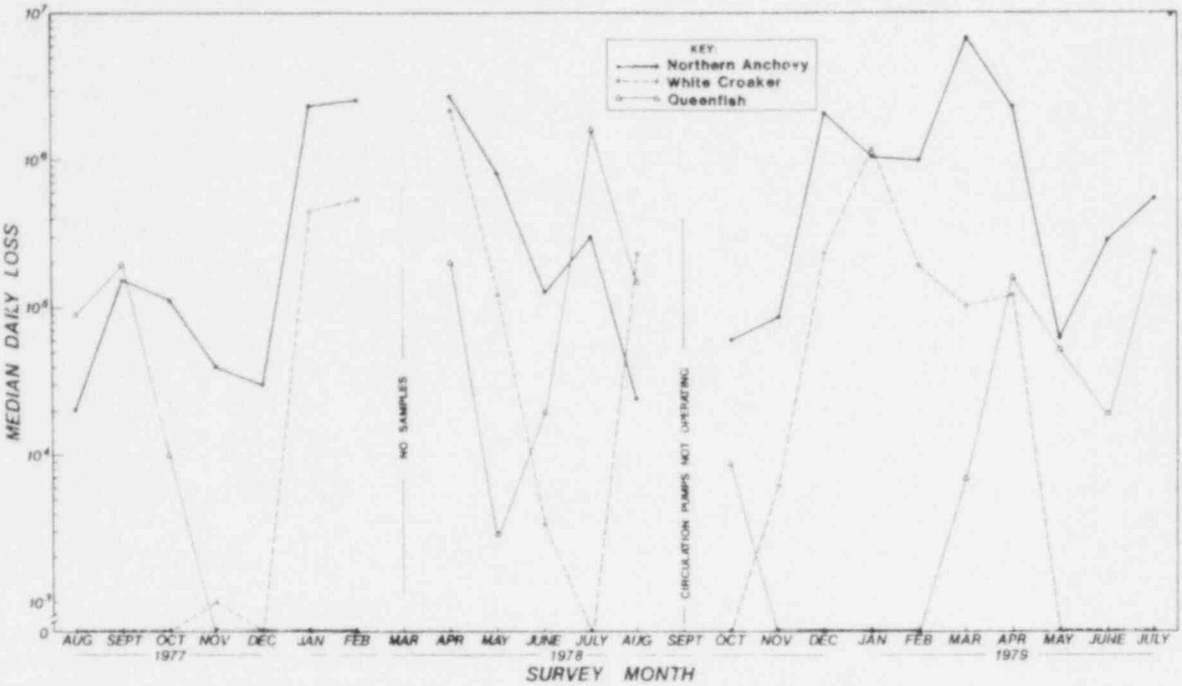

Figure 6A-12. Median daily loss of target species at the Unit 1 intake.

The annual estimate of loss at the Unit 1 intake was based on the assumption of continuous circulating pump operation. However, the pumps were not operational from late September through October 1978. In addition, there were other periods of the year when the pumps operated at only 50% capacity. Again, our estimate of intake loss was highly conservative. The time of year and duration of decreased circulation will influence the estimate of intake larval loss.

The effects of immigration and emmigration, whether passive in the ichthyoplankton or active in schools of spawning adults, will influence the estimate of larval entrainment loss. The pattern of entrainment was regulated by the current regime and other physical processes which continuously move a nearshore larval resource past the intakes. For our purpose the number of entrained larvae was assumed to reflect historical spawning patterns and the result of egg and larval transport.

San Onofre intakes mimic natural predation and other sources of larval mortality, e.g. limits in food availability. Cushing (1974) developed models of density dependent relations between spawning stock and recruitment of young-of-the-year with a mechanism of density dependent mortality during larval drift. Under such circumstances, increased mortality may actually increase subsequent survivorship for remaining members of a population. Conversely, MacCalls' (1979) analyses of historic Pacific sardine data indicate that density independent relationships between spawning stock and recruitment may occur in other marine species. For larvae, the mechanism determining this independence may be that oceanographic factors, which are patchy in time and space, control survival. This is apparently the case for northern anchovy larvae (Smith and Lasker 1978). MacCalls' model recreated annual population age compositions based on spawning and natural mortality rates as they historically varied from year to year. The result was that the population will recruit successfully under different fishing pressures, as long as a certain minimal spawning biomass is maintained. Thus, for this type of population, control of recruitment is not strongly dependent on egg or larval numbers above a minimal threshold. Further, increases in mortality, within limits, will have little adverse influence on recruitment. Considering that larval entrainment losses would translate to relatively minor adult losses by comparison with fishing pressure, it is unlikely that these losses will adversely influence the maintenance of entrained species.

RELATIONSHIP OF INTAKE AND NEARSHORE ICHTHYOPLANKTON

It may be demonstrated that differential size-selective entrainment of ichthyoplankton occurs at the Unit 1 intake. That is, the intake may selectively entrain specific size classes of target species which may be associated with specific levels of the water column.

It was previously demonstrated that the sampling position within the Unit 1 intake (standpipe) was biologically representative of ichthyoplankton collected from a known point (IUD) of completely mixed intake water (Schlotterbeck et al. 1979a). Non-parametric tests of data from ten size classes of four larval species indicated that the standpipe was equal to or a more effective sampler than the IUD. If the standpipe is collecting a representative sample of ichthyoplankton entering the intake, then the relationships of intake and nearshore samples may provide evidence of size selective entrainment which will influence the loss of potential adult biomass.

Size-selective entrainment was established for northern anchovy (Figure 6A-13a). Entrainment concentrations ranged from 40 to 80% of concentrations collected at Station T1 (adjacent to Unit 1 intake) for size classes up to 12 mm. However, intake concentrations of northern anchovy larvae larger than 12 mm were substantially greater than average Station T1 concentrations, which were integrated over the water column. Intake concentrations were 8.5 and 7.1 times greater than Station T1 concentrations for the 21 to 24 and 24 to 27 mm size classes, respectively (Figure 6A-13a). The source of this difference may be associated with net avoidance of larger northern anchovy in the nearshore collections, and/or the entrainment of a substantial volume from a vertical stratum of water containing larger and older larvae.

A plot of the concentrations of northern anchovy by size class for the neuston, midwater, and epibenthos (Figure 6A-13a) shows that larvae less than 6 mm dominate the neuston and midwater, while larvae from 6 to 15 mm generally occur in the midwater and epibenthos. Northern anchovy larvae from 15 to 27 mm are strongly epibenthic. At 27 to 30 mm, northern anchovy become polarized to the neustonic and epibenthic layers. Intake entrainment is influenced by all three vertical water column strata. The intake appears a highly biased entrainer of northern anchovy in the 18 to 27 mm size classes. The indication of greater concentrations of 18 to 27 mm northern anchovy larvae in intake samples than in either neustonic, midwater or epibenthic samples demonstrates that the distributions of larvae within these three vertical strata of the water column are not homogeneous, nor are substrata of each of the three levels equally entrained. It is hypothesized that the concentration of 18 to 27 mm northern anchovy larvae is greater within a substratum of the midwater. This substratum is subject to greater probability of entrainment than the average probability of entrainment for the midwater as a whole.

The plot of a comparative index, $\log_{10}$ [Intake night/T-1 net] (Figure 6A-13b) demonstrates a strong association of intake collections with a combination of midwater and epibenthic strata for larvae less than 6 mm. The apparent similarity of neustonic concentrations with the intake for the 0-6 mm size classes is considered a relic of the interaction of high midwater concentrations and low epibenthic concentrations. An increasing intake-epibenthic affinity is demonstrated for northern anchovy larvae larger than 6 mm. The apparent increasing neustonic-intake similarity for 21-30 mm larvae is due to increasing

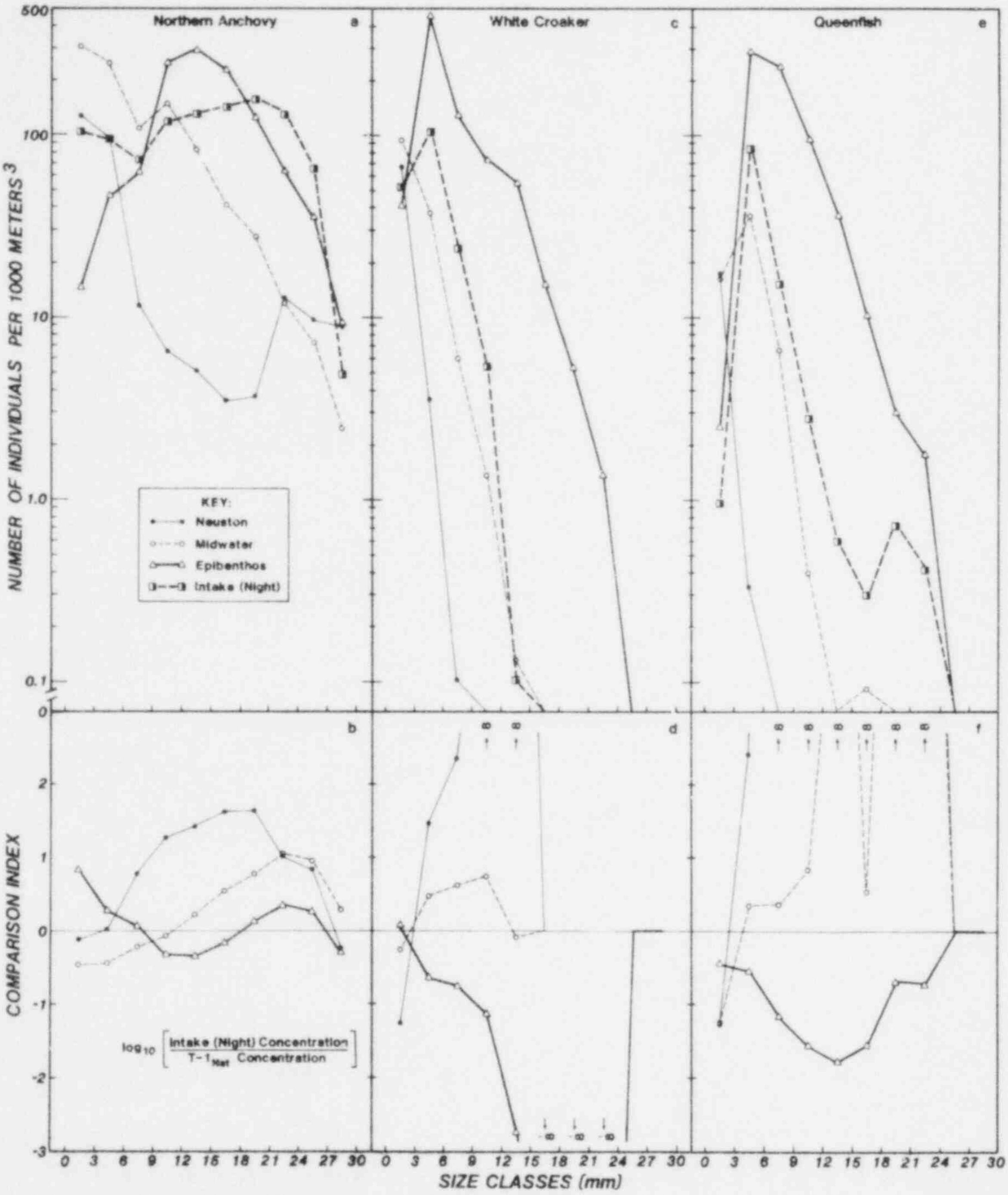

Figure 6A-13. Mean intake and Station T1 concentration and $\log_{10}$ [$Intake_{night}$/T-1] plots for northern anchovy (a and b), white croaker (c and d), and queenfish (e and f).

concentrations of larger northern anchovy larvae in the neuston becoming equal to and then exceeding the concentrations in the strata of entrained water, and not likely due to significant entrainment of neustonic water.

If the intake is considered as a sampling gear, with an effective mouth opening that entrains a subset of midwater and epibenthic strata, then one may use the increased sampling effor. of the intake to further elucidate vertical

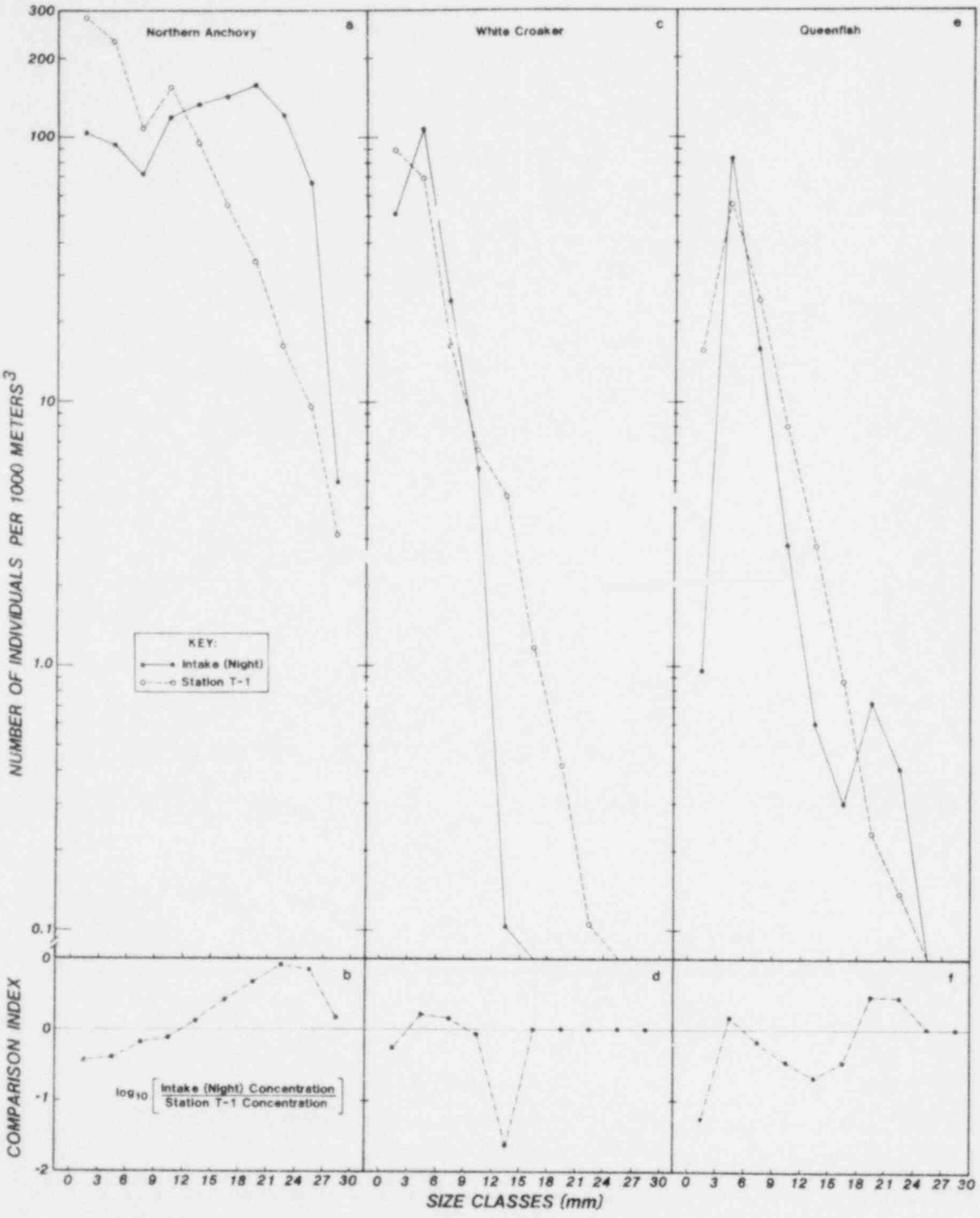

Figure 6A-14. Mean intake and Station T1 neuston, midwater, and epibenthos concentrations and $\log_{10}$ [$\text{Intake}_{night}/\text{T-1}_{net}$] plots for northern anchovy (a and b), white croaker (c and d), and queenfish (e and f).

distribution trends during larval development. A comparison of the patterns of neuston, midwater, epibenthic and intake concentrations (Figure 6A-13a) demonstrates an initial epibenthic migration of newly hatched northern anchovy larvae, followed by a subsequent return of many 21 to 30 mm larvae to the neuston. If one assumes equilibrium conditions, the approximately exponential decrease of the midwater concentrations of 9 to 27 mm northern anchovy larvae and 15 to 27 mm epibenthic larvae may be considered as an approximate natural mortality rate for these stages. Downward deviations from these natural mortality slopes then represent emmigration from a vertical stratum and upward deviations represent immigration to a stratum, and the relative magnitudes of the deviations should reflect the relative magnitudes of the vertical migrations. Data for the 0 to 3 mm size class is expected to represent an underestimate of the smaller larvae compared to estimates for larger larvae. Because northern anchovy larvae hatch at approximately 2.7 mm, their residence time in this size class is significantly less than for other classes, resulting in a lower probability of collection within the 0 to 3 mm size class. Figure 6A-13a presents a scenario of northern anchovies hatching at elevated concentrations in the neuston and upper midwater strata. These larvae migrate downward from the neuston into the midwater and older larvae move toward the epibenthic layer. For 9 to 27 mm size classes, the midwater, as a whole, reaches an approximate equilibrium; however, the continued downward migration of larvae is evident by the increasing concentrations of larger larvae in intake samples. By 15 to 18 mm, northern anchovy concentrations in the epibenthos reach an approximate equilibrium; but increasing concentrations in intake samples represent even greater abundances of the 18 to 24 mm larvae above the epibenthos in the lower midwater depths. Increasing concentrations of 18 to 24 mm larvae in the neuston represent an upward vertical migration for northern anchovy larvae, providing a polarization of larval concentrations at both the lower midwater and neuston. Finally, decreased larval concentrations in the midwater and epibenthos and a decrease in apparent mortality of neustonic larvae for the 27 to 30 mm size class provide evidence of the continued upward migration of northern anchovy larvae as they approach the juvenile stage.

Entrainment of white croaker larvae were more representative of nearshore collections than were northern anchovy (Figure 6A-14c). Intake concentrations were greater than nearshore concentrations only in the 3 to 9 mm size classes. The difference was 1.6 and 1.5 times the nearshore concentration for the 3 to 6 and 6 to 9 mm size classes, respectively (Figure 6A-14c). A log plot of the comparative index for the intake and nearshore concentrations by net type (Figure 6A-13d) indicates that midwater samples were generally most representative of intake collections, although the trend of intake collections is strongly influenced by epibenthic concentrations. White croaker are strongly associated with the epibenthos after 3 mm (yolk sac larvae are common in the neuston and midwater), and are almost entirely epibenthic after 6 mm (Figure 6A-13c). The plot of $\log_{10}$ [$Intake_{night}/T\text{-}1_{net}$] (Figure 6A-13d) clearly indicates that intake samples are closely associated with midwater concentrations. Because older white croaker larvae were not entrained by the Unit 1 intake the effect in loss of potential adult biomass is small.

Again, Figure 6A-13c may be considered to represent four sampling devices for the purpose of elucidating trends of vertical larval distribution. The relative straightness of most of the lines may be considered to represent an approximate linear trend of vertical migration during the larval development of white croaker. Highest concentrations of white croaker hatch in the upper midwater and neuston and immediately begin an epibenthic migration. The larvae dominantly occur in the lower midwater and epibenthos by 3 to 6 mm. The decreasing slopes of the midwater, intake, and epibenthic concentrations, respectively, for the larger larvae represent a continued, almost constant downward migration of white croaker larvae with time. The natural mortality rate would be represented by a slope intermediate to the slopes for the various water column strata.

Queenfish entrainment was generally representative of nearshore concentrations (Figure 6A-13e). Intake concentrations were greater than nearshore concentrations in the 3 to 6, 18 to 21, and 21 to 24 mm size classes. Although the difference was less than one individual 1000 m^{-3} for the latter two size classes intake concentrations were 3.1 and 2.7 times greater than nearshore concentrations, respectively (Figure 6A-14e). The log plot of intake and nearshore concentrations (Figure 6A-13e) indicates that intake samples are strongly influenced by the midwater and epibenthos. No larvae greater than 9 mm and 18 mm were collected in the neuston and midwater, respectively. The plot, $\log_{10}$ [$Intake_{night}/T\text{-}1_{net}$] (Figure 6A-13f) indicates that intake concentrations are most similar to midwater concentrations from 3 to 12 and 15 to 18 mm size classes and most similar to the epibenthos in the 0 to 3, 12 to 15, and 18 to 24 mm size classes. Substantially more older queenfish larvae were entrained than white croaker, and this effect was especially noticeable from 6 to 12 mm. Generally, the smaller size classes of both croakers were entrained and this results in less potential impact to the adult population.

Queenfish appear to have a similar vertical migration pattern as white croaker (Figure 6A-13e). The greatest concentration of queenfish larvae hatch in the neustonic and upper midwater. A relatively constant epibenthic migration of queenfish larvae, similar to that of white croaker, immediately follows hatching. At 15 to 24 mm, it appears that queenfish larvae become more strongly epibenthic. Increasing concentration of 12 to 24 mm queenfish larvae in the lower midwater and epibenthic region results in greater entrainment of these size classes. The absence of queenfish larvae larger than 24 mm is likely a result of net avoidance and/or chance, due to the extremely low concentration of preceeding size classes and the resultant low probability of capture based on sampled volumes.

SUMMARY

1. An ichthyoplankton investigation was conducted near the San Onofre Nuclear Generating Station from August 1977 through July 1979 as a special activity of the preoperational monitoring program for Units 2 and 3.

2. Samples of entrained ichthyoplankton were pumped from the Unit 1 intake riser via a 3 m standpipe. Intake samples were collected once each month during a 24 hr period.

3. Concurrent nearshore ichthyoplankton samples were collected from the neuston by Manta net, the midwater by Bongo net, and the epibenthos by Auriga net.

4. Twenty-five taxa comprised 99.9% of the intake collections. The dominant species were Engraulis mordax, northern anchovy (52.9%), Genyonemus lineatus, white croaker (14.1%), and Seriphus politus, queenfish (5.8%).

5. Estimates indicated that Unit 1 annually entrained about 900 million larvae.

6. Size selective entrainment was established for each target species. Maximum entrainment was from 9 to 21 mm for northern anchovy, 0 to 9 mm for queenfish and white croaker.

7. A comparison of intake and nearshore ichthyoplankton samples indicated that water entrained by the Unit 1 intake is biologically representative of the midwater, with occasional strong influences from the epibenthos.

8. The annual effect of intake losses on nearshore populations was considered conservative because: 1) the 100% mortality assumption; 2) circulation pumps did not operate continuously; and 3) natural compensatory processes.

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CHAPTER 6B

ADULT FISH FIELD STUDY

INTRODUCTION

The marine monitoring studies reported in this chapter are being conducted to meet objectives approved by the Nuclear Regulatory Commission (NRC) as specified in the Environmental Technical Specifications (ETS), Docket No. 50-206, Sections 3.12a (1) General Ecological Survey 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 objective of the PMP is 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 Pollutant 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.

All 1979 biological data analyzed in this report are presented in Volume IV of the Annual Operating Report, San Onofre Nuclear Generating Station-Biological Data 1979 (SCE 1980d). Physical data analyzed in this report are contained in Volume I of the 1979 Annual Operating Report (SCE 1980a).

APPROACH

The analysis of fish data treats seasonal variability of the fish community offshore of SONGS so as to develop a qualitative model of the system of fish and their environment. This model relates to the fish community and to populations of select fish species. Elements of the fish community include variation in species composition, abundance, and fish feeding guilds; elements of fish species populations include variation of numerical abundance, size (age) structure, sex composition, and ovarian development. Variation in these elements at the community and population levels is examined temporally and spatially within the potential area of influence and reference areas. The possible relationship between variation in biological factors and variation in hydrographic and climatic factors is also examined.

BACKGROUND

Fish sampling offshore SONGS has evolved from early semi-quantitative visual observations by divers to quantitative multi-gear sampling techniques. Quantitative data on fish populations prior to SONGS Unit 1 operation is limited. Visual observations by divers from 1963 to 1968 produced a species list consisting of demersal species (Hickman 1973). Similar observations were made during the initial operation of Unit 1, although they were often limited due to 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 assessment of SONGS fish populations. The gill nets set near SONGS produced minimal information due to the short fishing period (1 h). Randomly placed 10 min otter trawls 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 panels of various mesh sizes, and replicate sampling. Study sites included stations within the potential area of influence of SONGS, (Zone 0A) and a reference area near Don Light, approximately 7 km downcoast of SONGS (Zone 6; Figure 6B-1).

Preliminary surveys conducted in March 1978 evaluated the use of otter trawls off San Onofre, determined the number of replicate otter trawl and gill net samples needed for a given level of sampling precision, and established an upcoast reference area. These findings were subsequently incorporated into the PMP beginning April 1978.

METHODS

A detailed description of station locations and field methodology is given in ETS Fish Survey Procedures (SDE 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.

FIELD

The field sampling strategy is a "restricted systematic design". In this design 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 total of 14 gill net stations were established at three sites: 1) in an upcoast (San Mateo Point - Zones 3A, 3B) reference area; 2) an area directly offshore of SONGS Units 1, 2, and 3 (SONGS - Zones 0A, 0B); and 3) a downcoast (Don Light - Zone 6) reference area (Figure 6B-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 with the following sizes of bar mesh: 22, 25, 38, 46, 53, and 76 mm. All nets are set perpendicular to the shoreline over mostly cobble substrata and are retrieved after 24 h. The fishing period encompasses both dusk and dawn, the periods of greatest fish activity. Eight of the 14 stations (Stations 1, 2, 3, 6, 7, 8, 11, and 12) are located on the 9.1-m (30-ft) isobath. The remaining six stations (Stations 4, 5, 9, 10, 13, and 14) are located on the 13.7-m (45-ft) isobath (Figure 6B-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 6B-1).

Otter trawls are used to collect samples over sand substrata at nine stations at depths of 6.1, 12.2, and 18.3 m (20, 40 and 60 ft) in Zones 6, 2A, 0B, 3A, and 5 (Figure 6B-1). A 7.6-m (25-ft) semi-balloon otter trawl is used to make two sequential 5-min trawls per day at each station on two consecutive days during daylight hours (18 trawls/day for a total of 36 trawls/survey). Paired trawls at a station are considered as replicates. Trawl samples are collected during the same period that gill nets are fished. Trawl stations are located at

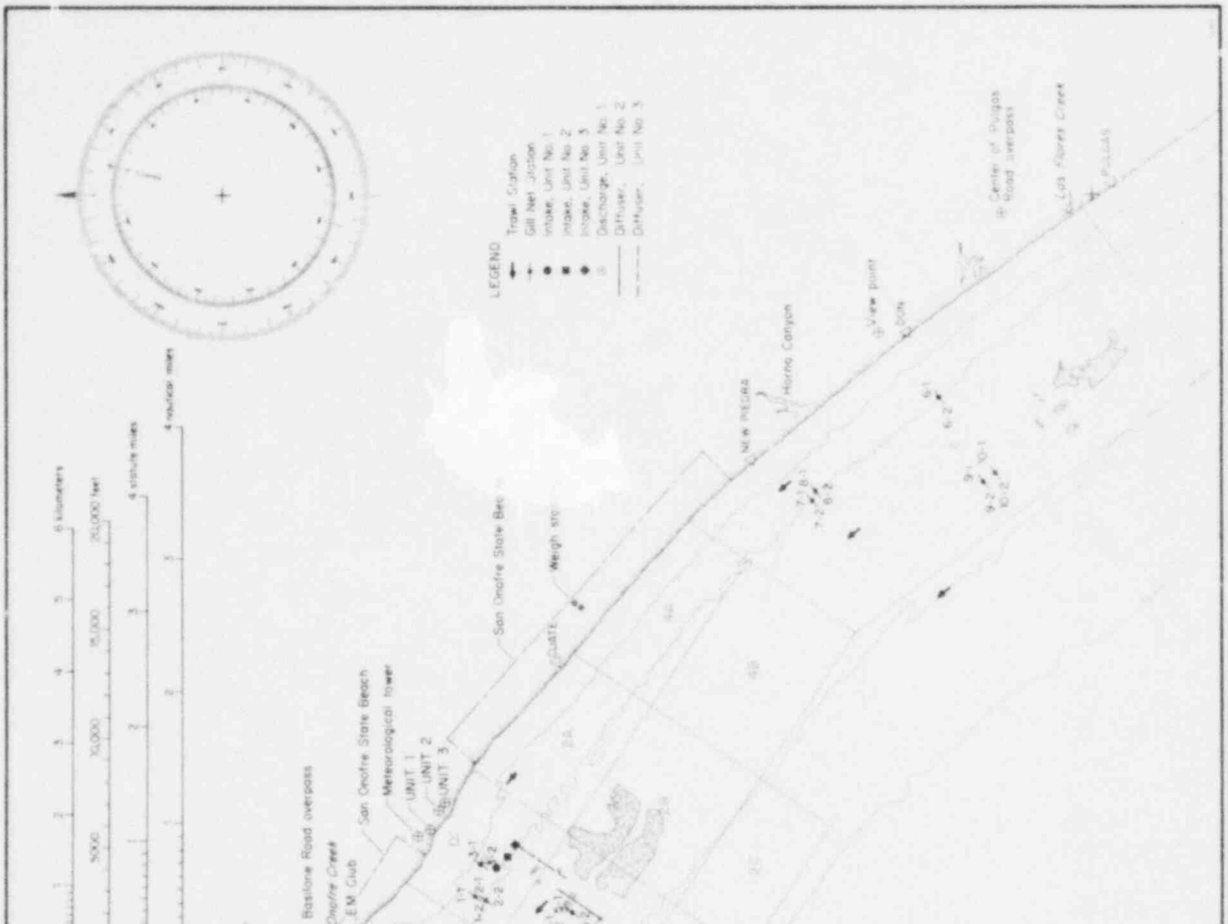


Figure 6B-1. ETS and PMP fish receiving water station locations at San Onofre Nucle-- Generating Station. Shaded areas represent the areal extent of the kelp canopies sampled in December 1979.

sites over sandy bottom in the same general areas as gill nets. Station sites 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 operational effects of Units 2 and 3.

Temperature and light transmissivity are measured daily at 1-m depth intervals from the surface to the bottom for the two days of the survey at each cluster of gill nets set at 9.1-m and 13.7-m.

Sampling with gill nets and otter trawls is conducted bimonthly. In 1979, combined ETS and PMP surveys were conducted on 15-16 February, 17-18 April, 27-28 June, 26-27 August, 16-17 October, and 12-13 December.

Laboratory

All fishes collected in gill net and otter trawl samples are identified, counted, and visually inspected for anomalies, diseases, and parasites. With the onset of the combined program in 1978 (LCMR 1978c), a group of select fish species has been studied more intensively. 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. The following is a list of the species selected.

Cynoscion nobilis	- White seabass
Genyonemus lineatus	- White croaker
Hyperprosopon argenteum	- Walleye surfperch
Paralabrax clathratus	- Kelp bass
Paralabrax maculatofasciatus	- Spotted sand bass
Paralabrax nebulifer	- Barred sand bass
Paralichthys californicus	- California halibut
Roncador stearnsii	- Spotfin croaker
Seriphus politus	- Queenfish

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 randomly selected individuals per species from each gill net and otter trawl sample are measured. A random subset of no more than 50 individuals per species are sexed (male, female, juvenile, indeterminate) by examining their gonads or by noting obvious secondary sexual characteristics. Indeterminate are defined as fish having recently spawned or are damaged such that sex cannot be determined. A maximum of 10 female Seriphus politus and 10 female Genyonemus lineatus per net are subsampled for gonosomatic index analysis. Gonad and total body wet weights are determined for each subsampled female with gonad weight divided by total body weight to calculate the index on a survey, area, depth, and gear basis.

DATA ANALYSIS

Gill net and otter trawl samples of fish from receiving waters are analyzed at community and population levels. Community level analysis evaluates species composition and relative abundances; population analysis evaluates abundance, size (age) structure, sex composition, and reproductive condition of select species populations.

Community level analysis utilizes species composition and relative abundance data to define the areas in which fish species live based upon their presence and abundance (classification of the fish community; Clifford and Stephenson 1975) and to construct feeding guilds (Allen 1974).

Analyses of offshore samples of selected species include abundance, length (age) frequency distributions, sex ratios, and reproductive condition. Abundance data are presented as geometric means + 90% confidence limits for gill net and otter trawl catches. Ori inal values ($\bar{x}$), 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 n longer correlated with means and tend to be homogeneous among samples. Val d 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 select 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 select species.

Sex ratios of select 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 1979.

Reproductive condition of Seriphus politus and Genyonemus lineatus are presented as mean gonosomatic indices (GSI). Mean GSI's are the arithmetic means of individual GSI's. Gonosomatic indices are compared within areas, between depths, through time using analysis of covariance (ANCOVA; Snedecor and Cochran 1967).

Physical ocenographic data consists of continuous measurements of surface and bottom water temperature along the 9.1-m isobath in the SONGS area (BC 1977, 1978; SCE 1979a, 1980a). Climatological data, obtained from the National Climatic Center, Environmental Data Service, consists of daily wind speed, wave height, and barometric pressure measurements from the U.S. Coast Guard station at San Mateo Point taken from 1 January 1975 to 21 November 1979. Rainfall data was obtained from meteorological observations made by the U.S. Coast Guard, Oceanside, California, and the City of Oceanside Fire Department from 1975 to 1978 and at Lindberg Field Airport, San Diego, California for 1979. In order to isolate and identify significant short-term oceanographic and climatic fluctuations (storms, upwelling) from a long time-series (1975 to 1979) climatological data (wind speed, wave height, barometric pressure) are analyzed via six-day moving averages. Total gill net catch and gill net catch of Seriphus politus from 1975 to 1979 are stratified by storm, non-storm, upwelling and non-upwelling periods. Comparisons of total and Seriphus gill net catch among these periods are made using a t-test assuming unequal variances (Walpole and Myers 1972).

RESULTS

POPULATION ANALYSES

Seriphus politus (Queenfish)

Abundance. Geometric mean abundance and 90% confidence limits for queenfish (Seriphus politus) collected in gill nets and otter trawls at San Mateo Point (upcoast control site), San Onofre (SONGS treatment site), and Don Light (downcoast control site) a. ~ presented in Figures 6B-2 through 6B-5.

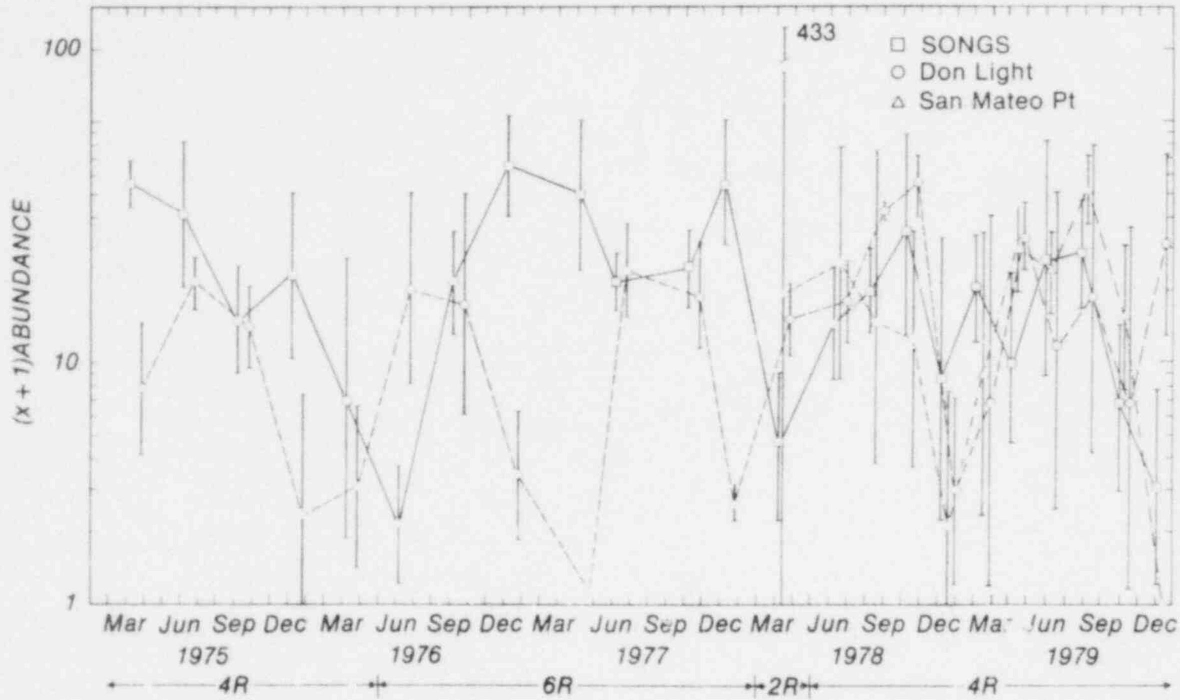


Figure 6B-2. Geometric mean and 90% confidence limits of *Seriphus politus* captured at 9.1 m gill nets set at SONGS and Don Light during the period from 1975 to 1979 and San Mateo Point from 1978 to 1979. The number of replicates (R) for all means are indicated below the abscissa.

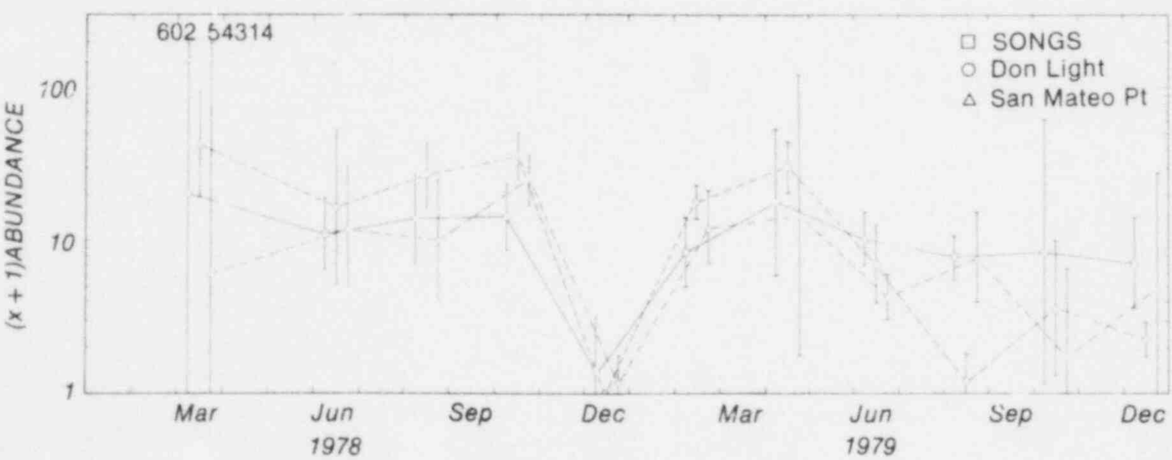


Figure 6B-3. Geometric mean and 90% confidence limits of *Seriphus politus* captured at 13.7 m in four replicate gill nets set at San Mateo Point, SONGS, and Don Light during 1979.

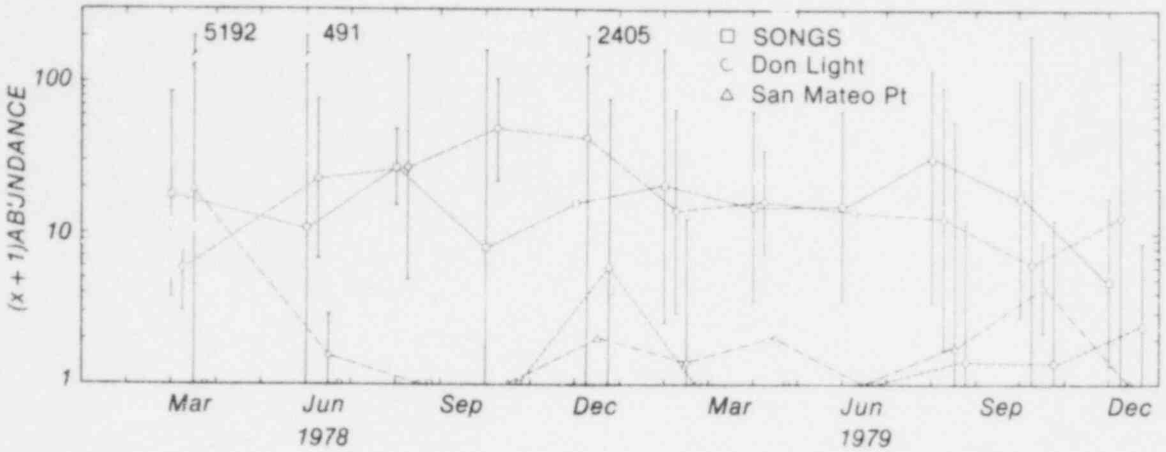


Figure 6B-4. Geometric mean and 90% confidence limits for *Seriphus politus* (◯), *Genyonemus lineatus* (□), *Hyperprosopon argenteum* (△), and *Phanerodon furcatus* (◯) from the two replicate gill nets set adjacent to the SONGS Unit 1 discharge.

Seasonal fluctuations in Seriphus abundance, estimated by gill net catches at 9.1 and 13.7 m, are depicted in Figures 6B-2 and 6B-3. The seasonal abundance patterns of Seriphus caught in gill nets set on the 9.1-m isobath in all areas were similar in 1978 and 1979. Prior to 1978 the catch of queenfish was generally greater in the treatment area compared to the downcoast control site (SCE 1979d). Since March 1978, however, more queenfish have generally been caught in the downcoast control site. The largest catches of queenfish occurred from April through October during both years with peak catches observed in October 1978 and August 1979 (Figures 6B-2 thorugh 6B-4). The seasonal pattern of queenfish catch in gill nets set immediately adjacent to the SONGS Unit 1 discharge station (9.1 m) has not changed appreciably over the past two years, even though decreased catches occurred in all other sampling locations in December of both years (Figure 6B-4).

Gill net catches of Seriphus during 1978 and 1979 at the offshore (13.7-m) isobath followed the post-March 1978 pattern (Figure 6B-3). Offshore catches during 1978 were uniform until December when catches drastically declined. In 1979 peak queenfish catch occurred in April and was variable for the remainder of the year (Figure 6B-3).

Mean catch of Seriphus politus collected by otter trawls over soft bottom substratum during 1978-1979 is depicted in Figure 6B-5. The greatest number of queenfish were caught in trawls fished inshore along the 6.1-m isobath. The seasonal catch pattern, i.e., high catches April through October, decreasing catches October through December at 6.1 m in 1978-1979, was similar to that for inshore gill nets in the treatment and upcoast control areas (Figure 6B-2). This pattern was not evident in the downcoast control area along the 6.1-m isobath.

The number of Seriphus caught in offshore trawls, conducted at the 12.2-m isobath, was generally lower than at the 6.1-m isobath throughout 1978-1979 (Figure 6B-5). Trawls conducted furthest offshore at 18.3 m caught very few queenfish during 1979.

Queenfish showed seasonal movement related to recruitment of young-of-the-year based on otter trawl sampling (Figure 6B-6). In 1978 and 1979 movement into the shallow (6.1 m) depths occurred in June or August. Later in the year,

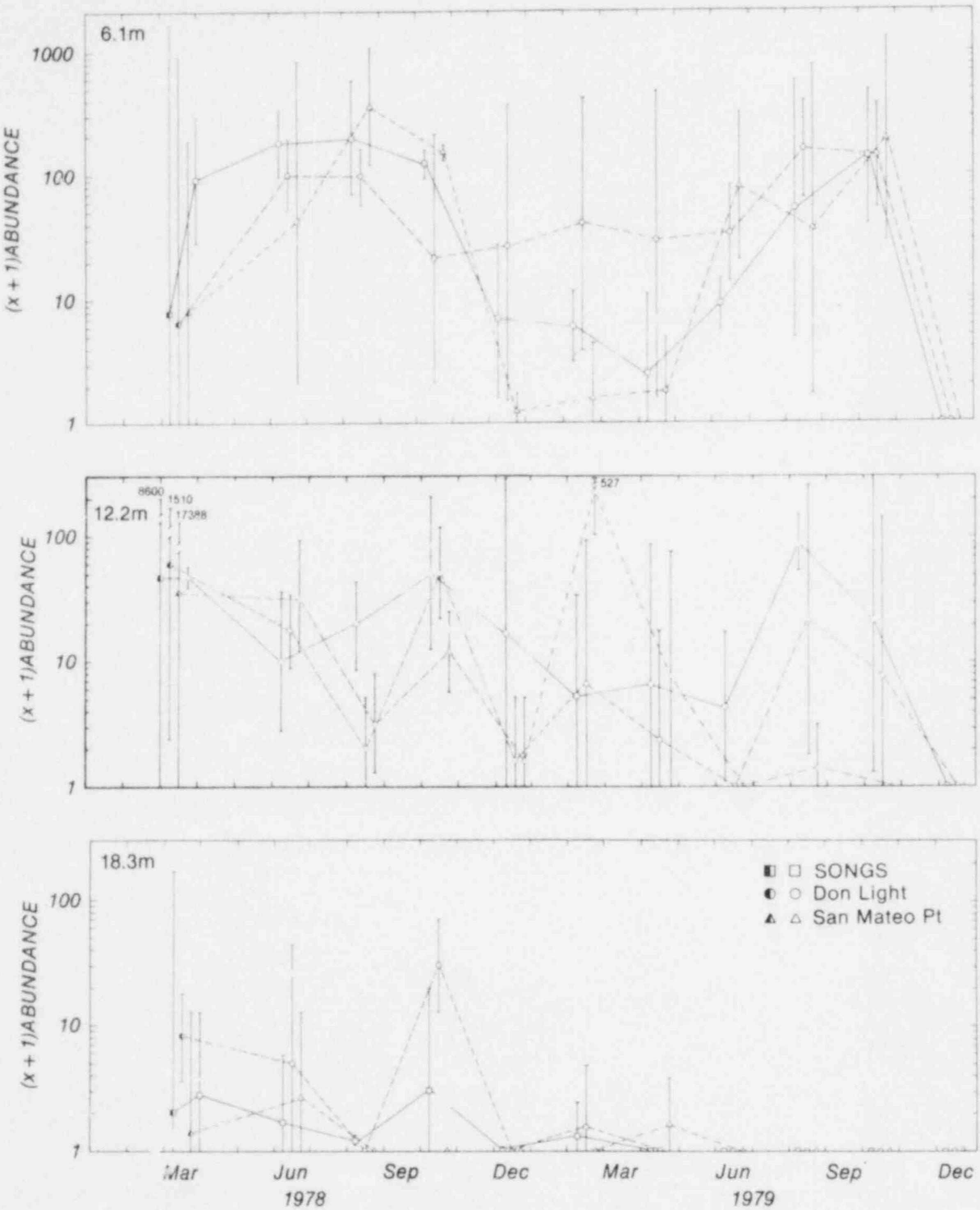


Figure 6B-5. Geometric means and 90% confidence limits of *Seriphus politus* caught at 6.1, 12.2, and 18.3 m in daytime otter trawls conducted at San Mateo Point, SONGS, and Don Light during 1979. Means from March 1978 preliminary trawls (half-shaded) are based on two replicates, all other means are based on four replicates.

offshore movement was evident in October 1978 and August 1979 when large numbers of queenfish (mainly juveniles) were caught at the 12.2-m isobath in the treatment and downcoast control areas. This pattern was not evident at the upcoast control site in either 1978 or 1979.

Length Frequency. Seriphus politus length frequency distributions derived from gill net and otter trawl samples are presented in SCE (1980d, p. II 57-83).

Seriphus collected in gill nets set on the 9.1-m isobath exhibited bimodal length frequency distributions in all areas throughout 1979. The length frequency structure of Seriphus caught in gill nets set at 9.1 m indicated that males comprised a 125-150 mm SL size group while females comprised a 160-195 mm SL size group, in all areas. Generally, the largest fish caught were females.

Gill nets set offshore on the 13.7-m isobath during February and April also caught queenfish with bimodal size distributions in all areas. After April 1979, however, few Seriphus were caught in gill nets set on the 13.7-m isobath.

Queenfish length frequency distributions represented by otter trawl catches consisted largely of juveniles ranging between 15-120 mm SL. Adult male and female Seriphus caught in otter trawls had size ranges similar to those collected by gill nets in all areas. The greatest number of juveniles were caught at the 6.1-m isobath in the treatment and downcoast control sites.

Sex Composition. The sex ratios of Seriphus politus are illustrated in Figure 6B-7 according to area, depth, and sampling gear.

Analysis of sex composition based on the total annual catch of queenfish indicated that significantly ($P \leq 0.05$) more females than males were captured in gill nets set both inshore (9.1 m) and offshore (13.7 m) in all areas (Figure 6B-7). This pattern was evident during all surveys of 1979 at the upcoast control site and in all but the December survey in the treatment area. The downcoast control and SONGS Unit 1 discharge areas displayed this trend only during the early spring through late summer surveys.

The generalized sex composition pattern from annual otter trawl catch data from the 6.1-m isobath was similar to that of inshore (9.1 m) gill net catches (Figure 6B-7). Significantly ($P \leq 0.05$) more females were caught in the fall survey (October) in all areas. Trawls in the control areas also contained significantly more females in the April and August surveys, respectively.

Otter trawl catches from the 12.2-m isobath were dominated by male queenfish during the winter and spring surveys in 1979 ($P \leq 0.05$, Figure 6B-7). Trawls conducted at the treatment area collected significantly ($P \leq 0.05$) more males during the August and October survey periods as well. Few queenfish were caught on the 18.3-m isobath.

Gonosomatic Index. Seriphus politus caught in gill nets set on the 9.1 and 13.7-m isobaths and in otter trawls on the 6.1 and 12.2-m isobaths (Figures 6B-8 and 9) exhibited a distinct seasonal reproductive pattern based on mean gonosomatic index (GSI) values. Otter trawls conducted on the 18.3-m isobath caught insufficient numbers of queenfish for analysis. The seasonal reproductive pattern consisted of an increase in gonad weight relative to total body weight from January to April. By June gonad weight decreased rapidly relative to body weight and continued to decrease through the summer resulting in low GSI values during the fall and winter. The rapidly rising GSI's between February and April suggest that gametogenesis was underway, while rapidly decreasing GSI's from April to August suggest spawning. Increased variability in GSI values during the spring and summer was due to a mixed catch of ripe and spawned queenfish females.

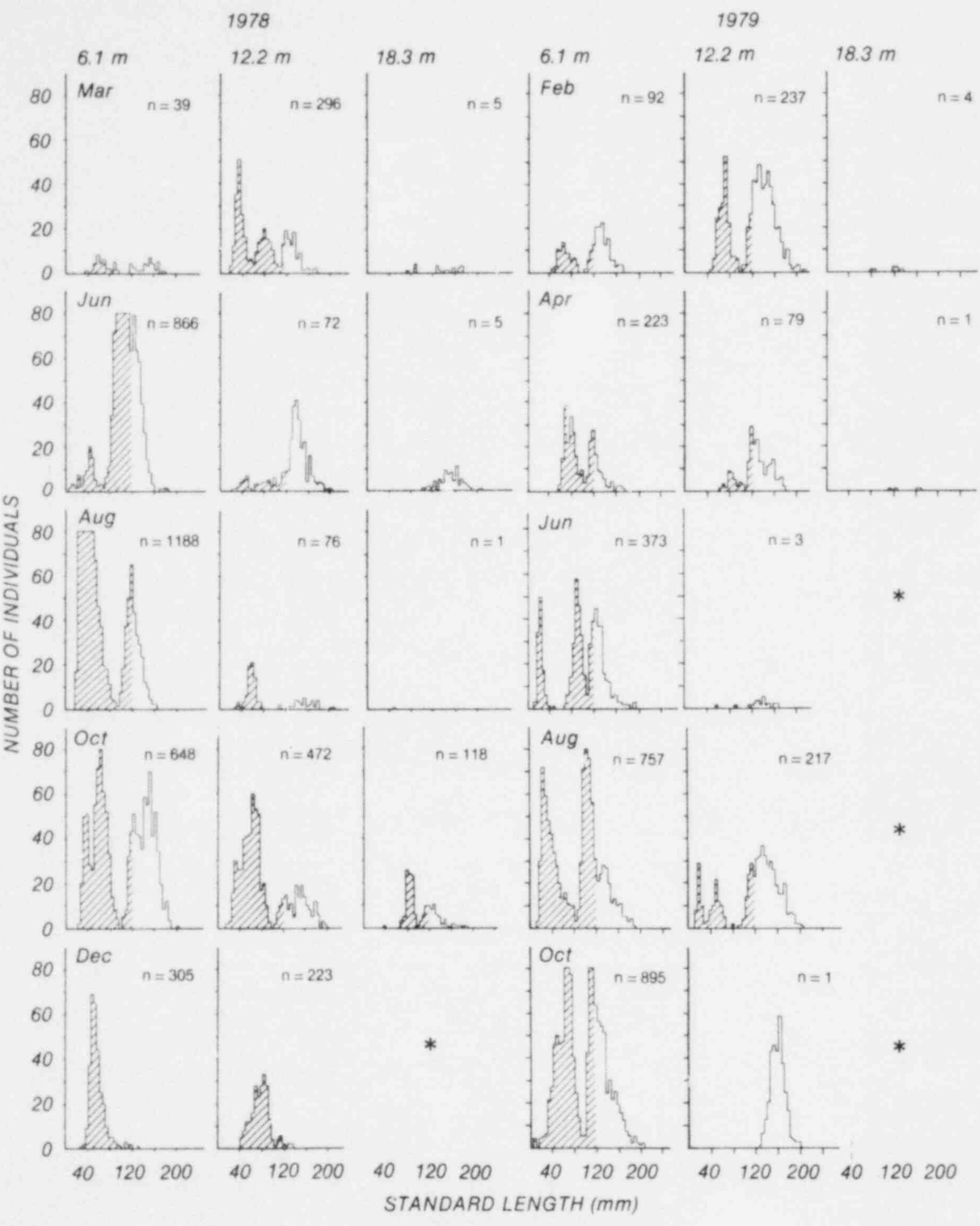


Figure 6B-6. Length frequency histograms of *Seriphus politus* collected at 6.1, 12.2, and 18.3 m in daytime otter trawls conducted at San Mateo Point, SONGS, and Don Light (combined) during 1978-1979. Juveniles (< 120 mm SL) are half-shaded. n = number of juveniles, * = no individuals caught.

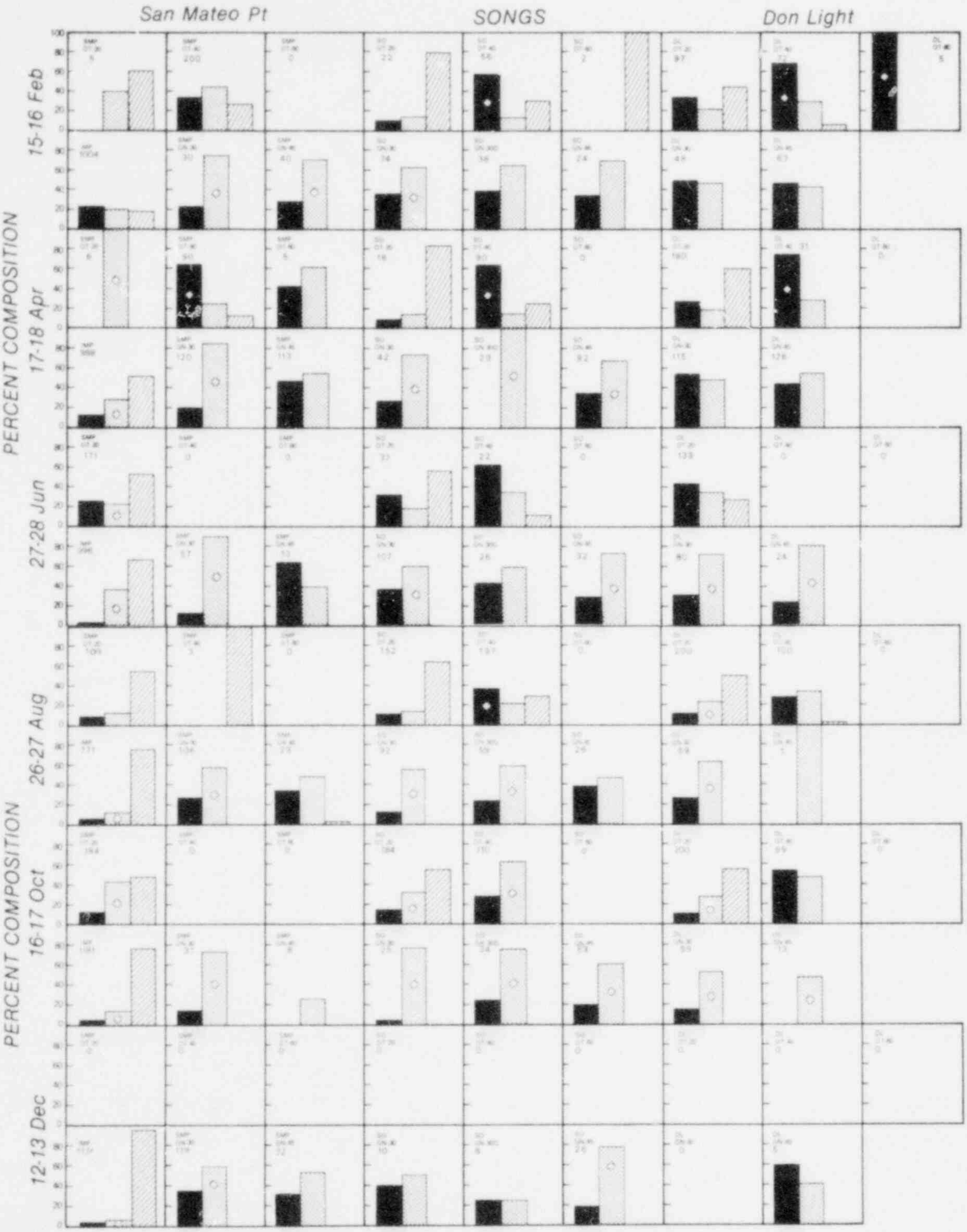


Figure 6B-7. Sex ratio bar graphs of *Seriphus politus* based on otter trawls, gill net, and impingement collections during 1979. Area and depth per sample are indicated in light face type, while bold face type indicates the number of specimens sexed. The balance of collections totalling less than 100% are composed of indeterminant (non-juvenile) fish; blank graphs in which individuals were caught indicate 100% indeterminants. Crosses (✧) indicate a significantly greater number of either males (■) or females (▤) based on chi square goodness of fit statistics ($p < 0.05$); juveniles indicated by (▨).

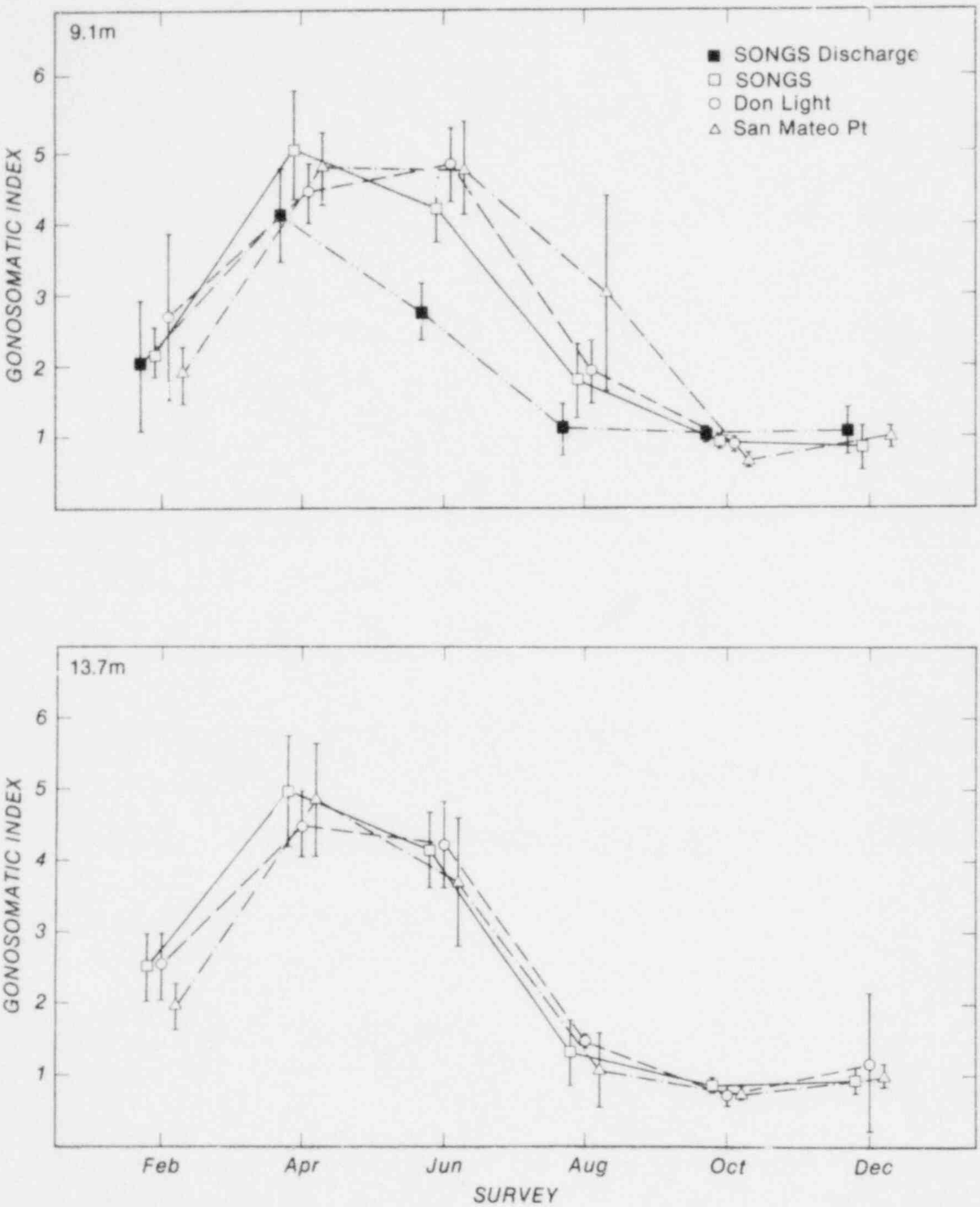


Figure 6B-8. Gonosomatic indices (gonad wet weight/total body wet weight X 100) of female *Seriphus politus* collected by gill net on the 9.1 and 13.7 m isobath at San Mateo Point, SONGS, and Don Light during 1979.

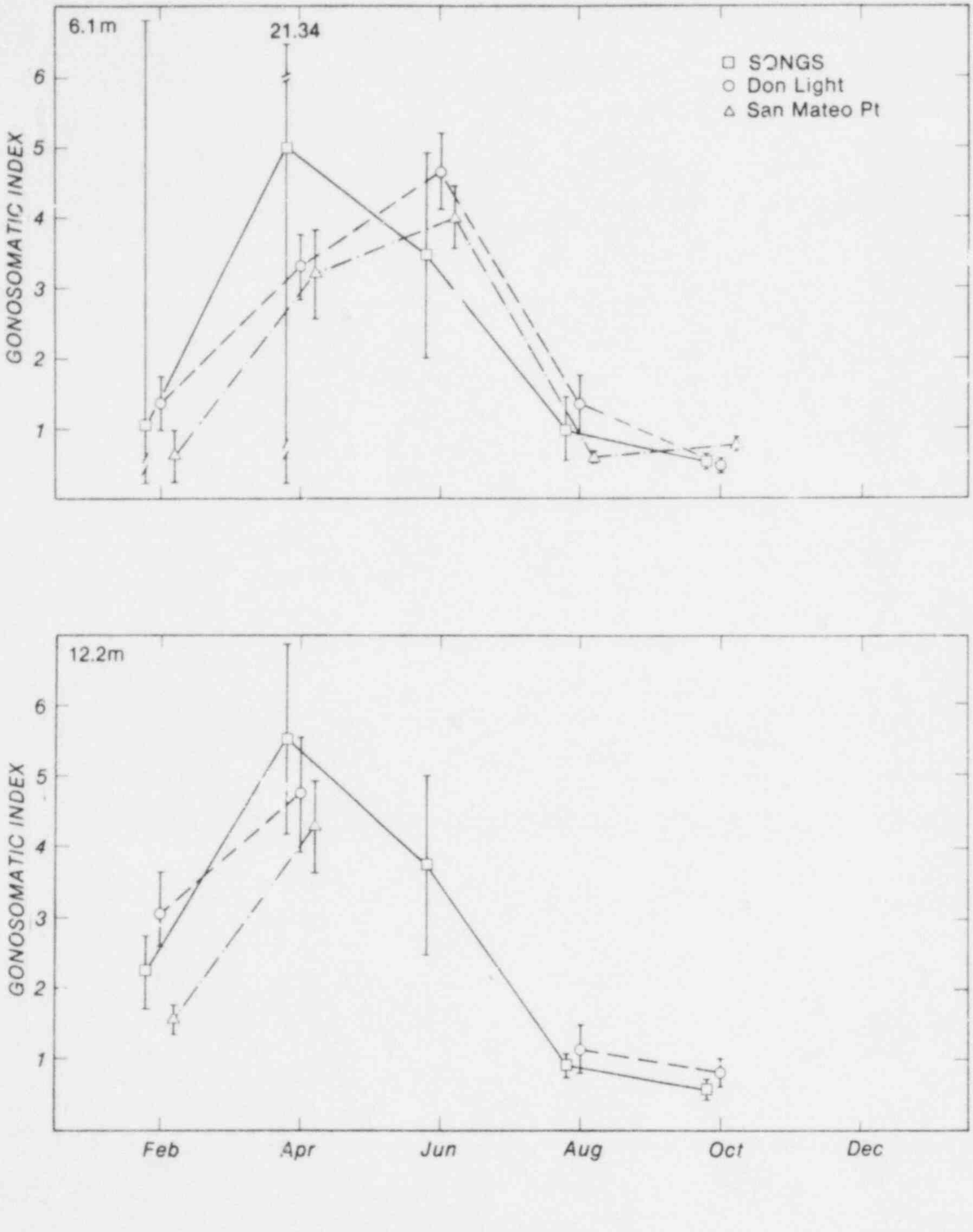


Figure 6B-9. Gonosomatic indices (gonad wet weight/total body wet weight × 100) of female *Seriphus politus* collected by otter trawl on the 6.1 and 12.2 m isobath at San Mateo Point, SONGS, and Don Light during 1979.

No significant temporal shifts in this reproductive pattern were discernible between areas or depths, but differences did occur in the magnitude of the GSI estimates observed. Mean GSI values generated from gill net catches at the SONGS Unit 1 discharge during June and August were significantly ($P \leq 0.05$) lower than other catches from the 9.1-m isobath (Figure 6B-8).

Analysis of covariance and Student-Newman-Keuls multiple range tests (Sokal and Rohlf 1969) were used to test for other significantly different spatial patterns in queenfish gonad weight. Comparisons of gonad weights from gill net samples arranged by depth within each area detected no significant differences between depths, thus allowing them to be combined for further analysis. Gill net catch data with depths combined revealed that mean gonad weights from queenfish collected near the SONGS Unit 1 discharge were significantly ($P \leq 0.05$) lower when compared to all other areas throughout the year. Queenfish gonad weights from otter trawl catches were so variable that each area sampled was significantly ($P < 0.001$) different from any other. Analysis by survey showed that from August to February surveys were similar and significantly ($P \leq 0.05$) lower in mean gonad weight than surveys from April and June. The April and June surveys were significantly ($P < 0.05$) different from each other, with *Seriphus* exhibiting the greatest gonad weights in April.

Genyonemus lineatus (White croaker)

Abundance. Figures 6B-4 and 6B-10 through 6B-12 depict the abundance patterns of *Genyonemus lineatus* collected by gill nets and otter trawls in treatment and control areas.

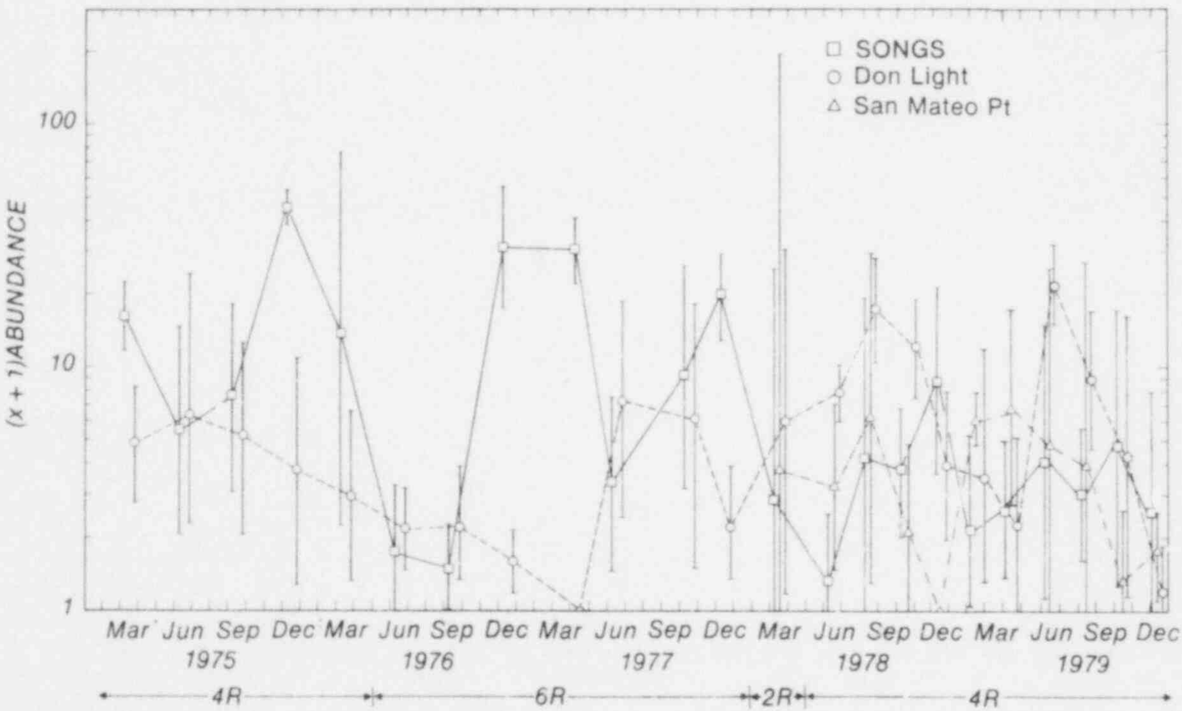
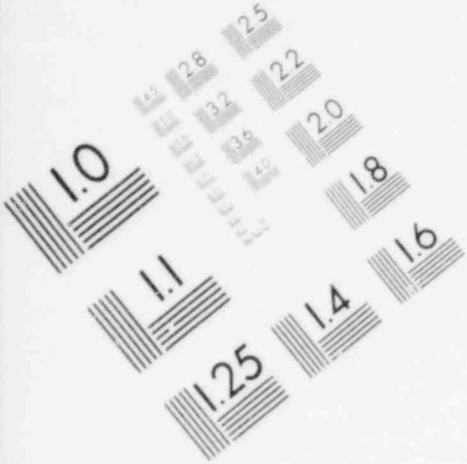


Figure 6B-10. Geometric mean and 90% confidence limits of *Genyonemus lineatus* captured at 9.1 m gill nets set at SONGS and Don Light during the period from 1975 to 1979 and San Mateo Point from 1978 to 1979. The number of replicates (R) for all means are indicated below the abscissa.



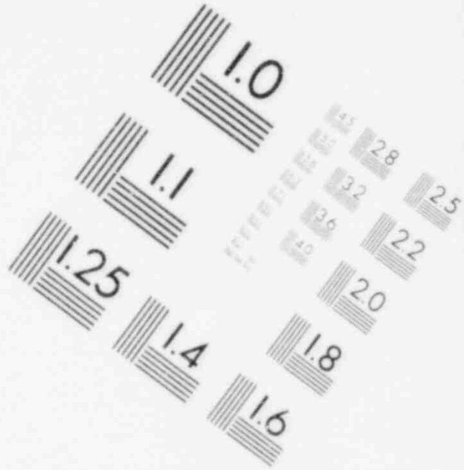
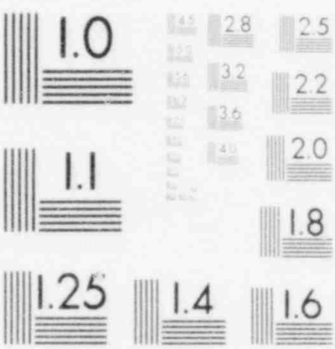


IMAGE EVALUATION
TEST TARGET (MT-3)



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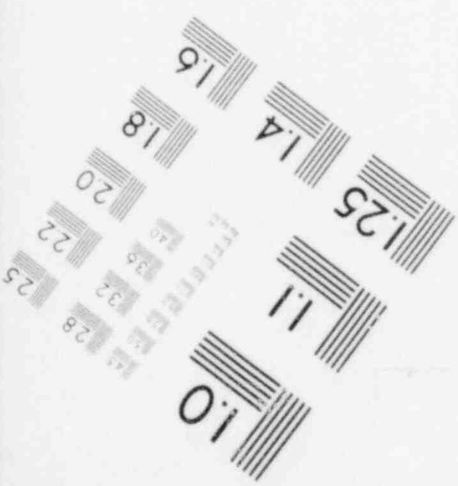
MICROCOPY RESOLUTION TEST CHART



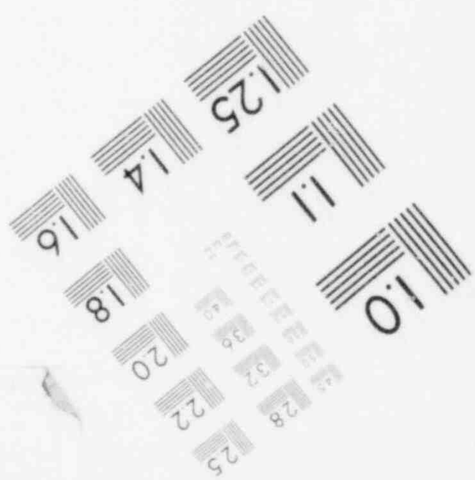
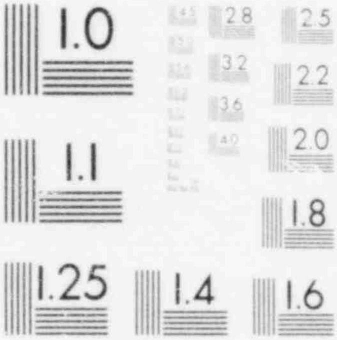


IMAGE EVALUATION TEST TARGET (MT-3)



6″

MICROCOPY RESOLUTION TEST CHART

There were no seasonal cycles of white croaker abundance based upon gill net catches on the 9.1-m isobath in any area in 1979 which is consistent with data collected since 1975 (Figure 6B-10). Seasonality (higher catches in February, March and June generally followed by decreased catches during rest of the year) was observed in catches made at 13.7 m (Figure 6B-11).

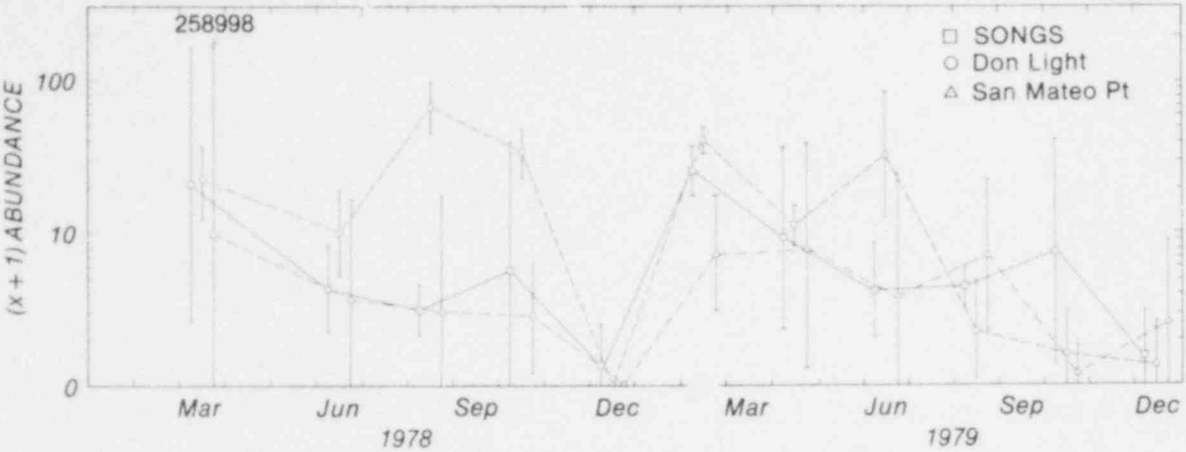


Figure 6B-11. Geometric mean and 90% confidence limits of *Genyonemus lineatus* captured at 13.7 m in four replicate gill nets set at San Mateo Point, SONGS, and Don Light during 1979.

Differences in abundance between treatment and control areas along the 9.1-m isobath have been pronounced over the past five years. Prior to 1978, treatment area gill nets caught the most white croaker (Figure 6B-10); peak mean abundances occurred during December through March 1975, December through April 1976, and December 1977. Since March 1978 the largest catches per net have been made at the downcoast control area.

Offshore gill net samples displayed a more uniform trend in mean white croaker catch (Figure 6B-11). Offshore gill net catches in the downcoast control area displayed the greatest mean abundances throughout 1978 and through June 1979; peak catches usually occurred during June.

Peak periods of mean white croaker abundance as sampled by otter trawls on the 6.1 and 12.2-m isobaths were similar to those described for gill net catches (Figure 6B-12). Like Seriphus, white croaker movements were more obvious from otter trawl catches than from gill nets primarily due to the catch susceptibility of young-of-the-year by otter trawl. Onshore movement from 12.2 to 6.1 m occurred during August 1978 in all areas, while offshore movement from 6.1 to 12.2 m occurred during June 1978 in all areas and during August 1979 in the treatment and upcoast control sites. Mean catches of Genyonemus offshore (18.3 m) were variable in 1978 and 1979.

Length Frequency. White croaker size structure throughout 1979 at all gill net stations was generally bimodal (160-175 and 190-220 mm SL; SCE 1980d, p. II 85-113). Smaller Genyonemus (115-135 mm SL) were first caught during April in offshore gill nets and continued to be caught through December. Smaller individuals were also caught at most inshore (9.1 m) gill net stations from June through October.

In contrast to queenfish, length frequency distributions of white croaker males and females caught in gill nets revealed little sexual dimorphism based upon length at any area or depth (SCE 1980d, p. II 85-113).

Otter trawl catches of Genyonemus were primarily composed of newly recruited juveniles during the April through October surveys. The < 120 mm SL cohort was consistently present throughout the year (Figure 6B-13).

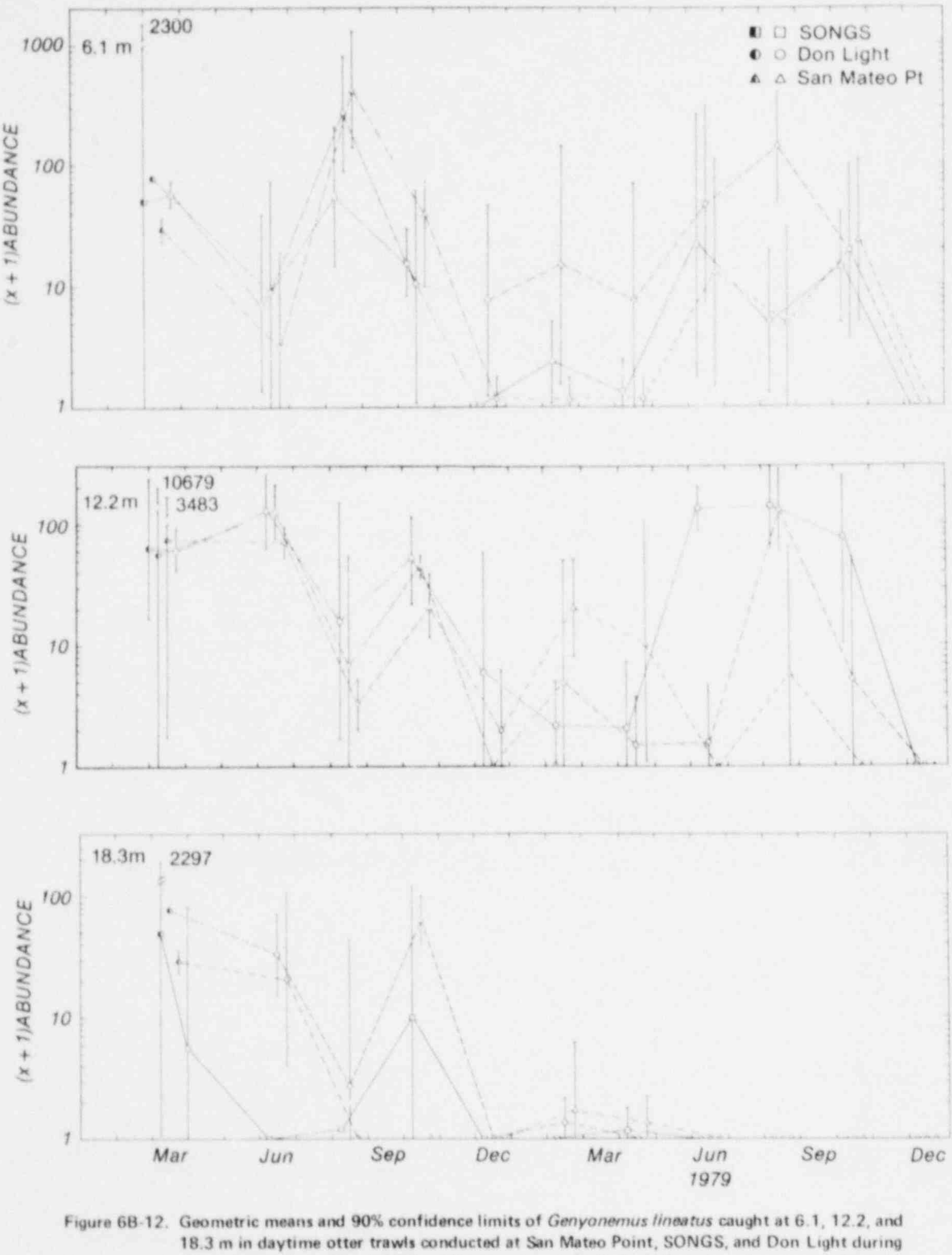


Figure 6B-12. Geometric means and 90% confidence limits of *Genyonemus lineatus* caught at 6.1, 12.2, and 18.3 m in daytime otter trawls conducted at San Mateo Point, SONGS, and Don Light during 1979. Means from March 1978 preliminary trawls (half-shaded) are based on two replicates, all other means are based on four replicates.

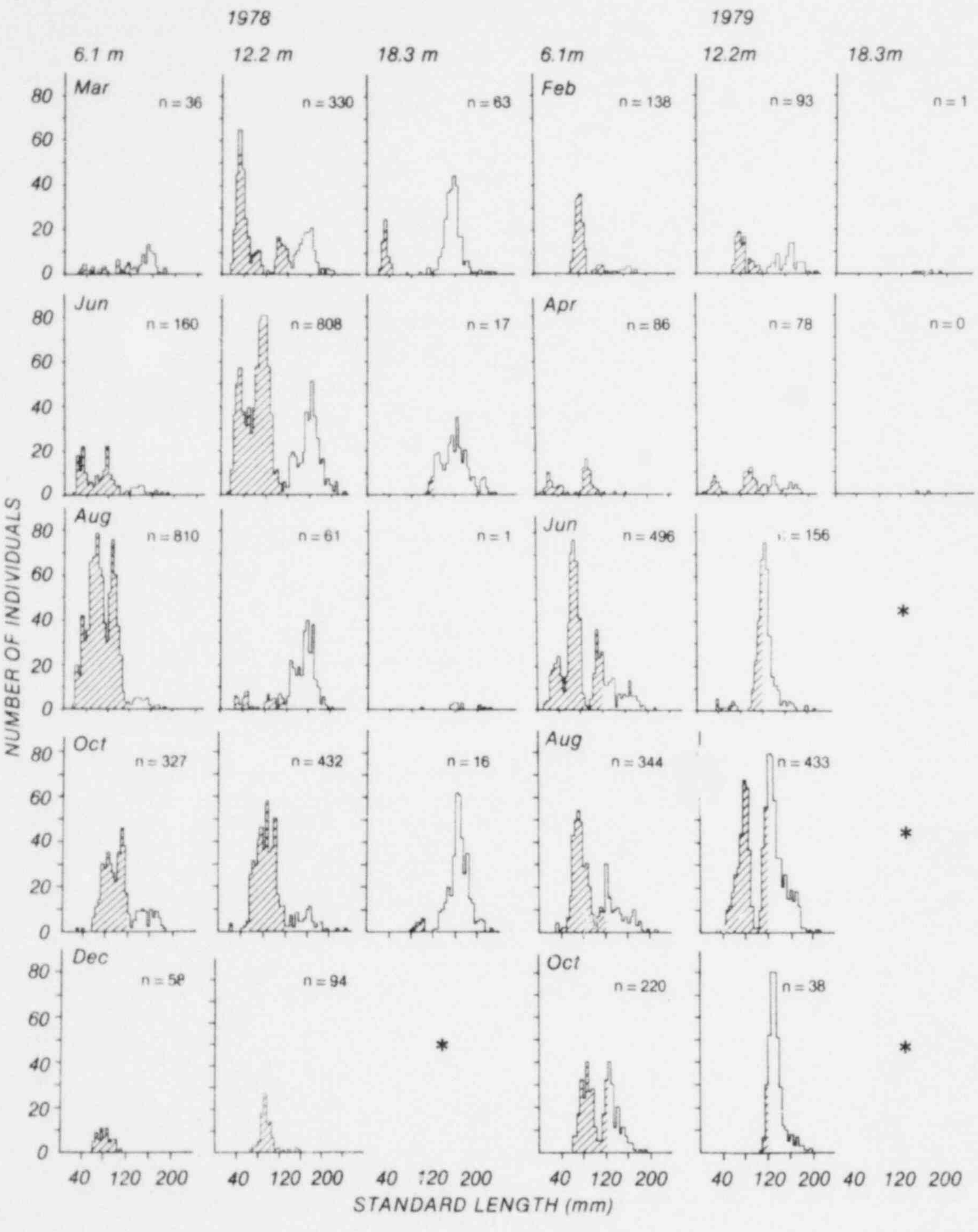


Figure 6B-13. Length frequency histograms of *Genyonemus lineatus* collected at 6.1, 12.2, and 18.3 m in daytime otter trawls conducted at San Mateo Point, SONGS, and Don Light (combined) during 1978-1979. Juveniles (< 120 mm SL) are half-shaded. n = number of juveniles, * = no individuals caught.

Sexual dimorphism based on size was apparent in otter trawl catches of Genyonemus as females (160-190 mm SL) were generally larger than males (120-170 mm SL) during the winter (February) and late spring (June) surveys. Size differences between males and females caught in otter trawls in all areas were not as pronounced during the summer and fall surveys (SCE 1980d, p. II 85-113).

Genyonemus caught in otter trawls demonstrated movements related to recruitment of young-of-the-year in 1978 and 1979 (Figure 6B-13). During February 1979 a remnant of the 1978 juvenile cohort was caught on the 6.1 and 12.2-m isobaths. During April 1979 individuals recruited between October 1978 and March 1979 were caught at both of these depths. By June maximum recruitment to the 6.1-m isobath occurred as evidenced by the presence of large numbers of juveniles (40 and 65 mm SL). In August 60-90 mm SL individuals were caught at the 6.1 and 12.2-m isobaths suggesting that rapid growth had occurred at these depths since June. Growth of young-of-the-year continued through October and by December no juveniles or adults were caught by trawling.

Sex Composition. A cohesive, repeatable pattern in Genyonemus sex composition was not evident from gill net catches (Figure 6B-14). Females significantly outnumbered ($P < 0.05$) males during the winter (February and December) and spring (April) immediately adjacent to the SONGS Unit 1 discharge. Males significantly outnumbered females ($P < 0.05$) during the spring and summer seasons (April, June, and October) on the 13.7-m isobath in the treatment area. Genyonemus were captured infrequently in the remaining sampling areas.

Genyonemus collected in otter trawls taken on the 6.1 and 18.3-m isobaths also lacked a consistent pattern of sexual composition. Males significantly ($P < 0.05$) outnumbered females at the 12.2-m downcoast control area during the spring, summer, and fall surveys of April, August, and October. The treatment area otter trawl catches at 12.2 m were similar to the catches downcoast. No trend was apparent from trawls made in the upcoast control area.

Juvenile white croaker numerically dominated the otter trawl catch at both the 6.1 and 12.2-m isobaths throughout much of 1979. Largest catches of juveniles occurred along the 6.1-m isobath during June, August, and October. The appearance of juveniles during this period corresponds with winter-spring spawning (Goldberg 1976) and subsequent growth to a size subject to capture by otter trawl.

Gonosomatic Index. White croaker exhibited a winter spawning period based on the mean gonosomatic index (GSI) of fish collected by gill nets set on the 9.1 and 13.7-m isobaths (Figure 6B-15). GSI values generated from otter trawl catches conducted on the 6.1 and 12.2-m isobaths showed a similar pattern (Figure 6B-16). Otter trawls conducted on the 18.3-m isobath collected too few white croaker to be analyzed.

The reproductive cycle of white croaker was distinctly different than the cycle described for queenfish in both time of occurrence and duration. A period of increasing mean GSI values from October through February suggested that gametogenesis (oocycte production) occurred during this period. Spawning was first observed in February and continued into June based upon GSI. This period corresponds with the presence of larval white croaker in ichthyoplankton collections (SCE 1980c). A resting period, identified by low mean GSI values and an absence of Genyonemus from ichthyoplankton samples, occurred during the summer period from June to October. Indices calculated from fish captured by gill nets set immediately adjacent to the SONGS Unit 1 discharge were consistently lower during the period of declining indices (February to June) and higher during the period of increasing indices (August to October) compared to other treatment and

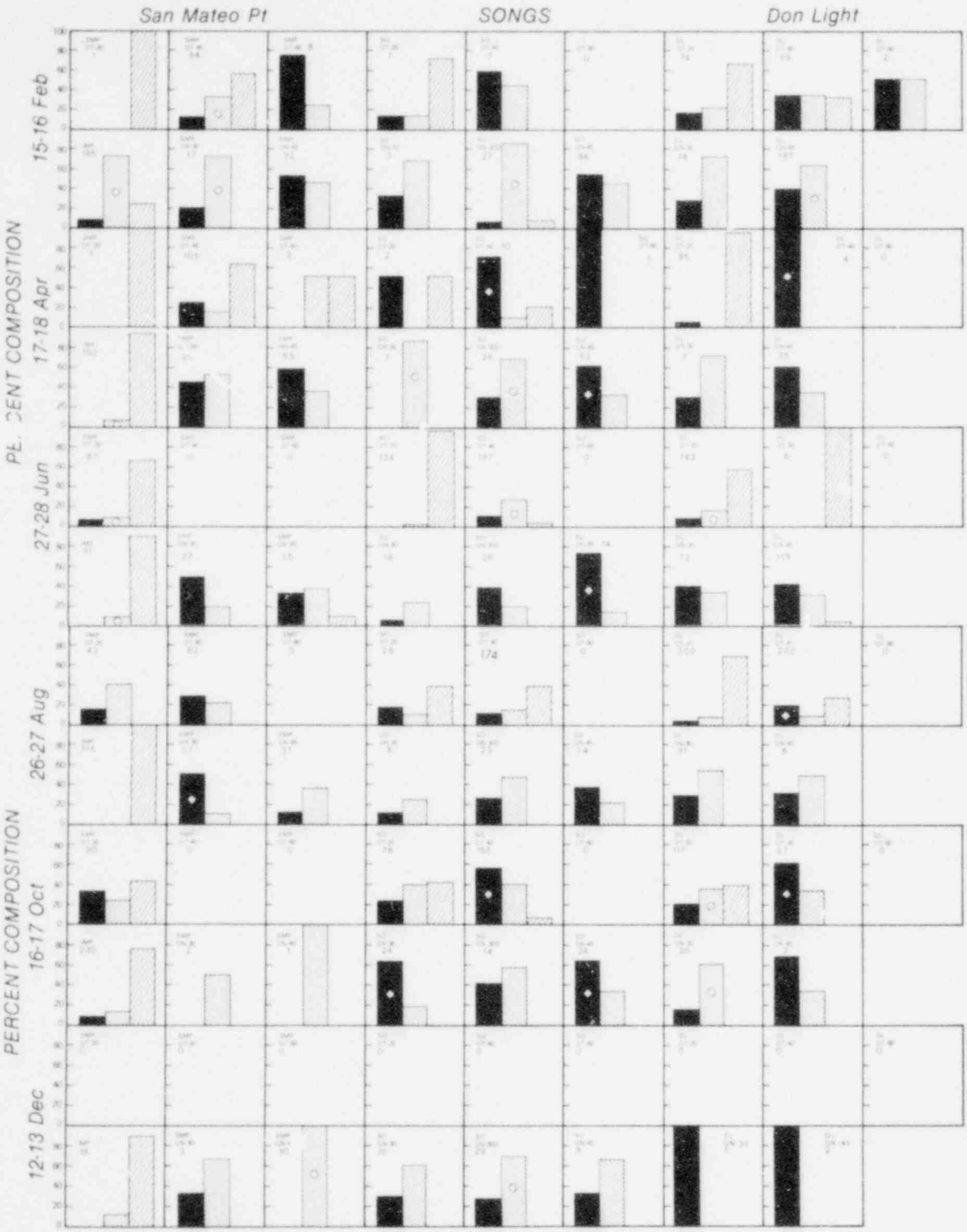


Figure 6B-14. Sex ratio bar graphs of *Genyonemus lineatus* based on otter trawls, gill net, and impingement collections during 1979. Area and depth per sample are indicated in light face type, while bold face type indicates the number of specimens sexed. The balance of collections totalling less than 100% are composed of indeterminant (non-juvenile) fish; blank graphs in which individuals were caught indicate 100% indeterminants. Crosses (✧) indicate a significantly greater number of either males (■) or females (□) based on chi square goodness of fit statistics ($p < 0.05$); juveniles indicated by (▨).

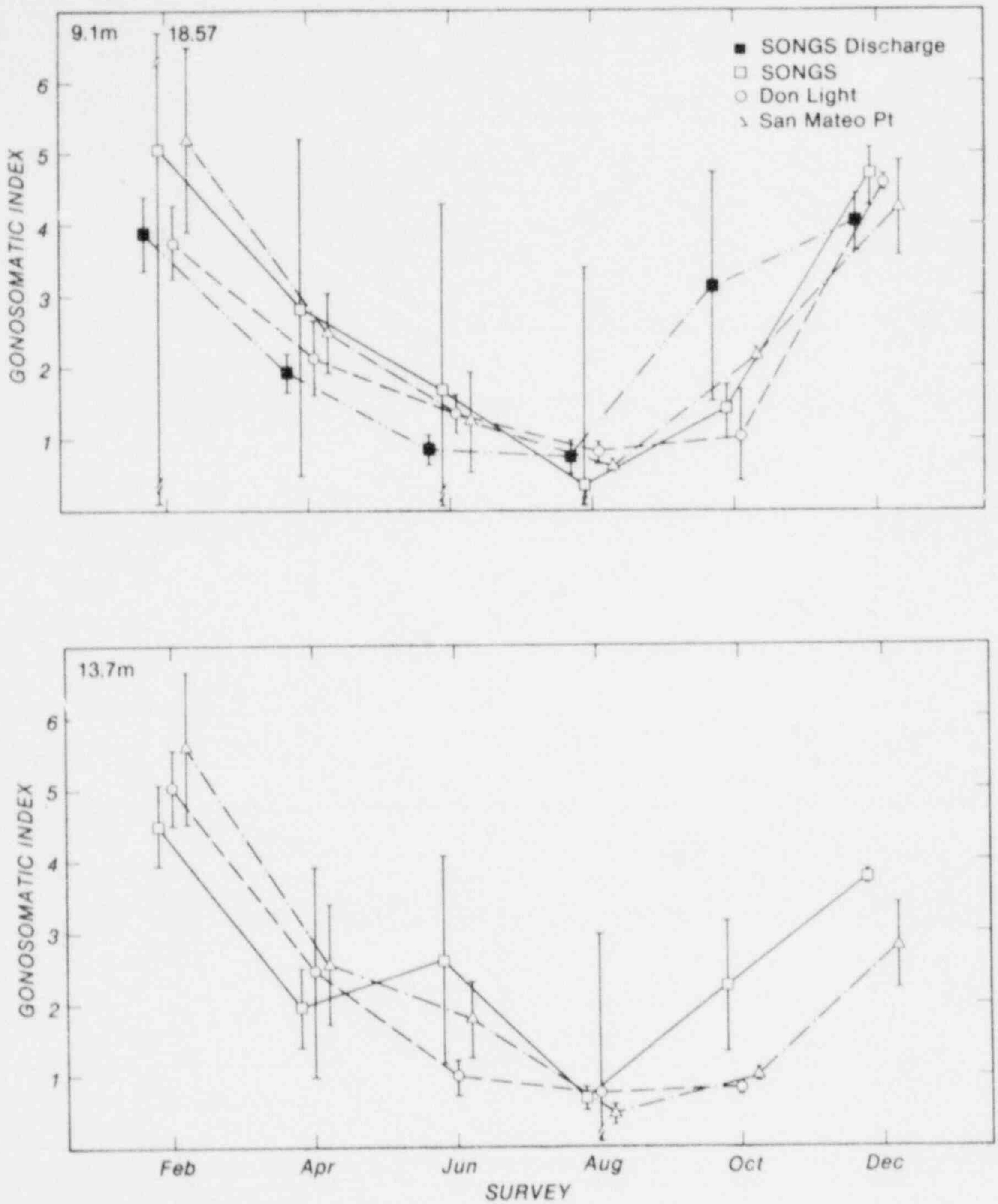


Figure 6B-15. Gonosomatic indices (gonad wet weight/total body wet weight X 100) of female *Genyonemus lineatus* collected by gill net on the 9.1 and 13.7 m isobath at San Mateo Point, SONGS, and Don Light during 1979.

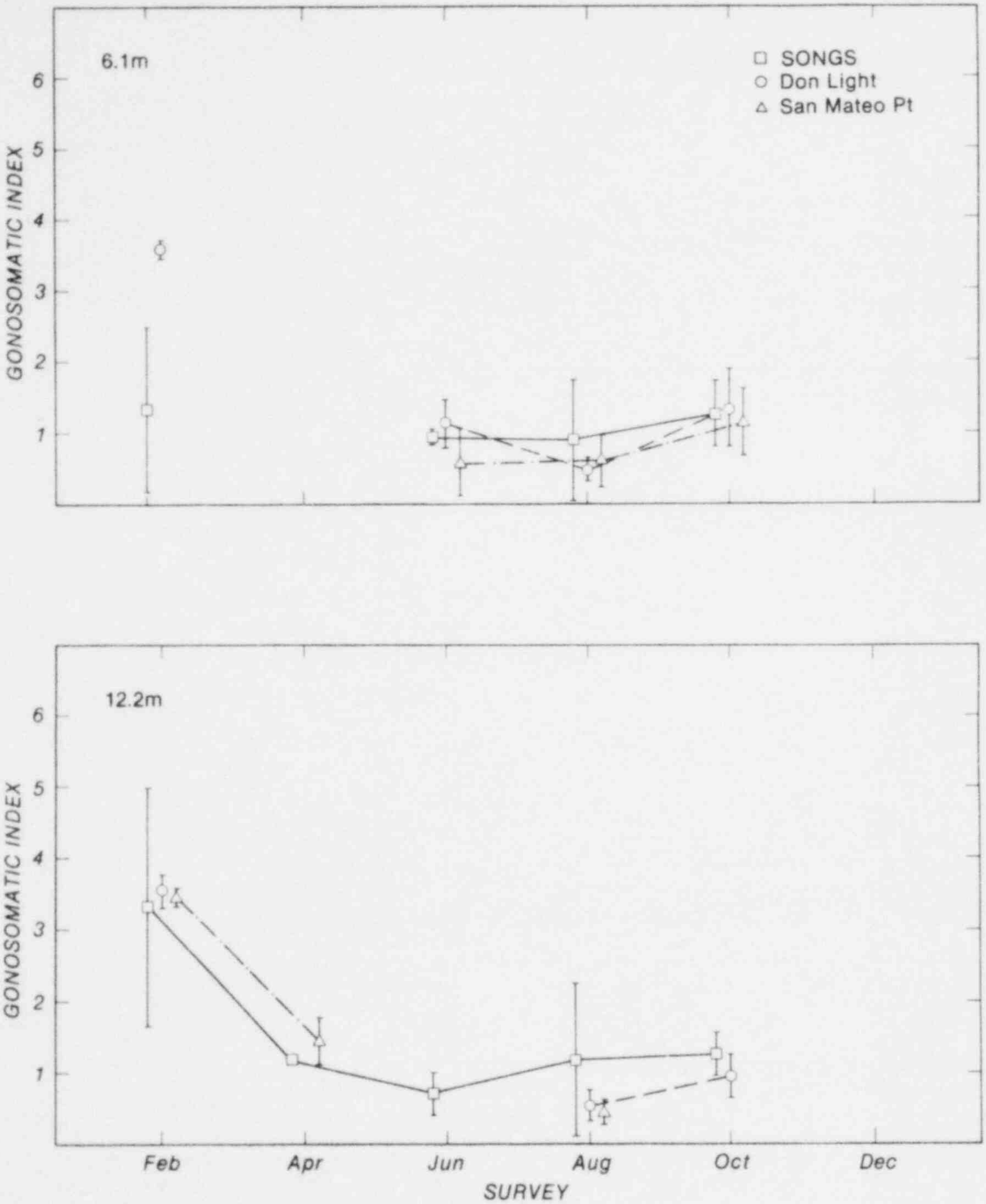


Figure 6B-16. Gonosomatic indices (gonad wet weight/total body wet weight X 100) of female *Genyonemus lineatus* collected by otter trawl on the 6.1 and 12.2 m isobath at San Mateo Point, SONGS, and Don Light during 1979.

control collections from the 9.1-m isobath (Figure 6B-15). Gill net catches from the 13.7-m isobath showed a similar pattern in the treatment area.

Genyonemus lineatus caught in gill nets during 1979 showed significantly different mean gonad weights among areas when compared by analysis of covariance and Student-Newman-Keuls multiple range test (Sokal and Rohlf 1969). The mean gonad weight of white croaker caught near the SONGS Unit 1 discharge was significantly ($P \leq 0.05$) less than mean gonad weights from all other areas throughout the year. Comparisons made between depths within each area revealed that mean gonad weights of fish collected within the immediate discharge area and the offshore (13.7 m) treatment area were significantly ($P < 0.05$) lower than other depths and areas. Mean gonad weight of white croaker collected by otter trawls showed no differences between any area or depth during 1979.

Analysis of mean gonad weight by survey revealed that Genyonemus collected during the reproductively active period from October to April had gonad weights significantly ($P \leq 0.05$) different from those collected during the resting period (August).

Overall, both the mean GSI values and gonad weights present a homogeneous picture of reproductive periodicity for white croaker. With the exception of the SONGS Unit 1 discharge area, Genyonemus did not show spatial or temporal asynchronous reproductive periodicity.

Hyperprosopon argenteum (Walleye surfperch)

Abundance. The mean abundance of Hyperprosopon argenteum caught in gill nets and otter trawls is presented in Figures 6B-4 and 6B-17 through 19. Walleye surfperch collected with both gear types were caught less often in the San Onofre region than queenfish or white croaker. The mean gill net catch of Hyperprosopon was low throughout 1979 in all areas and depths and although gill net catches are relatively small and variable, the mean catch has gradually declined in the study area since the sampling program began (Figure 6B-17). A slight increase in catch from June through October was observed at the offshore treatment (Figure 6B-18) and Unit 1 discharge (Figure 6B-4) stations. Average otter trawl catch was also low during the winter and spring. Walleye surfperch abundance, estimated from trawl catches, increased during the summer months along the 6.1-m (June-October) and 13.7-m (August) isobaths (Figure 6B-19). Hyperprosopon was generally limited to the nearshore (< 13.7 m) area. Periodic seasonal changes in gill net catches on the 9.1-m isobath, however, suggests that Hyperprosopon move into and out of the area (Figure 6B-14). Fish may also regularly move offshore at night, though such diel migrations were not detectable by the present sampling regime (Ebeling and Bray 1976).

Length Frequency. The relatively low catches of Hyperprosopon during each survey precluded a meaningful presentation of length structure by histograms. Length data for all surveys are presented in tabular form in SCE (1980d, p. II 115-172). Gill nets set at 9.1 and 13.7 m collected walleye surfperch with similar length frequency structure in most areas. The length structure of walleye surfperch caught in the treatment and upcoast control areas consisted of 110-160 mm SL individuals during most of the year. Smaller (75-90 mm SL) walleye surfperch were caught throughout the year at the 9.1-m isobath but were most abundant from August through October.

Otter trawl samples taken at 6.1 and 12.2 m collected adult Hyperprosopon with length frequencies similar to adults caught in gill nets. Juveniles (40-70 mm SL) were caught frequently during June along the 6.1-m isobath in all areas.

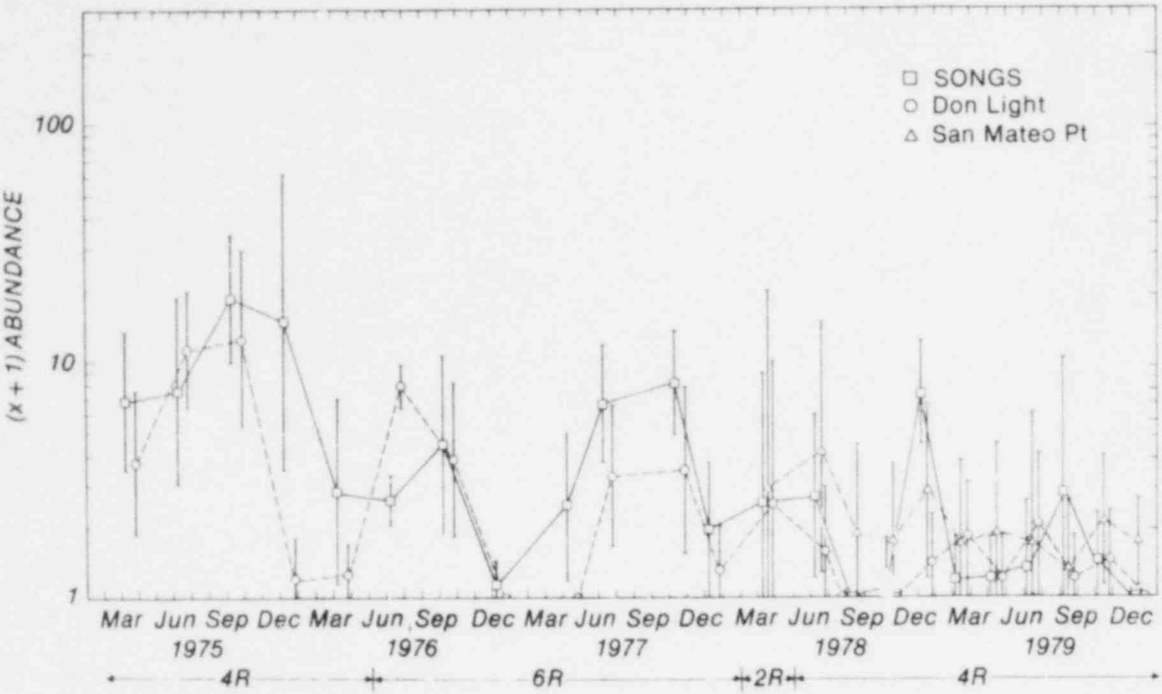


Figure 6B-17. Geometric mean and 90% confidence limits of *Hyperprosopon argenteum* captured at 9.1 m gill nets set at SONGS and Don Light during the period from 1975 to 1979 and San Mateo Point from 1978 to 1979. The number of replicates (R) for all means are indicated below the abscissa.

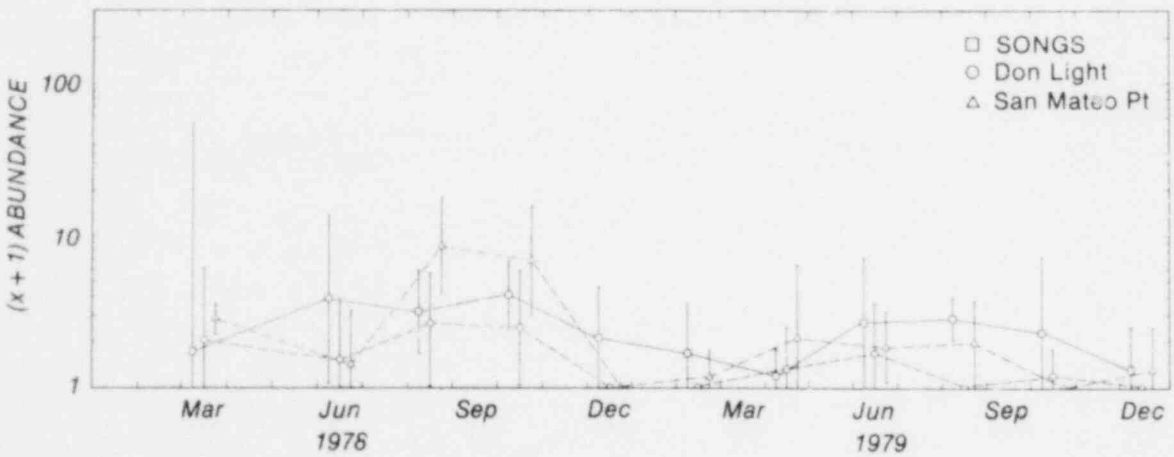


Figure 6B-18. Geometric mean and 90% confidence limits of *Hyperprosopon argenteum* captured at 13.7 m in four replicate gill nets set at San Mateo Point, SONGS, and Don Light during 1979.

The new recruits grew during August and October as evidenced by the presence of 60-85 mm SL walleye surfperch in all inshore areas. Walleye surfperch were not caught in December trawls and were rarely captured in trawls conducted on the 18.3-m isobath.

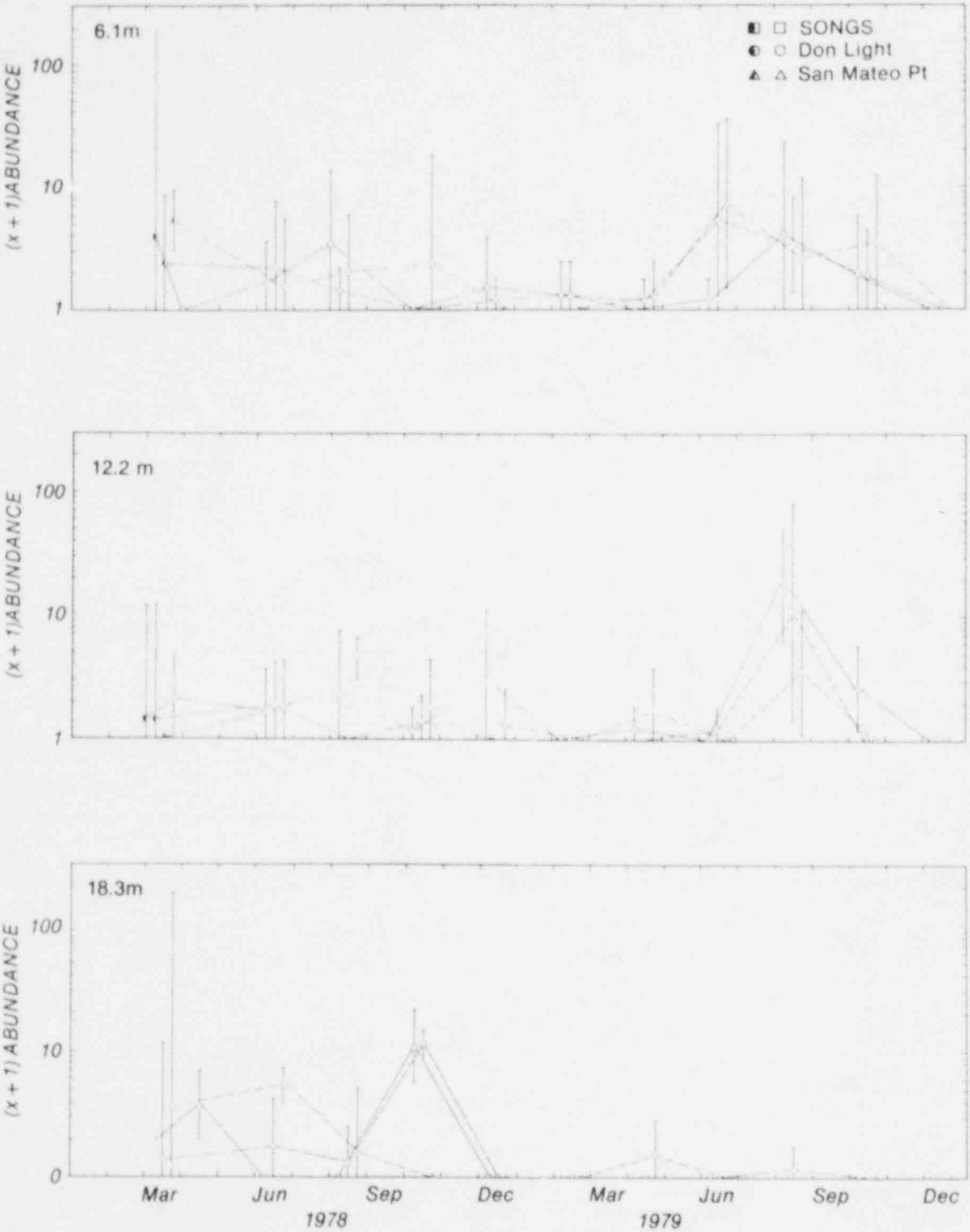


Figure 6B-19. Geometric means and 90% confidence limits of *Hyperprosopon argenteum* caught at 6.1, 12.2, and 18.3 m in daytime otter trawls conducted at San Mateo Point, SONGS, and Don Light during 1979. Means from March 1978 preliminary trawls (half-shaded) are based on two replicates, all other means are based on four replicates.

Sex Composition. Sex composition of Hyperprosopon is presented in Figure 6B-20. Because of relatively small catches, distinctive repeatable patterns in sex composition of walleye surfperch caught in gill nets were not evident in 1979. Isolated instances of female dominance occurred in April at inshore (9.1 m) stations at the upcoast control and treatment areas and in June at offshore treatment and inshore downcoast control area. Sex composition of Hyperprosopon caught in otter trawls also revealed no distinct pattern of male or female dominance throughout the year.

Juvenile Hyperprosopon comprised the entire trawl catch during April at the 6.1-m isobath and were predominant components of the August catch at this depth. This summer influx of young-of-the-year walleye surfperch was consistent with previous results and followed documented walleye surfperch breeding cycles (Feder, Turner and Limbaugh 1974, Eckmayer 1979).

Phanerodon furcatus (White surfperch)

Abundance. The mean catches of Phanerodon furcatus in gill nets and otter trawls during 1979 are presented in Figures 6B-4 and 6B-21 through 23. The mean catches of Phanerodon in gill nets set at 9.1 and 13.7 m were relatively low throughout the San Onofre region during 1979 (Figures 6B-21 and 22).

The catch of Phanerodon in gill nets set on the 9.1-m isobath has been seasonally predictable from 1975 to 1978. Historically, abundances increased from December through March and decreased thereafter; this pattern was not obvious based on 1979 gill net samples (Figure 6B-21). White surfperch mean abundances based on offshore gill net catch also lacked temporal pattern in 1979 (Figure 6B-22). Average otter trawl catches of Phanerodon increased during the August and October surveys along the 12.2-m isobath in all areas (Figure 6B-23). Otter trawl catches of white surfperch on the 6.1 and 18.3-m isobaths were low in all areas except the inshore, downcoast control area during June. White surfperch have been collected infrequently in gill nets set adjacent the SONGS Unit 1 discharge although a slight increase in catch occurred in December 1978 and 1979 (Figure 6B-4).

Length Frequency. Low catches of Phanerodon throughout 1979 precluded meaningful length frequency analysis by histograms. Length data for all surveys are presented in tabular form in SCE (1980d, p. II 115-172). As was the case with the other select species, gill nets captured more and larger Phanerodon than did otter trawls. Size classes of Phanerodon captured in gill nets were variable throughout the year, although 80-100, 120-135, 150-165, and 180-200 mm SL modal classes were most common. White surfperch ranging from 45 to 120 mm SL were predominant in otter trawl collections in all areas. Large catches of juveniles (35-55 mm SL) were made during June at 6.1 and 12.2 m throughout the San Onofre region.

Sex Composition. The sex composition of male and female Phanerodon furcatus caught in gill nets and otter trawls throughout the San Onofre region is presented in Figure 6B-24.

Female white surfperch significantly ($P < 0.05$) outnumbered males at the offshore, upcoast control site during April and August and in the treatment area during April, June, and August surveys. Significantly ($P \leq 0.05$) more females were also caught in otter trawls, particularily at 6.1 m in the upcoast control area during April, June, and August.

Juvenile white surfperch were a major constituent of the summer (August) and fall (October) otter trawl catch at 6.1 and 12.2 m in all areas.

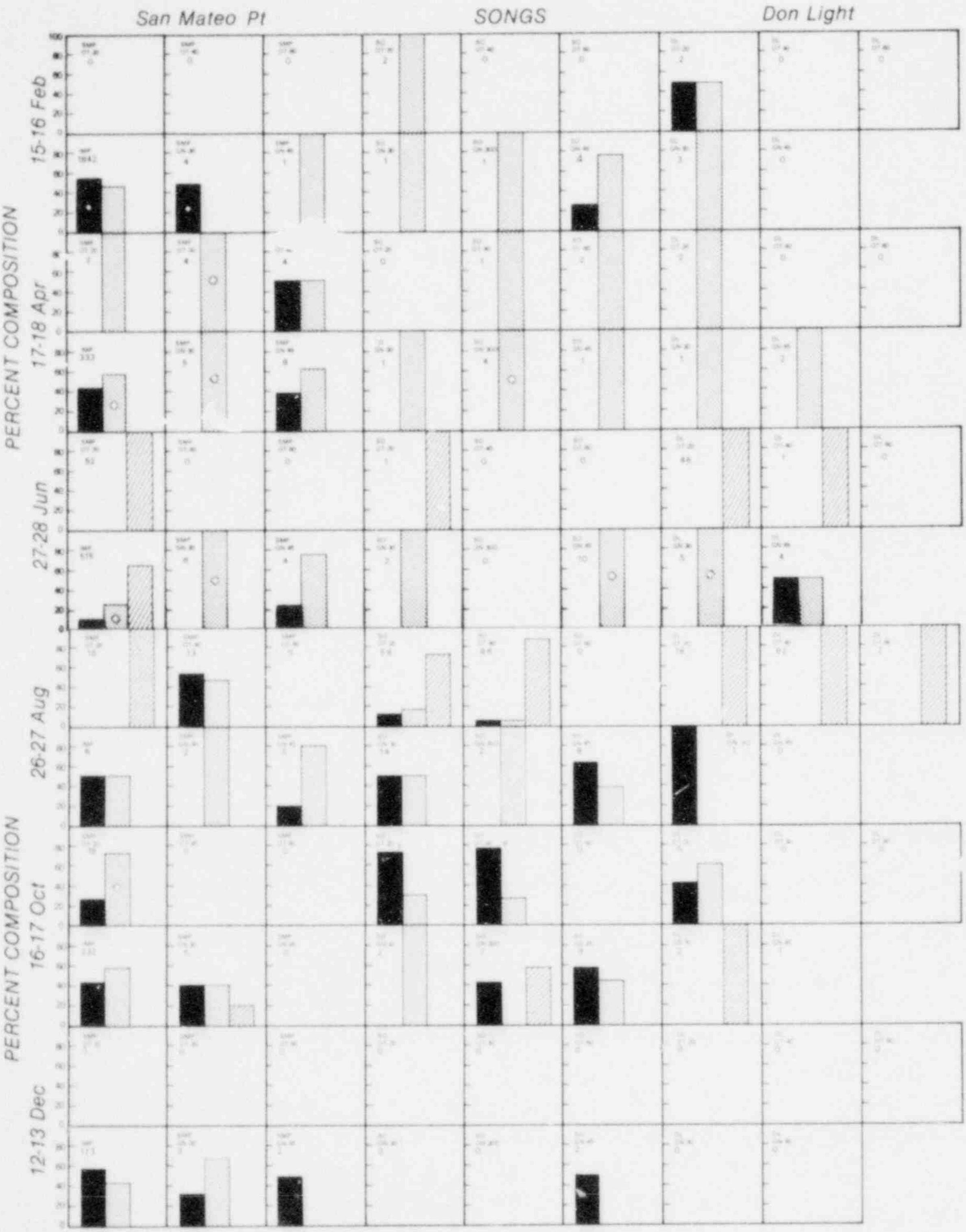


Figure 6B-20. Sex ratio bar graphs of *Hyperprosopon argenteum* based on otter trawls, gill net, and impingement collections during 1979. Area and depth per sample are indicated in light face type, while bold face type indicates the number of specimens sexed. The balance of collections totalling less than 100% are composed of indeterminant (non-juvenile) fish; blank graphs in which individuals were caught indicate 100% indeterminants. Crosses (◌) indicate a significantly greater number of either males (■) or females (□) based on chi square goodness of fit statistics ($p < 0.05$); juveniles indicated by (▨).

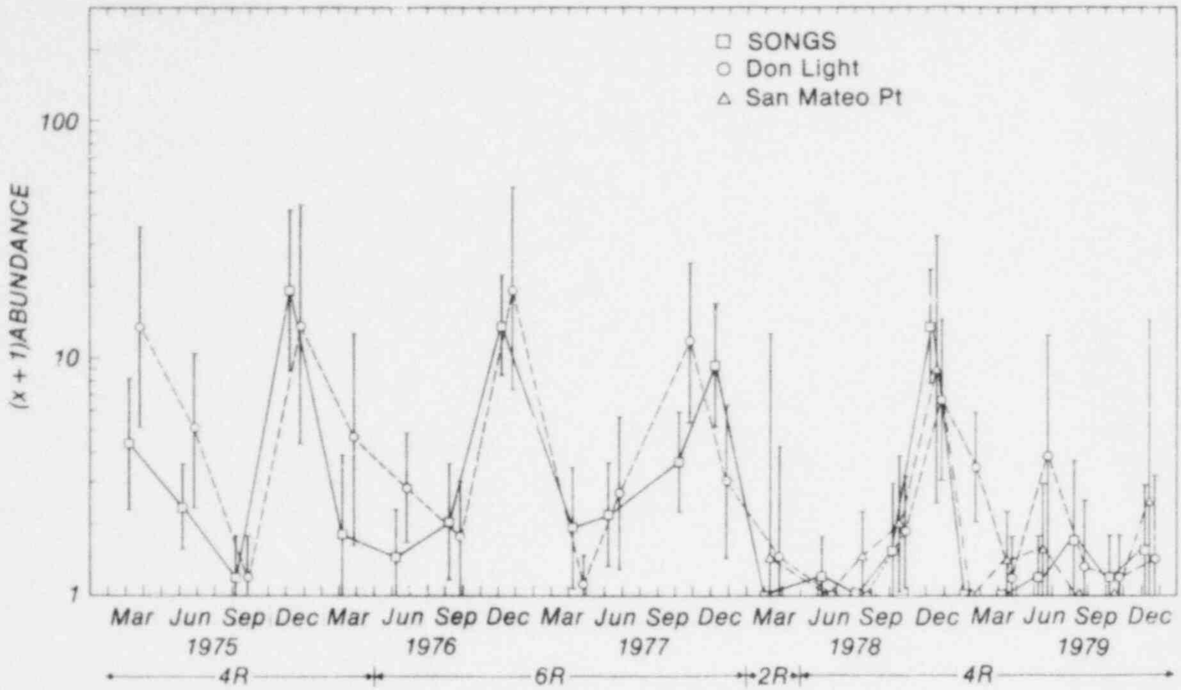


Figure 6B-21. Geometric mean and 90% confidence limits of *Phanerodon furcatus* captured at 9.1 m gill nets set at SONGS and Don Light during the period from 1975 to 1979 and San Mateo Point from 1978 to 1979. The number of replicates (R) for all means are indicated below the abscissa.

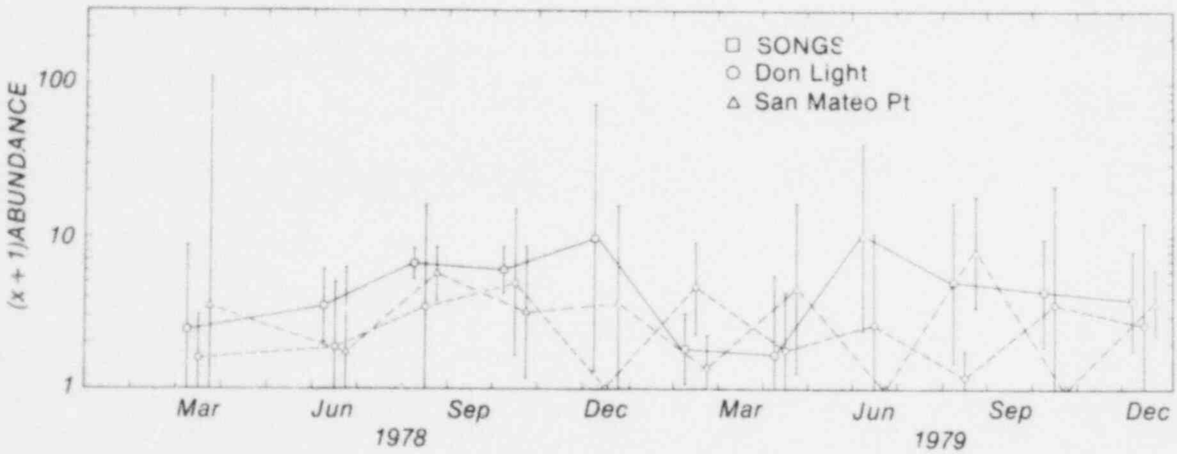


Figure 6B-22. Geometric mean and 90% confidence limits of *Phanerodon furcatus* captured at 13.7 m in four replicate gill nets set at San Mateo Point, SONGS, and Don Light during 1979.

COMMUNITY ANALYSIS

The fish community sampled by gill nets and otter trawls was analyzed with respect to species composition and abundance, classification analysis, and feeding guilds.

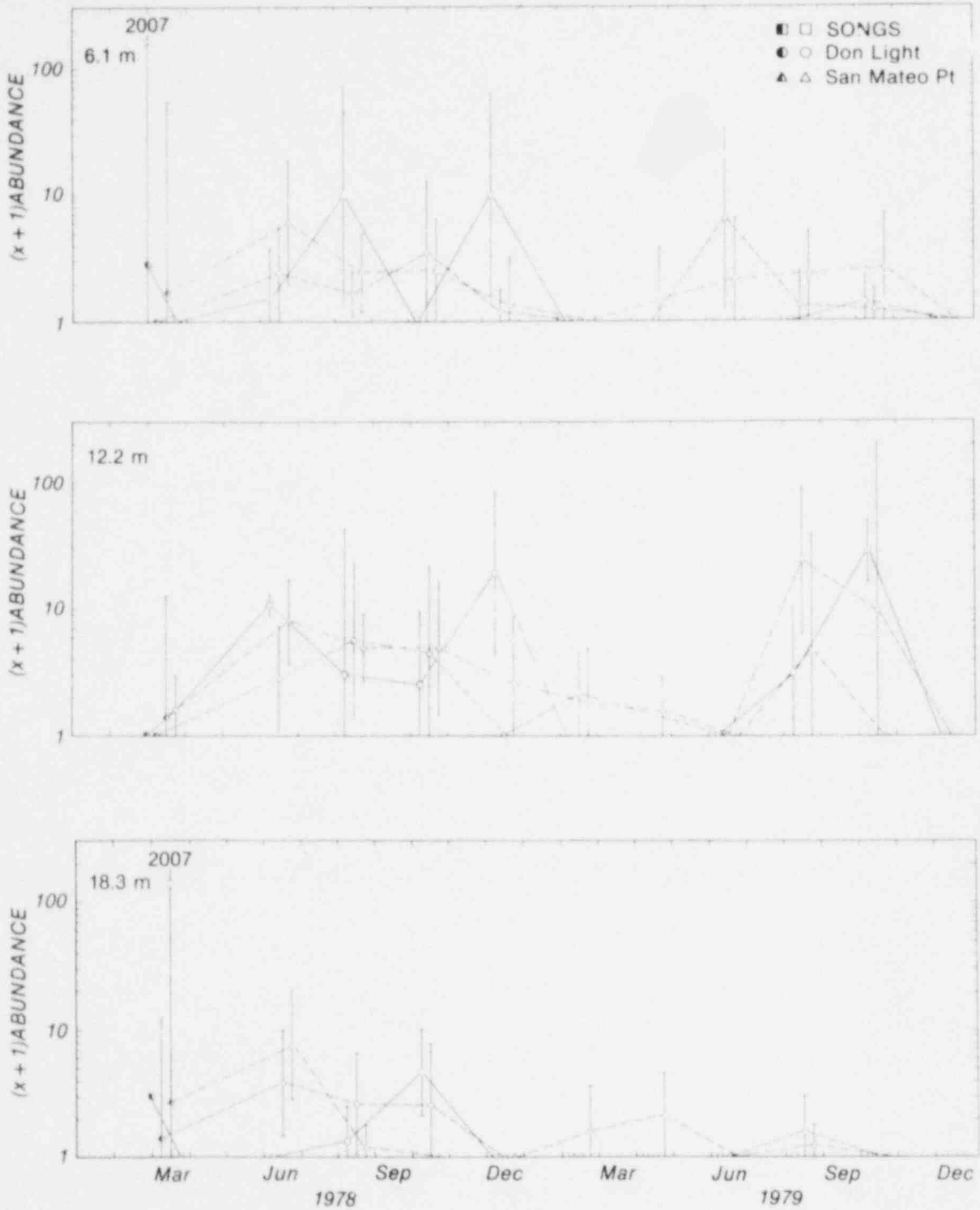


Figure 6B-23. Geometric means and 90% confidence limits of *Phanerodon furcatus* caught at 6.1, 12.2, and 18.3 m in daytime otter trawls conducted at San Mateo Point, SONGS, and Don Light during 1979. Means from March 1978 preliminary trawls (half-shaded) are based on two replicates, all other means are based on four replicates.

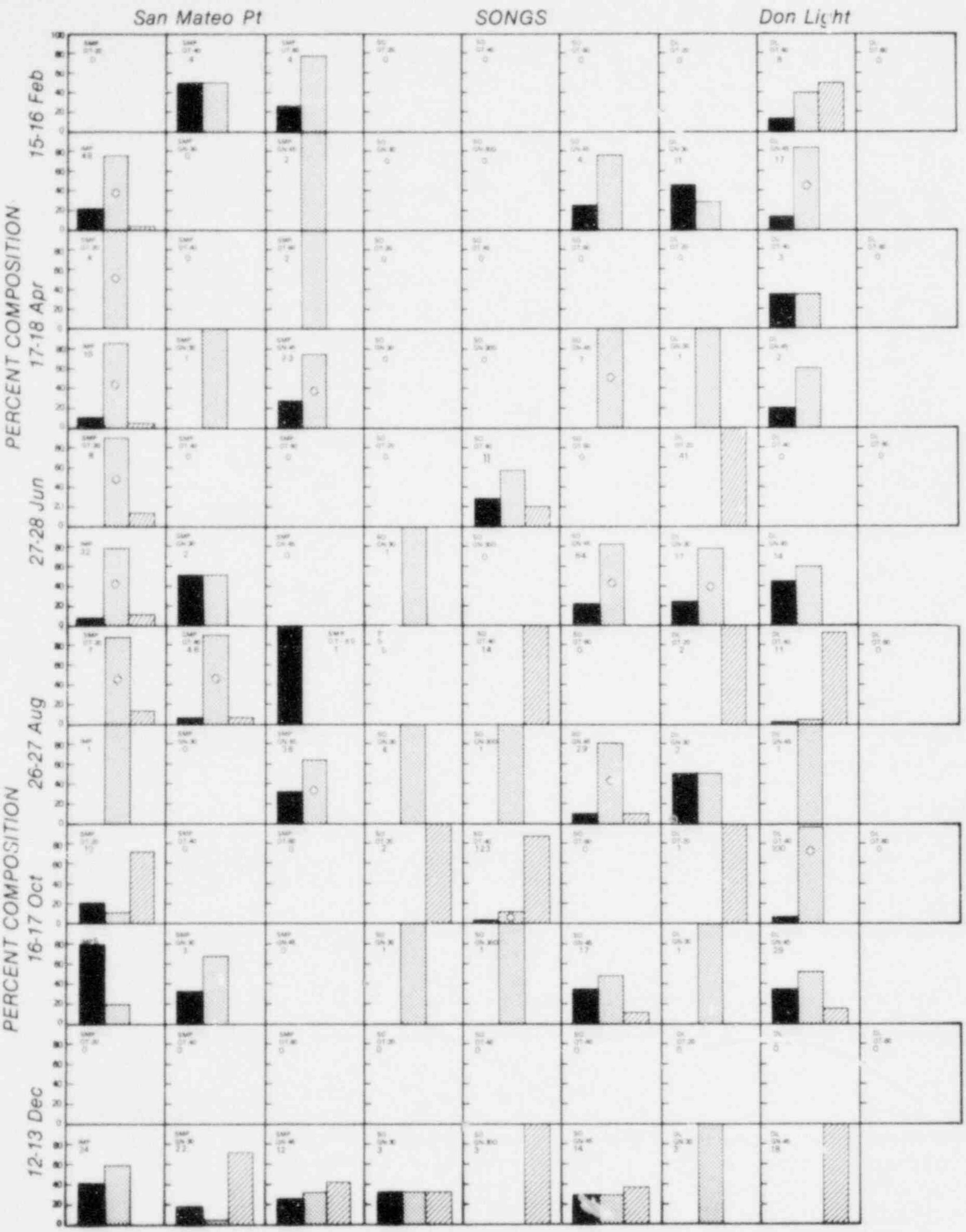


Figure 6B-24. Sex ratio bar graphs of *Phanerodon furcatus* based on otter trawls, gill net, and impingement collections during 1979. Area and depth per sample are indicated in light face type, while bold face type indicates the number of specimens sexed. The balance of collections totalling less than 100% are composed of indeterminant (non-juvenile) fish; blank graphs in which individuals were caught indicate 100% indeterminants. Crosses (⌘) indicate a significantly greater number of either males (■) or females (▦) based on chi square goodness of fit statistics ($p < 0.05$); juveniles indicated by (▨).

A total of 83 species and 49,287 individuals were caught in 1979 using gill nets and otter trawls. Gill nets caught 13.1% (6,440 individuals) of the total catch and otter trawls caught the remaining 86.9% (42,847 individuals, Table 6B-1). Compared to 1978, gill nets caught 434 more individuals in 1979 while the otter trawl catch declined by 7,144 individuals.

Table 6B-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 and 1979.

Category	1975*	1976*	1977*	1978**	1979
Number of species	49	46	41	89	83
Number of individuals	3,206	3,383	3,216	55,997	49,287

* The 1975, 1976, and 1977 survey data are based upon quarterly samples of 12 gill nets.

** The 1978 and 1979 survey data are based upon bimonthly gill net and otter trawl samples.

Community Classification Analysis

Seasonal patterns of species composition and abundance for the fish assemblages sampled by gill nets and otter trawls were resolved by cluster analysis (Clifford and Stephenson 1975). Seasonal clustering of sites and species was based upon surveys conducted in June, August, October, and December 1978 and 1979. Classifications from surveys conducted in February and April 1979, and March 1978 were not compared between years.

Gill Nets. "Sites" are the gill net stations in each of the sampling areas (Figure 6B-1). Clusters of sites with similar species composition (site groups) were identified by number and letter signifying the month (survey) during which the fish were collected (Figure 6B-25).

The number of site groups in 1978 (Figure 6B-25) ranged from two in June to four in August. Site groups from four (March, August, October, December) of the five bimonthly surveys in 1978 were determined by depth (Figure 6B-25). Within each group relations among the treatment area (SONGS) and control areas (Don Light and San Mateo Point) were inconsistent; Figure 6B-25.

Site classification for 1979 (Figure 6B-26) yielded from two (February, June) to four groups (August). With the exception of the February and October surveys, site group composition was determined by depth. Site affinities were inconsistent within the groups.

For the June, August, October, and December surveys in 1978 and 1979, the number and composition of site groups were compared between the treatment (SONGS) and control (Don Light and San Mateo Point) areas. The number of site groups is similar between the two years for each bimonthly survey. Gill net catches in June during both years resolved the fewest site groupings (2) while the August surveys produced the most (4). Three to four site groups were formed from gill net catches in October and December.

Site groups were formed on the basis of depth during certain times of the year (Figures 6B-25 and 6B-26). Site affinities within these groups were examined for consistent co-occurrence of the test site between years for each survey. In many cases the number of members within a group was similar between

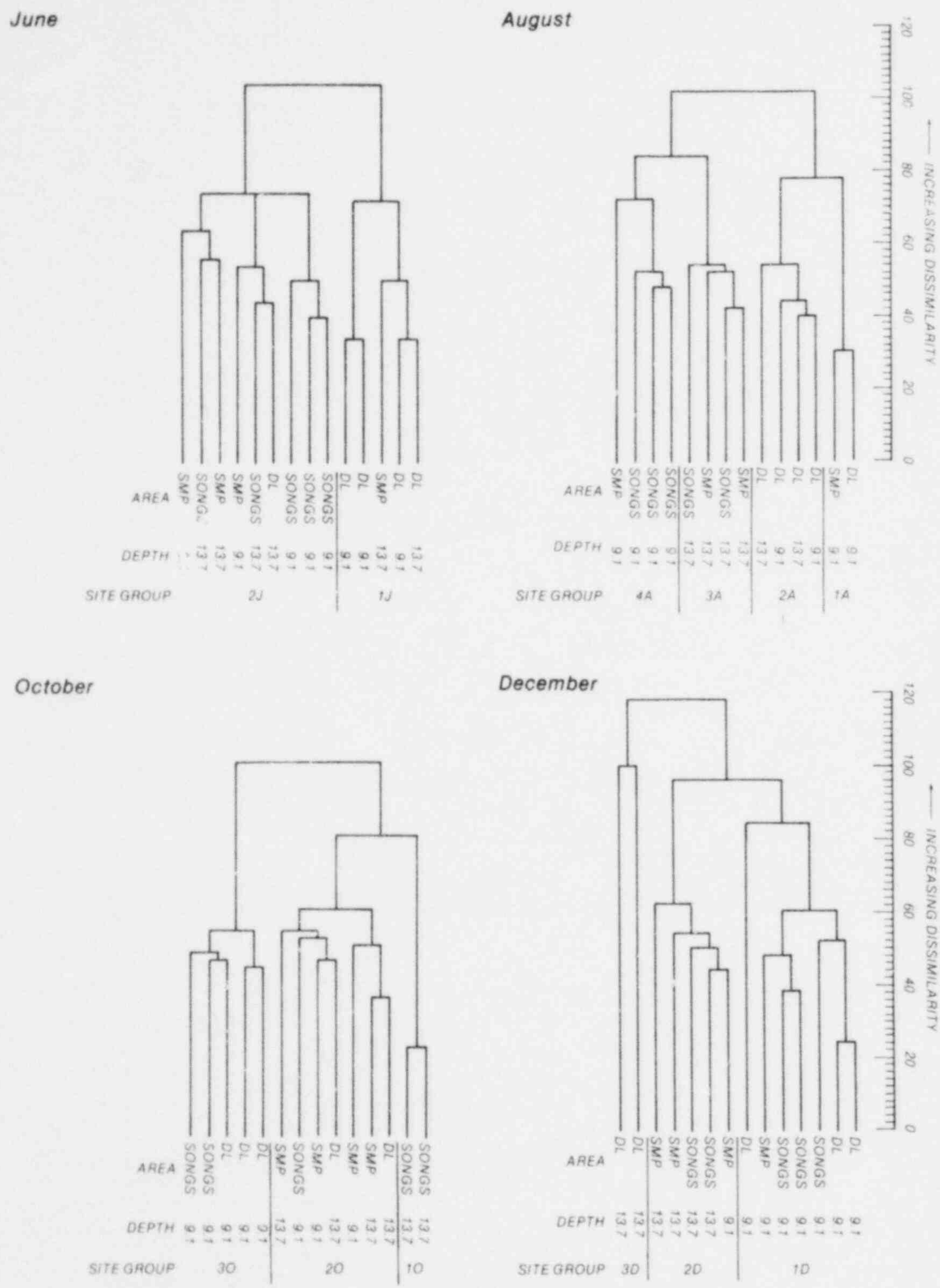


Figure 6B-25. Site classification of 1978 gill net catch by survey month.

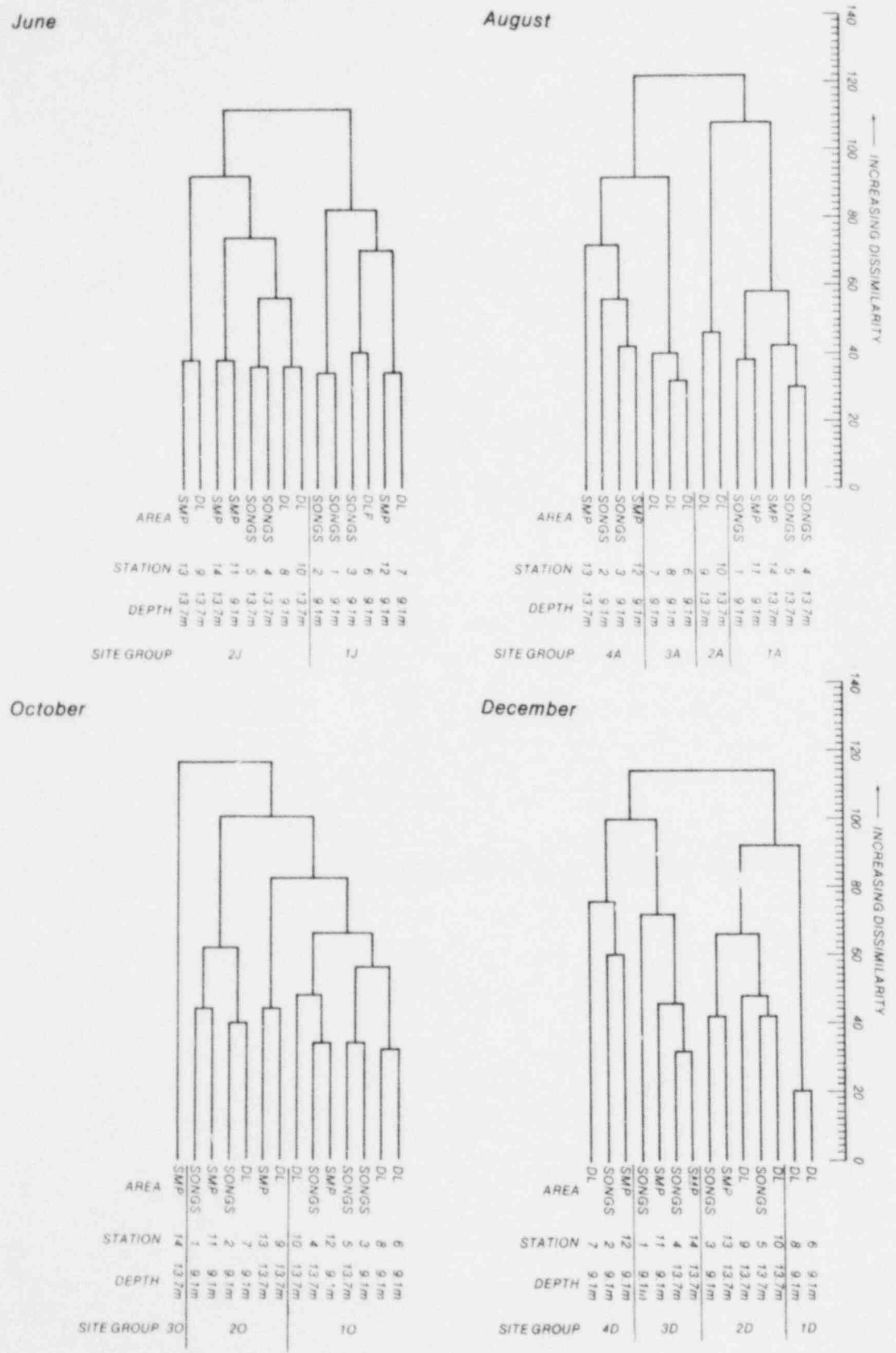


Figure 6B-26. Site classification of 1979 gill net catch by survey month.

years (2J, 4A, 2D, and 2D; Figures 6B-25 and 6B-26). However, consistent co-occurrence of the test site was not detected for the depth determined site groups.

The inverse classification of fish species by the sites where they are most abundantly caught resulted in a range of from three species groups in December to six in August 1978 (Figure 6B-27). Species groups generally contained diverse and variable assemblages of fish taxa. This is expected considering the heterogeneous habitat (level bottom, kelp-bed, water-column) and demersal species sampled by gill nets. Consistent temporal patterns in the co-occurrence of certain fish taxa were generally absent with the exception of species groups CM, DJ, EA, BD, and CD (Figure 6B-27). These groups included a suite of species with different feeding roles: water-column and substrata feeders (Seriphus politus), and bottom-feeding micro-mesocarnivores (Genyonemus lineatus, and Menticirrhus undulatus). Feeding guild analysis is presented in greater detail in the following section. These species recurred in each bimonthly survey, in virtually all site groups and showed greatest temporal consistency.

Other fishes having the same feeding role recurred in species groups with some temporal regularity. Species groups BM (March), AJ (June), CA (August), and EO (October) contain three to four demersal carnivores: rubberlip perch, Damalichthys vacca; pile perch, Rhacochilus toxotes; grass rockfish, Sebastes rastrelliger; and California sheephead, Pimelometopon pulchrum. These fishes consistently co-occurred in four of the five bimonthly surveys in 1978. Also, certain water-column and substrata feeders recurred in species groups resolved in most of the five bimonthly surveys. Among the water-column and substrata feeders included in species groups DM, DA, EO, and BD were the white seabass, Cynoscion nobilis, and the leopard shark, Triakis semifasciata (Figure 6B-27). Other members of this feeding guild which recurred temporally were the gray smoothhound, Mustelus californicus; the brown smoothhound, M. henlei; the barred sand bass, Paralabrax nebulifer; and the kelp bass, P. clathratus.

The number of species groups resolved from gill net catch data in 1979 ranged from three in February, October, and December to five in August. Species groups CF, DJ, AA, and CO contained the same Genyonemus-Seriphus-Menticirrhus association which was consistently present at most site groups in four of the six bimonthly surveys (Figure 6B-28).

Otter Trawls. "Sites" are now defined as the otter trawl stations in each of the sampling areas (Figure 6B-1). Thus, bimonthly surveys are here classified on the basis of nine otter trawl sites. Site groups were again identified by number and letter like those identifying gill net site groups (Figure 6B-29).

Classification of otter trawl sites by species in 1978 resolved two to three site groups per survey (Figure 6B-29). Four of the five bimonthly surveys (June, August, October, and December) contained two site groups the composition of which was determined by depth. During June, August, and December, species groups 1J, 1A, and 1D were composed exclusively of species collected at sites on the 6.1 and 12.2-m isobaths (Figure 6B-29). Site groups 2J, 2A, and 2D contained virtually all the stations on the 18.3-m isobath. During October, a shift in the composition produced a site group from the 6.1-m isobath (2O) and a site group containing 12.2 and 18.3-m stations (Figure 6B-29).

In 1979, site classifications resulted in the formation of two to three site groups (Figure 6B-30). Three groups were resolved from the February, June, and December surveys and two were formed from the April, August, and October surveys. Once again, group membership was determined by depth; however, the pattern of station recurrence differed somewhat from that observed in 1978. The June and

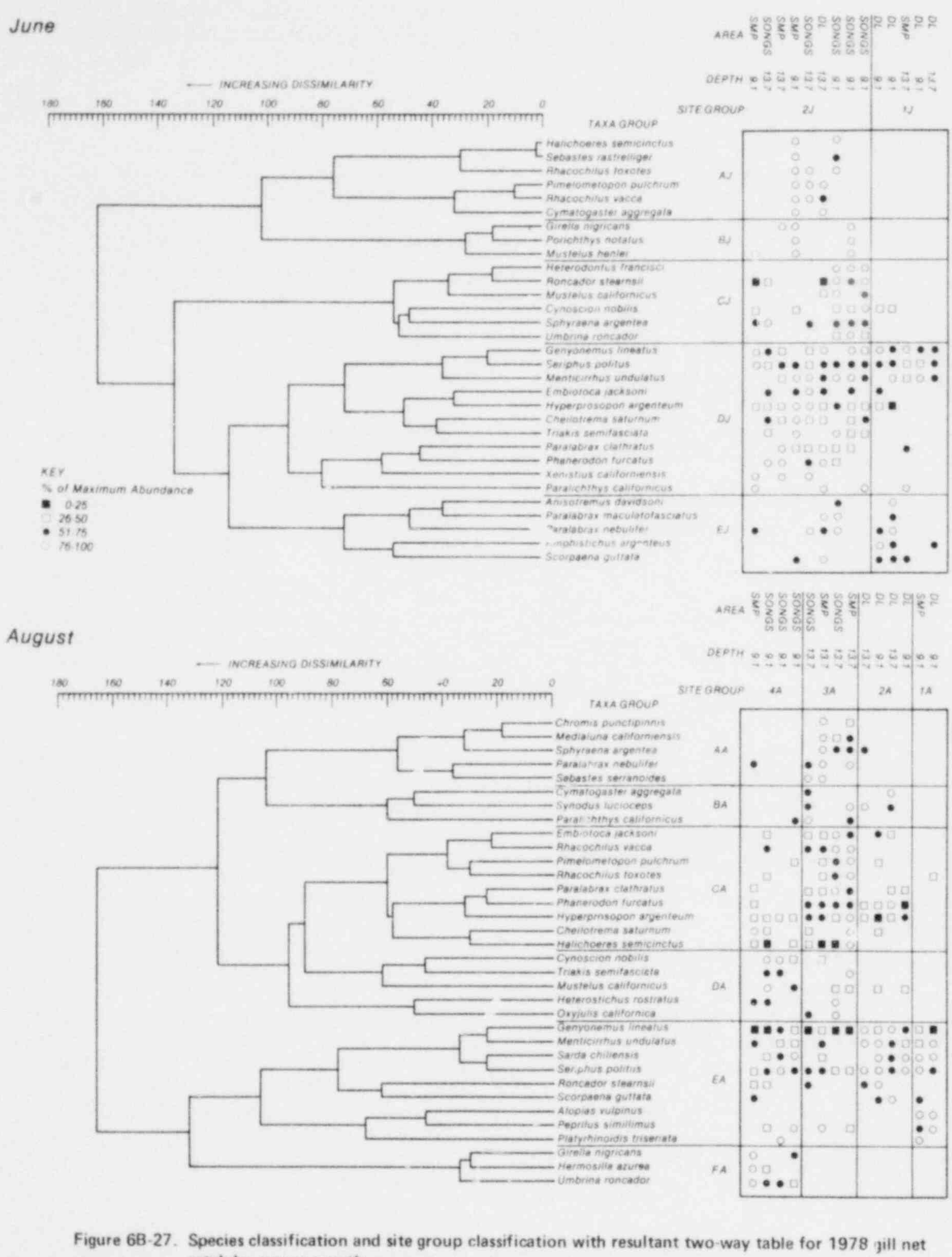


Figure 6B-27. Species classification and site group classification with resultant two-way table for 1978 gill net catch by survey month.

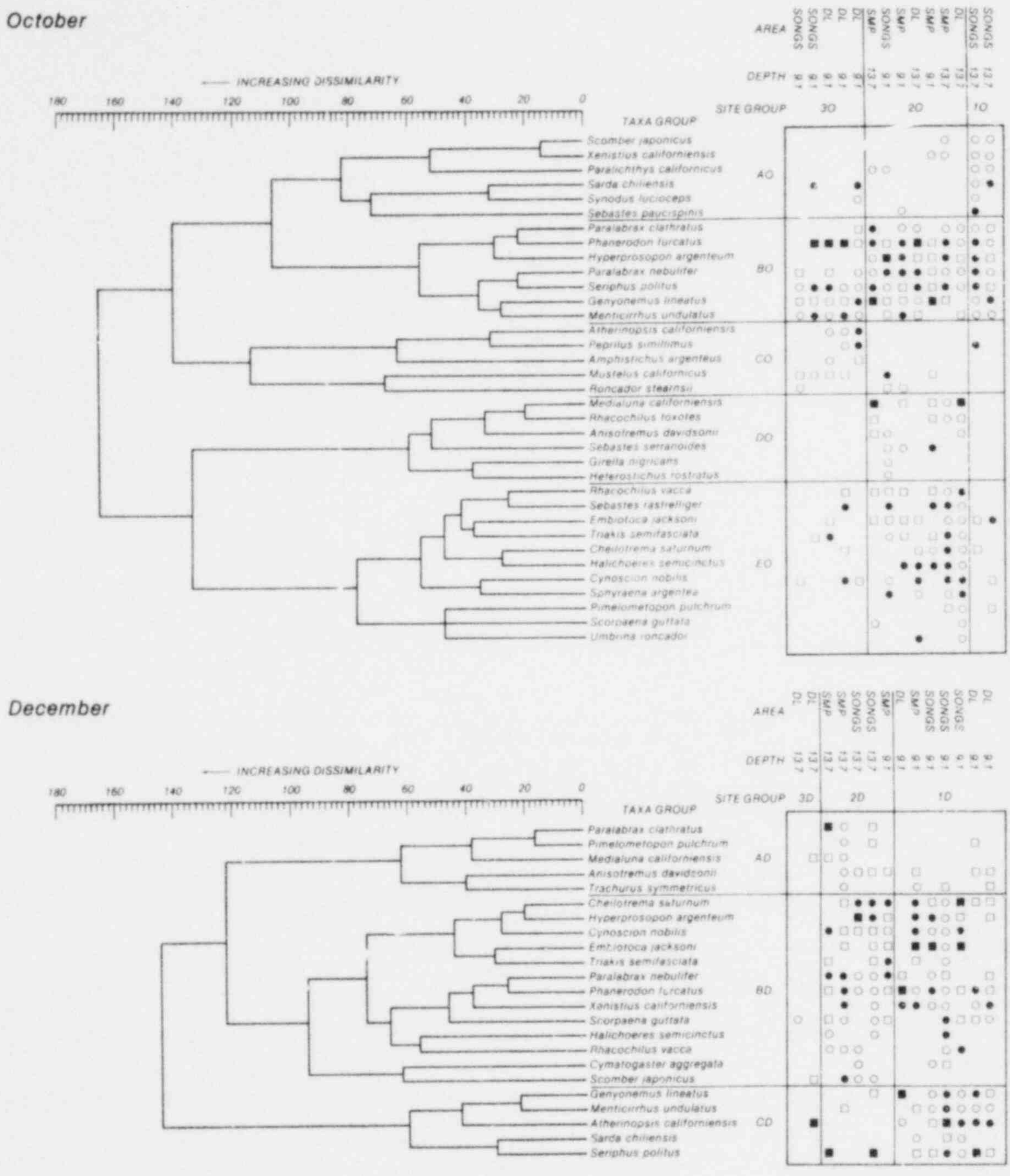


Figure 6B-27. (Continued)

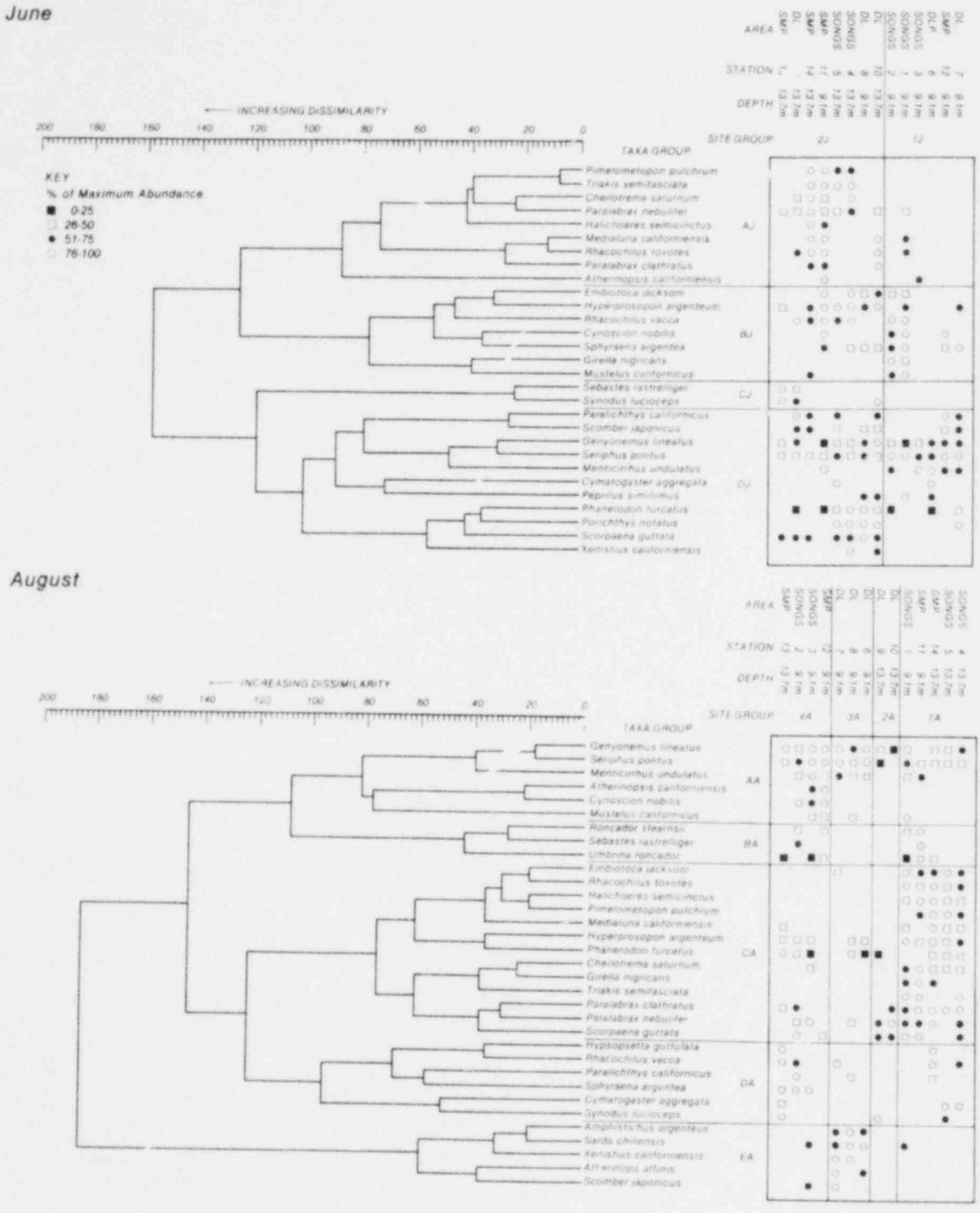
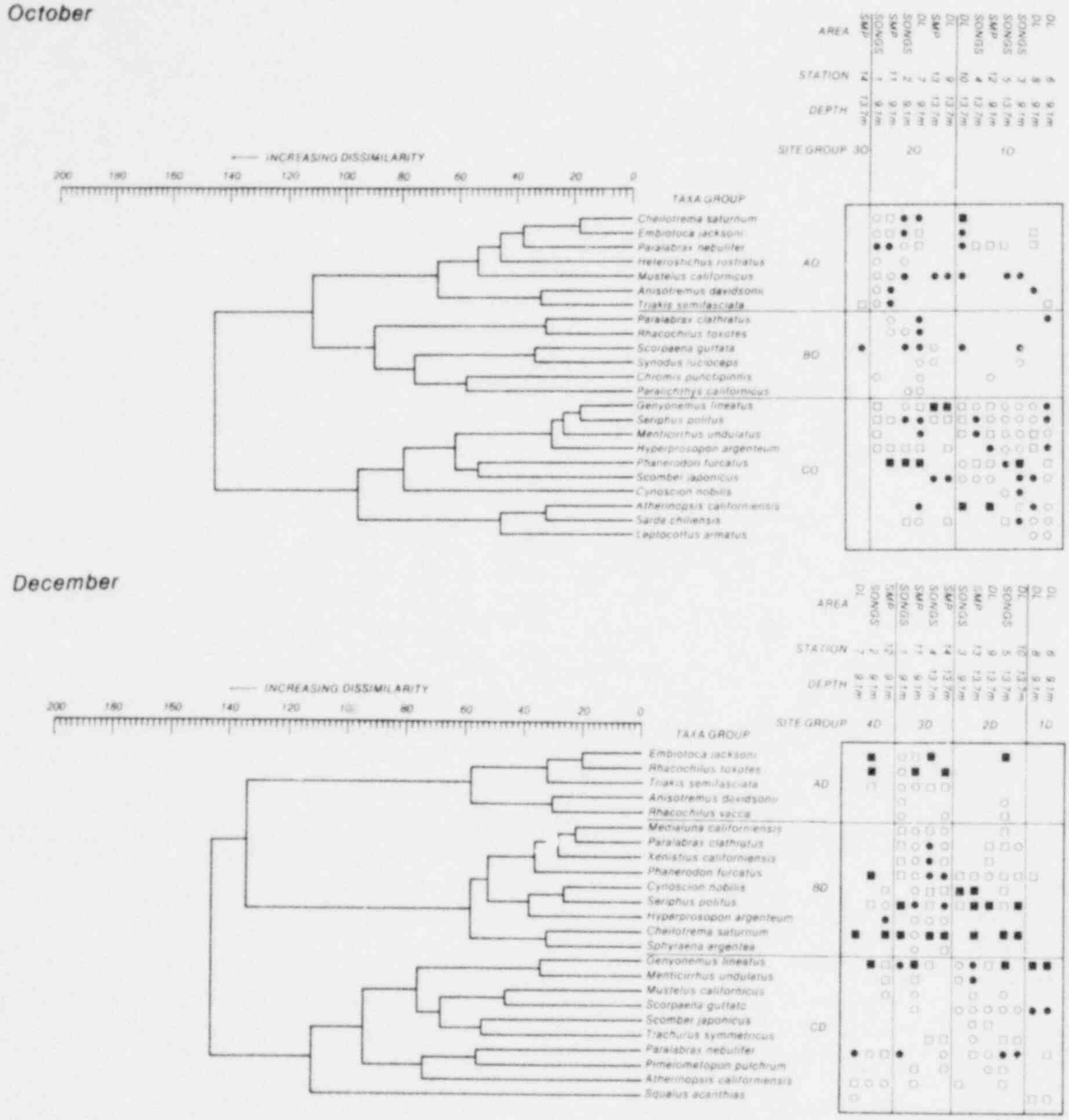


Figure 6B-28. Species classification and site group classification with resultant two-way table for 1979 gill net catch by survey month.



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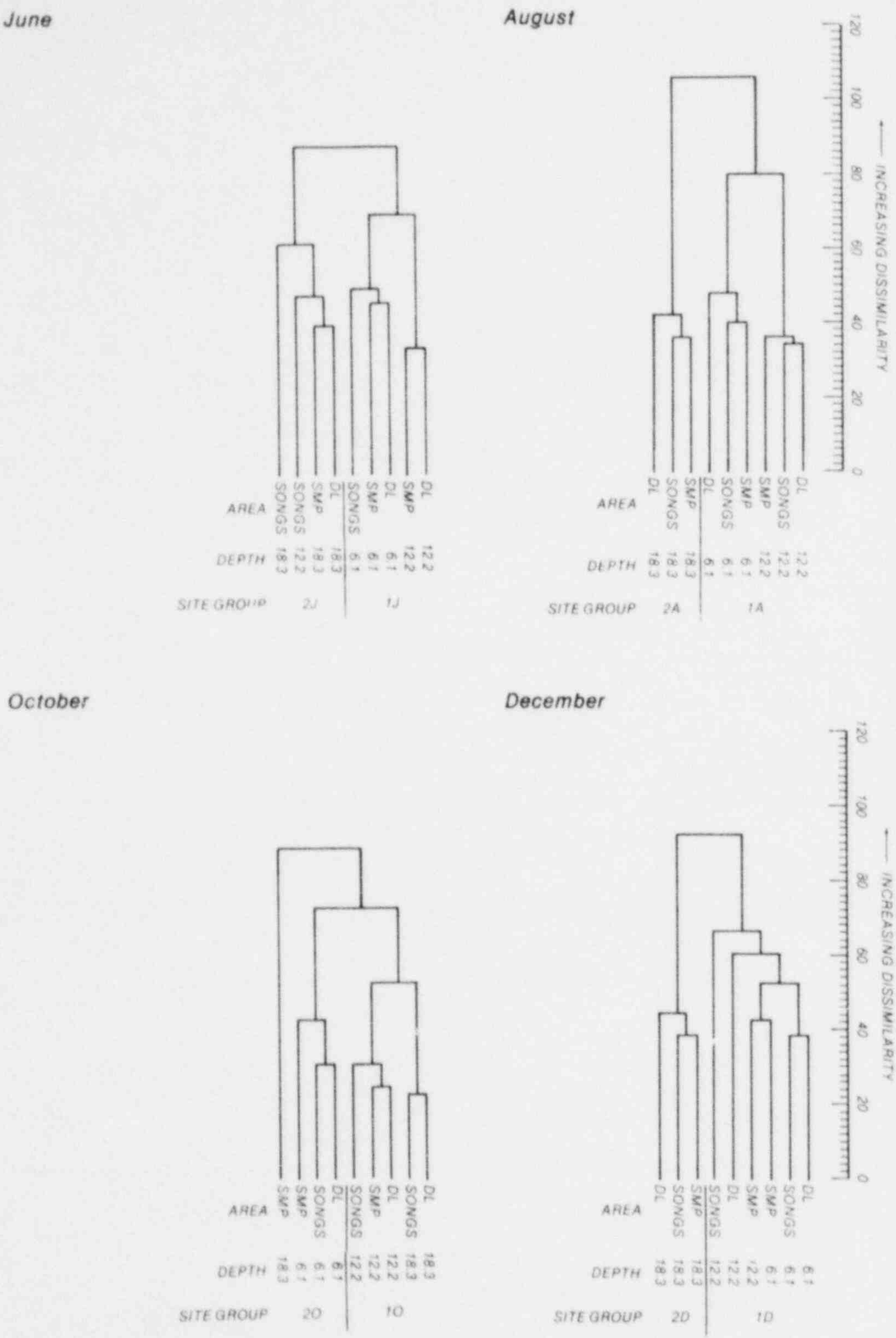


Figure 6B-29. Site classification of 1978 outer trawl catch by survey month.

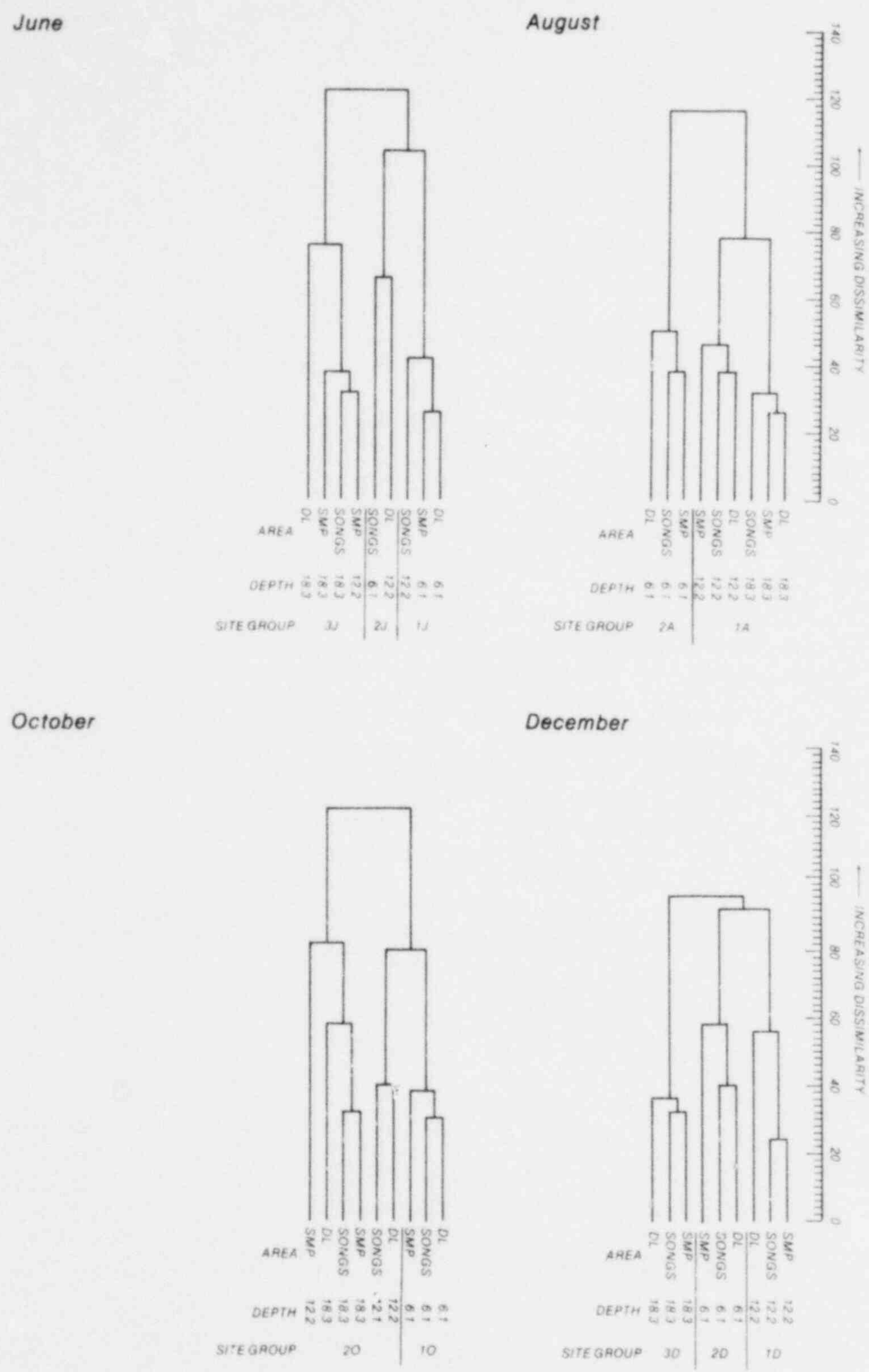


Figure 6B-30. Site classification of 1979 otter trawl catch by survey month.

October site-group cluster included stations on the 6.1-m isobath (1J and 10) and the 18.3-m isobath (3J and 20). Site groups in August contained stations on the 6.1-m isobath (2A) and the 12.2 and 18.3-m isobaths (1A). The December 1979 site groups were unique in that sites at each isobath (6.1, 12.2, and 18.3 m) regardless of area (San Mateo Point, SONGS, and Don Light) formed distinct clusters (Figure 6B-30). Treatment or control sites, alone, did not form clusters during any survey in 1978 or 1979.

The number of species groups resolved by the inverse classification of the five 1978 surveys ranged from two in October to six in June (Figure 6B-31). Although species groups contained members of different feeding roles, the same diverse species tended to recur repeatedly in groups throughout the bimonthly surveys. In fact the composition of three such groups of species recurring through time was related more to depth of habitat than feeding role. A ubiquitous group from all depths (BJ, BA, AD) was comprised of Engraulis mordax (filter feeder), Hyperprosopon argenteum (midwater planktivore), Phanerodon furcatus (water-column and substrata feeder), Genyonemus lineatus (bottom-feeding micro-mesocarnivore), Paralichthys californicus and Citharichthys stigmaeus (bothid flatfish that feed above soft-bottom); an inshore group (DJ, EJ, FJ, AA, BO) of Seriphus politus (water-column and substrata feeder), Amphistichus argenteus and Menticirrhus undulatus (both bottom feeding micro-mesocarnivores); Platyrhinoidis triseriata, Rhinobatus productus, and Urolophus halleri (all three feed on soft-bottom only); and an offshore group (CJ, CA, CD) of flatfishes Pleuronichthys decurrens, P. ritteri, P. verticalis, Parophrys vetulus (all soft-bottom only feeders), and Xystreurys liolepis (feeds above the soft-bottom). It is no surprise that the offshore group, which was sampled well outside the influences of rocky bottom and kelp, contained only fishes in soft bottom feeding roles. Inshore species consistently recurred in the 6.1 and 12.2-m site groups, while offshore species recurred regularly in 18.3-m groups. Ubiquitous species consistently reccurred in groups resolved from June, August, and October surveys (Figure 6B-31). In December many ubiquitous species were trawled at inshore stations exclusively. Distinction between inshore and offshore groups was clearest in June, August, and December (Figure 6B-31). In October, however, the high degree of temporal recurrence exhibited by inshore and offshore species in earlier surveys was not as apparent (Figure 6B-31).

The 1979 otter trawl catches resolved three to four species groups (Figure 6B-32), which recalled the ubiquitous inshore and offshore groups of 1978. Although composition of ubiquitous species remained similar between years the group was well defined only during August. During June and October many ubiquitous fishes clustered with inshore fishes (Figure 6B-32). In December, ubiquitous species were not caught by otter trawls. Groups of inshore and offshore species were well-defined during June, August, and October, but most of these fishes were not caught in December trawls.

Feeding Guilds

The concept of feeding guilds was used to analyze fish communities because the availability and/or kind of food may limit the abundance and distribution of fish. Given a disturbance, if one can predict the fate of the fish's food, one may predict the fate of the fish. The objective of this analysis, therefore, is to compare the feeding guilds of fishes in the treatment area with those in the control areas as a means of assessing the potential operating effects of SONGS Unit 1.

A guild is defined as a group of species that perform the same feeding role. In community ecology "...the feeding role is thought to be an ecological unit

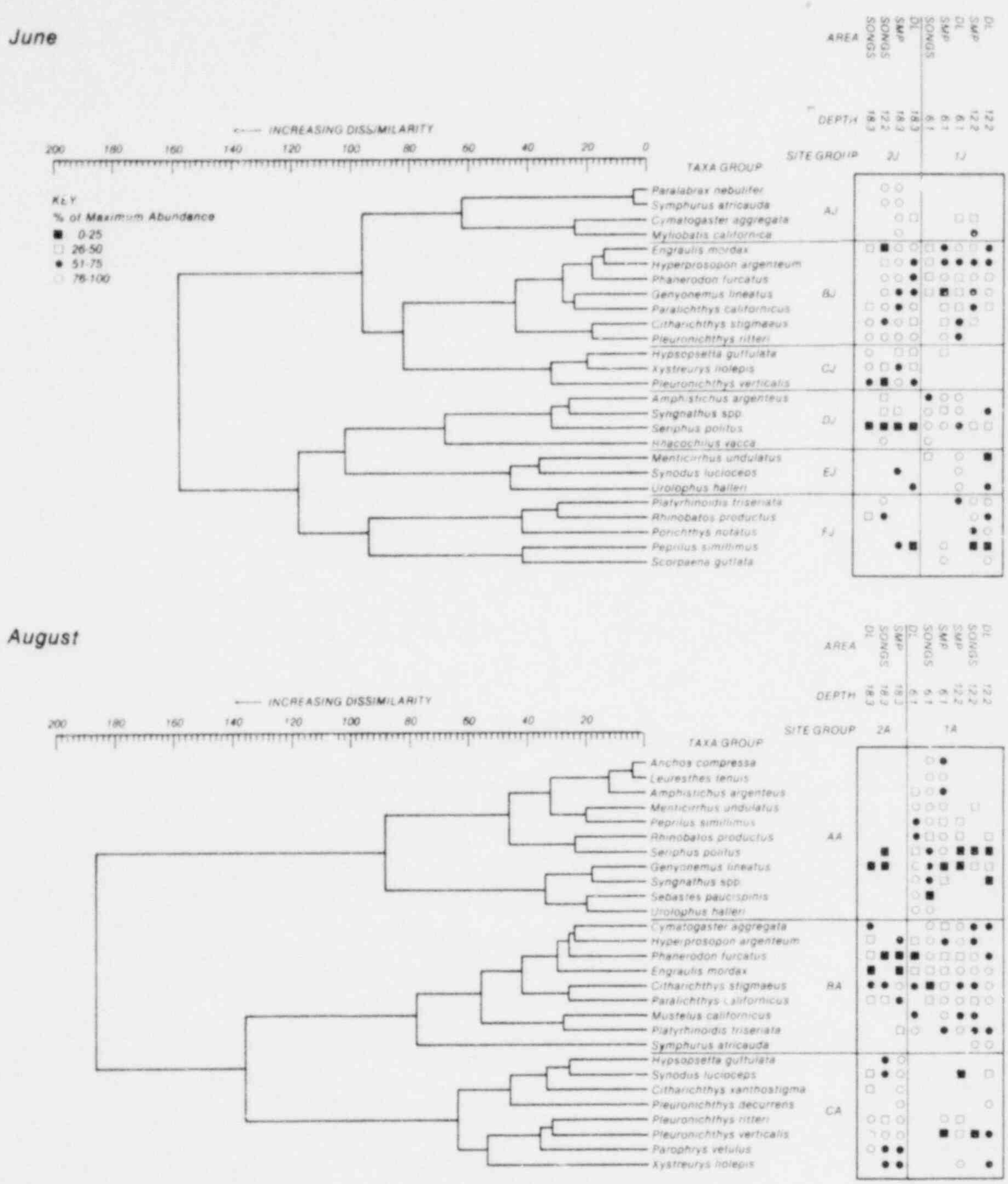
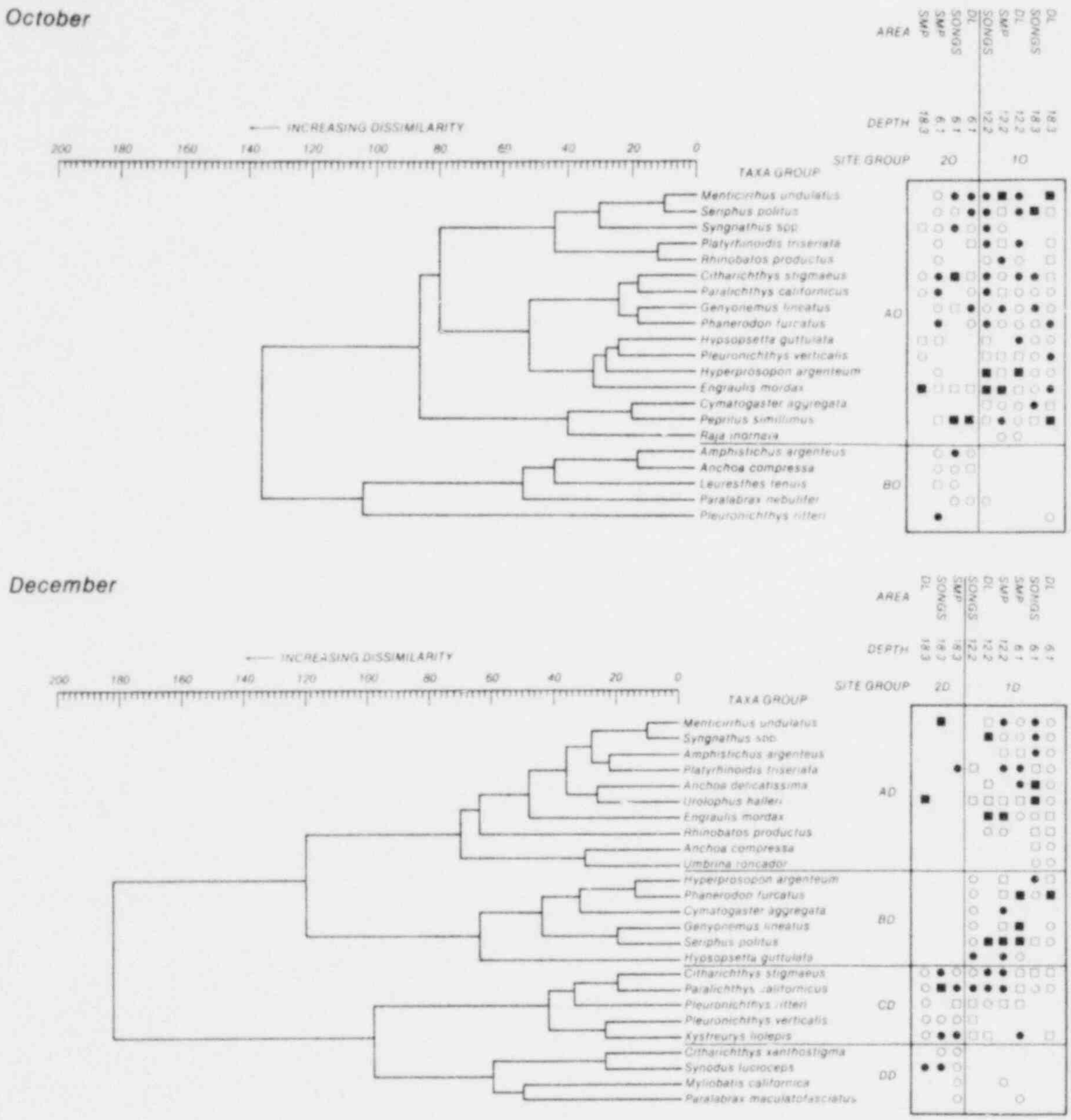


Figure 6B-31. Species classification and site group classification with resultant two-way table for 1978 otter trawl catch by survey month.



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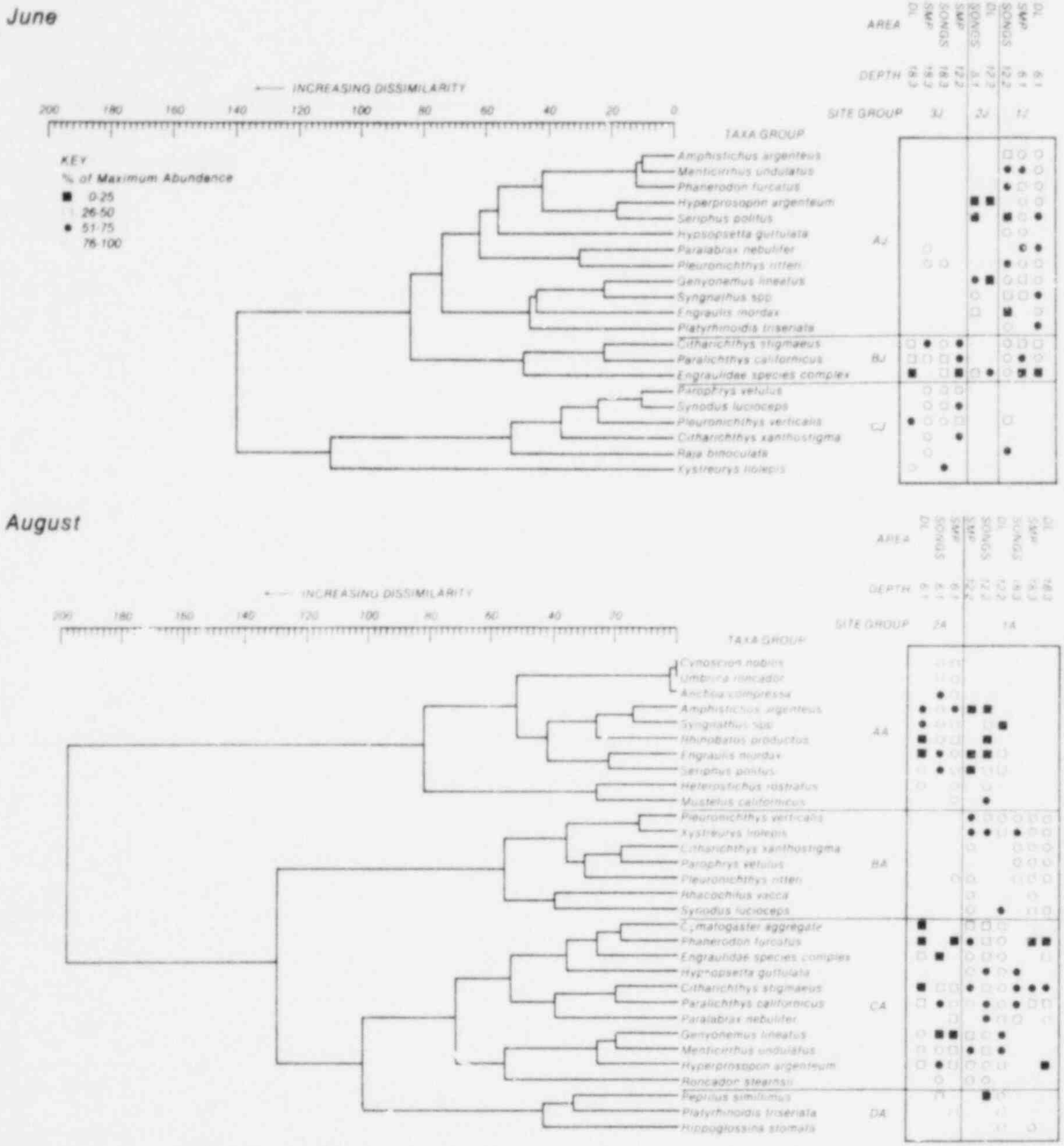


Figure 6B-32. Species classification and site group classification with resultant two-way table for 1979 otter trawl catch by survey month.

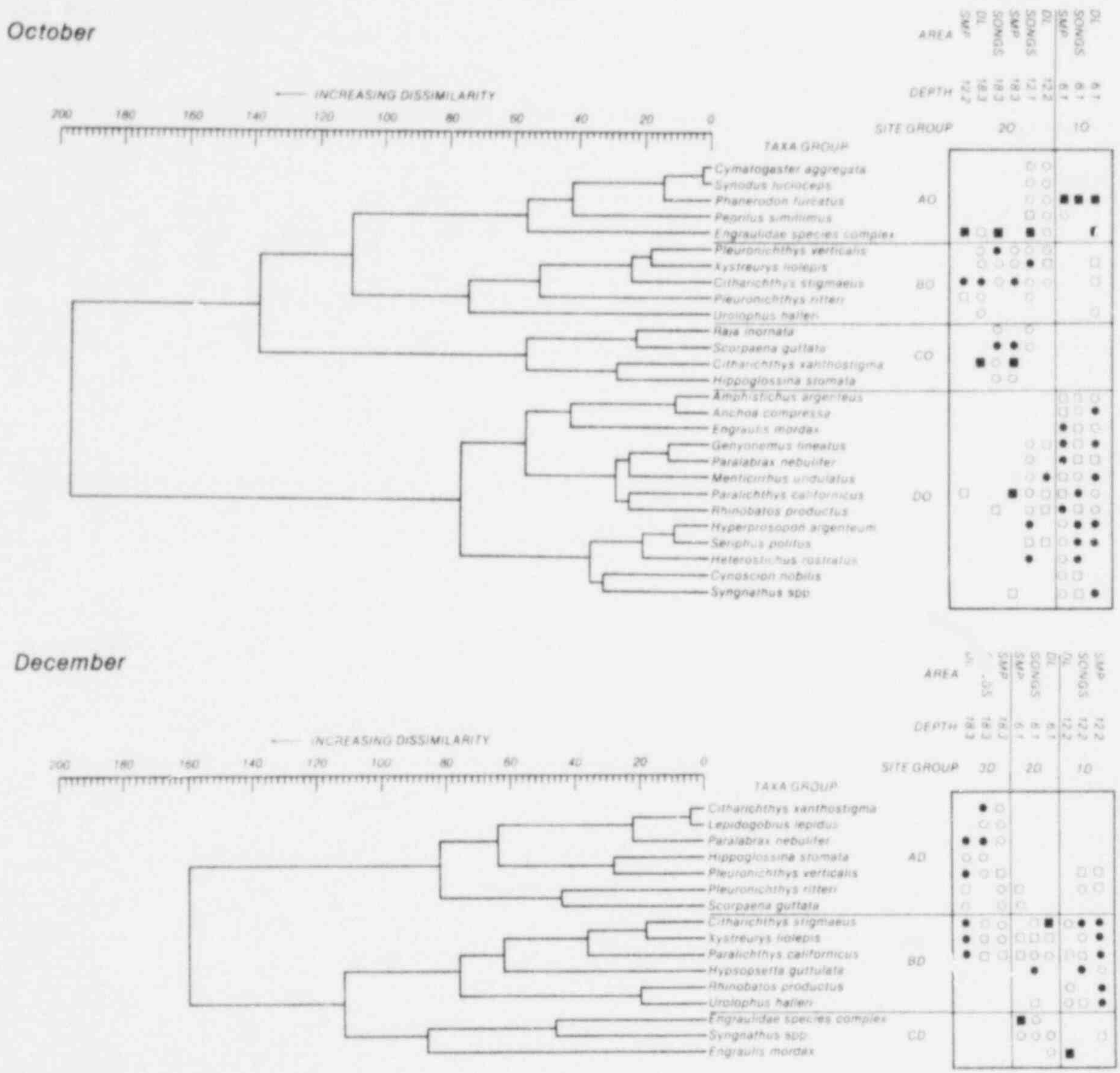


Figure 6B-32. (Continued)

above the species level that is important to an understanding of the organization of communities and one that is sensitive to nutrient related environmental differences" (Allen 1975). Fish species from the San Onofre area were classified into feeding guilds using generalized feeding roles established by Allen (1974, 1975). However, because Allen's feeding roles were based on soft-bottom fish only and the areas sampled around San Onofre consist of kelp, sand, and cobble substrata, the classification was expanded to include guilds associated with hard substratum as well (Ebeling, personal communication).

Fish were grouped into three major roles based on literature describing feeding roles, stomach contents, and functional feeding morphology. These roles include (1) strictly water-column feeders including filter feeders and mid-water planktivores; (2) water-column and substrata feeders including miscellaneous large predators of marginal and level bottom habitats, switch feeding carnivores (large-mouthed fishes that pursue nekton but often switch to eating plankton and other small prey), microcarnivorous pickers (small-mouthed fishes that usually pick small prey from plant surfaces), and plant cropping omnivores (small-mouthed fishes that browse almost exclusively on plants and epiphytic animals); (3) bottom-oriented feeders including demersal microcarnivores (small-mouthed fishes that select small prey that live in a carpet of "turf"), demersal mesocarnivores (large-mouthed species that eat relatively large prey in benthic refuges); and (4) bottom-feeding micro-mesocarnivores (fishes with medium-sized mouths that are food and habitat generalists). Most members of these guilds live on or about hard substrata. On surrounding level bottoms of sand and mud, bottom oriented feeders are classified as fishes that feed above the bottom only, feed on and above the bottom, and feed on the bottom only. Table 6B-2 lists guild members by feeding role.

To simplify the analysis and insure that feeding roles are adequately represented in fish samples, some guilds were combined as larger and more heterogeneous groups ("feeding roles"): all water column and substrata feeders (miscellaneous large predators, switch-feeding carnivores, microcarnivorous pickers) and demersal carnivores (demersal micro and mesocarnivores). Filter feeders, mid-water planktivores, and bottom-feeding micro-mesocarnivores were treated separately.

Gill Nets. Fish captured in gill nets set at the 9.1 and 13.7-m isobaths represented four feeding roles (Figure 6B-33). Degree of representation was measured by the sum of ranked relative abundances of the species within each

Key to symbols for Figures 6B-33 and 6B-34.

Group I. Fish that forage from the bottom.

- ○ those water-column and substratum feeders that forage above the bottom
- ◊ those demersal carnivores that forage on and above the bottom
- ☆ bottom-feeding micro-mesocarnivores that use sight to forage
- ▭ bottom-feeding micro-mesocarnivores that use other senses to forage

Group II. Fish that forage from the water column.

- ● filter feeders } strictly water column feeders
- ◐ midwater planktivores } strictly water column feeders
- ♦ those water-column and substratum feeders that forage mostly in the water column
- ★ those demersal carnivores that occasionally forage in the water column
- ▬ those bottom-feeding micro-mesocarnivores that enter the water column (croakers)

Table 6B-2. Feeding guild classification of adult fish species collected by gill net and otter tra-l in the San Onofre region during 1978-1979.

FISH THAT FEED FROM THE WATER COLUMN

Strictly Water - Column Feeders

Midwater Planktivores	References
Atherinops affinis	Quast 1960; Fronk 1969
Atherinopsis californiensis	Baxter 1960
Leuresthes tenuis	assumed
Seriphus politus (juvenile)	Hobson & Chess 1976
Cymatogaster aggregata	Odenweller 1975, Ellison 1978
Hyperprosopon argenteum	Hobson & Chess 1976; Ebeling & Bray 1976
Chromis punctipinnis	Hobson & Chess 1976; Ebeling & Bray 1976
Sebastes serranoides (juvenile)	Hobson & Chess 1976

Filter Feeders	References
Anchoa compressa	Klingbeil, Sandell, & Wells 1975
Anchoa delicatissima	Klingbeil, Sandell, & Wells 1975
Engraulis mordax	Baxter 1967
Engraulidae spp. complex	Berner 1959

Miscellaneous Large Predators of Marginal and Level-bottom Habitats	References
Mustelus californicus	Klingbeil, Sandell, & Wells 1975
Mustelus henlei	Klingbeil, Sandell, & Wells 1975
Triakis semifasciata	Klingbeil, Sandell, & Wells 1975
Squalus acanthias	Klingbeil, Sandell, & Wells 1975
Cynoscion nobilis	Skogsberg 1939
Sphyraena argentea	Pinkas 1966; Frey 1971
Torpedo californica	Bray & Hixon 1978
Sarda chiliensis	Oliphant 1971

Water Column and Substrata Feeders

Switch-feeding Carnivores	References
Peprilus simillimus	Bigelow & Schroder 1953, Horn 1970
Paralabrax clathratus	Love & Ebeling 1978
Paralabrax maculatofasciatus	Feder, Turner & Limbaugh 1974
Paralabrax nebulifer	Feder, Turner & Limbaugh 1974
Sebastes serranoides (adult)	Love & Ebeling 1978
Trachurus symmetricus	Feder, Turner & Limbaugh 1974
Sarda chiliensis (small)	Frey 1971
Scomber japonicus	Feder, Turner & Limbaugh 1974
Seriphus politus (adult)	Hobson & Chess 1976

Plant-Cropping Omnivores	References
Girella nigricans	Quast 1968; Ebeling & Bray 1976
Medialuna californiensis	Quast 1968
Hermosilla azurea	Quast 1968

Microcarnivorous Pickers	References
Syngnathus spp.	Quast 1968
Heterostichus rostratus	Quast 1968
Gibbonsia spp.	Quast 1968; Ellison 1978
Cymatogaster aggregata	Odenweller 1975
Micrometrus minimus	DeMartini 1969
Phanerodon furcatus	Bray & Ebeling 1975
Brachyistius frenatus	Bray & Ebeling 1975
Oxyjulis californica	Bray & Ebeling 1975
Xenistius californiensis	Quast 1968; Hobson & Chess 1976

Bottom Oriented Feeders

Demersal Microcarnivores	References
Amphistichus argenteus	Carlisle, Schott & Abramson 1960
Amphistichus koelzi	DeMartini 1969
Damalichthys vacca	Ebeling & Bray 1976
Embiotoca jacksoni	Ebeling & Bray 1976
Hypsurus caryi	Ebeling & Bray 1976
Rhacochilus toxotes	Ebeling & Bray 1976
Hypsypops rubicundus	Ebeling & Bray 1976
Halichoeres semicinctus	Limbaugh 1955; Quast 1968

Bottom Feeding Micro-Mesocarnivores	References
Cheilotrema saturnum	Limbaugh 1961
Menticirrhus undulatus	Joseph 1962, Maxwell 1975
Genyonemus lineatus	Skogsberg 1939
Umbrina roncador	Frey 1971
Roncador stearnsii	Joseph 1962
Caulolatilus princeps	Quast 1968
Anisotremus davidsonii	Quast 1968

Demersal Mesocarnivores	References
Heterodontus francisci	Nelson & Johnson 1970
Pimelometopon pulchrum	Limbaugh 1955; Quast 1968
Sebastes auriculatus	Limbaugh 1955
Sebastes atrovirens	Gotshall 1977
Sebastes carnatus	Larson 1972
Sebastes rastrelliger	Fitch & Lavenberg 1975; Gotshall 1977
Scorpaenichthys marmoratus	O'Connell 1953
Leptocottus armatus	Tasto 1975
Scorpaena guttata	Quast 1968

FISH THAT FEED FROM THE BOTTOM, MAINLY SOFT BOTTOMS

Fish That Feed Above the Bottom Only	References
Citharichthys stigmaeus	Ford 1965
Citharichthys xanthostigma	Ford 1965
Hippoglossina stomata	Ford 1965
Paralichthys californicus	Ford 1965; Haaker 1971
Xystreurys liolepis	Allen, pers. comm.
Squatina californica	Feder, Turner & Limbaugh 1974

Fish That Feed On and Above the Bottom	References
Synodus lucioceps	He..id 1977
Porichthys myriaster	Fitch & Lavenberg 1975
Porichthys notatus	Arora 1948
Otophidium scrippsi	Fitch & Lavenberg 1975
Hypsoblennius spp.	Quast 1968
Lepidogobius lepidus	assumed

Fish That Feed on the Bottom Only	References
Rhinobatos productus	Klingbeil, Sandell & Wells 1975
Platyrhinoidis triseriata	Feder, Turner & Limbaugh 1974
Raja binoculata	Bigelow & Schroder 1953
Raja inornata	Bigelow & Schroder 1953
Urolophus halleri	Babel 1967, Van Blaricom 1978
Myliobatis californica	Feder, Turner & Limbaugh 1974; Van Blaricom 1978
Hypsopsetta guttulata	Lane 1975, Lane, Kingsley & Thornton 1979
Parophrys vetulus	Ford 1965
Pleuronichthys coenosus	Ellison 1978
Pleuronichthys decurrens	Allen, pers. comm.
Pleuronichthys ritteri	Ford 1965
Pleuronichthys verticalis	Ford 1965
Symphurus atricauda	Allen, pers. comm.
Amphistichus argenteus	Carlisle, Schott, & Abramson 1960
Amphistichus koelzi	DeMartini 1969
Menticirrhus undulatus	Joseph 1962, Maxwell 1975
Umbrina roncador	Frey 1971
Roncador stearnsii	Joseph 1962

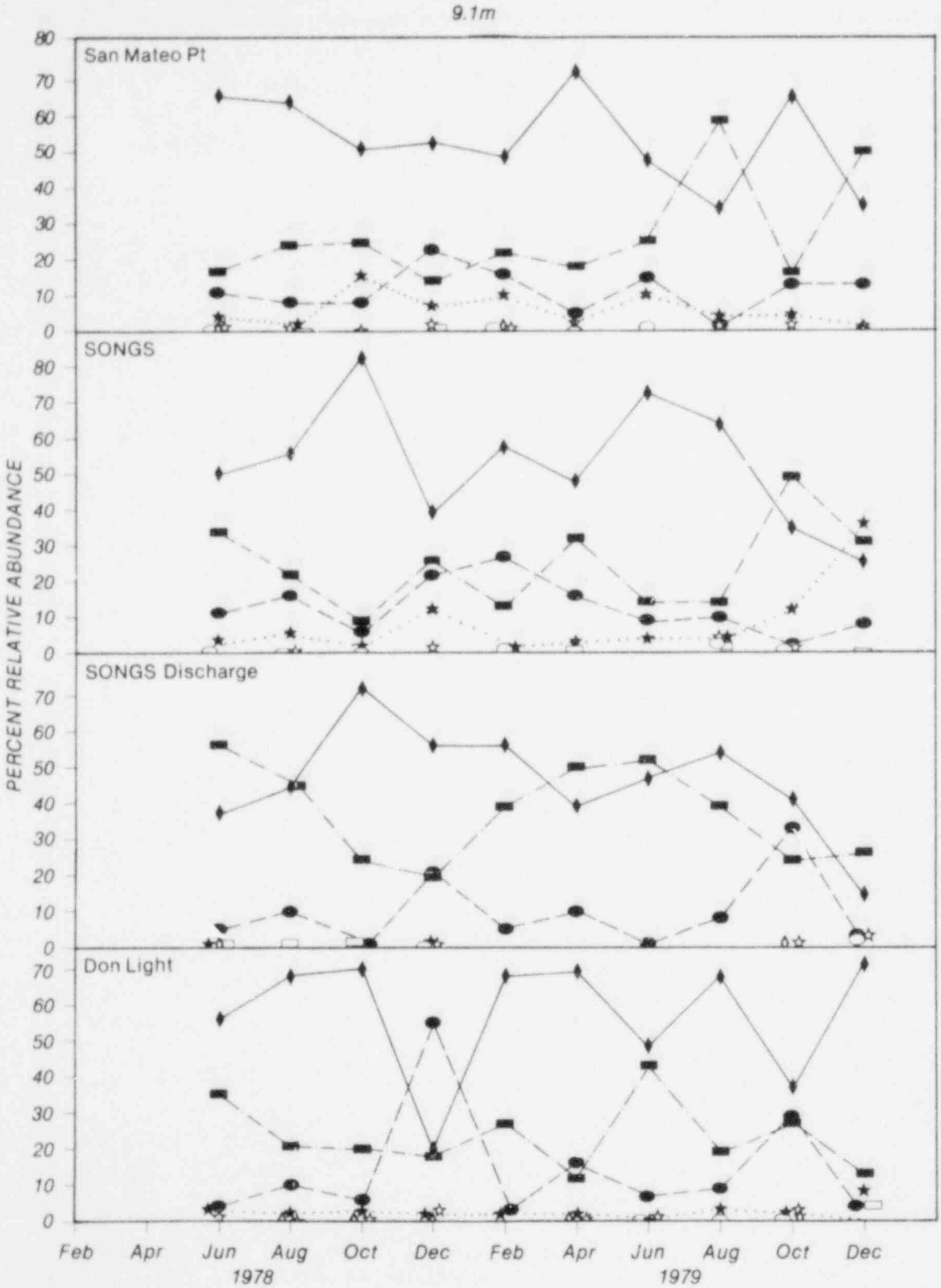


Figure 6B-33. Relative abundance of fish comprising demersal or water column feeding roles. Based on combined data from 1978-1979 gill net collections made at 9.1 m and 13.7 m in the San Mateo Point, SONGS, SONGS Unit 1 discharge, and Don Light areas.

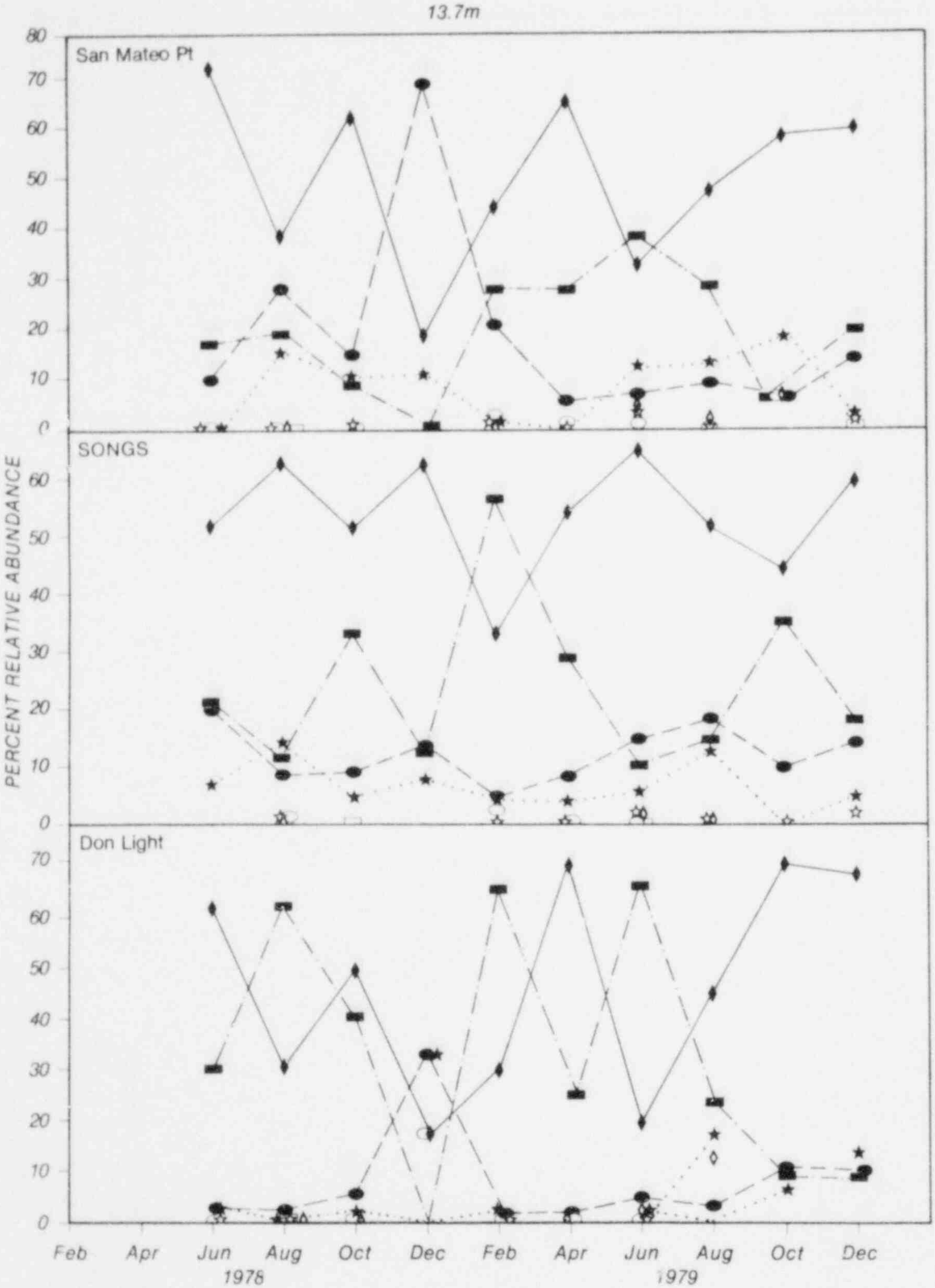


Figure 6B-33. (Continued)

feeding role (Table 6B-3): water-column and substrata feeders, bottom-feeding micro-mesocarnivores, midwater plantivores, and demersal carnivores. Water-column and substrata feeders were represented largely by adult queenfish, Seriphus politus, and to a lesser extent by white surfperch, Phanerodon furcatus, and basses such as Paralabrax spp. Bottom feeding micro-mesocarnivores were represented mainly by white croaker. Midwater planktivores included atherinids (topsmelt and jacksmelt), walleye surfperch, and juvenile queenfish. Demersal carnivores included cottids (sculpins), embiotocids (pile surfperch, Damalichthys vacca, and black perch, Embiotoca jacksonii) wrasses (California sheephead, Pimelometopon pulchrum, and rock wrasse, Halichoeres semicinctus), and various rockfish (Sebastes spp.). The order of rank sums was generally maintained during all surveys at all areas and depths. Water-column and substrata feeders dominated the gill net catches to a greater extent than members of more specialized feeding roles primarily because of the overwhelming abundance of Seriphus.

Rank order of feeding roles did not differ significantly between areas or depths during 1978 or 1979. Fewer feeding roles were represented in gill net catches made adjacent to the SONGS Unit 1 discharge than in catches from other areas primarily because of the absence of demersal carnivores.

Table 6B-3. Summed ranks of the four major fish feeding roles captured in gill nets set at 9.1 and 13.7-m isobaths at SONGS, San Mateo Point, and Don Light during 1978 and 1979.

Depth	Feeding Role	Area			
		San Mateo Point	SONGS	SONGS Discharge	Don Light
9.1 m	Midwater Planktivores	31	31	28	27
	Water-column and substrata feeders	12	13	15	11
	Demersal carnivores	38	36	40	39
	Bottom-feeding micro-mesocarnivores	19	20	17	23
13.7 m	Midwater planktivores	28.5	28	--	28.5
	Water-column and substrata feeders	12	11	--	24
	Demersal carnivores	34	38	--	34.5
	Bottom-feeding micro-mesocarnivores	25.5	23	--	22

Otter Trawls. The majority (> 90%) of fish species caught in otter trawls at the 6.1, 12.2, and 18.3-m isobaths were members of six feeding roles (Figure 6B-34). Trawling depth accounted for the largest difference in roles. The trawl catch at the 6.1-m isobath was dominated throughout 1978-1979 by four feeding roles: (1) mid-water planktivores (mainly juvenile Seriphus), (2) filter feeders (mainly anchovies), (3) water-column and substrata feeders (mainly adult Seriphus), and (4) bottom-feeding micro-mesocarnivores (mainly adult and juvenile Genyonemus, Figure 6B-34). Otter trawl catches of numerically dominant filter feeding fish were highly variable through time, indicating that filter feeders were patchily distributed at mid-depth (12.2 m). Nearshore (6.1 m), mid-water planktivore and water-column-substrata feeding groups were dominated by immature and adult Seriphus in 1978 and 1979. Likewise, high catches of Genyonemus dominated the bottom-feeding micro-mesocarnivore group throughout the study area.

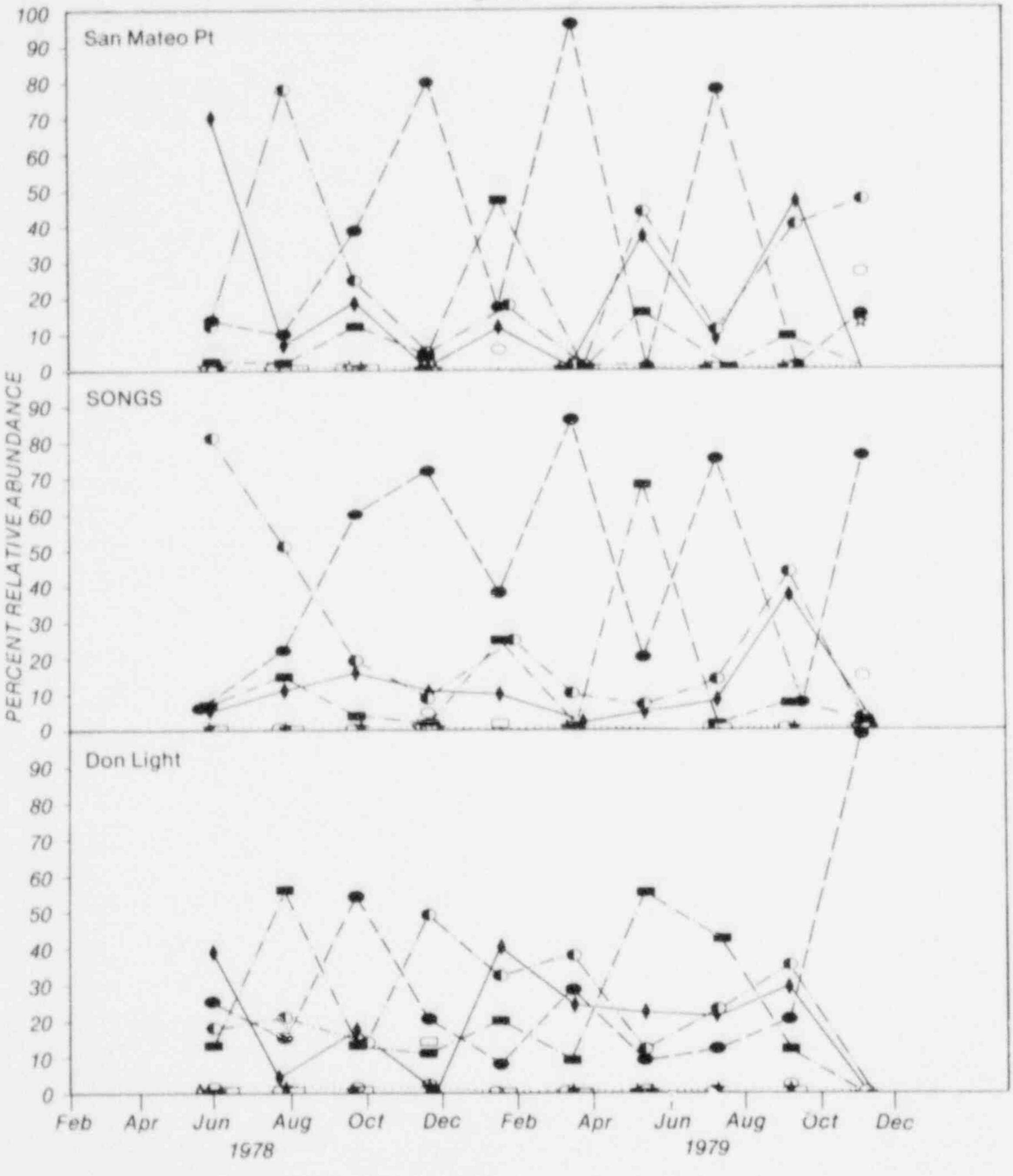
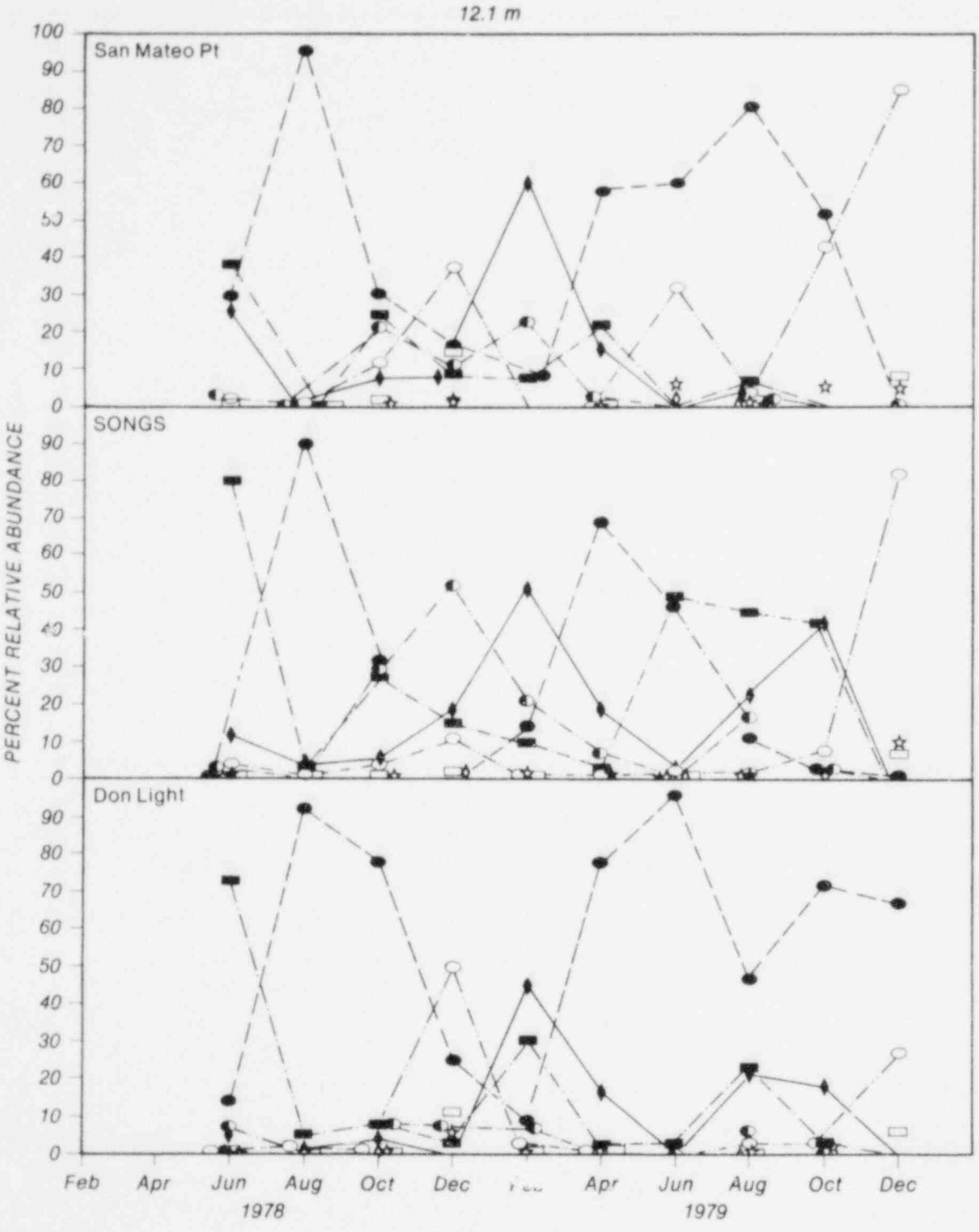


Figure 6B-34. Relative abundance of fish comprising demersal or water column feeding roles. Based on combined data from 1978-1979 otter trawl collections made at 6.1, 12.2, and 18.3 m in the San Mateo Point, SONGS, and Don Light areas.



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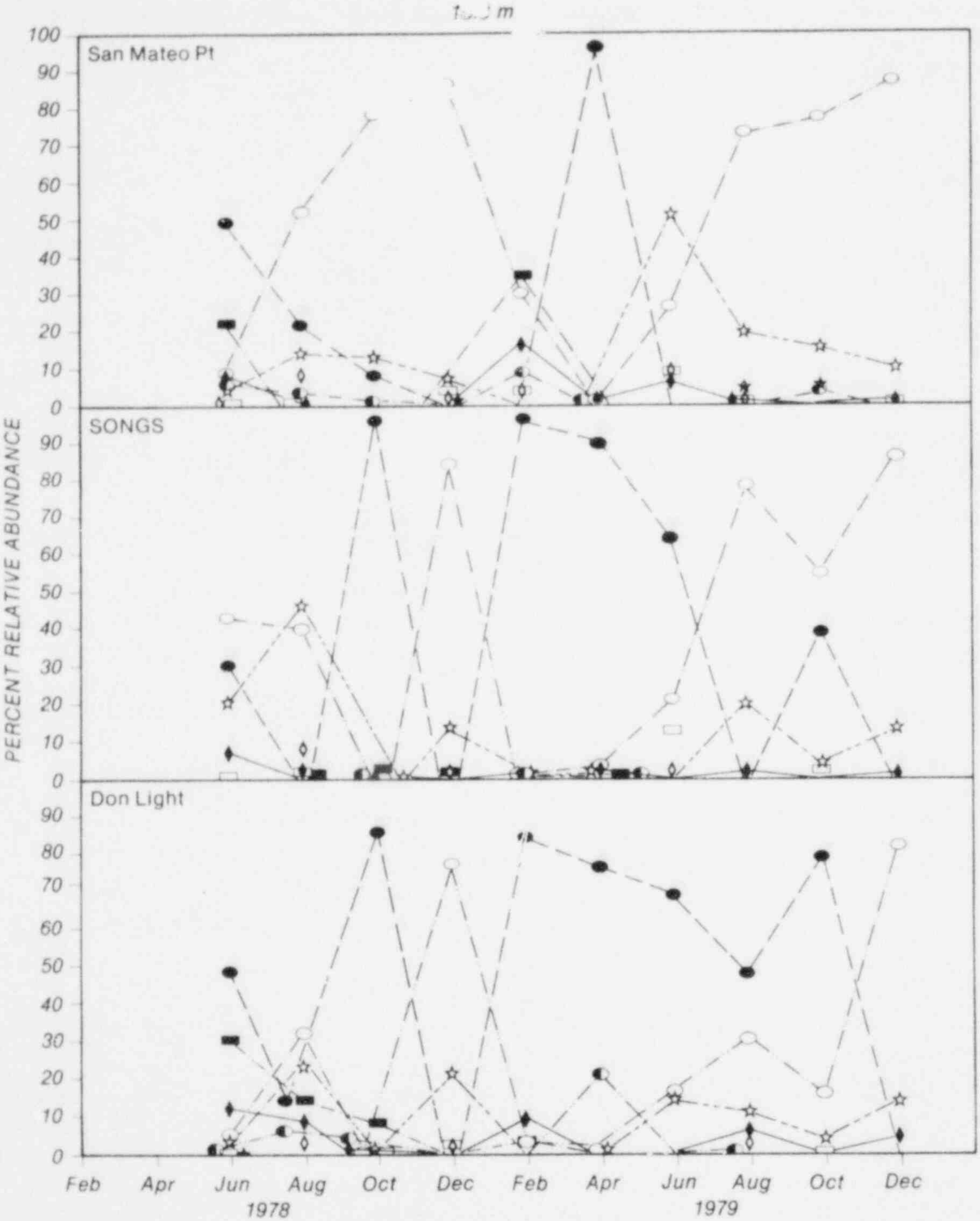

Figure 6B-34. (Continued)

The four roles dominant at the 6.1-m isobath were also dominant further offshore at the 12.2-m isobath. Along the 18.3-m isobath, however, high catches of two bothid flatfish, Citharichthys stigmaeus and Paralichthys californicus, represented a fifth role of soft-bottom fish that feed above the bottom and abundances of pleuronectid flatfishes (Pleuronichthys ritteri, P. verticalis, Parophrys vetulus) made up a sixth role of fish that feed on the bottom only (Figure 6B-34).

Feeding-guild rank order differed significantly among most areas and depths (Friedman's nonparametric ANOVA, $P \leq 0.05$; Table 6B-4). Rank orders of feeding

Table 6B-4. Summed ranks of feeding roles represented by otter trawl catches at San Mateo Point, SONGS, and Don Light during 1978 and 1979.

Depth	Feeding Role	Area: San Mateo Point	Area: SONGS	Area: Don Light
6.1 m	Pelagic			
	Filter feeders	20.5	16.5	26
	Midwater planktivores	19.5	20.5	20.5
	Water-column and substrata feeders	29	31.5	27
	Bottom-feeding micro-mesocarnivores	34	31.5	29.5
12.2 m	Demersal			
	Water-column and substrata feeders	32	38.5	39
	Pelagic			
	Filter feeders	17.5	29	14.5
	Midwater planktivores	34.5	32	36.5
	Water-column and substrata feeders	39.5	25.5	32.5
	Bottom-feeding micro-mesocarnivores	30.5	25	27.5
18.3 m	Demersal			
	Water-column and substrata feeders	16.5	19	26.5
	Demersal carnivores	28	27.5	31.5
	Pelagic			
	Filter feeders	40	28.5	20
	Midwater planktivores	41	48	48.5
	Water-column and substrata feeders	38.5	40.5	41.5
	Bottom-feeding micro-mesocarnivores	43	46.5	42

guilds at the SONGS 12.2-m sampling site were not significantly different through time. Unlike the 12.2-m isobath sampling sites at San Mateo Point and Don Light, the SONGS 12.2-m isobath produced more bottom carnivores and water-column-substrata feeders than filter-feeders (Figure 6B-34).

EFFECTS OF OCEANIC CLIMATE ON THE COMMUNITY AND SELECT SPECIES POPULATIONS

Seasonal patterns in the total number of individuals and a select species (Seriphus politus) caught in gill nets were compared with seasonal physical oceanographic and climatological patterns. The 1975-79 gill net samples from the 9.1-m isobath in the SONGS and Don Light areas were analyzed.

The late-fall through early-spring months (November-March) were characterized by well-mixed (no thermocline) surface and bottom waters. Beginning in late spring (April), a thermocline developed and was strengthened from June through October by the combined effects of solar heating of surface waters and intrusion of colder bottom water originating from the California current (Tont 1976, Hartline 1980). During the thermally stratified period (June to October), bottom water temperature was the coldest observed during the year. Marked fluctuations in temperature occurred during the stratified period compared to the non-stratified period (November-March): winds broke up the thermocline for short time periods (7 days) so that thermally dissimilar surface and bottom water masses subsequently mixed. Also, tides and internal waves caused daily fluctuations as much as 4-5°C in bottom temperatures during the thermally stratified period.

Daily rainfall totals and deviations from the six-day moving average of wind speed, wave height, and barometric pressure identified periods of storm activity. Storm periods showed increased wind speed and wave height (deviation above the moving averages), decreased barometric pressure (deviation below the moving average), and a measurable amount of rainfall.

After assigning total and select species (queenfish) abundances to either thermally or non-thermally stratified seasons, samples taken after storm or non-storm periods were compared within each "season". Separate comparisons were made for the treatment and downcoast control areas because the variance in catch usually differed significantly between the two areas (LCMR 1977a, 1978a, SCE 1979d). Total gill net catches made during calm, thermally non-stratified periods were significantly ($P \leq 0.05$) greater than catches made during stormy periods in both the SONGS and Don Light areas (Table 6B-5). Storm activity

Table 6B-5. Results of one-way analysis of variance comparing gill net (9.1-m isobath) of *Seriphus politus* between storm and non-storm periods during the thermally stratified portions of the year from 1975 to 1979 at SONGS and Don Light. Significance levels appear opposite the period (storm or non-storm) which had significantly greater catches.

		Area			
		SONGS		Don Light	
Period	Comparison	Total Catch	Seriphus	Total Catch	Seriphus
Thermally Non-stratified (Feb, Dec)	Non-Storm	$P \ll 0.05$**	$P \ll 0.05$	$P < 0.05$	NS
	vs				
	Storm	--	--	--	NS
Thermally Stratified (Mar, Apr, Jun, Aug, Sep, Oct)	Non-Storm	--	$P < 0.05$	NS	$P < 0.05$
	vs				
	Storm	$P < 0.05$*	--	NS	

* $P < 0.05$ Significant at $P \leq 0.05$ NS Not significant
** $P \ll 0.05$ Highly significant at $P < 0.05$

during the thermally stratified oceanic season had the opposite effect (Table 6B-5). Catches were actually greater after storms in the treatment area (SONGS), but catches made after storms in the downcoast control area (Don Light) did not differ significantly from catches after calm periods.

Seriphus politus catches were similarly analyzed. In both areas queenfish catches after calm periods were, generally, significantly ($P \leq 0.05$) greater than those made after periods of storm during both the thermally non-stratified (winter) and the thermally stratified (summer) periods (Table 6B-5).

DISCUSSION

The fish studies currently 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 for biological alterations associated with the operaton 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.

The fish community in the vicinity of SONGS is characterized by its structure and variability in time. At the species level, temporal variability was examined by following the population dynamics of selected species as measured by their abundance, length-structure (year-class strenth), sex composition and seasonal reproductive patterns. Whole community structure was analyzed by multivariate classifications of study sites by their species composition and of species by their representation at study sites. Feeding guilds were also defined within the community, then their composition was followed among depths, seasonal periods, and years.

POPULATION ANALYSIS

Seriphus politus

The nearshore habitat ($\leq$ 18.3 m) in the vicinity of San Onofre supports a queenfish, Seriphus politus, population throughout most of the year (LCMR 1976c, 1977a, 1978a). The temporal (seasonal) and spatial abundance patterns observed for gill net catches on the 9.1-m isobath from 1975 to 1979 were also observed for gill nets at 13.7 m and for 5-minute otter trawls conducted at the 6.1-m and 12.2-m isobaths in 1978 and 1979. In general, the adult queenfish population increased from April through October (peak catches in October 1978 and August 1979; Figure 6B-2). Seriphus during this time of the year are reproductively active as defined by gonosomatic indices (GSI) and the length structure of queenfish (juveniles) caught in otter trawls. Increasing mean GSI's from February through April indicated the onset of gametogenesis; spawning occurred from April through August, as shown by decreasing GSI's (Figure 6B-8). A recovery or resting period followed spawning and extended from August to February.

The dominance of juvenile queenfish in otter trawl catches from April through October provided further evidence for reproductive activity. Juveniles were first caught nearshore (12.2-m isobath) beginning in March and April (Figure 6B-6). These early arrivals probably migrated inshore from offshore spawning grounds (Skogsberg 1939; Watson, Barnett, and Sertic 1979). Time of spawning may have occurred as early as 25 days prior to the March or April surveys as the average pelagic phase of queenfish preflexion larvae is approximately 25 days (Walker 1979) or these juveniles may have resulted from spawning late in 1978. Recruitment of the young-of-the-year to shallow depths (6.1 m) continued from June to October. During this six month period, young-of-the-year utilized the shallow depths as nursery areas for early growth and development. By October, these individuals were sufficiently large to join the adult population and migrate to deeper water (Figure 6B-6). Offshore migration reduced the inshore population to a small remnant stock of adults and juveniles which over-wintered nearshore; juveniles reappear as one-year old individuals (approximately 120 mm SL) the following year. The adult segment of the queenfish population also displayed offshore migratory behavior as gill net catches of adults decreased dramatically from October to February (Figure 6B-2).

Physical factors which might initiate or mediate this distribution and abundance pattern are presently unknown, although oceanic "disturbances" such as storms and cold water intrusions (upwelling) may be partially responsible. An evaluation of long-term temperature cycles (BC 1978, SCE 1979a), climatological data, and queenfish catches indicate that onset of spawning and initial juvenile recruitment coincided with decreasing water temperatures generally associated with the intrusion of cold water derived from the California Current (Tont 1976, Hartline 1980). During the past two years (1978, 1979) four upwellings, defined by rapidly decreasing bottom temperatures, occurred coincident with fish surveys (August and October 1978; June and August 1979). These surveys were conducted under thermally stratified, non-storm conditions, (i.e., the water column was stable). Comparison of queenfish catch obtained in this period (August, October 1978; June, August 1979) with that obtained during thermally stratified storm periods preceeding surveys (April 1977, June 1976, September 1976, October 1979; i.e., water column instability), indicated significantly greater Seriphus catches during the calm periods.

It is suggested that upwelling may occur at a time when adult and juvenile queenfish are migrating inshore. Inshore migratory patterns may result from: (1) avoidance of the cold oxygen depleted upwelled water (Laevastu and Hela 1970); (2) avoidance of upwelled water combined with abundant food and cover nearshore; or (3) presence of abundant food and cover. It is interesting to note that high catches of juvenile queenfish (as small as 10 mm SL) in otter trawls were taken during the thermally stratified, calm (water column stability) months of August, October 1978 and 1979 (Figure 6B-6). This situation (water column stability and high abundance of larval and post-larval fish) parallels that shown for the northern anchovy, Engraulis mordax, in which temporal and spatial stability of the ocean is considered essential for survival and growth of first feeding larval Engraulis (Lasker and Zweifel 1978) and older larvae (Vlymen 1977).

The reasons for offshore migration of queenfish in October to December in 1978 and 1979 are also uncertain. During the thermally non-stratified (water column instability) part of the year (December), catches of queenfish were reduced following storm periods. This reduction indicates that queenfish may migrate offshore to avoid heavy surge and terrestrial runoff accompanying winter storms.

Female Seriphus dominated gill net collections inshore (9.1 m) and offshore (13.7 m) except in the beginning of the year at Don Light (Figure 6B-7). Inshore (6.1 m) otter trawl catches also contained mostly females (Figure 6B-7). However, male queenfish dominated the offshore (12.2-m) otter trawl catches. Perhaps gill nets are more efficient at catching the relatively larger females, yet the inshore offshore distribution of sex ratios reflects the overall sex composition of queenfish populations observed off San Onofre during 1978 (SCE 1979b).

Mean queenfish catch from gill nets set near the SONGS Unit 1 discharge structure remained uniform during winter in contrast to declining catches in all other areas on the 9.1-m isobath (Figure 6B-4). Mean GSI values indicated that fish collected near the SONGS Unit 1 discharge were in differenct reproductive condition than those sampled in other areas. Queenfish in this localized area appear to have matured and spawned earlier (as indicated by depressed GSI's) than queenfish in other areas (Figure 6B-8). The hypothesis that the thermal discharge influences the maturation of these fish seems highly unlikely because migratory patterns indicate that fish may continually move in and out of the area of the thermal plume. Perhaps short-term exposure to slightly elevated temperatures ("thermal stress") induces spawning in females that are already ripe (Jalabert 1976). Larger queenfish naturally begin spawning earlier than average size females (DeMartini and Fountain 1979), but the size distribution of females from the SONGS Unit 1 discharge area resembled that of fish collected at the same depth in other areas. No other effects of the Unit 1 discharge were noted for queenfish populations.

Genyonemus lineatus

The nearshore habitat of San Onofre also supports a large population of white croaker, Genyonemus lineatus throughout the year (LCMR 1976c, 1977a, 1978a). The temporal and spatial patterns observed in gill net catches from the 9.1-m and 13.7-m isobaths in 1978 and 1979 indicate that fish move inshore from March to December (Figures 6B-10, 11). By February, white croaker have moved offshore again, where the cycle repeats itself. Evaluation of GSI's for white croaker indicate that adults enter spawning condition in October and apparently spawn offshore at depths deeper than 20 m (Chapter 6A Ichthyoplankton; Walker 1979; Watson, Barnett, and Sertic 1979; DeMartini personal communication). Spawning continues through April. Beginning in February or March, a larval recruitment pattern similar to that for queenfish, was evident from length frequencies of fish caught in otter trawls. Young-of-the-year begin appearing in trawl catches at the 12.2-m site in March (Figure 6B-13). From March through October continued recruitment and growth occur nearshore (Figure 6B-13) until December, when overall numbers decline. Like queenfish laggards, the remaining Genyonemus make up a remnant or maintenance population which over-winters in the SONGS vicinity.

The similarity in spatial and distributional patterns between queenfish and white croaker from March to December in 1978 and 1979 suggests that fluctuation in weather between unstable periods of upwelling or storms and stable periods of water column stratification (August, October) affect distribution of juvenile white croaker in much the same manner as postulated for queenfish.

Unlike queenfish, white croaker were not sexually dimorphic in size, in time of maturation, or in spatial distribution. These 1979 results agree with the 1978 results (SCE 1979d).

Like queenfish, female white croaker caught in gill nets set near the Unit 1 discharge had depressed GSI's as though they were either less fecund to begin with or induced to spawn early (Figure 6B-15). The implications of this are obscure. Since, like queenfish, members of the croaker family are highly fecund, broadcast spawners producing several thousand eggs per spawning (DeMartini and Fountain 1979), it seems unlikely that a lowered fecundity in one segment of the population would affect the whole. Relatively few highly fecund fishes with this kind of "high fecundity, high mortality" reproductive strategy can maintain the population at large; i.e., fecundity is generally uncorrelated with the size of the adult population at any given time (Rounsefell 1975). Large predatory fishes that usurp localized areas of thermal discharge gain a metabolic advantage over their prey in cooler peripheral areas (Coutant, et al. 1979). If such predators so deploy themselves at SONGS, they may differentially crop more vulnerable prey (gravid females) in the immediate vicinity. Perhaps SONGS catches reflect this.

Hyperprosopon argenteum

The temporal and spatial abundance patterns of the walleye surfperch, Hyperprosopon argenteum, somewhat resemble those of Seriphus and Genyonemus. The series of gill net catches from 1975 to 1979 at the 9.1-m isobath and from 1978 to 1979 at the 13.7-m isobath indicate that adults tend to move offshore from December to June and inshore from June through October (Figures 6B-17 and 6B-18). Otter trawl catches of walleye surfperch indicate that recently born juveniles accompany the adults during the offshore movement (Figure 6B-14).

Female walleye surfperch probably move inshore to bear young conceived in October-December (Rechnitzer and Limbaugh 1952). Maximum otter trawl catches of pregnant females occurred inshore during June (Figure 6B-19). The time between fall mating and the presence of 40-70 mm SL juveniles inshore corresponds to the six month gestation period described by Richnitzer and Limbaugh (1952). Juvenile Hyperprosopon probably remain nearshore for a relatively short time (1-2 months), because 60-85 mm SL individuals (90% of the catch) were caught offshore (12.2 m) only 1-2 months later in August (Figure 6B-19). Like queenfish and white croaker, walleye surfperch may have left the sampling area during December 1979 in response to relatively severe storm activity.

The mean catch of Hyperprosopon in the study area has declined gradually since the sampling program began in 1975. Although gill net catches of Hyperprosopon are relatively small and variable this trend is clear (Figure 6B-17). Mean catches of Hyperprosopon in 1979 were generally lower than any previous year. The reason for this decline is presently unknown but may be related to their reproductive strategy and localized movement patterns. Like all embiotocids, walleye surfperch have a "low fecundity, low mortality" reproductive strategy. Females bear relatively few but large and robust young, a relatively large proportion of which survive to maturity (Rechnitzer and Limbaugh 1952). Surfperches also display a limited range of movement during their lifetime as evidenced in tagging and observational studies (Carlisle, Schott, and Abramson 1960; Hixon 1979, Halderson 1980). Regardless of the reason for the decline, these characteristics suggest that walleye surfperch are not compensating for the decline by births or immigration.

Phanerodon furcatus

Phanerodon furcatus, the white surfperch, exhibits a reproductive strategy similar to that of Hyperprosopon. Its seasonal cycle of mating and birth coincides with that of Hyperprosopon (insemination during fall and winter; birth in April and May). However, the spatial distribution of Phanerodon during the reproductive portion of the year differs from that of Hyperprosopon. Unlike Hyperprosopon, Phanerodon tends to remain offshore (9.1-m isobath) during the breeding season, rather than moving inshore (Figures 6B-21, 22, and 23). The series of gill net catches from 1975 to 1978 (Figure 6B-21) indicate that this cycle occurred regularly through 1978. Yet in 1979, mean catches of Phanerodon were significantly reduced. Surface and bottom water temperatures during November and early December in 1979 were 2-3°C cooler than in the previous years. Cooler water prior to, or during the reproductive season may have delayed breeding.

The general decline in walleye surfperch catch from 1975 to 1979 was not matched by Phanerodon during this period (Figure 6B-21). Yet a decline in both might have been expected because both surfperches have similar distribution patterns and reproductive strategies.

COMMUNITY ANALYSIS

A multivariate classification (cluster analysis) of the fish community represented by gill net catch offshore SONGS indicated that the composition of the fish community as measured by groups of associated sampling sites or of fish species varied most with depth and that this variation persisted somewhat through time. The absence of similar predictability in species composition among sampling areas (stations) may reflect localized and, for the most part, unknown movement of fish between cobble and marginal habitats where the gill nets were set. With the exception of those of a persistent ubiquitous group of fishes with different feeding roles (Seriphus politus, Genyonemus lineatus, and California corbina, Menticirrhus undulatus), a more localized group of demersal carnivores (pile surfperch, Damalichthys vacca, rubberlip surfperch, Rhacochilus toxotes, grass rockfish, Sebastes rastrelliger, California sheephead, Pimelometopon pulchrum); and a diverse group of water-column and substrata feeders (white seabass, Cynoscion nobilis, leopard shark Triakis semifasciatas, gray smoothhound, Mustelus californicus, kelp bass, Paralabrax clathratus, barred sandbass, Paralabrax nebulifer), consistent distributional and abundance patterns were not readily apparent. The absence of pattern observed from gill net catches likely stems from the inability to accurately sample moving fish assemblages at fixed sites.

Considerable evidence (Bray and Ebeling 1974, Murdock, Avery and Smith 1975, Love and Ebeling 1978) indicates that predatory fish may switch prey items depending upon season, geographic area and faunal mix, changing habitat, and density of prey. Although many of the fish taxa in the San Onofre vicinity exhibit distinct feeding roles there is evidence (Quast 1968b) that considerable dietary overlap exists between demersal carnivores for heavily utilized prey such as gammarid amphipods and crabs. Localized movements, therefore, may be related in part to mutual foraging activity by resident species whose diets broadly overlap.

Changes (short-term or long-term) in nearshore oceanic climate and its effect on nearshore fish community dynamics, until recently, have either been unrecognized or understated (Mearns 1978). In an intensive study by the Southern California Coastal Water Resources Project (SCCWRP) of nearshore (10 to 360 m) demersal fish communities in the Southern California Bight, significant community changes were correlated with long term (10 year) changes in oceanic temperatures (Mearns 1978). On the shorter term, yearly changes were associated with onset of upwelling. When upwelling occurred, many demersal fish species avoided the intruding, cold, oxygen depleted water by moving inshore or upward in the water column and offshore (SCCWRP 1973). In addition, "... it seems reasonable to presume that demersal fish will also avoid other kinds of water mass changes, such as those associated with strong storm runoff..." (SCCWRP 1973). In the present study off San Onofre analysis of the relationship between total gill net catch and storm activity for the 9.1-m isobath from 1975 to 1979 substantiates this hypothesis for the thermally non-stratified portion of the year (November, December, January, February). The total fish catch was significantly reduced during the unusually stormy periods of December 1978 and December and February 1979 (Table 6B-5). During the thermally stratified portion of the year (June, August, September), however, when breeding and newly recruited populations of two croaker species (queenfish and white croaker) are very abundant nearshore (LCMR 1978c), total catches were actually higher after relatively mild summer storms. Perhaps the breeding population, which remain inshore, are most vulnerable to gill nets then (May, Trent and Pristas 1977).

The site and species classifications based on otter trawl catches resolved well-defined spatial and temporal groups within the demersal fish community sampled on soft substrata. Consistent differences in group composition with depth was most likely related to seasonal breeding and recruitment patterns and to a habitat discontinuity at the 18.3-m isobath. An inshore group including queenfish, barred surfperch, Amphistichus argenteus, California corbina, and thornback ray, Platyrhinoidis triseriata, best illustrate the predictable spatial and temporal pattern. Juvenile and adult queenfish numerically dominate otter trawl catches from June through October. Their distribution appears to be limited to the 6.1 and 12.2-m isobaths from April through September. Then from October through December they move offshore, either leaving remnant populations inshore between the 6.1 and 12.2-m isobaths (as in 1978) or evacuating the inshore area completely (as in 1979). Reasons for the prolonged residence time (April through September) and the offshore movement are little known. Aside from the presence of sexually mature female queenfish in nearshore waters as predicted by their reproductive pattern (Skogsberg 1939), large numbers of young-of-the-year and year-old queenfish have dominated nearshore otter trawl catches for the past two years from June through October (see discussion of select species populations). Perhaps during the thermally non-stratified portion of the year (January through April) maintenance populations of the inshore species group reside inshore. Beginning in March some species (queenfish) start spawning and continue until August (DeMartini 1979). Coincident with initial larval recruitment and spawning, upwelling drives juveniles and spawning adults inshore where they avoid the cold water (Mearns 1978). Juvenile fish remain inshore where cover and food (possibly resulting from phytoplankton blooms) are plentiful throughout the thermally stratified portion of the year. Then winter storms, dwindling food resources and/or changes in feeding behavior drive the majority of the population offshore again. Corroborative evidence for such oceanic events affecting distribution and abundance patterns and cohort strength of fish species are provided by Lasker and Zweifel (1978), Mearns (1978), Parrish and MacCall (1978), and Hayman and Tyler (1980).

As sampled by a combination of gill net and otter trawl catches over the past several years, the fish community offshore SONGS contains a diverse assemblage of demersal and water-column fishes displaying a wide variety of feeding habits. Distributional variability in time and space probably results from localized foraging movements during much of the year combined with movements associated with spawning and juvenile recruitment. Oceanic events, including upwelling and storm activity (including rainfall), may mediate these movement patterns and serve as "forcing functions". Superimposed on these long-term onshore-offshore shifts in fish abundance are daily shifts bypassed by present sampling. For example, walleye surfperch and queenfish move offshore at night (DeMartini 1979) to eat plankton (Ebeling and Bray 1976; Hobson and Chess 1978). The treatment site (SONGS) did not contain unique fish groups relative to the control areas nor did a given species group numerically dominate the treatment site. Operation of SONGS Unit 1, therefore, had no apparent effect on fish community structure evaluated by classification analysis.

FEEDING GUILDS

Analysis of feeding guilds was designed to assess spatial and temporal predictability of the distribution of fishes, that have similar feeding (trophic) roles in the community. Water-column and substrata feeders, represented abundantly by such switch feeding carnivores as adult queenfish, kelp bass, and barred sand bass, made up the most predictable (in terms of their rank abundance among areas and through time) guild caught in gill nets, followed by bottom micro-mesocarnivores, (generalized feeders that eat both small and medium-sized prey from the bottom in a variety of level-bottom habitats), midwater planktivores, and demersal carnivores (fish that select prey from benthic refuges).

The spatial predictability of these groups probably relates to substrata type and onshore coastal physiography. Quast (1968a) conducted an intensive study of the rocky inshore fish fauna off of Del Mar, California and two sites further south. He suggested that substratum character was of primary importance to the species composition of rocky inshore fishes. Comparing the composition of the San Onofre feeding guilds with those of Quast reveals many similarities. In particular, groups of fishes caught in gill nets in the SONGS vicinity resembled Quast's (1968a) "Zone II" and "Zone III" fish assemblages. The substratum at San Onofre gill net stations consists primarily of a low-relief (< 30 cm) mosaic of cobble and boulders interspersed with sand channels and patches. Quast's Del Mar site (and other sites) also had channels and patches of sand breaking up the predominantly rocky sample site. Similarities in the coastal physiography of the Del Mar and San Onofre sampling sites may also partly account for their similar fish assemblages. Both sites are characterized by extensive areas of sand beach exposed to heavy surf. Poorly compacted, eroding sea cliffs criss-crossed by discontinuously flowing streams and creeks form the inshore boundary of the beach. These streams discharge substantial amounts of terrigenous sediment during periods of high rainfall, thereby contributing additional material to the seasonal cycle of sand accretion and erosion, and increasing nearshore turbidity (Chapter 5B).

High rank orders of some guilds were first thought to simply reflect overwheliming numbers of adult queenfish, a water-column and substrata feeder, and white croaker, a bottom micro-mesocarnivore. Eliminating these species from the analysis, however, did not alter the spatial or temporal patterns observed. This suggests that as entire groups of several species the guilds ranked highest in total abundance (water-column and substrata feeders, and bottom micro-mesocarnivores), also have the functionally dominant feeding roles in the San Onofre study area. The relatively low rank of midwater planktivores (blacksmith, Chromis punctipinnis; northern anchovy, Engraulis mordax; and jacksmelt, Atherinopsis californiensis) in gill net catches is expected for two reasons. First, the absence of high relief substrata excludes large numbers of blacksmith, which shelter in rock holes at night (Ebeling and Bray 1976), and second, slender fish of the other species may be relatively adept at avoiding entanglement in gill nets. The lowest ranking guild of demersal carnivores contains many species that may be relatively rare in the SONGS sampling sites. Some demersal carnivores like the rubberlip surfperch, gopher rockfish, Sebastes carnatus, and sheephead, eat prey such as crabs associated with thick algal turf and complex refuges, and require shelter in rock holes or crevices. Since these requirements are generally not met in the study areas, abundances of these fishes are low. Other demersal carnivores like the black surfperch, Embiotoca jacksoni, and pile surfperch, require only the turf food source and algal cover for their young. Therefore, they occur in fair numbers over the cobble bottom under San Onofre Kelp, and so are taken frequently, though not abundantly in gill nets at the periphery of their habitat. Thus they are predictably represented in the samples.

Although the movement patterns of many of the species comprising the feeding guilds are unknown, the consistency of their rankings among seasons indicates that many of the member species are resident off San Onofre during most of the year. The switch-feeding carnivores, a subset of water-column and substrata feeders, including queenfish, kelp bass, and barred sand bass best exemplify such resident species which have always been recorded at San Onofre. Historical gill net catch records off San Onofre (LCMR 1976d, 1977b, 1978c) consistently documented the occurrence of queenfish throughout most of the year. Intensive tagging of adult kelp bass off southern California indicated that recaptures (80%) were near the release sites (Collyer and Young 1953, Young 1963). The regularity with which water-column and substrata feeders are sampled indicates that most member species may remain and feed within a definite area.

Midwater planktivores (e.g., juvenile queenfish and walleye surfperch), filter feeders (northern and deepbody anchovies), water-column and substrata feeders (adult queenfish), and bottom-feeding micro-mesocarnivores (mainly adult and juvenile white croaker) predominated in otter trawl catches. Unlike feeding guilds as sampled by gill net, guilds sampled by otter trawl were highly variable in distribution, both in time and space.

Feeding roles varied mostly with depth of sampling site. The general category of fish that forage near or on the bottom most clearly shows how guild composition may vary bathymetrically. Between inshore-shallow (6.1 and 12.2 m) and deep (18.3 m) stations, fish that feed on or above soft bottoms (Table 6B-2; flatfishes including the longfin sanddab, Citharichthys xanthostigma; hornyhead turbot, Pleuronichthys verticalis; spotted turbot, P. ritteri; and fantail sole, Xystreurys liolepis) replace bottom-feeding micro-mesocarnivores of mixed-bottom habitat (black croaker, Cheilotrema saturnum; California corbina, and white croaker). Predictably, then, marked difference in habitat occurs between the 18.3-m and 12.2-m isobaths. Inshore of the 18.3-m isobath, the substratum surrounding otter trawl stations is a mosaic of cobble and sand, while the bottom habitat seaward of the 18.3-m isobath is predominantly sand (LCMR 1975e). This bathymetric change between inshore and offshore habitats results in two different guilds assuming the same general feeding role. This supports Allen's (1974) suggestion that species having similar feeding roles are often found at different depths and/or habitats.

Perhaps much of the temporal variability in feeding guilds as sampled by otter trawl is caused by complex onshore-offshore movements of the most abundant species, which are difficult to follow through fixed sampling sites. Near SONGS (SCE 1979d) juvenile and adult queenfish and white croaker exhibit distinct seasonal movement patterns related to their reproductive activity (spawning), growth of juveniles in nearshore areas, and eventual recruitment of adults in offshore feeding grounds. Over the past two years (1978-1979) queenfish moved inshore during spring (spawning and juvenile recruitment in a relatively predator-free environment) and offshore during fall and winter. Sampling such migrating populations along with very patchily distributed filter feeders (Engraulis mordax) makes for what appears to be a dynamic and vagarious sampling universe.

In addition to the natural variability mentioned above, a physical disturbance related to construction activities of Units 2 and 3 may have also contributed to catch variability. At the time (August and December 1979) when filter feeders ranked highest in abundance in all other sampling areas and depths, they ranked lowest at the SONGS 12.2 m site. During the preceeding week the mean dredge displacement volumes were greater (1001 and 1678 yd^3 during the seven day period prior to and including the 27 August and 17 October, 1979 surveys, respectively) than before any other 1979 surveys (SCE 1980a). Transmissivity values at the SONGS 12.2 m isobath sampling site were lower (SCE 1980a) than at the reference areas. Perhaps coinciding increase in dredge spoil displacement and decrease in transmissivity discouraged the filter feeding species which generally avoid turbid waters (Livingston 1976).

Other than ephemeral effects resulting from construction activities, SONGS Unit 1 operations did not effect fish feeding guilds; further, the guilds present at San Onofre are those expected for cobble-mosaic habitats in Southern California.

SUMMARY

A detailed analysis of the 1979 data compared with 1975, 1976, 1977, and 1978 results indicated the following.

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

2. The fish community offshore SONGS is composed of a diverse assemblage of demersal fish displaying a wide variety of feeding habits. Temporal and spatial variability of distributions of fish may reflect their localized foraging movements during much of the year superimposed on seasonal inshore breeding migrations and subsequent recruitment offshore.

3. Climatic disturbances, including upwelling and storm activity may act in consort with seasonal variation in temperature to initiate and control these movements either directly of indirectly by affecting the fishes' food supply and refuge.

4. Analysis of population abundances of Seriphus politus, Genyonemus lineatus, and Hyperprosopon argenteum caught in gill nets and otter trawls revealed that seasonal increases occurred from April through October followed by a sharp decrease in December. Abundances of Phanerodon furcatus were low throughout the year in gill net catches, but increased during June and August in otter trawl catches. Increasing abundances of sciaenids and embiotocids during the summer were related to recruitment of young, while winter population declines were related to either offshore or upward movements in the water column.

5. Length frequencies of Seriphus politus and Genyonemus lineatus were bimodal for most of the year. Large catches of juvenile queenfish and white croaker during March through October in shallow depths (6.1 to 12.2 m) indicate that recruitment was high during this period in 1979 and that nearshore waters are nursery grounds for both sciaenids and embiotocids. The 1978 results show a similar pattern.

6. Analysis of sex ratios revealed no seasonal trends for Genyonemus or Hyperprosopon. Female Seriphus predominated gill net catches at 9.1 m throughout the San Onofre region. Phanerodon females were dominant in gill net catches near offshore kelp beds. Otter trawl samples were dominated by juveniles of both sciaenid species (Genyonemus and Seriphus) throughout most of the year.

7. Seasonal variation in reproductive condition of Seriphus and Genyonemus, based on gonosomatic indices, indicates that they spawn during the summer and winter, respectively. Female queenfish and white croaker caught near the Unit 1 discharge had relatively low GSI's indicating that they had spawned earlier in the season or were less fecund.

8. 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 fish species.

9. It appears that much of the variability in species composition and abundance may be attributable to natural onshore-offshore movements which may be influenced either directly or indirectly by oceanic events such as upwelling and storm activity.

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CHAPTER 6C

ADULT FISH IN-PLANT

INTRODUCTION

The ongoing marine monitoring studies reported in this chapter are being conducted to meet objectives approved by the Nuclear Regulatory Commission (NRC) Section 3.1.2a(2) Impingement of Organisms for San Onofre Nuclear Generating Station (SONGS) Unit 1. Broadly stated the ETS objective is to determine the effects of SONGS Unit 1 impingement on the marine fish resources in the vicinity of the generating station. These studies are also being conducted in compliance with the National Pollutant 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.

All 1979 biological data analyzed in this chapter is presented in Volume IV of the Annual Operating Report, San Onofre Nuclear Generating Station-Biological Data 1979 (SCE 1980d).

This chapter presents the objectives of the fish impingement studies, the approach used to meet these objectives, and a review of past studies at 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.

This 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. The relationship between impingement and various climatic variables is also discussed.

BACKGROUND

In order to place the study objectives and results into perspective, a brief description of past impingement studies is presented.

Comprehensive impingement studies at SONGS began in July 1974 and continue to date. The objectives of the fish impingement program are to define the magnitude of fish impingement and to relate this information to offshore fish populations. In-plant sampling during heat treatments and normal operation periods was initiated in 1974 to achieve these objectives. Historical impingement over four previous years (1975, 1976, 1977, 1978) has averaged approximately 332,833 individuals weighing an average of 29,977 lb per year. The abundant species impinged, by number, for these years are queenfish, walleye surfperch, white croaker, and white surfperch.

METHODS

HEAT TREATMENT

Heat treatments practiced at SONGS Unit 1 involve recirculating approximately two-thirds of the normal discharge flow back through the condenser to achieve a lethal temperature of 105°F in the screenwell, which controls biofouling. The intake conduit is heat treated in this manner every six weeks.

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 resident species (Reference: letter of 4 December 1974 from J. E. Fitch, California Dept of Fish and Game to A.R. Strachan, SCE) are estimated from subsamples when posssible.

NORMAL OPERATION

During normal plant operation samples were taken at least weekly. The total weight and number of fish, by species, removed from the traveling screens and bar racks over a continouous 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 select species catch, (2) describing the length frequency distributions of the select species, (3) estimating sex ratios of select species and (4) relating impingement catch to climatic variables from 1975 through 1979.

The annual impingement catch in weight and numbers of fish is estimated as the sum of monthly means weighted by the total number of operational plant days per month. An operational day is defined as any day during which circulating pumps are operating. This sum, calculated from the monthly stratified samples, estimates total annual impingement under normal flow conditions. The standard error of the stratified sample total is the sum of monthly values and is expressed as:

$$S(I) = \sqrt{\Sigma\ (N_h - n_h)\ \frac{N_h}{n_h}\ S_h^2}$$

where $S(I)$ = standard error of total impingement

N_h = total number of operational plant days in stratum h (month)

S_h2 = 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 which consistently comprises the greatest part of the SONGS Unit 1 impingement catch. Analysis of length frequency samples for other select species (see Chapter 6B) taken under normal flow and heat treatment operations suggests that individuals of these species are impinged soon after entrapment rather 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 (13, 15, 16 February; 17, 19, 22 April; 24, 27, 28 June; 24, 29,31 August; 12, 16,19 October; and 11, 14, 19, December) as fish surveys in receiving waters. Since impinged fish were sampled during the period that fish in receiving water samples were collected, 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.

The analysis of the relationship between impingement and meteorological events (i.e., storms) consisted of removing (filtering) seasonal trends from impingement and weather data via weighted moving averages and applying a multiple linear regression model to the filtered data. The weather variables used in the analysis consist of daily wind speed, wave height, and barometric pressure data obtained from U.S. Coast Guard weather station at San Mateo Point, Ca. Impingement data (number of fish impinged) were transformed using a ln (x + 1) transformation and then standardized by the number of days per impingement sample.

Weighted moving averages were calculated by assigning a weight of 60 (2 months) to the first impingement sample (nodal point). Remaining samples receive a weight which linearly decreases with distance (days) from the nodal point, with a weight of zero being reached at 60 days from the nodal point. New weighted means are calculated using the same procedure but in the reverse direction. Values used in these calculations are those from the first estimate.

The maximum R-squared improvement technique multiple regression model was used to evaluate the relative importance of each weather variable with respect to impingement. Three values for each weather variable except barometric pressure, were entered into the model: the average of the daily average values (WIAVE = average wind; WVAVE = average wave), the maximum of the daily maximum values (WIMAX = maximum wind; WVMAX = wave maximum; BPH = maximum barometric pressure), and the minimum of the daily maximum values (WIMIN = minimum wind; WVMIN = minimum wave; BPL = minimum barometric pressure).

RESULTS

ANNUAL IMPINGEMENT ESTIMATE

The estimate of 1979 fish impingement is based upon 93 normal flow impingement samples and six heat treatment samples. Heat treatment samples consisted of an assessment of all fish impinged during the heat treatment, while normal plant operation samples evaluated individuals impinged during a 24-h period of normal plant operation (i.e., circulator pumps operating in normal configuration). A complete account of all species enumerated from the 93 normal operation samples and six heat treatment samples is presented in SCE 1980d. Table 6C-1 shows the rank order of abundance by number of individuals observed in samples collected in 1980. Estimated monthly impingement catches for total fish and select species by individuals and weight are presented in Table 6C-2. Table 6C-3 presents annual

Table 6C-1. Rank order of abundance by number of individuals.

Rank	Species	Common Name	Number of Individuals	Percent of Total
1	Seriphus politus	Queenfish	112,737	68.3221
2	Hyperprosopon argenteum	Walleye surfperch	23,141	14.0242
3	Engraulis mordax	Northern anchovy	6,714	4.0689
4	Genyonemus lineatus	White croaker	6,369	3.8598
5	Atherinops affinis	Topsmelt	5,036	3.0520
6	Phanerodon furcatus	White surfperch	2,618	1.5860
7	Cymatogaster aggregata	Shiner surfperch	1,862	1.1284
8	Peprilus simillimus	Pacific butterfish	899	0.5448
9	Anisotremus davidsoni	Sargo	847	0.5133
10	Atherinopsis californiensis	Jacksmelt	571	0.3460
11	Anchoa compressa	Deep body anchovy	509	0.3085
12	Embiotoca jacksoni	Black surfperch	369	0.2236
13	Urolophus halleri	Round stingray	306	0.1854
14	Paralabrax nebulifer	Barred sandbass	212	0.1285
15	Leuresthes tenuis	California grunion	211	0.1279
16	Damalichthys vacca	Pile surfperch	193	0.1170
17	Torpedo californica	Pacific electric ray	191	0.1158
18	Porichthys notatus	Plainfin midshipman	181	0.1097
19	Menticirrhus undulatus	California corbina	173	0.1048
20	Squalus acanthias	Spiny dogfish	171	0.1036
21	Xenistius californiensis	Salema	170	0.1030
22	Scorpaena guttata	Sculpin	166	0.1006
23	Cheilotrema saturnum	Black croaker	146	0.0885
24	Paralichthys californicus	California halibut	116	0.0703
25	Medialuna californiensis	Halfmoon	114	0.0691
26	Umbrina roncador	Yellowfin croaker	94	0.0570
27	Syngnathus spp.	Pipefish	76	0.0461
28	Rhinobatos productus	Shovelnose guitarfish	73	0.0442
29	Platyrhinoidis triseriata	Thornback	55	0.0333
30	Paralabrax clathratus	Kelp bass	50	0.0303
31	Roncador stearnsi	Spotfin croaker	45	0.0273
32	Porichthys myriaster	Specklefin midshipman	44	0.0267
33	Heterostichus rostratus	Giant kelpfish	42	0.0255
34	Rhacochilus toxotes	Rubberlip surfperch	41	0.0248
35	Citharichthys stigmaeus	Speckled sanddab	38	0.0230
36	Cynoscion nobilis	White seabass	36	0.0218
37	Sebastes rastrelliger	Grass rockfish	35	0.0206
38	Chromis punctipinnis	Blacksmith	34	0.0206
39	Mustelus californicus	Gray smoothhound	33	0.0200
40	Girella nigricans	Opaleye	22	0.0133
41	Brachyistius frenatus	Kelp surfperch	21	0.0127
42	Gymnura marmorata	California butterfly ray	20	0.0121
42	Hypsoblennius jenkinsi	Mussel blenny	20	0.0121
42	Otophidium scrippsi	Basketweave cusk eel	20	0.0121
43	Hypsopsetta guttulata	Diamond turbot	18	0.0109
44	Myliobatis californica	Bat ray	17	0.0103
44	Sebastes paucispinis	Bocaccio	17	0.0067
45	Amphistichus argenteus	Barred surfperch	11	0.0067
45	Pimelometopon pulchrum	California sheephead	11	0.0067
46	Hypsoblennius gilberti	Rockpool blenny	10	0.0061
47	Heterodontus francisci	Horn shark	9	0.0055
47	Pleuronichthys ritteri	Spotted turbot	9	0.0055
47	Sebastes serranoides	Olive rockfish	9	0.0055
48	Scorpaenichthys marmoratus	Cabezon	7	0.0042
48	Sphyraena argentea	California barracuda	7	0.0042
48	Triakis semifasciata	Leopard Shark	7	0.0042
49	Trachurus symmetricus	Jack mackerel	6	0.0036
50	Pleuronichthys coenosus	C-O turbot	5	0.0030
50	Xystereurys liolepis	Fantail sole	5	0.0030
51	Leptocottus armatus	Staghorn sculpin	4	0.0024
51	Paralabrax maculatofasciatus	Spotted sand bass	4	0.0024
51	Pleuronichthys verticalis	Hornyhead turbot	4	0.0024
52	Hypsypops rubicunda	Garibaldi	3	0.0018
52	Squatina californica	Pacific angel shark	3	0.0018
53	[illegible]odus lucioceps	California lizardfish	2	0.0012
54	Amphistichus koelzi	Calico surfperch	1	0.0006
54	Dorosoma petenense	Threadfin shad	1	0.0006
54	Gibbonsia montereyensis	Crevice kelpfish	1	0.0006
54	Gymnothorax mordax	California moray	1	0.0006
54	Halichoeres semicinctus	Rock wrasse	1	0.0006
54	Hermosilla azurea	Zebra perch	1	0.0006
54	Hypsurus caryi	Rainbow surfperch	1	0.0006
54	Micrometrus minimus	Dwarf surfperch	1	0.0006
54	Mustelus henlei	Brown smoothhound	1	0.0006
54	Sarda chiliensis	Pacific bonito	1	0.0006
54	Sebastes auriculatus	Brown rockfish	1	0.0006

Table 6C-2 Number and weight of fish impinged by SONGS during 1979.

Month	*Genyonemus lineatus* No	*Genyonemus lineatus* kg	*Hyperprosopon argenteum* No	*Hyperprosopon argenteum* kg	*Phanerodon furcatus* No	*Phanerodon furcatus* kg	*Seriphus politus* No	*Seriphus politus* kg	Total Individuals No	Total Individuals kg	Number of Samples
Jan	462	11.7	2,935	89.0	393	22.2	15,851	345.6	22,396	3,687.21	9
Feb	1,188	63.8	14,549	488.1	370	18.3	44,481	1,834.0	65,591	4,079.58	7
Mar	717	53.7	1,568	46.7	403	22.5	72,478	1,488.4	79,502	2,781.94	7
Apr	464	12.1	539	20.1	207	14.5	26,166	426.0	28,843	1,172.59	7
May	353	11.8	438	13.6	725	31.6	26,916	540.4	30,093	1,376.32	8
Jun	2,401	186.2	3,103	38.1	3,115	28.3	37,770	692.5	55,001	1,413.05	5
Jul	5,845	100.7	10,946	93.7	3,248	23.4	57,595	1,151.9	94,123	2,712.26	9
Aug	8,719	340.2	3,786	60.6	1,042	10.5	43,261	841.9	60,404	1,619.21	8
Sep	1,552	36.3	3,052	66.3	268	7.3	37,837	726.9	46,853	1,113.25	9
Oct	1,705	36.3	1,164	19.5	93	5.0	34,706	671.3	38,822	1,114.42	9
Nov	141	2.4	8,997	173.8	170	18.0	16,853	146.7	27,474	643.51	8
Dec	102	2.9	850	20.6	244	14.9	14,676	100.9	16,833	1,014.85	7

Table 6C-3. Annual estimate of number and weight of total fish and select species impinged during normal operation and heat treatments by SONGS Unit 1 during 1979 based upon 93 24-h samples out of 365 operational days. Estimates for normal operation are total catch ± 1 standard deviation of the total. Heat treatment values represent actual numbers and weights of fish impinged.

Taxa	Number of Fish: Normal Operation	Number of Fish: Heat Treatments	Weight of Fish (kg): Normal Operation	Weight of Fish (kg): Heat Treatments
Genyoneums lineatus	23,649 ± 5,957	145	858.68 ± 289.79	8.05
Hyperprosopon argenteum	51,927 ± 11,145	9,237	1.130.52 ± 308.62	457.79
Phanerodon furcatus	10,277 ± 2,242	116	217.03 ± 26.42	10.52
Seriphus politus	428,589 ± 43,034	2,377	8,967.34 ± 1,217.23	56.59
Total Individuals	565,934 ± 56,937	18,713	22,728.20 ± 2,412.52	1,274.32
Combined Total	584,647		24,002.52	

estimates of the number and weight of total fish and selected species using weighted monthly averages of catch (see Methods: data analysis section).

Seven species accounted for approximately 96% of the total (normal and heat treatment) impingement catch in 1979 (Table 6C-1). Queenfish (*Seriphus politus*) numerically dominated the catch followed by walleye surfperch (*Hyperprosopon argenteum*), northern anchovy (*Engraulis mordax*), white croaker (*Genyonemus lineatus*), topsmelt (*Atherinops affinis*), white surfperch (*Phanerodon furcatus*), and shiner surfperch (*Cymatogaster aggregata*).

Estimated monthly normal operation impingement ranged from a maximum of 94,123 individuals weighing a total of 2,712 kg (5,980 lb) in July to a minimum of 16,833 individuals weighing 1,014 kg (2,235 lb) in December (Table 6C-2). Impingement of individuals was highest for queenfish in March, for white croaker in August, for white surfperch in July, and for walleye surfperch in February. Highest impingement by weight occurred during February for queenfish, August for white croaker, May for white surfperch and February for walleye surfperch.

An estimated 565,934 + 56,937 (1 standard error of the total) individuals weighing 22,728.20 ± 2,412 kg (5,306.4 lb) were impinged under normal operational conditions by SONGS Unit 1 in 1979. Individually, queenfish comprised 75.7% of the normal flow impingement by number, white croaker 4.2%, white surfperch 1.8% and walleye surfperch 9.2%. Collectively, these species accounted for 90.9% of the estimated total normal flow impingement by number. Queenfish, by weight, accounted for 39.4% of the total estimated normal flow impingement, followed by white croaker (3.8%), walleye surfperch (5.0%), and white surfperch (1.0%).

A total of 18,713 individuals weighing 1,274 kg (2,809 lbs) were impinged in heat treatment operations in 1979, with queenfish, walleye surfperch, white croaker, and white surfperch comprising 12.7%, 49.4%, 0.8% and 0.6% of the total, respectively, on a number basis. Walleye surfperch by weight accounted for 35.9% of the heat treatment impingement, queenfish 4.4%, white croaker 0.6% and white surfperch 0.8%. Collectively, 63.5% of the total heat treatment impingement by number and 41.7% by weight was attributed to these four species.

Combined totals for estimated normal flow and heat treatments equalled 584,647 individuals weighing 24,002.52 kg (5,307.54 lb) for a mean weight of 0.04 kg/fish (0.09 lb/fish) (Table 6C-3).

LENGTH FREQUENCY ANALYSIS

Analysis of size structure of Seriphus from receiving water samples and impingement samples is presented to see if Unit 1 is selectively removing a size class or classes from offshore populations. Seriphus was selected for study because it dominated gill net and otter trawl catches and because it has historically been a major component of the total annual impingement catch. Comparisons were made between length frequency histograms obtained from impingement, gill net, and otter trawl catches for the SONGS area only. Genyonemus is not considered because impingement, gill net and otter trawl catches of this species were highly variable in 1979.

Figures 6C-1 through 6C-5 depict the size structure of Seriphus for impingement, gill net, and otter trawl catches during February, April, June, August, and October 1979. December is not presented because of extremely small Seriphus catches in gill nets and otter trawls.

The length structure of juvenile queenfish (< 120 mm SL) impinged in 1979 was unimodal from February through August although modal length gradually increased from 70 mm SL in February to 100 mm SL in August (Figures 6C-1 through 6C-4). In October two juvenile cohorts were impinged with estimated modal length classes of 65 and 110 mm SL (Figure 6C-5). Juvenile queenfish 40 mm SL or smaller did not appear in impingement catches.

Juvenile queenfish caught in otter trawls displayed unimodal length frequencies (70-75 mm SL) during February and April surveys and bimodal frequencies throughout the remaining surveys in 1979 (Figures 6C-1 through 6C-5). Queenfish as small as 10 mm SL were caught in otter trawls (Figure 6C-4).

Comparison of the catch of adult queenfish in-plant and offshore were similar between impingement and otter trawls throughout 1979; the length frequencies of Seriphus sampled by these methods were unimodal with the modal length class varying from 130 mm SL (April) to 160 mm SL (October) (Figures 6C-1 through 6C-5).

Gill net catches of adult queenfish were bimodal in all months except October (Figures 6C-1 through 6C-5). Both cohorts (mode) contained some fish of size classes similar to those in the adult cohorts captured by otter trawls and the plant. Gill nets, however, caught no queenfish smaller than 120 mm SL and were more effective at catching the relatively large females.

SEX STRUCTURE

The sex ratios of male and female Seriphus, Genyonemus, Hyperprosopon, and Phanerodon represented by impingement, gill net, and otter trawl samples are presented in Figures 6B-17, 6B-24, 6B-30, and 6B-34 (Chapter 6B). Again, impinge-

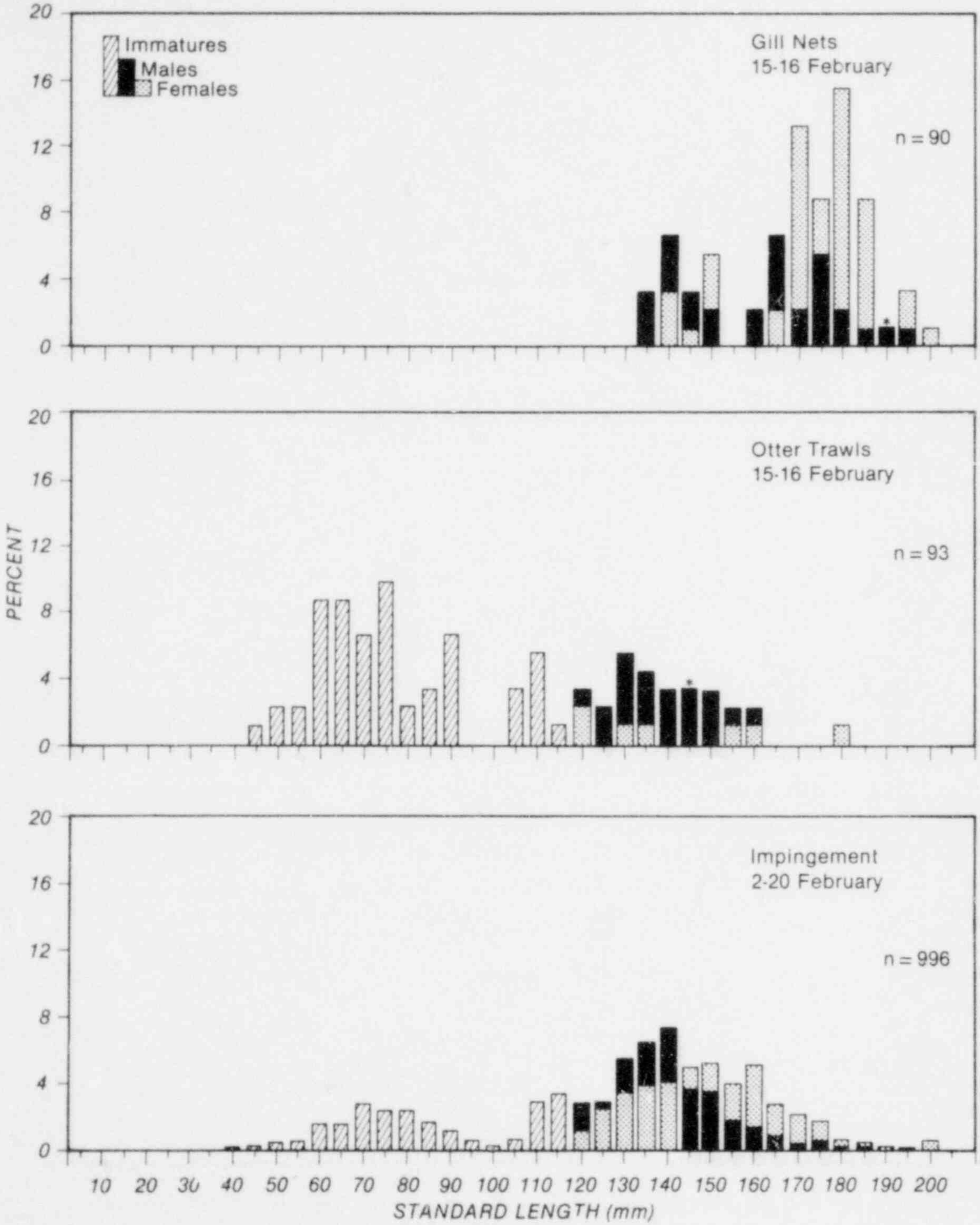

Figure 6C-1. Length frequency histograms of *Seriphus politus* from normal operation impingement, offshore gill net and otter trawl samples taken in February 1979. Percentages for males and females are not additive within a given 5 mm length increment. Asterisk (*) indicates equal number of males and females in length class.

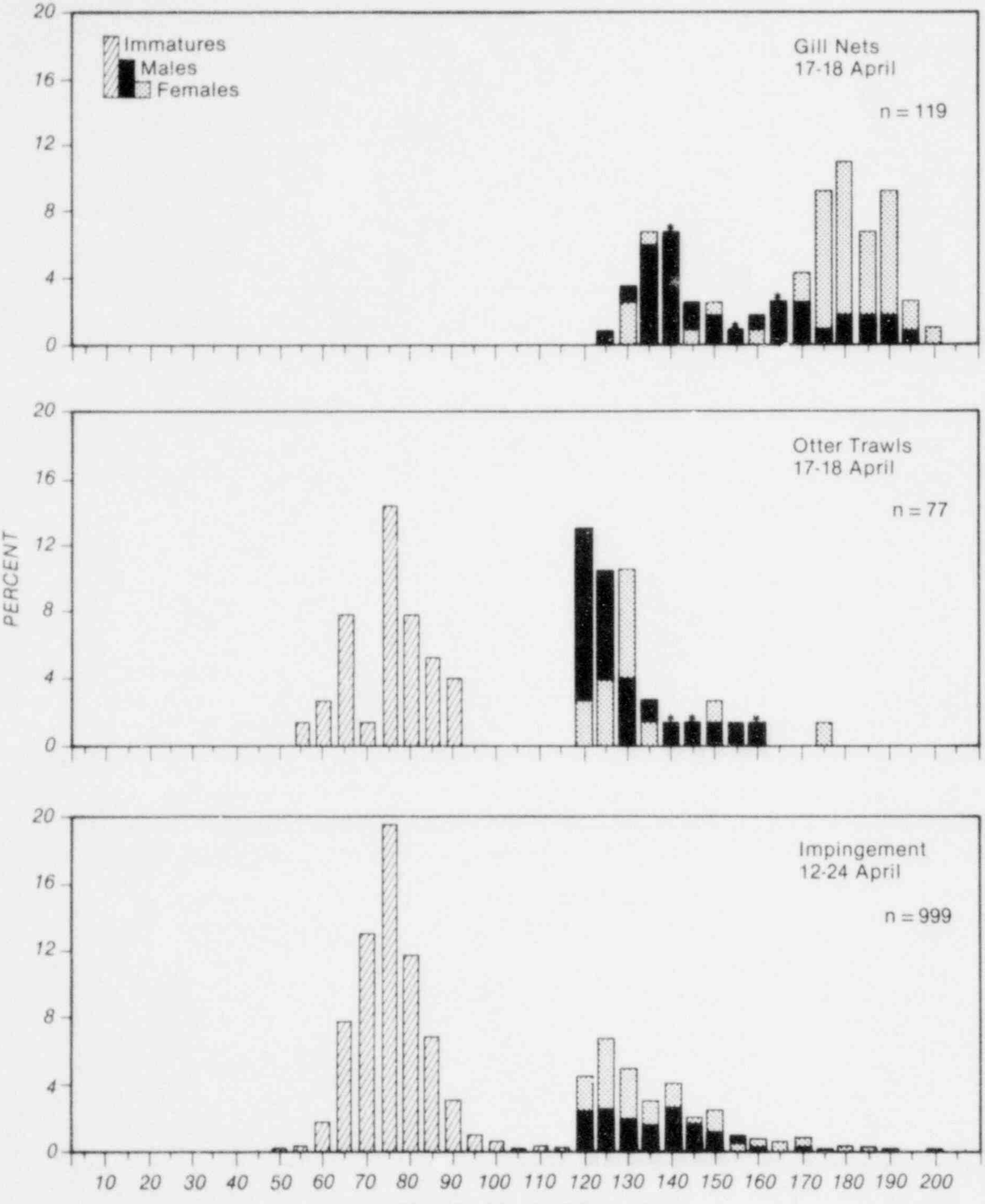

Figure 6C-2. Length frequency histograms of *Seriphus politus* from normal operation impingement, offshore gill net and otter trawl samples taken in April 1979. Percentages for males and females are not additive within a given 5 mm length increment. Asterisk (*) indicates equal number of males and females in length class.

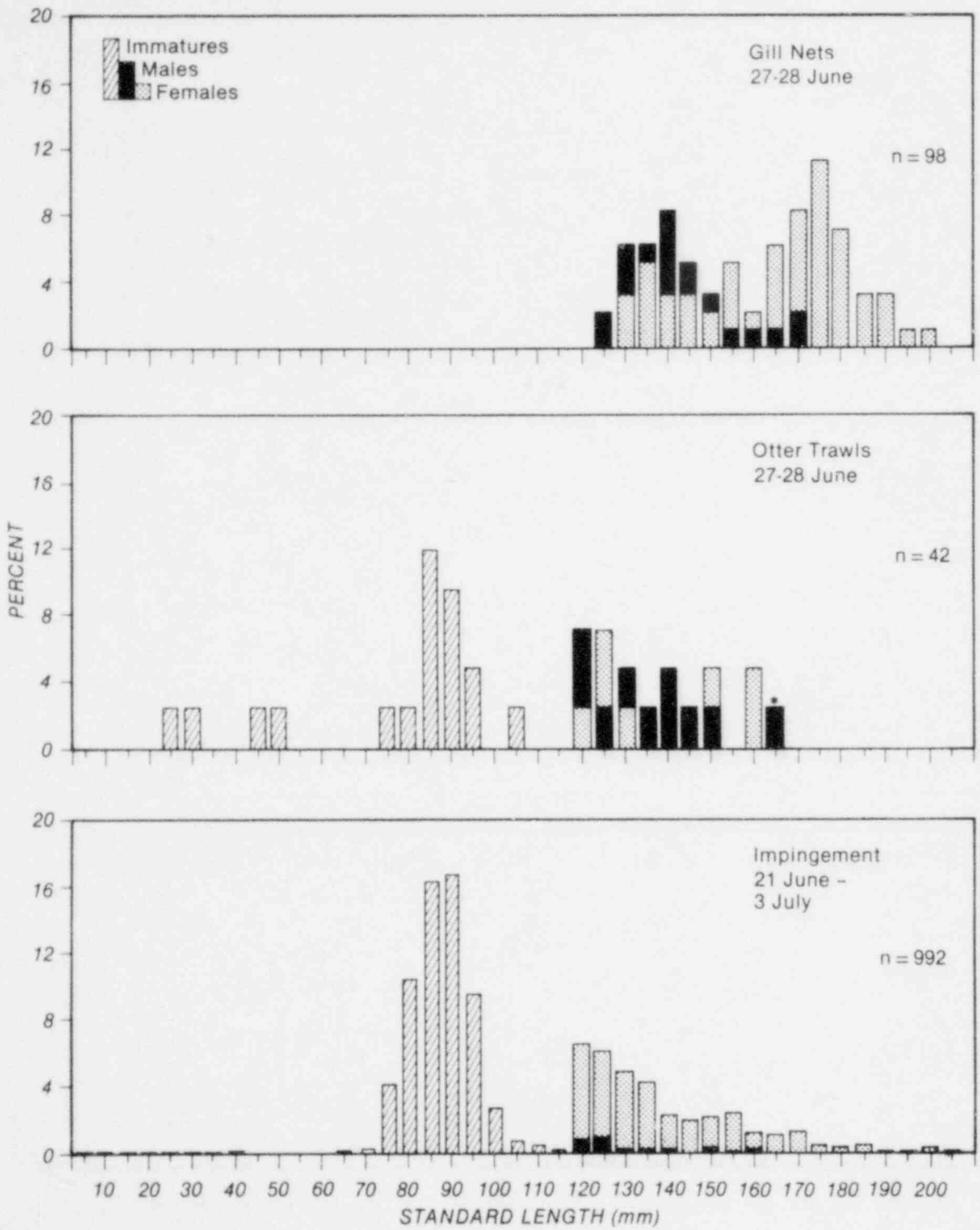

Figure 6C-3. Length frequency histogra. . s of *Seriphus politus* from normal operation impingement, offshore gill net and otter trawl samples taken in June-July 1979. Percentages for males and females are not additive within a given 5 mm length increment. Asterisk (*) indicates equal number of males and females in length class.

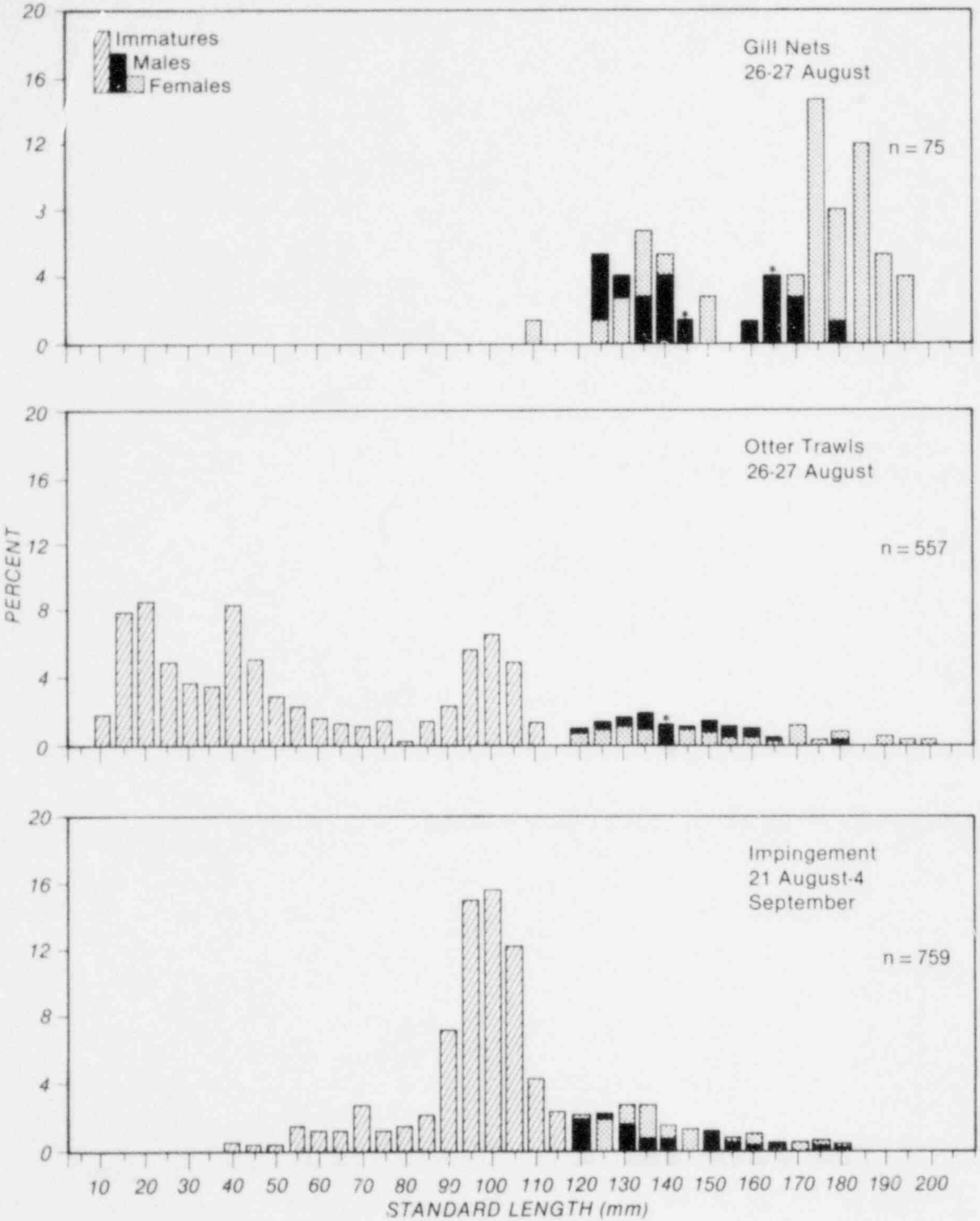

Figure 6C-4. Length frequency histograms of *Seriphus politus* from normal operation impingement, offshore gill net and otter trawl samples taken in August-September 1979. Percentages for males and females are not additive within a given 5 mm length increment. Asterisk (*) indicates equal number of males and females in length class.

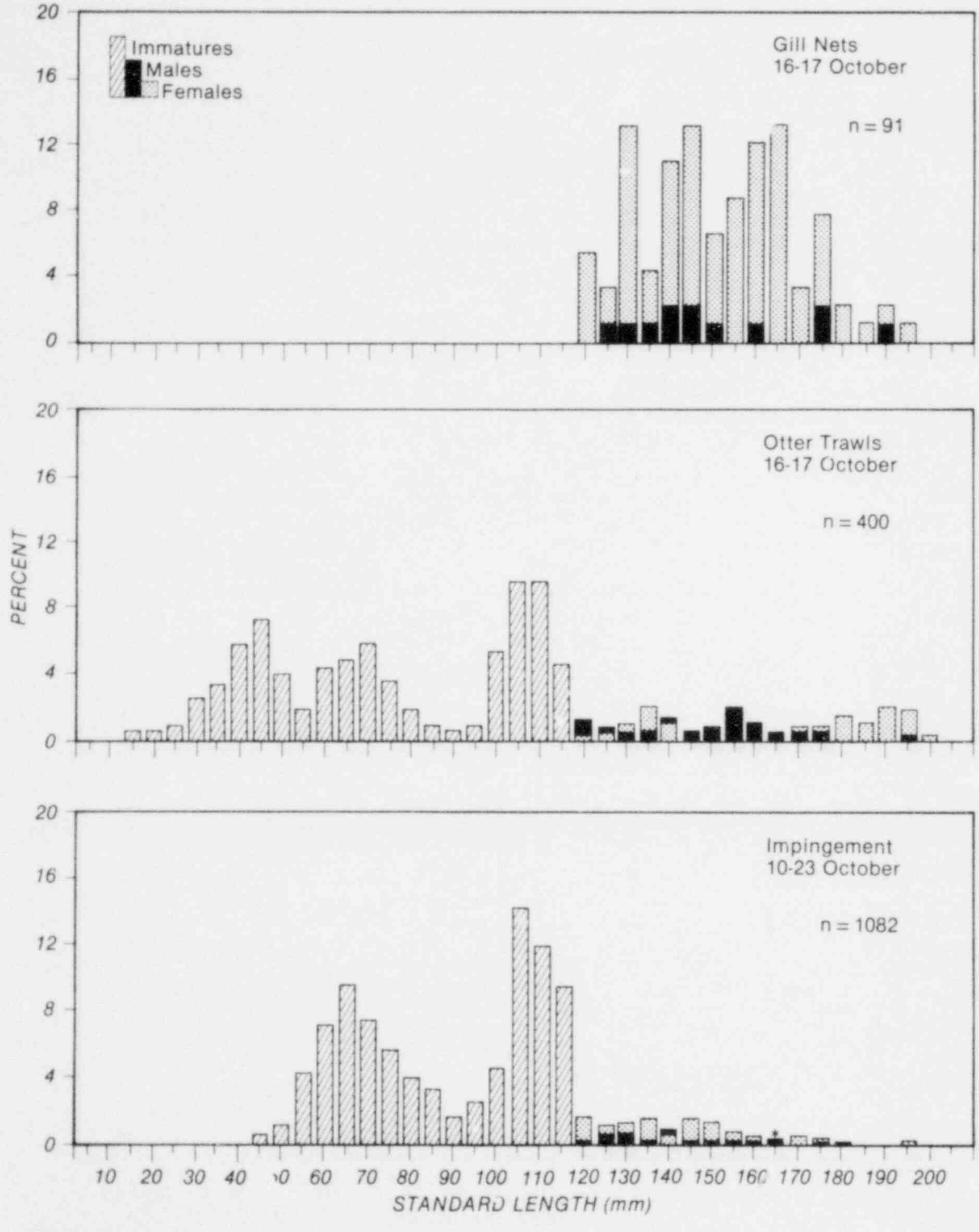

Figure 6C-5. Length frequency histograms of *Seriphus politus* from normal operation impingement, offshore gill net and otter trawl samples taken in October 1979. Percentages for males and females are not additive within a given 5 mm length increment. Asterisk (*) indicates equal number of males and females in length class.

ment samples were grouped within each month so that they coincided, as closely as possible, with offshore fish survey dates.

The number of female queenfish impinged was significantly greater ($P < 0.05$) than the number of males in all periods except February (Figure 6B-17). This pattern of female queenfish dominance in-plant was similar to that observed during 1978 (SCE 1979d).

Although in-plant catches of sexable Genyonemus were limited, the pattern of female dominance exhibited by queenfish, was also observed in Genyonemus (Figure 6B-24). This trend was most evident in February during the reproductive season of Genyonemus. At no time did females significantly outnumber males in the 1978 impingement catch.

The pattern of female dominance was also evident in the walleye and white surfperches (Figures 6B-30 and 6B-34) although significantly greater catches of male walleye surfperch were observed in February. From August to December no significant differences in sex ratios were observed in these two species. The patterns for these two species were concordant with the results of impingement samples in 1978 (SCE 1979d).

An analysis of the ratio of female Seriphus to total sexable Seriphus caught in-plant, in gill nets, and in otter trawls was performed to determine if SONGS Unit 1 was impinging a disproportionately large number of females relative to the offshore numbers of females. In order to reduce the bias due to gear selectivity the ratio of female Seriphus to total sexable Seriphus was calculated for 5 mm length increments common to impingement, gill net, and otter trawl samples. The assumption was made that each gear-type (plant intake, gill nets, otter trawls) took an unbiased sample of females to total sexable Seriphus in each 5 mm length class common to the gear-types. A Friedman two-way analysis of variance (Sokal and Rohlf 1969) was used to test for differences in sex ratios within 5 mm size classes among gear-types. Results of the test indicate that Unit 1 impinged a disproportionately large number of female queenfish ($P < 0.05$) compared to otter trawl and gill net queenfish catches in February, April, and June 1979 (Table 6C-4).

An apparent change in the spatial distribution pattern of queenfish or gear selectivity for reproductively active female queenfish or both occurred in August and October 1979. Results of the Friedman test indicated that gill nets caught a disportionately large number of females relative to impingement catches, which in turn, caught more females than otter trawls (Table 6C-4).

Table 6C-4. Summed ranks for ratios of female *Seriphus* to total sexable *Seriphus* taken in impingement, gill net, and otter trawl samples in February, April, June, August, and October 197? . Underlined ranks are not significantly different from one another at $P = 0.05$. All other ranks are ... ficantly different at $P \leq 0.05$.

Survey	Impingement	Gear Type: Otter Trawl	Gear Type: Gill Net
Feb	14	8	8
Apr	21	11	10
Jun	23	13.5	11.5
Aug	32	17.5	40.5
Oct	28	15	35

IMPINGEMENT AND METEOROLOGICAL EVENTS

Results of the multiple regression analysis indicated that a small portion of the total variability in impingement catch was explained by weather variables as evidenced by low R^2 values (Table 6C-5). Average wind speed (WIAVE) consistently explained the most variability in impingement catch. No apparent pattern was evident for the remaining variables and the variability explained by them was small (Table 6C-5).

Table 6C-5. Correlation coefficients (R^2) and relative importance of physical variables used in the stepwise multiple regression analysis of impingement catch of select species and meteorological events.

Species	Step	R^2	Improvement	Meteorological Variables							
				WIMAX	WIMIN	WIAVE	WVMAX	WVMIN	WVAVE	BPH	BPL*
Genyonemus lineatus	1	0.13	-						X		
	2	0.19	0.06			X					
	3	0.24	0.05		X						
	4	0.26	0.02								X
	5	0.26	-							X	
Seriphus politus	1	0.08	-			X					
	2	0.10	0.02							X	
	3	0.11	0.01				X				
	4	0.11	-								X
Hyperprosopon argenteum	1	0.02	-			X					
	2	0.04	0.02		X						
	3	0.05	0.01					X			
	4	0.05	-								X
Phanerodon furcatus	1	0.01	-			X					
	2	0.01	-								X
Total Catch	1	0.07	-			X					
	2	0.09	0.02							X	
	3	0.10	0.01				X				
	4	0.11	0.01		X						

* WIMAX = maximum wind; WIMIN = minimum wind; WIAVE = average wind; WVMAX = maximum wave; WVMIN = minimum wave; WVAVE = average wave; BPH = maximum barometric pressure; BPL = minimum barometric pressure

DISCUSSION

The 1979 annual estimate of total fish and select species impinged by SONGS Unit 1 was similar to that for 1978 (Table 6C-6). Compared to annual impingement estimates for SONGS Unit 1 in 1975, 1976, and 1977, the 1978 and 1979 estimates were 2.0 to 3.0 times greater. The mean weight per fish impinged decreased from 0.12 lb/fish in 1976 to 0.07 lb/fish in 1978, and increased to 0.09 lb/fish in 1979.

Table 6C-6. Estimated annual impingement values for five years of the ETS program.

Impingement	1975	1976	1977	1978	1979
Total Number of Individuals	296,319	198,266	235,555	601,193**	584,647
Aggregate Weight (lb)	30,832	24,631	20,625	43,820	52,916
Days of Operation	317	270	283	302	365
Daily Mean Number of Individuals	935	734	832	1,897*	1,602
Daily Mean Weight (lb)	97	91	73	141*	145
Mean Weight (lb) Per Fish	0.104	0.124	0.086	0.073	0.091

* Unweighted means
** Based upon weighted monthly mean catches taken during an unusually stormy weather year.

Since Seriphus made up 68.3% of the total estimated impingement catch by number in 1979, the increase in annual impingement catch is likely the result of impingement of juvenile queenfish, as was the case in 1978. Comparing 1978 and 1979 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, which probably accounts for the lower estimated impingement in this year.

Comparison of the size structure and numbers of juvenile Seriphus sampled by otter trawls and impingement screens indicated that both sample similar modes, from 70 mm SL in February to 105 mm SL in October. Otter trawls sampled a smaller mode ranging from 20-45 mm SL from June to October, which was not observed in impingement samples. The 70 to 105 mm SL individuals probably represent last year's recruits while the 20-40 mm SL class appearing from June through October represent young-of-the-year. Juveniles were numerically dominant in four of the five impingement and three of the five otter trawl samples. Juvenile queenfish were not captured by gill nets. Adult queenfish sampled offshore by otter trawls and gill nets and in-plant samples produced a prominant mode at approximately 130 mm SL from February to August. Gill net samples also contain a distinct mode at 180 mm SL (with major contributions from large females) during the same time period. A similar but much smaller mode was also present for impingement but not from otter trawl samples. Impingement, otter trawl, and gill net samples from October reflect a more even distribution of individuals between size classes and no distinct modes. The impingement catch, therefore, appears to be sampling the same size classes available in the offshore population as measured by otter trawls and gill nets, with the exception of juveniles in the 20-40 mm SL class and larger (> 170 mm SL) females caught in gill nets. The absence of 20-40 mm SL juveniles in impingement samples is most likely the result of this size class passing through the generating station's traveling screens and being entrained in the Unit 1 cooling water system.

The spatial and temporal abundance patterns related to reproduction, upwelling, and storm activities for Seriphus, Genyonemus, Hyperprosopon, and Phanerodon are reflected in the impingement catch during 1978 and 1979.

Impingement catches of Seriphus in 1979 were greatest during the period from March through October. This is the time of the year when recruitment to nearshore areas is at its greatest (see Chapter 6B). Juvenile and adult female queenfish predominate in nearshore depths. Length structure and sex ratios of impinged queenfish during this period validates the observed offshore pattern. Additionally, the results of the Friedman ANOVA indicate that Unit 1 is impinging a disproportionately large number of female queenfish from February through June (Table 6C-4); further, these individuals are impinged during the initial portion of the breeding season. The effect of the removal of these reproductively mature individuals on the local population is presently unknown; however, the high fecundity of females indicates that the population can probably compensate for losses due to impingement as well as natural mortality (Rousenfell 1975; Chapter 6B).

Although Genyonemus characteristically spawns in winter months, juvenile recruitment to shallow depths occurs from June through October (Chapter 6B). This pattern is reflected in increased impingement catches from June through October and the decrease in weight per fish caught in July (Table 6C-2). As for queenfish, the effect of impingement mortality on the local Genyonemus population is unknown; like the queenfish, however, this species has a "high fecundity-high mortality" reproductive strategy and can probably compensate for added losses.

Impingement of walleye surfperch (Hyperprosopon), however, may affect the SONGS population over the long term. Monthly impingement catches (Table 6C-2) peak in February and July. The February peak coincides with offshore movements of pregnant females which were inseminated in shallow water (3-4 m deep; Rechnitzer and Limbaugh 1952) during fall and early winter. February is usually the stormiest part of the year. The offshore movements of burdened females at a time of severe weather disturbance may make them most vulnerable to impingement. Additionally, pregnant female surfperch tend to have reduced ability to avoid intake current velocities as measured by their swimming performance (Dorn, et al. 1979). During a calmer period between April and May when young-of-the-year are born and the population may be less migratory, impingement decreases. But, beginning in June walleye impingement increases again and reaches a second peak in July when adults and young-of-the-year move inshore. Such movement of small individuals with the others is indicated by the observed decrease in the weight per individual impinged during July (Table 6C-2). Therefore, their migratory pattern may jeopardize walleyes twice in the course of a year. Further, increased impingement of pregnant females during their offshore movement and young-of-the-year during their move inshore essentially doubles the impact on young recruits to the population. This may tend to reduce the total SONGS population. Because, unlike queenfish and white croaker, the walleye shows a "low fecundity-low mortality" reproductive strategy, each relatively large and robust embryo has a relatively good chance of reaching adulthood. Therefore, the size of the embryonic and juvenile populations are relatively good predictors of the size of the populations of adults. Thus, the sizes of the young and adult populations are significantly correlated and any disturbing effects on one will be transmitted to the other.

The pattern of impingement of Phanerodon furcatus generally resembles that for Hyperprosopon. In particular, the increased catches and decreased weight per individual of white surfperch in June, July, and August coincide with the period that young-of-the-year white surfperch are born. But unlike walleyes, white surfperches do not show marked inshore-offshore breeding migrations; pregnant female white surfperch tend to remain offshore (Chapter 6B) while bearing young. Therefore, all potential and new recruits (embryos and juveniles) are less vulnerable to impingement.

The analysis of impingement and meteorological events was designed to evalute the importance of two non-random factors likely to influence the number of fish impinged at any one time: (1) number of fish in the area and (2) external factors such as weather and water conditions. Examination of the second factor requires that the effects of the first be eliminated or minimized via filtering; however, filtering will not always accurately estimate the number of fish in the area because short-term factors (e.g., diurnal movement patterns) affect the local level of fish abundance and cause further deviations from the seasonal estimate. It appears that short-term factors are equally or more important than meteorological disturbances (i.e., storms) in explaining the variability associated with impingement at SONGS Unit 1 as evidenced by the low correlation coefficients associated with the weather variables tested (Table 6C-5) and impingement catch.

SUMMARY

The estimate of 1979 fish impingement by SONGS Unit 1 is based on 93 normal flow impingement samples and six heat treatment samples.

1. An estimated 565,934 ± 56,937 (1 standard error of the total) individuals weighing 22,728.20 ± 2,412.52 kg (5,306.4 lb) were impinged under normal operational conditions by SONGS Unit 1 in 1979.

2. The numerically dominant species impinged during normal flow were queenfish (75.7%), white croaker (4.2%), white surfperch (1.8%), and walleye surfperch (9.2%).

3. A total of 18,713 individuals weighing 1,274.32 kg (2,809 lbs) were impinged during heat treatments in 1979. Queenfish, walleye surfperch, white croaker, and white surfperch comprised 12.7%, 49.4%, 0.8%, and 0.6% of the total heat treatment catch by number, respectively.

4. Analysis of the length structure of Seriphus impinged by Unit 1 reflected the seasonal cycle of young-of-the-year recruitment from April through October which was observed in the receiving water samples.

5. Analysis of sex composition data for queenfish impinged by Unit 1 indicates that a disproportionately large number of female queenfish are being impinged relative to the number of females in the receiving waters.

6. Maximum impingement catches of the walleye surfperch, Hyperprosopon argenteum, occurred in February and July coincident with offshore movements of gravid females and inshore movement of adults and young-of-the-year, respectively.

7. Meteorological variables (wind speed, wave height, barometric pressure) explained a minimum of variability associated with impingement catch from 1975 to 1979 suggesting that impingement catch variability may be better explained by short-term biological factors or other physical variables.

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CHAPTER 6D

SPORT FISHERIES STATISTICS

INTRODUCTION

The 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 San Onofre Nuclear Generating Station (SONGS) Unit 1. 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. These studies are also being conducted in compliance with the National Pollutant 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.

Fisheries data analyzed in this report are presented in Volume IV of the Annual Operating Report, San Onofre Nuclear Generating Station - Biological Data 1979 (SCE 1980d).

This chapter presents the objectives of the sport fishery studies, the approach used to meet these objectives, and a review of past studies. Methods of data collection and analysis are also included. Results are discussed in light of specific topics directed toward the study objectives.

APPROACH

The objective of this chapter is to augment the assessment of generating station effects on the area fishery resources. This will be accomplished by examining the importance of the sport fishery resource offshore SONGS relative to the local sport fishery (Oceanside-Dana Point) and the southern California Bight sport fishery resources, respectively.

BACKGROUND

In order to place the study objectives and results into perspective, a brief description of the environment offshore SONGS and past and ongoing fisheries studies are presented.

The California Department of Fish and Game (DFG) has divided coastal waters into numbered blocks of 10 min latitude by 10 min longitude (about 10 miles by 10 miles) oriented true north and south for recording the source of sport fish catches. The relationship of SONGS to these blocks is presented in Figure 6D-1. San Onofre Nuclear Generating Station is located in Block 756. Figure 6D-2 shows the major geographic features of the block and their relationship to SONGS. The areas of the block most frequently used by commercial sport fishing vessels (party boats) are the nearshore kelp beds at San Mateo Point and San Onofre, and the "rock fish banks" in 60 to 180 m of water near the offshore perimeter of the block. The nearshore areas are characterized by kelp forests attached to substrata composed of varying amounts of boulders, cobbles, and sand in a complex mosaic. The offshore areas of this block are characterized by water depths up to about 150 m and a bottom composed primarily of mud.

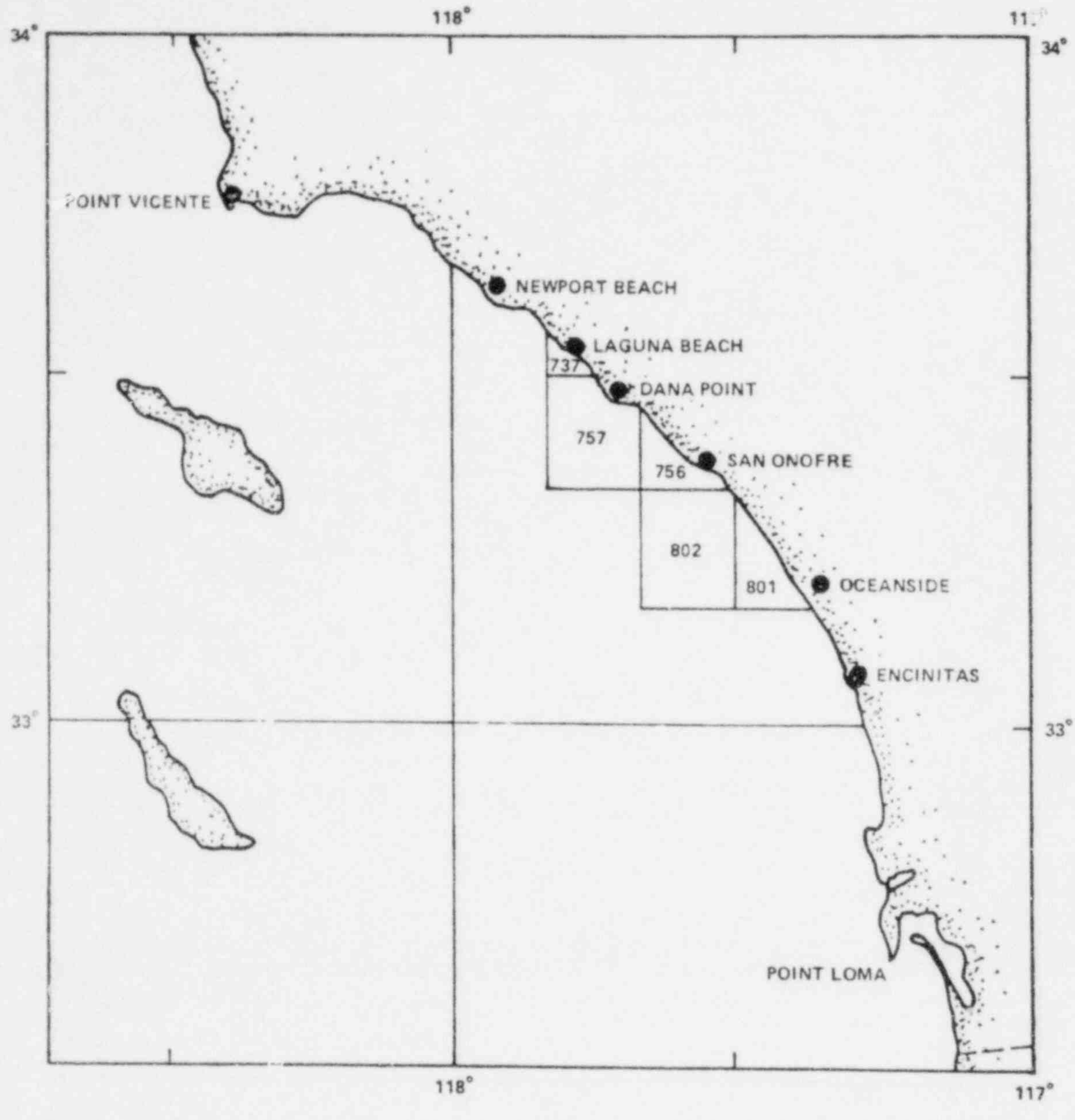

Figure 6D-1. California Department of Fish and Game catch statistic blocks in the vicinity of San Onofre.

Early sport catch records from 1962 to 1970 are summarized by Hickman (1973), who concluded that SONGS has had a significant influence on the fishery in Block 756. Before construction of SONGS the San Onofre area was not a noteworthy fishing area, however many boats now fish the area near SONGS. From 1970 to 1974 fisheries data were reported to the California Regional Water Quality Control Board, San Diego Region, in fullfillment of the Marine Environmental Monitoring requirements. In November 1974, coordination of environmental monitoring efforts resulted in acceptance of the SONGS Unit 1 Environmental Technical Specification (ETS) program which contains a sport fishery evaluation task that fulfills the requirements of the California Regional Water Quality Control Board and the Nuclear Regulatory Commission.

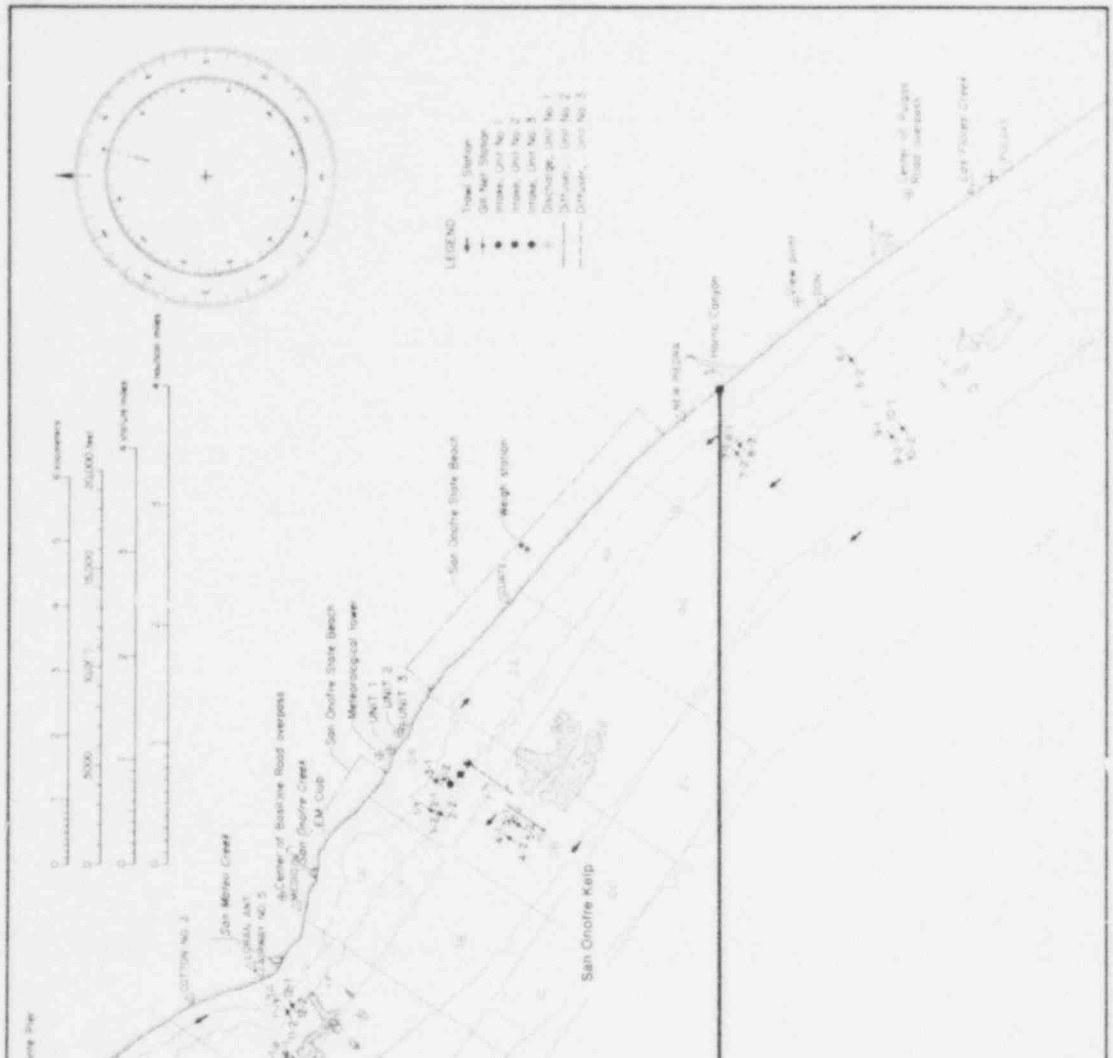

Figure 6D-2. Location of Fish Block 756, showing geographic features and relationships to ETS and PMP fish receiving water station locations at San Onofre Nuclear Generating Station. Shaded areas represent the areal extent of the kelp canopies in December 1978.

METHODS

Unpublished sport fishing catch data from commercial sport fishing vessels for the blocks in the vicinity of SONGS were obtained from the Department of Fish and Game. These data summarize the monthly landings of each species in each block as the number of fish caught, number of anglers, number of angler hours, and number of boat days. Additional data summarizing catches for major party boat ports in the vicinity of SONGS (Oceanside-Dana Point) and all of the southern California area, were also obtained (Anon 1976, 1977, 1978, 1979).

Data from 1975 to 1978 have been analyzed. The 1978 data represent the most recent year that sport fishery catch data have been summarized by the DFG. A co-ocurrence table showing the rank order of abundance of the four most abundant fish species for Block 756 catch, total landings at Oceanside-Dana Point, and total landings for Southern California was constructed to compare the species composition of the sport catches in each geographic area. The catch of species consistently taken in the sport fishery during the four year period are plotted as bar graphs to show the sport catch of Block 756 relative to the Oceanside-Dana Point area and to Southern California catch. Total fishing effort and catch per unit effort data are used to describe long-term trends and further evaluate the significance of Block 756 to the total area wide sport fishery of Southern California.

RESULTS

The rank order of abundance of the four most abundant species for sport catch in Block 756, at Oceanside-Dana Point, and for Southern California is presented in Table 6D-1. The sport catch in Block 756, Oceanside-Dana Point, and all of Southern California, was dominated by rockfishes, Sebastes spp. The barred sand bass, Paralabrax nebulifer, and the kelp bass, Paralabrax clathratus, were consistently ranked among the most abundant species in all four years in Block 756 and Oceanside-Dana Point landings. The Pacific mackerel, Scomber japonicus, Paralabrax nebulifer, and the Pacific bonito, Sarda chilensis, ranked among the most abundant species for all of Southern California in three of four years.

Table 6D-1. Rank order of abundance of the four most abundant fish taken by the sport fishery in Block 756, landed by the sport fishery at Oceanside-Dana Point, and total for landings in all southern California.

Species	Block 756				Oceanside-Dana Point				Total Southern California			
	75	76	77	78	75	76	77	78	75	76	77	78
Sebastes spp.	1	1	3	-	1	1	1	4	1	1	1	1
Paralabrax nebulifer	2	2	1	3	3	4	4	-	-	4	-	-
Paralabrax clathratus	4	3	4	4	2	2	3	3	2	2	3	3
Scomber japonicus	-	-	2	1	4	-	2	1	4	-	2	2
Sarda chiliensis	3	-	-	2	-	3	-	2	-	3	4	4
Sphyraena argentea	-	4	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	-	-	-	-	-	-	-	-	3	-	-	-

In order to put the Block 756 catch for select species into perspective, the percent contribution of Block 756 to the total landings for Oceanside-Dana Point and for Southern California were calculated. These data are summarized in Figure 6D-3. During the four year period from 1975 to 1978 Sebastes spp., P. nebulifer, P. clathratus, Scomber, Sarda, and Sphyraena catches from Block 756 represented a mean of 29.3, 52.3, 27.0, 29.6, 42.6, and 53.4% of the catch for these species landed at Oceanside-Dana Point, respectively. Similarly, the catch of these species accounted for 1.0, 16.5, 3.8, 3.9, 8.8, and 9.0% of the total landings for Southern California, respectively.

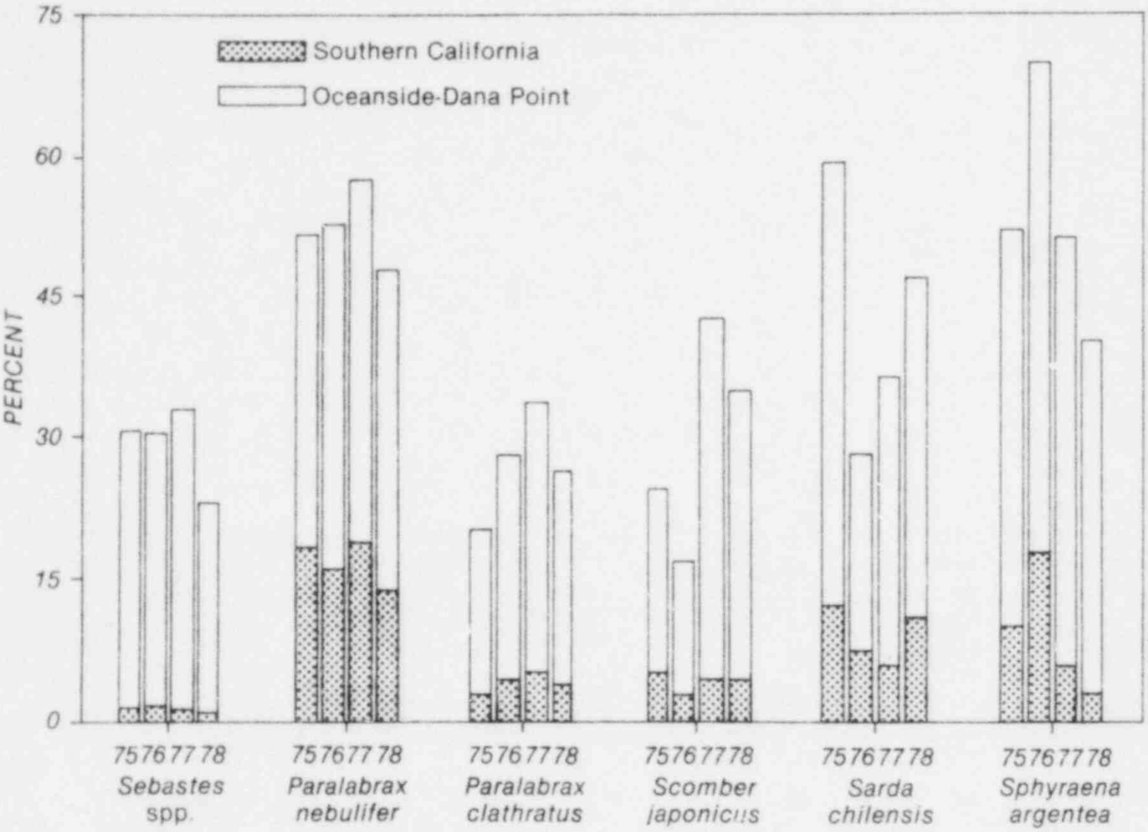

Figure 6D-3. Percent contribution of Block 756 catch of select species to Oceanside-Dana Point landings and total southern California landings from 1975 to 1978.

Total fishing effort, expressed as angler hours and catch per unit effort (CPUE) or fish per angler hour data for recent years in Block 756 and adjoining blocks are presented in Table 6D-2. Comparison of log transformed CPUE statistics by block and year utilizing a two-way analysis of variance (ANOVA) indicated that the CPUE was significantly greater in 1978 than from 1973 to 1977 ($P \leq 0.001$) and that the CPUE for Block 756 was significantly lower than other blocks ($P \leq 0.05$). Comparison of log transformed data of total angler hours for the same time period revealed that a significantly greater effort was expended in Block 756 ($P \geq 0.05$) relative to other blocks. There was no significant difference between years.

Table 6D-2. Total fishing effort expressed as angler hou⁻: and catch per unit effort (CPUE) statistics, for San Onofre area Blocks from 1973 through 15.8.

Year	Effort	Blocks 737	756	757	801	802
1973	Angler Hours	30,313	131,806	32,369	24,359	51,440
	CPUE	0.97	0.84	0.90	1.12	0.94
1974	Angler Hours	15,600	135,335	20,772	26,180	21,703
	CPUE	1.06	0.91	0.92	0.91	0.96
1975	Angler Hours	17,345	99,922	14,632	20,673	28,600
	CPUE	1.55	0.89	1.24	0.96	1.17
1976	Angler Hours	26,712	119,301	21 [illegible] 7	18,376	27,052
	CPUE	1.01	0.96	[illegible] 6	1.14	1.07
1977	Angler Hours	27,341	108,630	40,084	22,361	29,858
	CPUE	0.98	0.88	1.08	0.90	1.09
1978	Angler Hours	27,534	100,911	49,950	31,894	18,147
	CPUE	1.39	1.18	1.55	1.48	1.86

DISCUSSION

During the period from 1974 to 1978 numerically dominant and frequently occurring members of the Block 756 sport catch included rockfish, Sebastes spp.; barred sand bass, Paralabrax nebulifer; and kelp bass, P. clathratus. Other less frequently occurring but numerically dominant species include the Pacific mackerel, Scomber japonicus; the Pacific bonito, Sarda chiliensis; and the California barracuda, Sphyraena argentea. This suite of species is representative of the Southern California sport catch based on comparisons with Oceanside-Dana Point and total southern California landings (Table 6D-1).

The sport fishery effort for these game fish in the Oceanside-Dana Point area is greatest in spring, summer, and fall (Nielsen, personnel communication). Numerous site visits (LES, unpublished field observations) indicate that party boats fishing in Block 756 frequent San Onofre and San Mateo Kelp beds. These kelp beds serve as a highly visible landmark, marking a fishing area containing bonito, barracuda, kelp bass, and barred sandbass (Feder, Turner and Limbaugh 1974) all of which are desirable fish from the standpoint of party boat fishermen. During the winter when these sport species are not present or not catchable, party boat effort is directed toward rockfish which inhabit the deeper water of Block 756 and adjacent blocks (Nielsen, personnel communication).

The overall importance of the Block 756 catch relative to the Oceanside-Dana Point and Southern California areas was analyzed by calculating the percent contribution of the Block 756 catch to the Oceanside-Dana Point and total Southern California landings between 1975 and 1978 on a species by species basis. The six species considered predominant in the sport catch comprise pelagic and resident species groups. The pelagic species, Sphyraena, Sarda, and Scomber, caught in Block 756 during the four-year period represent 53.4, 42.6, and 29.6% of the total landings for these species at Oceanside-Dana Point, and 9.0, 8.8, and 3.9% of the Southern California catch, respectively (Figure 6D-3). The resident species, P. nebulifer, Sebastes spp., and P. clathratus, caught in Block 756 accounted for 52.3, 29.3, and 27.0% of the total landings for these species at Oceanside-Dana Point and 16.5, 1.0, and 3.8% of the Southern California catch, respectively. These species, therefore, represent a considerable portion of the local sport catch and, in the case of P. nebulifer, a considerable portion of the total Southern California catch. Although the reasons for the high catch of barred sand bass in Block 756 are unclear, increased fishing pressure, seasonal availability and catchability, and the abundance of preferred habitat (sand-rock ecotone; Turner, Ebert, and Given 1969) in the San Onofre and San Mateo Point areas (Chapter 5B this volume) may add to the increased catch in Block 756.

The high proportion of the catch represented by Block 756, relative to adjacent blocks, may be the result of increased fishing pressure, since a comparison of pressure (angler hours) between blocks and years (1973-78) indicated that significantly more angler hours were expended in Block 756 than adjacent blocks between Oceanside and Dana Point. An analysis of variance (ANOVA) of catch per unit effort (CPUE) data revealed that CPUE was significantly greater in 1978 than previous years and that Block 756 had a significantly lower CPUE than other blocks from 1973 to 1978. When the increased pressure is considered with the reduced CPUE, it appears that Block 756 has been overfished, except in 1978 when CPUE increased. This increase in CPUE in 1978, however, appears to be associated with a substantial increase in the catch of two pelagic species, Sarda and Scomber. The significantly greater fishing effort in Block 756 compared to adjoining blocks could contribute to changes in sport fish populations (e.g., reduction in the number of large adults) and the fish community (e.g., reduced cropping by prey species) which could affect the overall community structure.

Possible reasons for this increased pressure in Block 756 include proximity to party boat ports, availability of desirable game, and the kelp beds which mark the fishing area. Mearns (1977) observed that fishing pressure at municipal outfall sites was at least 10 times greater than coastal sites as a whole. He also noted that the increased pressure at these sites was probably related to their proximity to nearby harbors.

SUMMARY

Unpublished sport fishing data for the statistical blocks in the vicinity of SONGS were obtained from the California Department of Fish and Game. The data include monthly landings by species in each block, and number of angler hours. Analyses of these data and comparison with sport catch from Southern California indicated the following.

1. Rockfish, Sebastes spp.; the barred sand bass, Paralabrax nebulifer; the kelp bass, P. clathratus; the Pacific mackerel, Scomber japonicus; the Pacific bonito, Sarda chiliensis; and the California barracuda, Sphyraena argentea were important components of the Block 756 (the block containing SONGS) sport fishery.

2. During the four-year period from 1975 to 1978, Sebastes spp., P. nebulifer, P. clathratus, S. japonicus, S. chiliensis, and S. argentea catches from Block 756 represented means of 29.3, 52.3, 27.0, 29.6, 42.6, and 53.4% of the catch of these species landed at Oceanside-Dana Point, respectively. Similarly the catch of these species accounted for 1.0, 16.5, 3.8, 3.9, 8.8, and 9.0% of the total landings for Southern California.

3. The catch per unit effort (CPUE) for the blocks in the vicinity of SONGS was significantly greater in 1978 than from 1973 to 1977. The CPUE for Block 756

was significantly lower than the other blocks. Fishing effort, experessed in angler hours, was significantly higher in Block 756.

4. The significantly greater fishing effort in Block 756 when compared to adjoining blocks could contribute to changes in sport fish populations which could affect community structure.

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CHAPTER 7

KELP

INTRODUCTION

The sea floor off SONGS is composed of mixed sediments including sand, sand and cobble, cobble, and boulders. Most of the nearshore cobble areas undergo periodic burial due to natural sand transport, which prevents establishment of a stable attached biota (MBC 1978). Offshore the rock and cobble areas are apparently less subject to periodic burial. It is at these offshore areas of cobble and bolders that the giant kelp, Macrocystis, has established itself, forming kelp beds that support relatively varied and abundant marine biota.

The present kelp program was initiated in December 1976 to monitor the health of the San Onofre kelp bed during the offshore construction period associated with the construction of SONGS Units 2 and 3. The program also includes the monitoring of the San Mateo and Barn kelp beds, the two other kelp canopies of the San Onofre region (Figure 7-1).

The kelp beds of the San Onofre region for the past 70 years have been periodically investigated. The first investigation was conducted by W. C. Crandall (1912) during 1910 and 1911. The San Onofre kelp beds were not investigated again until the 1950's when the Kelco Company (unpublished data) mapped the canopies by aerial photography. Approximately 24 years passed before the canopies were monitored again. In 1974, Dr. Wheeler J. North of the California Institute of Technology (unpublished data) began annual aerial photographic mapping surveys of the canopies. In 1977, his aerial mapping surveys were increased to quarterly periods. Beginning in 1978 and continuing through 1979, Dr. North's aerial mapping surveys were increased to monthly intervals, weather permitting.

In conjunction with Dr. North's aerial mapping surveys, the kelp canopies of the San Onofre region have been mapped quarterly since 1974 using an electronic positioning system (Lockheed Center for Marine Research [LCMR] 1974; 1975 a,b,c,d,e; 1976 a,b,c; MBC 1978; SCE 1979c).

Over the 70 years that the kelp beds of the San Onofre region have been monitored, several major changes in density and extent of the kelp beds have taken place (Figure 7-2). Though the exact cause of the changes are unknown, several factors acting independently or together are probably responsible for the changes noted. These factors include: storms, nutrient availability, loss of suitable substrate to sand encroachment and siltation, grazing, poor recruitment due to various factors, and possibly high water temperatures.

MATERIALS AND METHODS

The kelp investigation was conducted from January 1979 through February 1980 at the San Onofre kelp bed (SOK) and at two control kelp beds, the San Mateo (SMK) and the Barn kelp (BK) beds. Study tasks at the three kelp beds included: 1) quarterly mapping of the areal extent of the kelp canopies and contiguous bottom topography using an electronic positioning system; 2) monthly mapping (weather permitting) of the kelp beds by aerial infrared photography; 3) monthly

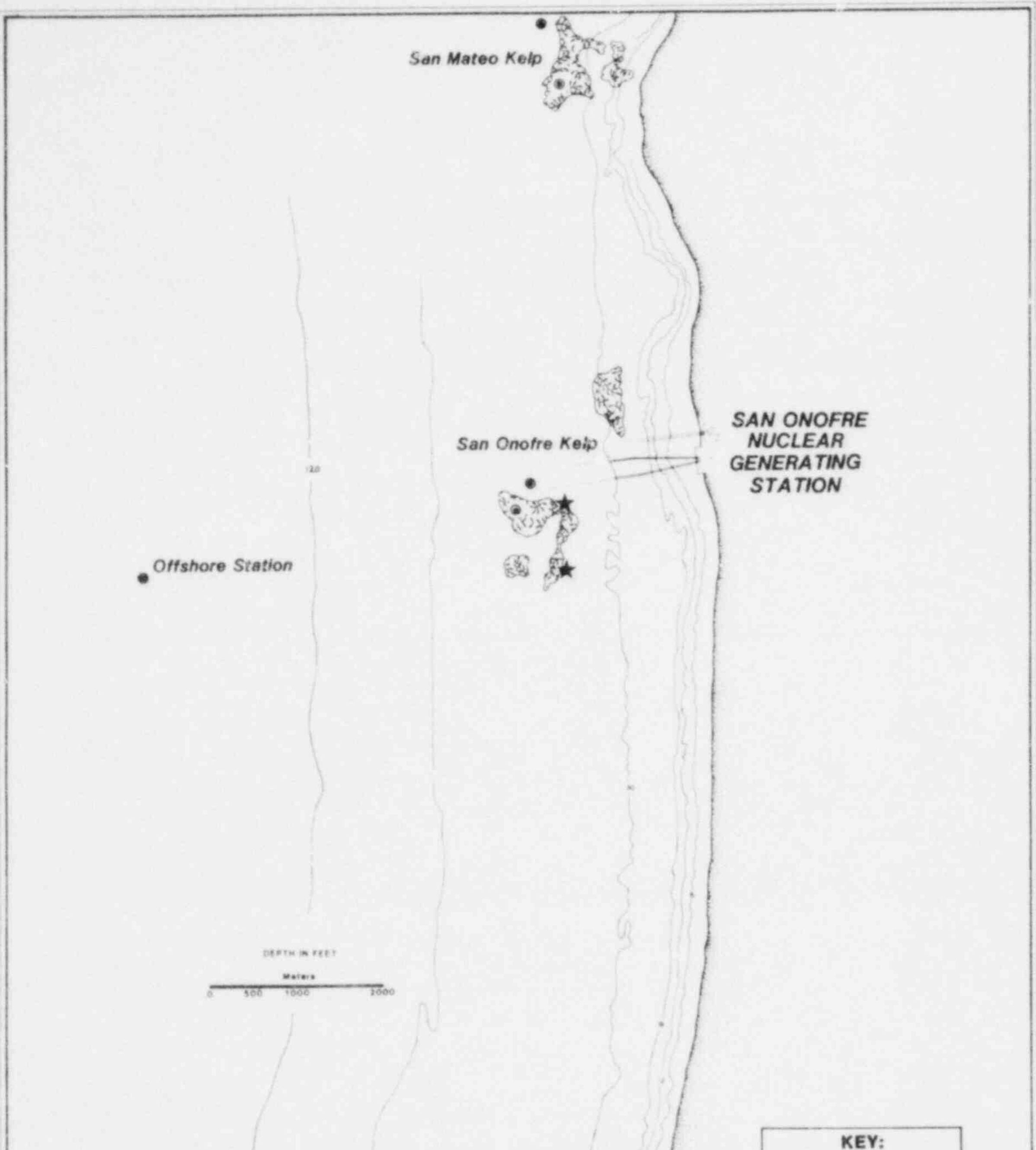


Figure 7-1. Study area of the kelp bed survey.

determination of primary nutrient concentrations (NO_2 + NO_3, NH_4, PO_4) of surface and bottom waters 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 May, September, and December.

At SOK, sedimentation rates were determined for each of the 12 monthly periods at a permanent station in the upcoast and downcoast sections of the kelp bed.

KELP CANOPY MAPPING

The areal extent of the kelp canopies and associated bottom topography were mapped quarterly by Ecosystems Management Associates, Inc. The Kelp canopy maps, which included both surface canopy and pre-adult plants of high frond density, were mapped using a Motorola Miniranger III and a Klein Associates side-scanning sonar. 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 were determined with a planimeter from the maps developed during the field surveys.

On a monthly basis, weather permitting, aerial infrared photographs were taken of each of the three kelp canopies to monitor changes in density and general boundaries. Photographs were taken from an altitude of approximately 10,000 ft. Results of the photographic surveys are presented in Appendix VI.

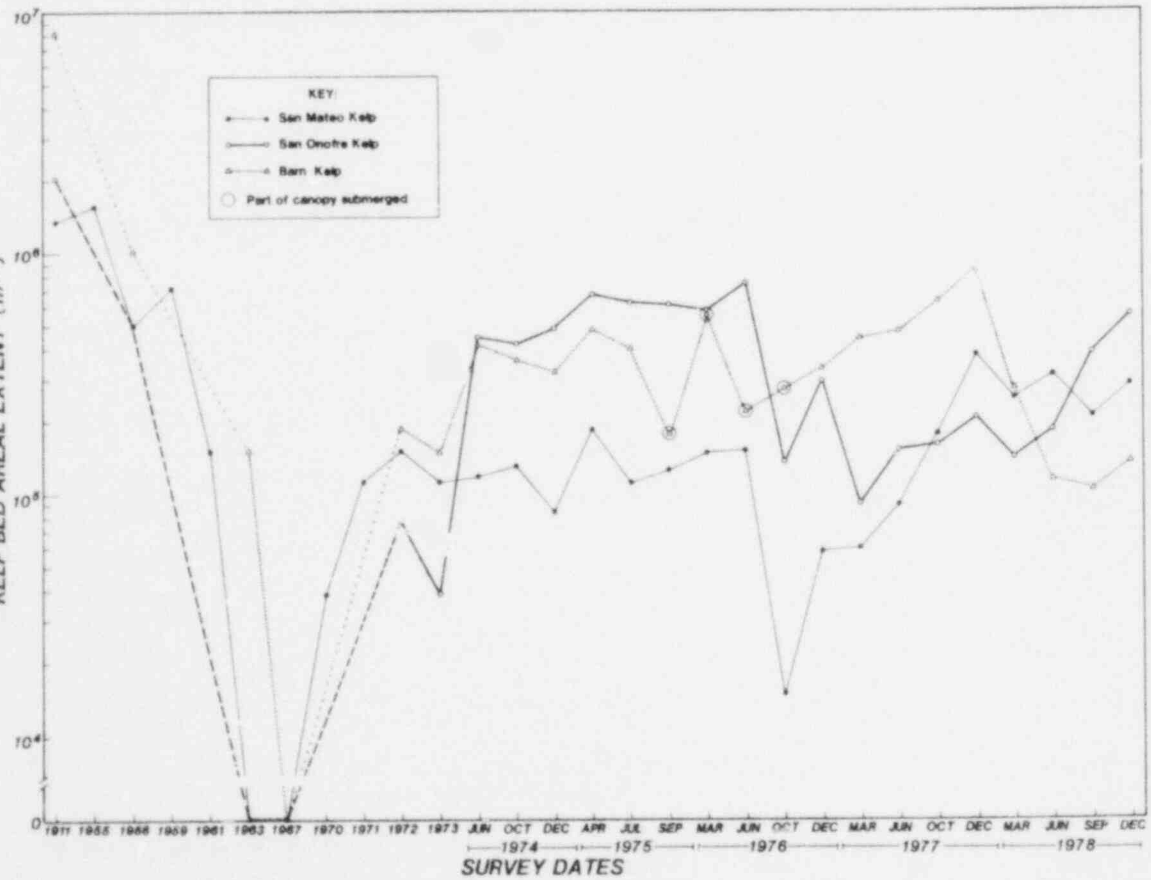


Figure 7-2. Estimated areal extent of the San Mateo, San Onofre, and Barn kelp canopy from 1911 through 1978.

BOTTOM TOPOGRAPHY

The bottom composition adjacent to the kelp canopies was determined quarterly by Ecosystems Management Associates, Inc. The bottom substrate was plotted using the combination of a down-looking and side-scanning sonar with a two-channel recorder. Ground truth work was conducted by divers, at various sites during each survey to verify the sonar readings. Substrate composition was divided into four general categories for the purpose of mapping. These categories were: 1) grater than 90% sand; 2) 10 to 30% cobble; 3) 31 to 60% cobble; and 4) 61 to 100% cobble and boulders.

MONTHLY SEDIMENTATION RATES

The monthly sedimentation rates at the upcoast and downcoast areas of SOK (Figure 7-1) were determined using sediment traps. A description of the design of the sediment traps and holders is presented in Chapter 2D, Sedimentology. Sedimentation rates were reported as gm (dry wt)/m^2/day.

WATER COLUMN NUTRIENTS

Stations within and approximately 100 m upcoast of the SOK, SMK, and BK together with a station approximately 4.3 km offshore of the SOK (Figure 7-1), were occupied monthly to determine the concentrations of ammonia (NH_4), nitrogen (NO_2 + NO_3), and orthophosphate (PO_4) within the water column. At each station within and adjacent to the kelp beds, water samples for nutrient analysis were collected from the bottom and surface waters, while at the offshore stations water samples were collected from the surface, 15 m, 30 m, and 45 m. All samples were collected by Van Dorn bottle. The water samples to be analyzed for nitrogen and phosphate content were filtered through a Whatman GF/F glass fiber filter and frozen in the field. Unfiltered samples for ammonia determination were frozen following the recommendations of Solorzano (1969). In the laboratory, the samples were thawed and nutrient concentrations determined by spectrophotometric techniques described by Strickland and Parsons (1968) and Solorzano (1969).

KELP TISSUE NITROGEN ANALYSIS

Monthly analyses were conducted of the nitrogen content of kelp fronds from SMK SOK and BK. Kelp fronds from an individual stipe were collected by divers in each of the three kelp beds. Every 10th frond on an individual stipe beginning with a sporophyll frond (reproductive 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_2 + NO_3) of each frond was then determined by Kjeldahl nitrogen analysis as described in Standard Methods (Rand et al. 1976). Results were reported in percent nitrogen per gram of dry weight.

KELP BED RECONNAISSANCE

Qualitative assessments of the health of kelp plants in the established beds of the San Onofre region were made by diver-biologists during three surveys in 1979. Concurrently with these observations, a quantitative estimate of the success of the kelp recruitment was conducted. Observations were made at single stations in each of the three kelp beds (Figure 7-3). Additional observations were made along an 1100 m transect (Transect B) in SOK.

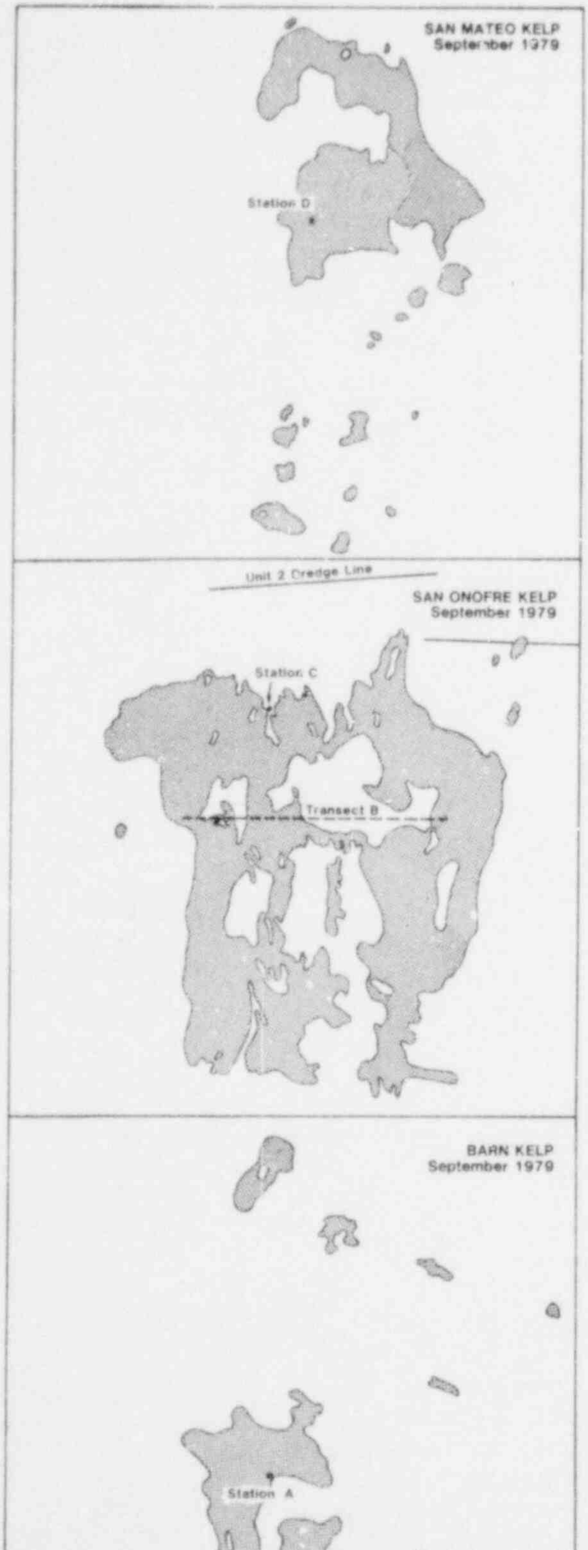


Figure 7-3. Location of stations and transect occupied for assessment of general health of kelp plants within the San Mateo, San Onofre, and Barn kelp beds from January through December 1979.

RESULTS

AREAL EXTENT OF KELP CANOPIES

As adult kelp plants are added to or lost from a kelp bed for various reasons, the density and/or perimeter of the kelp canopy reflect the changes. In the present investigation, the areal extent of the kelp canopies of the San Onofre region were estimated quarterly and the density of these canopies mapped monthly (weather permitting) to qualitatively assess changes in the kelp beds.

Beginning in July 1979 mapping activities were expanded at SOK to include a new section of offshore canopy not previously mapped. The kelp canopy maps presented herein include sections of the kelp beds composed of high density fronds that may not have reached the surface.

San Mateo Kelp Bed

The SMK canopy increased from April to July and then decreased through February 1980 (Table 7-1). In April 1979, the canopy was composed of two major sections (Area 1 and 2) with isolated patches of canopy located downcoast. During this period, the major section (Area 1) was located in the inshore area of the kelp bed (Figure 7-4).

By the July survey, the inshore section of the canopy (Area 1) had fragmented, with the offshore edge combining with Area 2. Area 2 had expanded substantially as had the scattered canopy located downcoast of the main kelp bed (Figure 7-4).

Results of the November survey indicated that the inshore section of the canopy had disappeared completely, while the offshore section had contracted from its September position. By February 1980 the offshore edge of Area 2 had contracted further, while the inshore Area 1 had reappeared (Figure 7-4).

San Onofre Kelp Bed

The SOK canopy increased from 515,000 m^2 in April 1979 to 1,238,800 m^2 in February 1980. Part of this increase was the result of the expansion of the area mapped beginning with the July 1979 survey. Even without the additional area mapped, the San Onofre kelp canopy increased approximately 1.6 times between April 1979 and February 1980.

Table 7-1. Estimated area extent of the kelp canopies (m^2) of the San Onofre region from April 1979 through February 1980.

Date	San Mateo Kelp Bed	San Onofre Kelp Bed	Barn Kelp bed
April 1979	324,920	515,000	88,000
September 1979	550,700	845,600	240,800
November 1979	335,800	966,000	245,300
February 1980	334,300	1,238,800	262,700

*Estimates supplied by Kelp Ecology Projects, Marine Review Committee.

In April 1979, the SOK canopy was separable into three major sections. Area 1 was located on the inshore perimeter of the kelp bed, Area 2 on the offshore perimeter, and Area 3 on the downcoast perimeter. Within the area encompassed by these three major sections of canopy were small isolated patches of varying size (Figure 7-5).

The July mapping results indicated that the sections of the SOK canopy had expanded in all directions. The inshore section (Area 1) had expanded to a point where it encompassed much of the scattered canopy found in the center of the kelp bed in April. The offshore section (Area 2) had increased outwardly in all directions and was connected to Areas 1 and 3 (Figure 7-5).

The kelp canopy again underwent a major expansion between July and September. The major sections of the canopy (Areas 1, 2, and 3) were now fused and covered much of the kelp bed area. A new section of the San Onofre kelp canopy (Area 4) had also appeared upcoast and inshore of the SONGS Unit 2 diffuser line (Figure 7-5).

Between November 1979 and February 1980, the shape of the SOK canopy underwent a major change. Much of the downcoast section of the kelp canopy disappeared while the upcoast section expanded in an offshore-onshore direction (Figure 7-7). The new section of the canopy (Area 4), expanded to approximately 381,880 m^2.

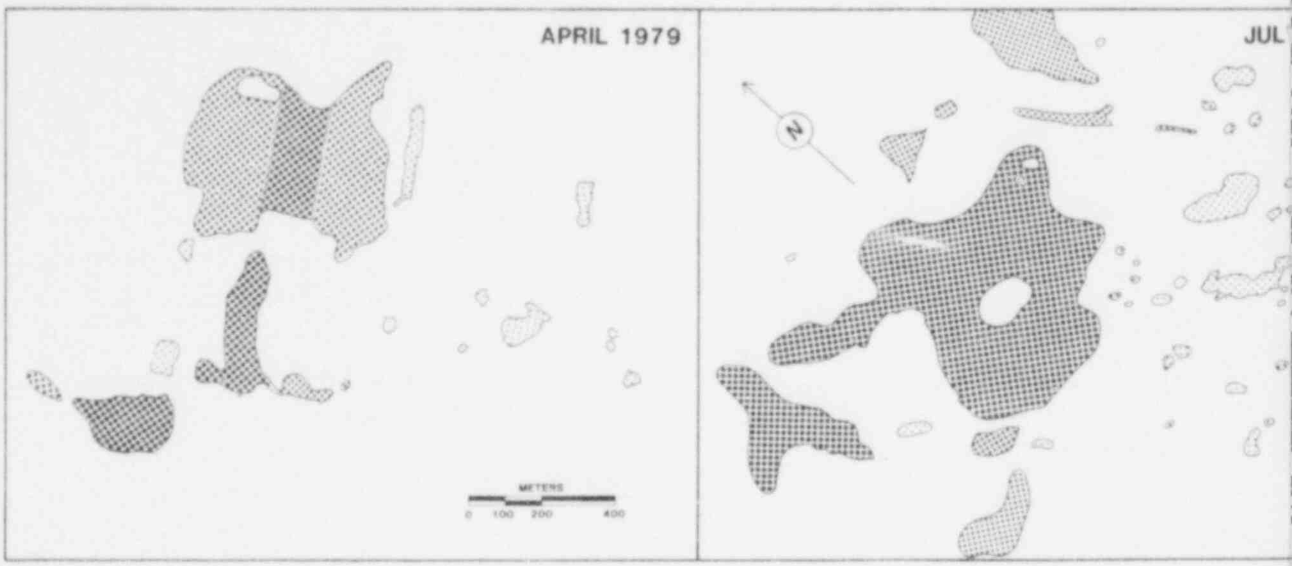
Barn Kelp Bed

The BK canopy was the smallest of the three canopies mapped, ranging in size from approximately 88,000 m^2 in April 1979 to 262,700 m^2 in February 1980 (Table 7-1). In April the kelp bed consisted of scattered patches of canopy with the largest occurring in the offshore-downcoast region (Area 1). By July many of the small fragments of canopy began to coalesce, especially in Area 1 where the areal extent of the canopy increased considerably. Little change in the extent of the Barn kelp canopy was noted between July 1979 and February 1980 (Table 7-1), although its configuration underwent major changes (Figure 7-6).

KELP BED SUBSTRATE

Suitable substrate (i.e. rock, cobble, or reef) is one of the major factors in controlling the expansion and maintenance of the kelp beds. Loss of suitable substrate may result from burial of the rocky areas by either bedload movement or sedimentation. The movement of bedload is the result of physical processes associated with wave and current action, while sedimentation is the result of either man-made or natural processes.

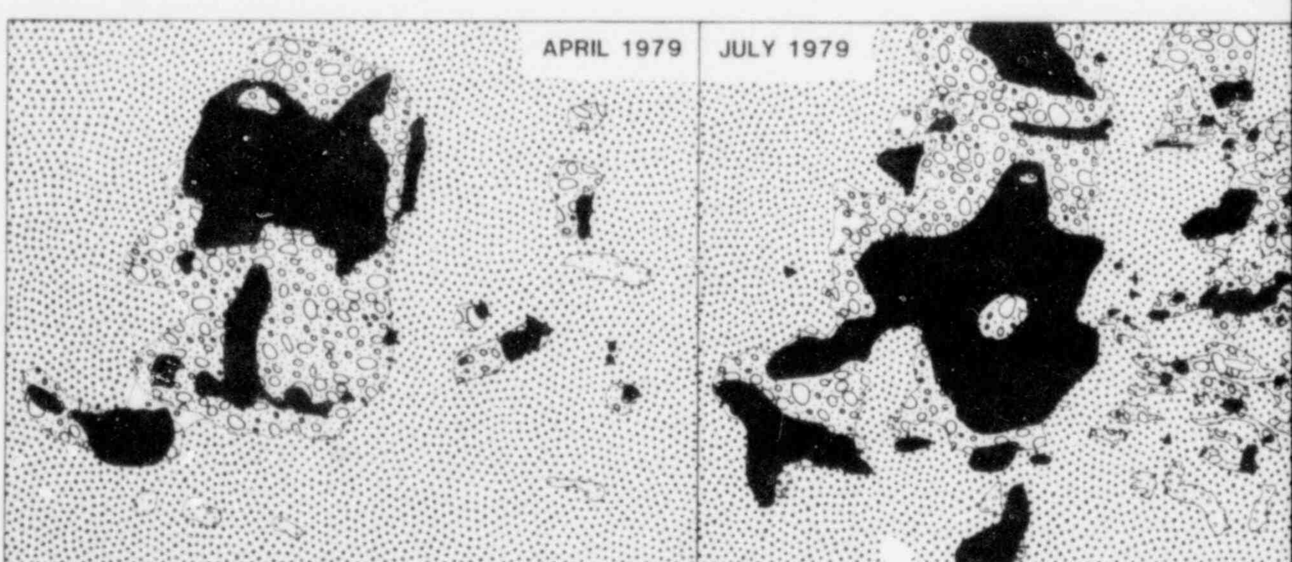
The purpose of this segment of the investigation was to qualitatively examine the changes in general substrate composition of the three kelp beds under examination, and to examine the relationship, if any, between changes in the areal extent of the kelp canopies and availability of suitable substrate.



Key: HIGH DENSITY

GREATER THAN 90% SAND

10% - 30% COBBLE



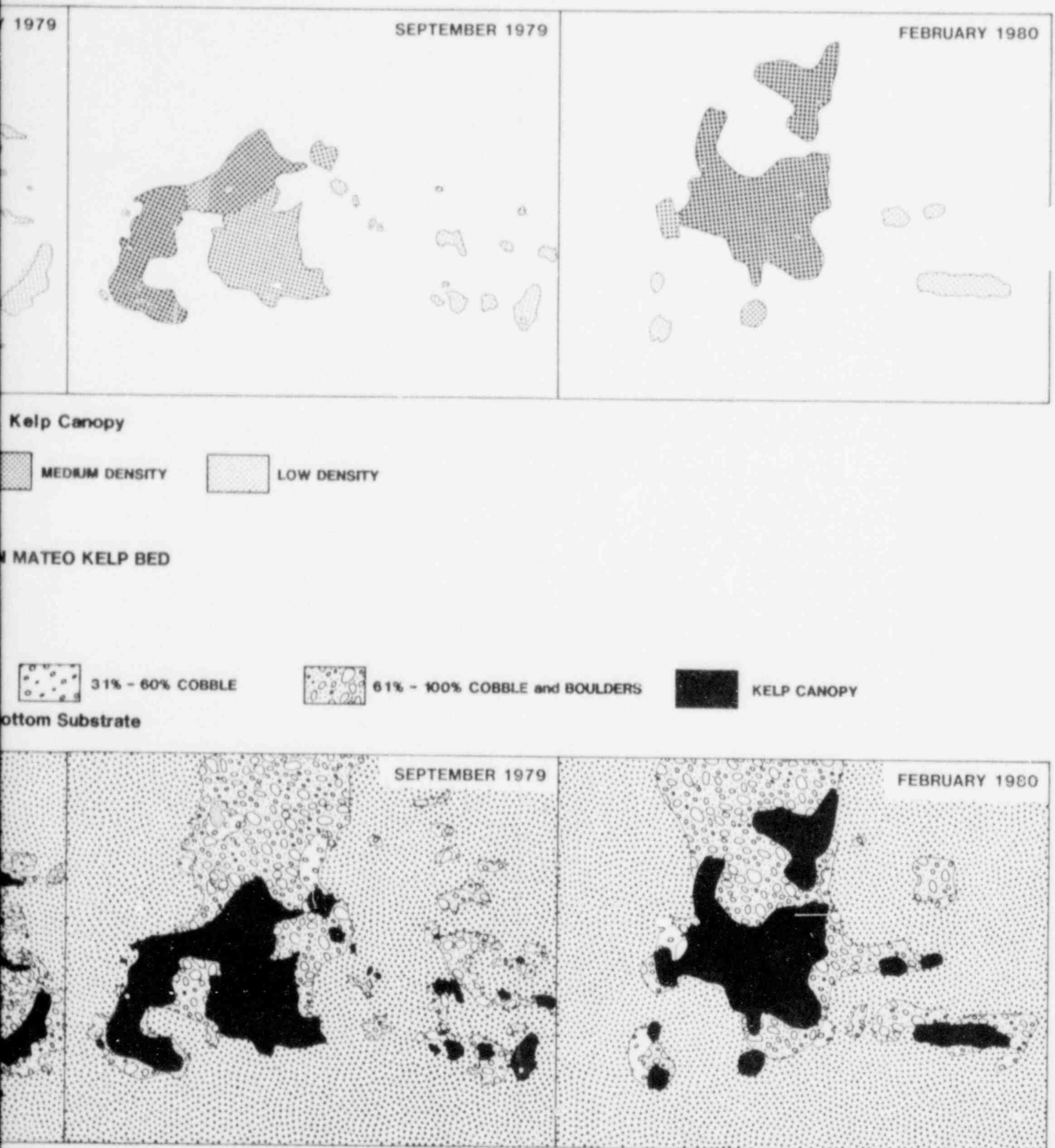


Figure 7-4. Kelp canopy configuration, relative canopy density, and substrate composition of the San Mateo kelp bed from April 1979 through February 1980 (data supplied by Ecosystem Management Associates, Inc.).

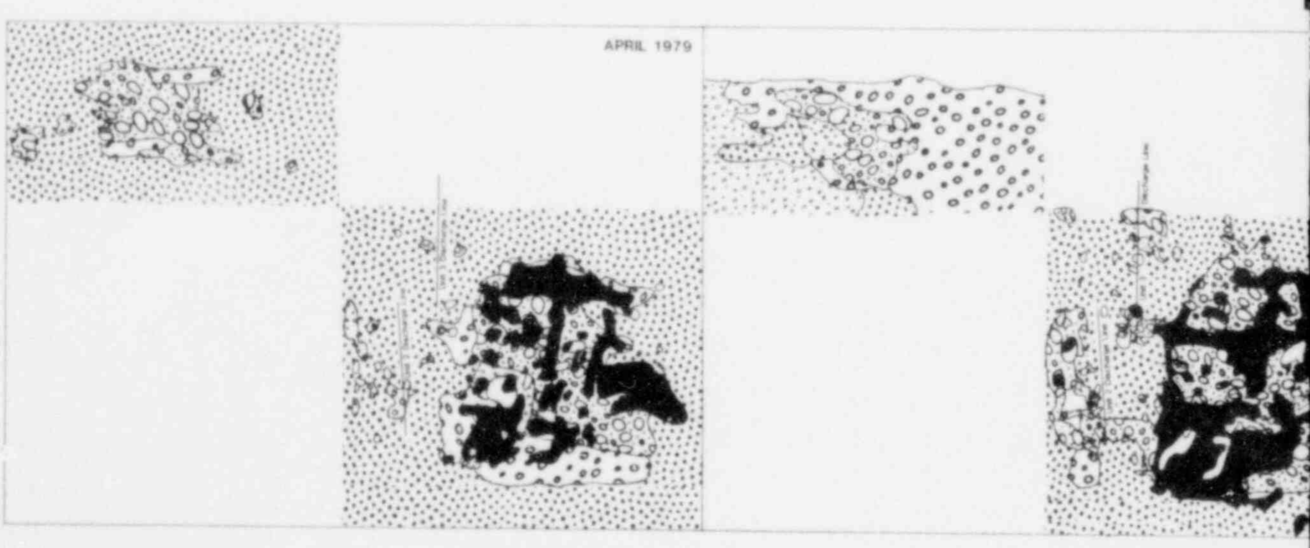
Key: HIGH DENSITY

SAN

GREATER THAN 90% SAND

10% - 30% COBBLE

3



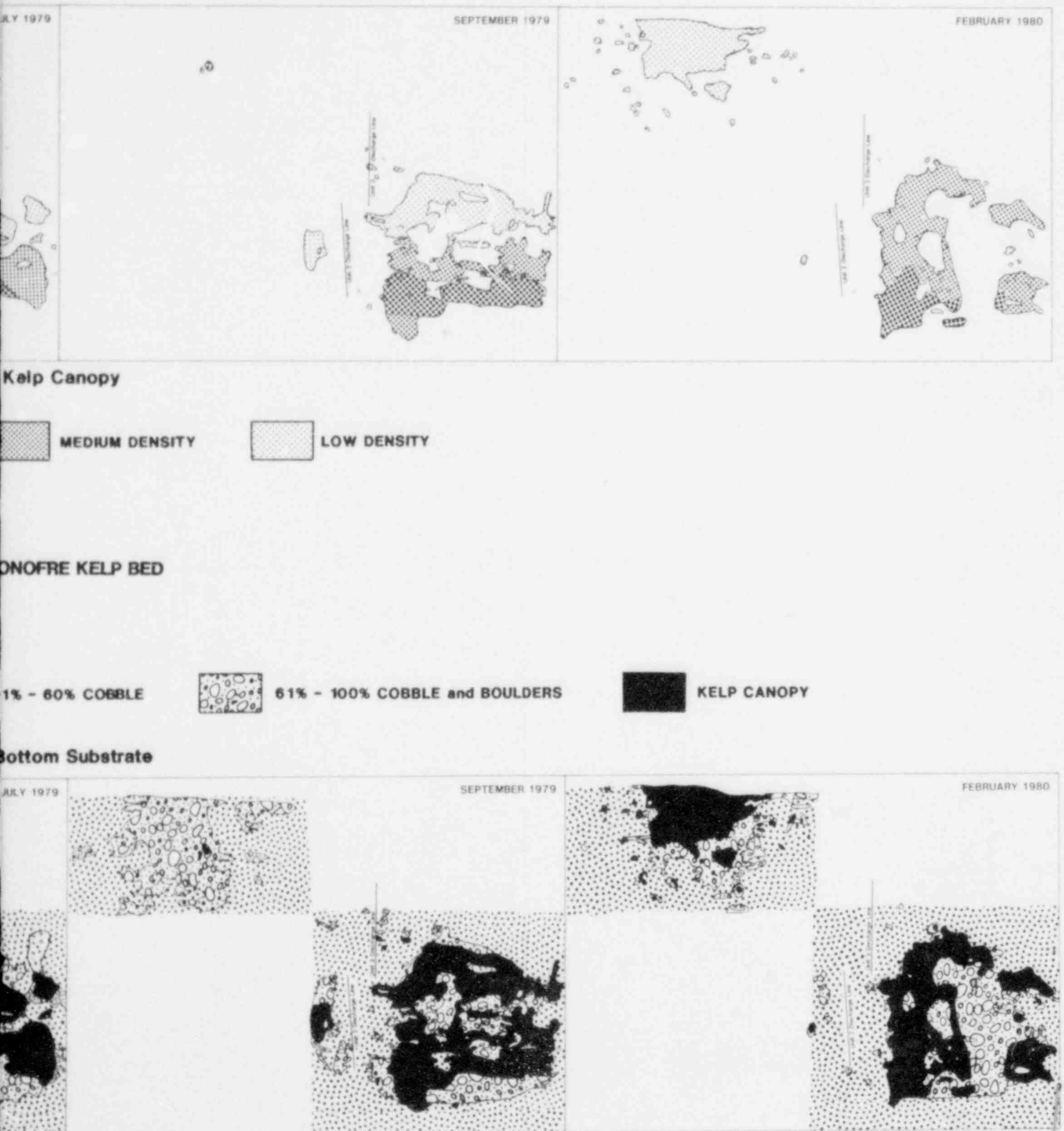


Figure 7-5. Kelp canopy configuration, relative canopy density, and substrate composition of the San Onofre kelp bed from April 1979 through February 1980 (data supplied by Ecosystem Management Associates, Inc.).

Key: HIGH DENSITY

BA

GREATER THAN 90% SAND

10% - 30% COBBLE

B

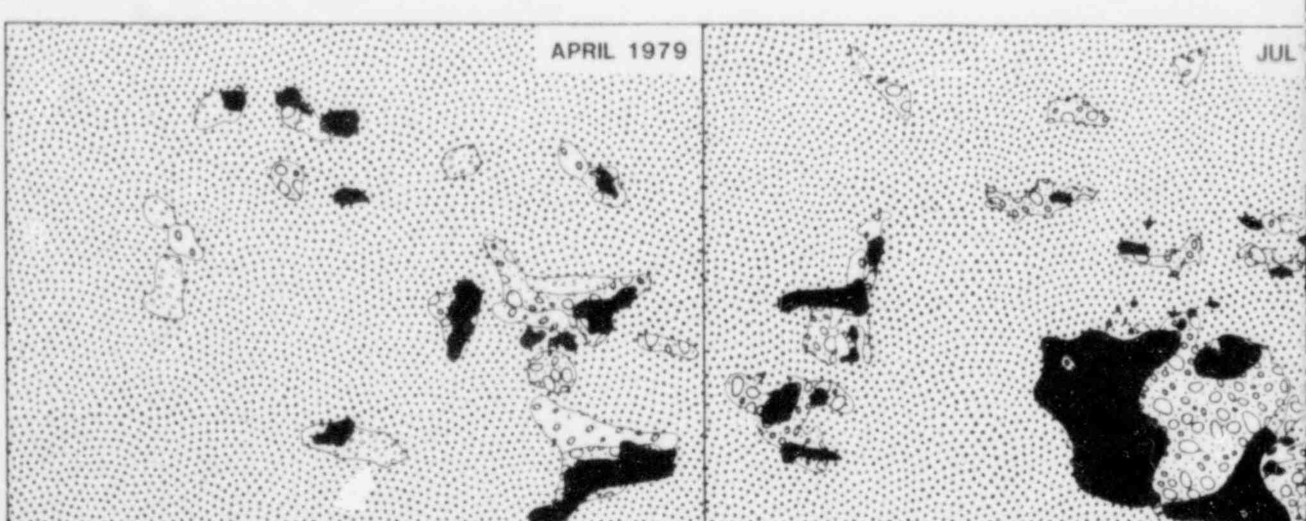


Figure 7-6. Kelp canopy configuration, relative canopy density, and substrate composition of the Barn kelp bed from April 1979 through February 1980 (data supplied by Ecosystem Management Associates, Inc.).

San Mateo Kelp Bed

The substrate associated with the SMK bed was almost entirely high density (60 to 100%) cobble and boulders throughout 1979 (Figure 7-4).

Availability of suitable substrate appears to have limited outward expansion of the SMK canopy. During all four surveys, the outer perimeter of the canopy occurred in the cobble-boulder-sand interface (Figure 7-4).

The major areas of the canopy never completely covered the inner area of the kelp bed in 1979 even though suitable substrate was apparently available. The change in configuration of the kelp canopy between each survey suggests that these areas were inhabited by Macrocystis plants, but the plants were not part of the canopy.

San Onofre Kelp Bed

The kelp canopy of the SOK bed was also associated almost entirely with a substrate of 60 to 100% cobble and boulder. The area of cobble-boulder substrate increased substantially from April to July 1979 and then changed very little between July and February 1980 (Figure 7-5).

The outward expansion of the kelp canopy also appears to have been related to the availability of suitable substrate during 1979. The outer edge of the canopy during the April, July, and November surveys corresponded closely to the cobble-boulder-sand interface or areas of high sand content. In February 1980, a majority of the downcoast cobble-boulder substrate was lacking canopy.

Barn Kelp Bed

The substrate of BK was composed of a high percentage of sand throughout the survey period. In the April survey, the 60 to 100% cobble and boulder substrate was restricted to a few relatively small areas scattered throughout the study area. Beginning in July and continuing through February 1980, a major section of the cobble and boulder substrate appeared in the offshore-downcoast region of the Barn kelp. This region of Barn kelp supported most of the canopy recorded during the survey period (Figure 7-6).

MONTHLY SEDIMENTATION RATES

To investigate the relationship between dredging, sedimentation, and changes in substrate composition, sedimentation rates were determined monthly at two areas within the SOK bed. One sediment trap was located in the upcoast section of the kelp bed approximately 780 m from the SONGS Unit 3 dredge line, while the second trap was located in the downcoast section of the kelp bed approximately 1560 m from the dredge line. Each sediment trap was located adjacent to a LCMR benthic macrobiota transect (Figure 7-1) from which quarterly changes in sand cover were obtained.

Sedimentation rate data from the two kelp bed stations were compared with a control station located approximately 2500 m downcoast of the dredge line and a station located 250 m downcoast of the dredge line at similar depths. (Stations F3 and D3, respectively, of the SONGS benthic infaunal Construction Monitoring Program). Sediment trap data is presented in Appendix VI.

Results of the investigation indicate that monthly sedimentation rates were approximately 2 to 12 times higher at the upcoast section of the kelp bed than at the downcoast kelp bed, the control station (F3), or the station adjacent to the dredge line (D3). There was no apparent relationship between the temporal pattern of sedimentation recorded at the upcoast kelp bed station and the remaining three stations.

Monthly sedimentation rates at the downcoast kelp bed station were very similar to those reported at the control station for most of the year. Downcoast values in the kelp beds were also similar from January through April, to that recorded at Station D3 (Figure 7-7).

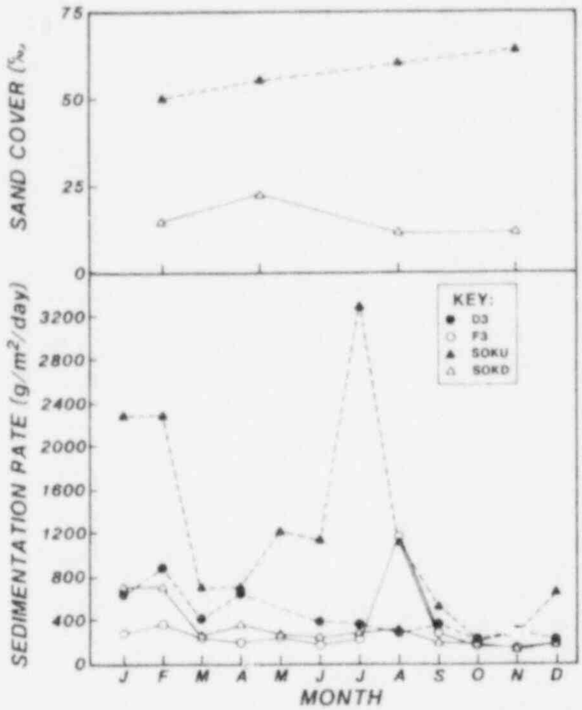


Figure 7-7. Monthly sedimentation rate and quarterly percent sand cover at the upcoast and downcoast San Onofre kelp bed sediment trap stations during 1979.

There appeared to be little, if any, relationship between sedimentation rates and changes in sand cover at the two kelp bed stations (Figure 7-7). The lack of relationship in sedimentation and substrate sand cover was especially evident at the upcoast kelp bed station. This was probably due to the nature of the suspended sediments within the water column. Although the grain size of the sediments within the traps was not determined, visual observations indicated that the sediments were composed of fine material which was probably easily removed from the study area by current and surge action before they could accumulate (Figure 7-7).

WATER COLUMN NUTRIENT ANALYSIS

Surface and bottom water concentrations of nitrogen (NO_2 + NO_3), ammonia (NH_4), and phosphate (PO_4) were determined monthly at stations inside and outside of the SMK, SOK, and BK beds. In addition, a station approximately 4.3 km offshore of the San Onofre kelp bed was occupied monthly to monitor upwelling in the area. At the offshore stations, water samples were collected from the surface and depths of 15 m, 30 m, and 45 m.

Nutrient concentrations from inside and outside the kelp beds were averaged for the following presentation because of a lack of a noticeable pattern between the two areas. All raw nutrient data are presented in the SONGS Oceanographic Data report (SCE 1980).

Nitrogen Concentrations

The temporal distributional pattern of nitrogen concentration was similar among the three kelp beds during 1979. In the surface waters, concentrations decreased from January through March, peaked in May, and then decreased sharply in June. From June through November, concentrations underwent little change. In December, nitrogen levels increased sharply at BK, while only a minimal increase was observed at SMK, and a decrease was recorded at SOK (Figure 7-8).

Nitrogen levels in the bottom waters decreased from January through March. Major increases in nitrogen levels were recorded in April, May, July, and October through November (Figure 7-8).

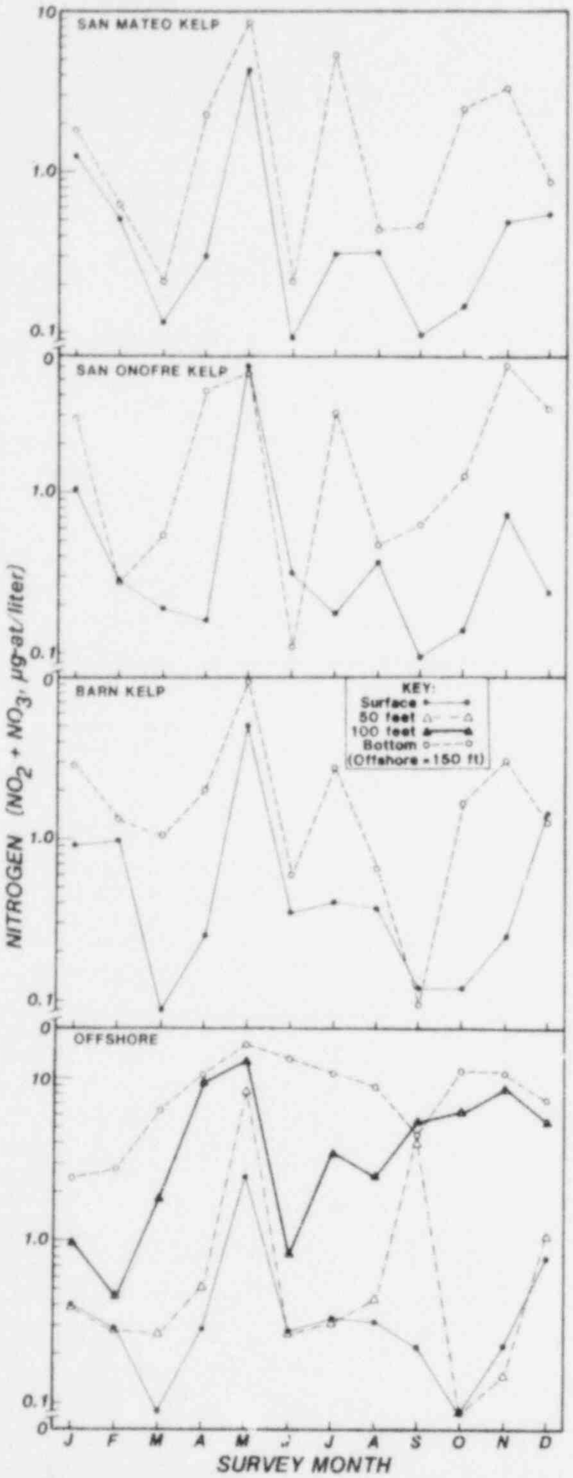


Figure 7-8. Average monthly concentrations of total nitrogen in the surface and bottom waters at the San Mateo, San Onofre, and Barn kelp beds and at the surface, 15, 30, and 40 m depths at the offshore stations from January 1979 through December 1979.

Examination of data from the 45 m depth at the offshore station indicated that upwelling, signified by increased levels of nitrogen, began in March and peaked in May. Upwelling appears to have continued through August, although the magnitude decreased steadily from May through August. The 45 m nitrogen data indicated that a second upwelling pulse occurred from October through November and possibly into December (Figure 7-8).

The 30 m depth also reflected the upwelling pulses in March through May and again in October and November, while elevated levels of nitrogen were recorded at the 15 m depth only in May and September and at the surface only in May.

Ammonia Concentrations

Surface ammonia concentrations were minimal from January through March, peaked in May at all three kelp beds, then declined sharply through July. From July through December, ammonia concentrations exhibited only slight variations (Figure 7-9).

Bottom water ammonia concentrations generally tracked those of the surface waters from January through July, except at BK where a minor increase was reported in February. From August through December, ammonia concentrations underwent minor fluctuations (Figure 7-9).

The temporal distribution of ammonia levels at the offshore station tracked that recorded at the three kelp beds with peak concentrations recorded during May and June. A second major increase was recorded in the surface waters in December, while a minor increase was recorded at the 15 and 30 m depths.

Phosphate Concentrations

Phosphate levels at the three kelp beds, unlike nitrogen and ammonia levels, underwent constant fluctuations. In the surface waters, peak levels of phosphate were recorded in April at SMK, and May at SOK and BK (Figure 7-10).

In the bottom waters, phosphate levels peaked in May and July with secondary increases from September through December at the three kelp beds (Figure 7-10).

Phosphate levels at the offshore station peaked between April and June in the upper 50 m of the water column, while minimum values were recorded in August. A secondary increase was recorded in September at the 15 through 50 m depths. Increase was not recorded in the surface waters until December (Figure 7-12).

KELP TISSUE ANALYSIS

Nitrogen content of kelp blades varies according to availability of inorganic nitrogen compounds (primarily nitrate and ammonia) in the surrounding waters. Values of 1.0 to 1.2% of the dry weight of kelp tissue as nitrogen probably represent healthy mature tissue which lacks nutrient reserves (W. J. North personal communication). The following results represent the monthly average kelp leaf nitrogen content (based on 15 observations) at the San Mateo, San Onofre, and Barn kelp beds. Raw data are presented in the SONGS Biological Data report (SCE 1980a).

The annual distribution of kelp leaf nitrogen levels, as expected, followed the distribution of water column nitrogen levels. In the three kelp beds investigated, kelp leaf nitrogen levels underwent a major increase in May, followed by a secondary increase in October and December at the SOK and SMK beds. Kelp leaf nitrogen levels in the Barn kelp bed exhibited a minor pulse in July, followed by secondary peaks in November and December (Figure 7-11).

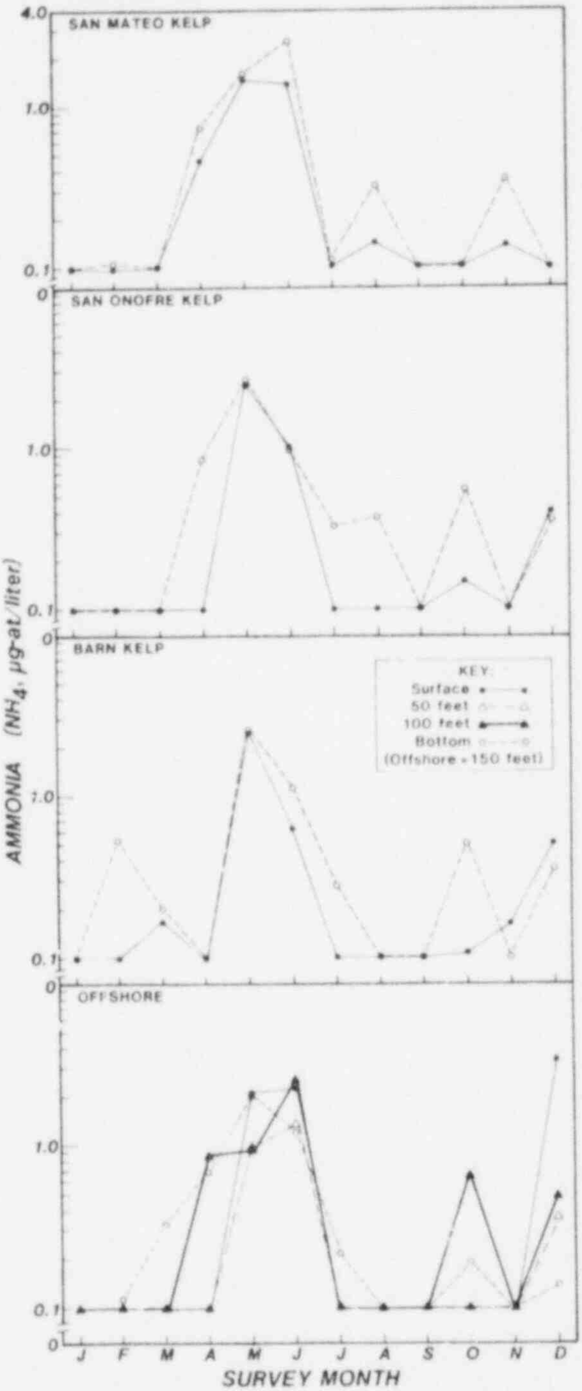


Figure 7-9. Average monthly concentrations of total ammonia in the surface and bottom waters at the San Mateo, San Onofre, and Barn kelp beds and at the surface, 15, 30, and 40 m depths at the offshore stations from January 1979 through December 1979.

An examination of the nitrogen levels of individual kelp leaves collected suggest that kelp plants within SOK and BK may have been difficient in nitrogen during several months in 1979. In the SOK bed, half or more of the kelp leaves collected (a total of 15 per month were collected) were below the 1% nitrogen level by weight during July, August, and 1% nitrogen level in half or

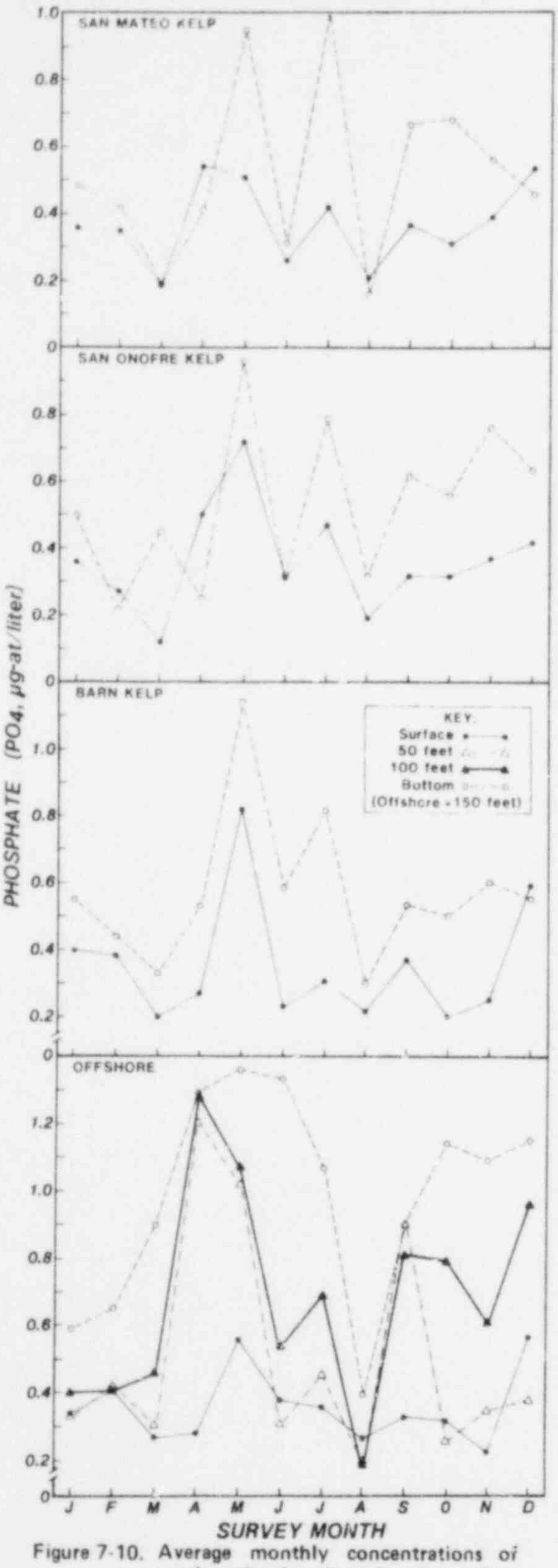


Figure 7-10. Average monthly concentrations of total orthophosphate in the surface and bottom waters at the San Mateo, San Onofre, and Barn kelp beds and at depths at the offshore stations from January through December 1979.

more of the leaves collected in January, April, July, and September. By comparison, only during November did the nitrogen level in any kelp leaf collected in the SMK bed (20% of leaves collected) fall below the 1% level.

GENERAL HEALTH OF KELP PLANTS

The general health of the kelp plants inhabiting the SMK, SOK and BK was determined on May 24, September 28, and December 16, 1979. The purpose of the surveys was to qualitatively assess the health of the kelp plants within the three kelp beds and determine if the condition of kelp plants in the San Onofre kelp bed was comparable to that in the San Mateo and Barn kelp beds.

May Survey

Kelp plants at the SMK bed appeared to be in good condition in May. There was no sign of disease. Bryozoan colonies on the kelp blades were minimal. New growth on existing kelp plants was evident and the kelp tissue exhibited good color. Throughout most of the kelp bed investigated, juvenile *Macrocystis* plants were sparse. In a few areas of the kelp bed, the growth of juvenile plants appeared to be light limited.

Kelp plants in both the offshore and inshore areas of the SOK bed appeared healthy both at and below the surface although some senile fronds and moderate bryozoan growth on kelp leaves was noted in the inshore region. Scattered juvenile *Macrocystis* plants were observed near the onshore origin of Transect B (Figure 7-3). Approximately 320 m offshore of the transect origin, sea urchins (primarily *Strongylocentrotus franciscanus*) dominated the area. Within the same area, a moderate number of small juvenile *Macrocystis* (mostly single blades) were observed. Juvenile and young *Macrocystis* were also common in areas of the offshore kelp bed.

The kelp plants in the northern offshore section of the Barn kelp (Station A) were similar to those plants observed at the SOK bed. Some

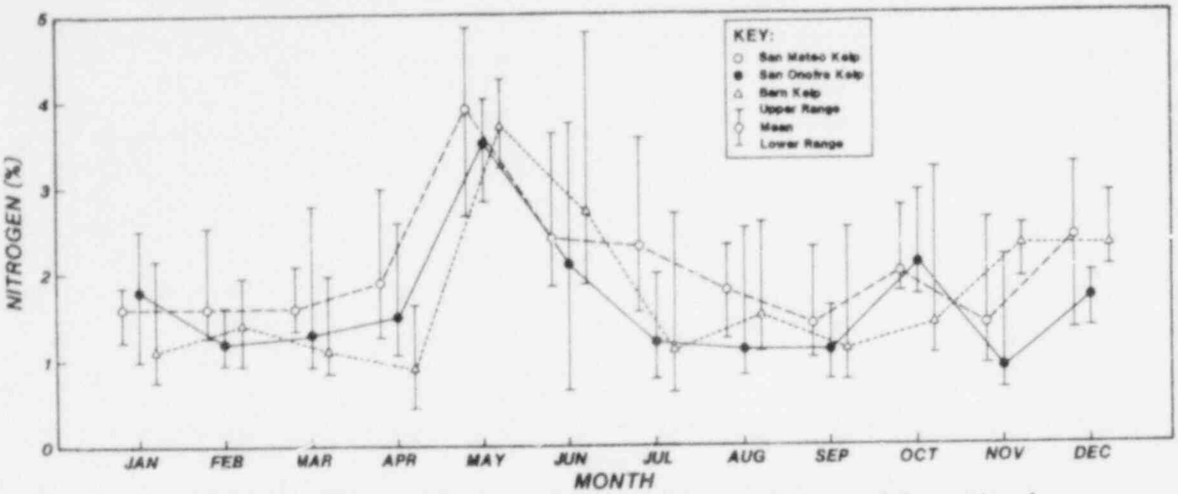


Figure 7-11. Mean nitrogen concentration, expressed as a percentage of dry weight, of the kelp leaves occurring in the San Mateo, San Onofre, and Barn kelp beds from January 1979 through December 1979.

senile fronds were present and moderate bryozoon growth was present on the kelp leaves. Adult kelp plants were sparse and patchy.

The inshore and offshore southern sections of the BK bed contained healthy plants with good blade color and minimal bryozoan growth. New growth, on adult plants, was evident in both sections.

September Survey

Adult kelp plants at Station D of SMK appeared in good health with no deterioration noted at either the hold fast or stipes. Bryozoans were almost absent from the kelp leaves observed. Very few juvenile Macrocystis were observed during the survey.

The kelp canopy in the offshore SOK bed was sparse in September. Adult plants in this area exhibited black rot and the leaves were moderately covered with bryozoan colonies. The kelp leaf color was generally pale. Approximately 20-40% of the kelp fronds examined were in good condition while less than 1% were senescent.

The canopy at the inshore section of the SOK beds was also generally sparse. Adult Macrocystis along the inshore section of Transect B appeared healthy. Holdfasts were well anchored, sporophyll clusters were in good condition and few sunken fronds were observed. Juvenile Macrocystis were common along the first 200 m of the inshore segment of Transect B.

Juvenile Macrocystis were also common at Station C in the SOK bed. There was some sediment present on the rocks and kelp blades in this area.

The canopy at the BK bed was sparse with approximately 10 to 30% of the fronds in a senescent condition. Kelp leaves were generally pale with some black rot present. Moderate concentrations of bryozoans were present on the kelp leaves observed. Some deteriorating holdfasts were observed.

December Survey

A Kelco vessel was harvesting the kelp in the area of the SMK bed Station D on the day of the survey. Consequently, the investigation was conducted at the western edge of the main section of the kelp bed to avoid the harvesting process.

All kelp plants in the area investigated were healthy, the tissues were deeply colored, and the bryozoan cover was moderate. There was some sediment on the kelp leaves. Juvenile Macrocystis plants were observed wherever open space occurred and sunlight could penetrate to the bottom. The kelp bed had expanded to the seaward limits of the rock substrate.

Juvenile Macrocystis as well as other algal species were abundant on approximately the first 150m of the inshore section of SOK Transect B. For approximately the next 140m the transect consisted of barren cobble dominated by sea urchins (primarily Strongylocentrotus franciscanus).

Dense clusters of juvenile Macrocystis were encountered at approximately 1,133 m and 1,233 m from the origin of the transect (inner and outer margins of the offshore section of the bed).

Kelp plants in the offshore section of the transect were generally in good health although a few fronds had lost buoyancy and were floating in the water column or resting on the bottom.

At Station C in the SOK bed young Macrocystis up to 10 to 20 feet in height were abundant. Scattered smaller plants were also observed. Approximately 1cm of sediment was present on the rocky substrate while some was noted on the kelp leaves.

The kelp canopy at Station A of the BK bed was held under by a current, apparently because the kelp leaves were densely encrusted by bryozoans. This contrasted with canopies on the surface approximately 30m away.

A few scattered juvenile Macrocystis were observed in open areas where canopy shading was absent, particularly along the inshore rock-sand interface. Bases of adult plants were in good condition, firmly attached, and with prolific clusters of sporophylls. Much of the rock substrate was covered by approximately 1cm of sediment.

DISCUSSION

The present kelp program was instituted in December 1976 to monitor the "health" of the SOK bed during the construction phase of SONGS Units 2 and 3. Construction activities, specifically dredging, can adversely effect the development, growth and maintenance of a kelp bed by increasing ambient turbidity and sedimentation. Turbidity can adversely effect recruitment success of Macrocystis by reducing bottom irradience below the compensation level resulting in retarded growth or loss of newly settled plants depending on the length of irradiance reduction (Deysher and Medler 1978; Dean 1979 a,b). Sedimentation may also adversely affect Macrocystis recruitment by reducing the substrate available for sporophyte and gametophyte settlement or burying developing gameophytes (Devinny and Volse 1978). Either increased turbidity, sedimentation, or a combination of both can reduce, and in extreme cases eliminate, an existing kelp bed over a period of time.

Observations and data collected to date suggest 1) dredging activities did substantially increase turbidity and sedimentation in the upcoast section of SOK; 2) no major loss of kelp canopy accompanied the increased turbidity and sedimentation (although what effect dredging activities had on the development and expansion of the San Onofre kelp bed is not known); and 3) qualitative observations made in the upcoast section of SOK suggested that "health" of the adult plants were not affected by the dredging operations.

Based on bimonthly light transmittance data (SCE 1979a, 1980a) it appears that the major increases in turbidity were the result of dredging and backfill activities associated with the construction of SONGS Units 2 and 3 diffuser line. Although bi-monthly surveys covered only a fraction of the time dredging activities were conducted, the data suggest that the dredge related turbidity "plume" was in contact with the upcoast section of the kelp bed through much of the spring and summer of 1978 and through May 1979. Further, sedimentation rates in the upcoast San Onofre kelp bed were increased approximately 2 to 12 times ambient (see Figure 7-7).

Although turbidity and sedimentation were substantially elevated in the upcoast section of the kelp bed, there was no decrease in the areal extent of the canopy directly attributable to dredging activities. Kelp mapping data, in fact, indicated that some expansion of the upcoast canopy did occur in the direction of the dredge line and a new inshore section of the canopy developed between 500 to 1500 m north of the dredging activities in 1979.

Although canopy mapping investigations have shown no substantial decrease in the kelp canopy there is evidence to suggest that dredging activities may have reduced the potential expansion of the offshore SOK canopy. Deysher and Medler (1978) documented the presence of a "substantial" population of juvenile Macrocystis in the area of the Unit 2 diffuser dredgeline and Macrocystis of medium to high frond density approximately 300m downcoast of the dredgeline prior to dredging activities. Neither of these stands of Macrocystis have formed a canopy during the course of the investigations suggesting that their growth was suppressed.

Investigations conducted at SONGS on the relationship of turbidity on Macrocystis recruitment and juvenile growth (Deysher and Medler 1978; Dean 1979 a,b) further suggest that dredging activities probably had a negative effect on successful Macrocystis recruitment in the upcoast section of the kelp bed. Deysher and Medler (1978) and Dean (1979 a,b) have demonstrated that reduced irradiance (below $1E/M^2$/ day) and/or scouring associated with turbidity can suppress or prevent gametogensis and sporophyte development while Dean (1979a) has indicated that elevated turbidity can significantly suppress the growth of young kelp plants. Quantification of turbidity affects in the present study cannot be documented because of a lack of irradiance data and quantative Macrocystis recruitment data. These qualitative investigations did indicate, however, that successful recruitment occurred during the latter part of both 1978 (SCE 1979b) and 1979 and appeared to be especially successful at the inshore origin of Transect B and at Station C. The recruitment did correspond to an absence of dredge related turbidity (SCE 1979a, 1980a) but also corresponded to reduced levels in ambient turbidity: thus with the available data it is not possible to hypothesize a direct cause and effect relationship.

The effect of dredge related sedimentation on the availability of rock and cobble necessary for Macrocystis recruitment within and adjacent to the kelp bed is difficult to determine. Sediment trap data does indicate that monthly sedimentation rates were approximately 2 to 12 times ambient at the upcoast kelp bed station in 1979. A conversion of monthly sedimentation rates to daily deposition rates (see subtidal sediment section) indicates that there was the potential for the average daily deposition of roughly 3.3 cm of sediment per day at the upcoast station. In comparison, the average daily potential at the downcoast kelp bed station was roughtly 0.3 cm per day. Data collected from subtidal and infaunal stations within and outside of the influence of the dredging activities suggest that a majority of the sediment was not deposited but was in a state of flux. Further, change in sediment composition within the kelp bed recorded between substrate mapping surveys were probably normally accretion and attrition related to oceanographic conditions (see Chapter 2D). This is supported by estimates of sand cover at the LCMR transect adjacent to the upcoast sediment trap, although the observations are at best a gross estimation of existing conditions.

Dredging related activities do appear to have substantially affected the availability of suitable substrate for Macrocystis recruitment in the area between the dredge line and the upcoast section of the kelp bed. A comparison of substrate composition adjacent to the SONGS Units 2 and 3 diffuser dredge line prior to the initiation of dredging activities in December 1977 (Deysher and Medler 1978) with the composition mapped in December 1978 (SCE 1979c) and February 1980 (present investigation) indicates that a substantial fraction of the cobble substrate (a possible area for kelp bed expansion), present in 1978 has been buried. By February 1980 a corridor of sand approximately 200 m on either side of the dredge lines had been formed. Accumulation of large grain-size sediments from dredging activities is probably responsible for at least part of the change in substrate composition. Other factors such as alteration of the normal littoral drift and storm related activities probably also contributed to the noted change in substrate composition. The data does suggest that directly or indirectly, dredging activities may have limited the upcoast expansion of the San Onofre kelp bed.

Examination of adult Macrocystis plants for their relative state of health during the course of the investigation provided no indication that dredging activities had a measureable effect on their general health. Signs of poor health (i.e. black rot, senility, off-colored tissue, etc.) in the adult plants were noted following 1) the major period of canopy deterioration in the summer of 1976; 2) the major storm systems of February and March 1978; 3) the periods of normal summer deterioration (North 1971); and 4) following the winter storms of 1979. In each instance, major episodes of kelp deterioration or stress in adult Macrocystis was associated with naturally occurring events.

Signs of poor health (i.e. black rot, senility, etc), were prevalent in the SOK canopy following the major period of canopy deterioration in 1976, and through much of 1977 (MBC 1978). Natural processes (possibly reduced nutrient levels, W. J. North personel communication) were responsible for the deterioration. Dean (1979b) suggested that elevated copper levels associated with SONGS operation may have aggravated the condition, although no evidence of copper toxicity has been documented. The deterioration was also present in the San Mateo kelp bed although the Barn kelp bed exhibited virtually no deterioration. Following the period of deterioration approximately 80% of the SMK and SOK canopy was lost while the BK canopy underwent little change (MBC 1978).

The major storm systems that passed through the study area in February and March 1978 left much of the SOK canopy tattered. Further, large deposits of sediment were noted in the kelp bed, covering the cobble substrate (SCE 1979c).

The winter storms of 1978 apparently affected the BK bed substantially more than either the SMK or SOK beds. Between December 1977 and June 1978 the BK canopy was reduced approximately 90% (SCE 1979c). As of February 1980 the BK canopy remains relatively small, comprising approximately 25% of the pre-storm canopy.

Prior to the initiation of the present kelp bed investigation in December 1976, the SOK bed and to a lesser extent the SMK bed, underwent a major period of deterioration (MBC 1978). It was suggested that the deterioration was due to a reduction of water column nutrient levels in the summer of 1976 (W. J. North personal communication). In order to examine the relationship between nutrient levels and future episodes of major kelp deteroration, a kelp tissue and water column nutrient monitoring program was initiated in May 1977.

No relationship between nutrient levels and major episodes of kelp deterioration was observed during the three year investigation. The BK bed canopy did significantly diminish in areal extent following the major storms of early 1978, but the loss of most of the canopy appears to have been related to storm damage and possibly other factors (burial of suitable substrate, etc.) associated with the storms. Total nitrogen concentrations throughout the year were similar among the three kelp beds. All beds showed the April to May and November to December peaks (Figure 7-8).

W. J. North (personal communication) has suggested that kelp tissue nitrogen levels, below 1% of dry weight over an extended period of time, is probably detrimental to the maintenance and growth of the adult kelp plants. Though nitrogen below the 1% level were often common in kelp tissue collected from one or more of the kelp beds during the summer months, concentrations rarely remained below the 1% level for any extended period of time. An increase in mean kelp tissue nitrogen concentrations was observed in all three kelp beds during May 1979 and was coincident with the increase in water column total nitrogen for that period. This was not particularly reflected in an increased overall canopy size, as all three beds continued to increase in size throughout the year.

Water column and tissue nutrient levels did suggest that nutrient concentrations often varied between individual kelp beds (MBC 1978, SCE 1979c, present investigation). Further, the nutrient data indicated that the nutrient regime in the study area varied considerably from year to year. Differences were mainly the result of terrestrial runoff associated with the major storms of early 1978 (SCE 1979c) and the second major episode of upwelling in the fall of 1979.

The areal extent of the kelp canopies of the San Onofre region have undergone several major changes since they were first mapped in 1911. Often changes in one canopy, especially the SOK canopy, have been independent from changes noted in the other canopies of the region. Until the causes mechanisms (i.e. interaction of nutrients, light levels, sedimentation, etc.) controlling canopy size are better understood, it will be difficult to interpret future changes in the SOK canopy and distinguish between naturally occurring changes in canopy extent and those induced by the operation of SONGS.

SUMMARY

Studies of the kelp beds in the San Onofre region were conducted from January 1979 through February 1980. The investigations included: 1) mapping the areal extent of the canopy and associated substrate of the San Mateo, San Onofre and Barn kelp beds; 2) determination of sedimentation rates in the upcoast and downcoast section of the San Onofre kelp bed; 3) nutrient analysis of the waters in and adjacent to the three kelp beds; 4) determination of nitrogen concentrations of kelp leaves of the three kelp beds; and 5) a qualitative assessment of the general health of the kelp plants within the three kelp beds.

1. Dredging activities did substantially increase turbidity and sedimentation above ambient conditions in the upcoast section of the San Onofre kelp bed.

2. No substantial loss of kelp canopy accompanied the increased turbidity and sedimentation although what effect dredging activities had on bed development and expansion is not known.

3. Successful Macrocystis recruitment in the upcoast section of the San Onofre kelp bed was observed from September through December in both 1978 and 1979.

4. Qualitative observation suggests that dredging had no measureable effect on the adult Macrocystis plants of the San Onofre kelp bed.

5. During this three year investigation (1977, 1978, 1979), neither water column nor tissue nutrient levels could be correlated with changes in kelp canopy size.

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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.

Autocorrelation — Describes the general dependence of the values of the data at one time on the values of another time.

$$R_x(t) = \lim_{T \to \infty} \frac{1}{T} \int_0^T x(t)x(t+\tau)\,dt$$

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 Cross-Sectional Area — (See Beach Profile Area)

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.

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.

$$\text{Chlorophyll } \underline{a} \ (mg/m^3) = \frac{\frac{Fo/Fa_{max}}{(Fo/Fa_{max})-1} \ (k_x)(Fo-Fa)}{\text{liters filtered}}$$

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.

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 Terrigeneous Sediments

Mineral and rock particles washed from areas that have been eroded during approximately the last 7,000 years. 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).

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.

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.

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.

Insolation — The radiation from the sun received by a surface; the rate of such radiation per unit of surface.

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).

Normal 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_.

$$\text{Phaeo-pigments (mg/m}^3\text{)} = \frac{\dfrac{Fo/Fa_{max}}{(Fo/Fa_{max})^{-1}}(k_x)\left[Fo/Fa_{max}(Fa)-Fo\right]}{\text{liters filtered}}$$

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	Describes the general frequency composition of data in terms of the spectral density of its mean square value.
Power Spectral Density	The separation from a solution or suspension by physical or chemical change.
Predator	A species which actively preys 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.
Protandric Hermaphrodite	A sexual pattern found in various invertebrates in which sex changes with age; males being young and small, and after a short intersex stage metamorphosing into larger adult females.
Quadrat	Generally a rectangular frame enclosing a sampling plot for ecological or population studies.

Raptorial	Predatory beha·ior 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 $^0/oo$).
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 substratum.
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 (σI)

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).

$$\sigma_I = \frac{\phi_{84}-\phi_{16}}{4} + \frac{\phi_{95}-\phi_5}{6.6}$$

Sourc. 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.

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.

APPENDIX I - TEMPERATURE

TABLES

Table I-1. Mean and range of surface, mid-depth, and bottom temperature (°C) during 1979 bimonthly surveys.

	Depth	Item	Jan 11	Mar 14	May 16	Jul 11	Sep 5	Nov 7	Nov 27	Year
Operational Stations	Surface	Min/Sta[a]	15.0/FO	14.6/FO	15.1/FO[b]	18.0/A2S	20.0/C20N	15.6/E2S	15.8/FO[b]	14.5/FO
		Max/Sta[a]	18.1/XO	21.3/XO	20.7/XO	21.8/XO	22.5/XO	21.4/XO	20.0/XO	22.5/XO
		Mean Std Dev	15.7 0.64	15.5 1.04	16.2 0.87	19.4 0.88	20.9 0.49	16.1 0.82	16.6 0.79	17.2 5.79
	Mid-Depth	Min/Sta	14.6/C4N[b]	14.4/F14N	15.0/D2N[b]	16.0/E2S	17.9/E2S	15.8/E2S[b]	15.5/A2S	14.4/F14N
		Max/Sta	15.4/B1N	15.6/HO	16.8/HO	20.9/HO	20.9/C6N	16.8/A2N	17.0/B,5N[b]	20.9/HO[b]
		Mean Std. Dev	14.9 0.28	14.9 0.30	15.7 0.47	18.8 0.55	20.1 0.56	15.9 0.19	16.0 0.36	16.6 0.38
	Bottom	Min/Sta	14.4/F14N	13.6/FO	12.8/FO	12.9/F14N	13.4/FO	15.2/E2S[b]	14.7/E2N	12.6/FO
		Max/Sta	15.7/A2N	16.0/A1N	16.9/A1N[b]	19.6/B,5S	20.8/AO	16.6/A2N	17.0/A1N	20.8/AO
		Mean Std Dev	14.8 0.26	14.6 0.52	14.6 1.04	16.8 1.46	17.9 1.50	15.7 0.27	15.3 0.46	15.6 0.84
Preoperational Stations	Surface	Min/Sta	14.7/HO	14.4/HO[b]	14.1/M2S	17.8/M4N	19.6/M2N	15.9/F2N&S[b]	15.7/F24S[b]	14.1/M2S
		Max/Sta	15.5/F2N	15.6/F24S	16.8/F20N	19.7/F24S[b]	21.1/F24S	16.9/F22S[b]	16.4/F20N	21.1/F24S
		Mean Std Dev	14.9 0.17	14.7 0.36	15.1 0.69	18.4 0.60	20.3 0.52	16.3 0.32	16.0 0.76	16.5 0.42
	Mid-Depth	Min/Sta	14.7/HO[b]	14.1/M2S[b]	13.4/M2S	17.5/M4N	14.2/M2N	15.4/J4S	15.7/F2S[b]	13.4/M2S
		Max/Sta	15.2/F14S[b]	15.1/F24S[b]	15.9/F24S	19.1/F20N	20.8/F22S	16.3/F22S[b]	16.4/F20N	20.8/F22S
		Mean Std Dev	14.8 0.15	14.5 0.24	14.8 0.67	18.2 0.41	19.0 0.60	16.2 0.28	15.8 0.16	16.3 0.19
	Bottom	Min/Sta	14.2/M8N	11.9/M8N	11.2/M2N[b]	10.8/M8N	11.9/M8N	12.3/M8N	14.7/F2N	10.8/M8N
		Max/Sta	15.0/F24S[b]	14.6/F24S[b]	11.6/F2S[b]	14.6/F14S	16.6/F2N	15.5/F24S	15.6/F20N	16.6/F2N
		Mean Std Dev	14.6 0.21	13.2 0.72	13.8 0.76	12.1 0.45	15.8 1.45	14.1 1.11	15.1 0.27	13.7 0.80

[a] Minimum or maximum temperature and station where measured.
[b] Minimum or maximum observed at more than one station; value closest to discharge presented.

Table I-2. Yearly mean and range of surface, mid-depth, and bottom temperature (°C) at each station.

Station	Surface Min/Survey	Surface Max/Survey	Surface Mean ± Std Dev	4 Meters Min/Survey	4 Meters Max/Survey	4 Meters Mean ± Std Dev	Bottom Min/Survey	Bottom Max/Survey	Bottom Mean ± Std Dev
A2N	15.9/Jan	21.6/Sep	17.4 ± 1.93	a	a	a	15.9/Mar	21.5/Sep	17.1 ± 2.02
A1N	16.0/Nov ?	21.0/Sep	17.5 ± 1.65	a	a	a	15.1/Jan	20.3/Sep	16.8 ± 1.59
A0	15.9/Nov ?	21.0/Sep	17.3 ± 1.75	a	a	a	14.8/Jan	20.8/Sep	17.1 ± 1.94
A2S	15.5/Mar	20.3/Sep	16.9 ± 1.59	15.2/Jan	20.2/Sep	16.6 ± 1.77	15.2/Jan	20.2/Sep	16.3 ± 1.75
A4S	15.4/Jan	20.6/Sep	16.9 ± 1.89	15.1/Mar	20.4/Sep	16.7 ± 1.89	15.0/Jan	20.0/Sep	16.3 ± 1.80
A6S	15.6/Jan	20.7/Sep	17.1 ± 1.84	15.2/Jan	20.6/Sep	16.9 ± 1.90	15.1/Mar	20.7/Sep	16.7 ± 1.84
A8S	15.5/Jan	20.9/Sep	16.8 ± 2.01	a	a	a	15.1/Jan	20.7/Sep	16.7 ± 2.04
B4N	16.1/Jan	21.7/Sep	17.7 ± 2.05	14.8/Mar	20.8/Sep	16.8 ± 2.13	14.8/Mar	18.6/Sep	16.0 ± 1.53
B2N	16.1/Jan	21.7/Sep	17.9 ± 2.03	14.7/Jan	20.2/Sep	16.7 ± 1.91	14.6/Mar	19.7/Sep	16.4 ± 1.61
B1N	16.5/Jan	21.4/Sep	18.0 ± 2.03	14.7/Jan	20.2/Sep	16.9 ± 1.90	14.4/Mar	19.1/Sep	16.2 ± 1.76
B.5N	16.6/Jan	21.9/Sep	18.2 ± 1.74	14.7/Jan	20.8/Sep	17.1 ± 2.18	14.6/Mar	19.5/Sep	16.1 ± 1.75
B0	15.8/Nov ?	21.7/Jul	18.4 ± 2.03	15.0/Jan	20.9/Jul	17.2 ± 2.25	14.9/Jan	18.6/Jul	16.3 ± 1.47
B.5S	15.0/Mar	20.8/Jul	17.4 ± 2.21	14.8/Mar	20.1/Sep	16.8 ± 2.14	14.7/Mar	19.6/Jul	16.1 ± 1.73
B1S	14.9/Mar	20.5/Sep	17.1 ± 1.94	14.8/Mar	20.2/Sep	16.8 ± 1.94	15.1/May	19.2/Jul	16.3 ± 1.62
B2S	15.1/Mar	20.6/Sep	16.9 ± 1.80	15.1/Mar	20.1/Sep	16.6 ± 1.70	14.6/Mar	18.7/Sep	16.2 ± 1.74
B4S	15.4/Mar	20.3/Sep	17.0 ± 1.72	15.5/Jan	20.0/Sep	16.7 ± 1.64	14.3/May	18.8/Jul	15.7 ± 1.61
B6S	15.5/Mar	21.3/Sep	17.2 ± 2.01	15.0/Jan	20.5/Sep	16.8 ± 1.92	15.1/Jan	18.2/Jul	16.0 ± 1.12
C20N	15.1/Jan	20.0/Sep	16.5 ± 1.91	14.7/Mar	20.1/Sep	16.7 ± 1.99	13.0/May	17.0/Sep	14.9 ± 1.14
C14N	15.0/Mar	20.6/Sep	17.0 ± 2.06	14.7/Jan	20.1/Sep	16.7 ± 1.98	12.7/May	17.4/Sep	15.0 ± 1.44
C10N	15.4/Mar	20.8/Sep	17.0 ± 2.03	15.1/Mar	20.4/Sep	16.8 ± 1.87	13.9/May	19.1/Sep	15.7 ± 1.93
C8N	15.1/Jan	20.8/Sep	17.0 ± 2.16	14.8/Jan	20.1/Sep	15.6 ± 1.95	13.9/May	18.6/Sep	15.8 ± 1.54
C6N	15.2/Mar	21.0/Sep	17.1 ± 1.99	14.8/Jan	20.8/Sep	16.6 ± 2.18	13.8/May	18.4/Sep	15.2 ± 1.47
C4N	16.0/Jan	21.2/Sep	17.6 ± 2.08	14.8/Jan	20.8/Sep	16.6 ± 2.15	14.1/May	17.4/Jul	15.5 ± 1.23
C2N	15.4/Mar	21.2/Sep	17.4 ± 2.12	14.6/Mar	20.4/Sep	16.7 ± 2.02	14.0/Mar	18.1/Sep	15.7 ± 1.54
C0	15.8/May	21.4/Sep	17.5 ± 2.24	15.2/Jan	20.7/Sep	16.8 ± 2.03	14.3/May	18.3/Jul	15.6 ± 1.36
K0	18.3/Jan	22.5/Sep	21.0 ± 1.32	14.7/Mar	18.5/Jul	16.1 ± 1.55	14.6/Mar	17.5/Jul	15.1 ± 1.14
C2S	15.0/Mar	20.4/Sep	16.7 ± 1.83	15.0/Mar	19.9/Sep	16.4 ± 1.71	14.5/Mar	17.6/Jul	15.1 ± 1.08
C4S	15.2/Mar	20.2/Sep	16.7 ± 1.73	15.0/Mar	19.8/Sep	16.6 ± 1.58	14.5/Mar	17.0/Jul	15.5 ± 0.81
C6S	15.2/Mar	21.2/Sep	15.9 ± 0.05	15.0/Jan	20.1/Sep	16.7 ± 1.83	14.1/May	17.4/Jul	15.6 ± 1.11
C8S	15.2/Mar	21.1/Sep	17.1 ± 2.16	15.0/Jan	20.7/Sep	16.8 ± 2.06	15.0/Mar	18.7/Jul	15.9 ± 1.2[illegible]
C10S	15.2/Jan	21.0/Sep	17.1 ± 2.24	15.2/Jan	20.6/Sep	16.9 ± 2.01	15.0/May	19.0/Jul	15.9 ± [illegible]
C14S	15.2/Jan	21.2/Sep	17.2 ± 2.25	15.0/Mar	20.7/Sep	16.9 ± 2.11	15.0/Mar	18.9/Jul	16.4 ± [illegible]
C22S	15.0/Mar	20.7/Sep	17.0 ± 2.12	14.9/Mar	20.7/Sep	16.8 ± 1.88	14.5/Mar	18.2/Jul	16.0 ± [illegible]
C24S	15.0/Mar	21.2/Sep	17.0 ± 2.21	15.0/Mar	20.7/Sep	16.8 ± 1.99	14.6/Mar	18.8/Sep	16.5 [illegible]
C26S	15.0/Mar	20.8/Sep	17.0 ± 2.16	15.0/Mar	20.7/Sep	16.9 ± 2.00	14.8/Mar	18.6/Sep	16.2 ± [illegible]
Kern Kelp	15.1/Mar	21.1/Sep	17.7 ± 2.62	15.1/Mar	20.7/Sep	17.5 ± 2.41	13.6/Jul	16.6/Sep	14.8 ± 1.14
D6N	15.1/Mar	20.7/Sep	17.1 ± 1.90	14.5/Mar	20.2/Sep	16.5 ± 1.99	13.9/May	17.6/Sep	15.3 ± 1.18
D4N	15.3/Mar	21.2/Sep	17.4 ± 2.01	14.7/Mar	20.5/Sep	16.6 ± 2.06	14.0/May	17.0/Sep	15.2 ± 1.08
D2N	14.9/Mar	21.0/Sep	17.2 ± 2.14	14.7/Mar	20.4/Sep	16.5 ± 2.05	13.9/May	17.5/Sep	15.0 ± 1.14
D0	14.7/Mar	20.8/Sep	16.9 ± 1.99	14.7/Mar	20.2/Sep	16.5 ± 1.95	14.0/May	16.8/Sep	14.9 ± 0.83
D2S	14.9/Mar	20.1/Sep	16.6 ± 1.72	14.5/May	19.8/Sep	16.1 ± 1.81	13.9/May	16.4/Sep	14.9 ± 0.84
D4S	15.2/Mar	20.7/Sep	16.8 ± 1.89	15.0/Mar	20.2/Sep	16.6 ± 1.83	14.1/May	17.0/Sep	15.1 ± 0.90
E4N	14.9/Mar	21.0/Sep	16.9 ± 2.09	14.6/Mar	20.1/Sep	16.4 ± 1.90	13.9/May	16.7/Sep	15.1 ± 1.02
E2N	15.0/Mar	20.8/Sep	17.0 ± 2.06	14.6/Mar	20.0/Sep	16.4 ± 1.91	13.6/May	17.0/Jul	15.2 ± 1.20
E0	14.6/Mar	20.6/Sep	16.7 ± 1.95	14.5/Mar	20.4/Sep	16.4 ± 1.59	13.5/May	19.2/Jul	15.2 ± 1.15
E2S	14.8/Mar	20.3/Sep	16.4 ± 1.87	14.5/Mar	18.0/Jul	16.0 ± 1.27	13.5/Jul	16.2/Sep	14.7 ± 0.88
F20N	15.1/Mar	21.1/Sep	17.2 ± 2.10	14.8/Mar	20.2/Sep	16.9 ± 1.93	12.2/May	15.6/Nov 27	14.0 ± 1.36
F14N	15.1/Jan	21.8/Sep	17.2 ± 2.28	14.4/Mar	21.4/Sep	16.9 ± 2.12	12.7/May	15.8/Sep	14.4 ± 1.25
F6N	15.1/May	20.7/Sep	16.8 ± 2.02	14.5/Mar	20.1/Sep	16.4 ± 1.99	12.8/May	17.2/Sep	14.6 ± 1.15
F2N	14.8/Mar	21.1/Sep	16.8 ± 2.08	14.6/May	19.5/Sep	16.1 ± 1.79	13.0/Jul	16.6/Sep	14.6 ± 1.12
F0	14.6/Mar	20.1/Sep	16.4 ± 1.93	14.5/Mar	20.0/Sep	16.3 ± 1.97	12.4/[illegible]	16.1/Jul	14.8 ± 1.09
F2S	14.8/Mar	20.4/Sep	16.5 ± 1.89	14.5/Mar	20.3/Sep	16.1 ± 1.86	13.0/[illegible]	16.2/Sep	14.6 ± 1.00
F6S	15.0/Mar	19.7/Sep	16.6 ± 1.95	14.8/Mar	20.6/Sep	16.5 ± 1.96	13.9/May	16.0/Sep	14.8 ± 0.71
F14S	15.2/Jan	21.2/Sep	17.1 ± 2.21	14.6/Mar	20.1/Sep	16.7 ± 1.88	14.5/May	16.1/Sep	15.1 ± 0.52
F22S	15.0/Jan	21.0/Sep	17.1 ± 2.11	15.0/Mar	20.8/Sep	16.9 ± 2.02	13.6/May	15.7/Sep	14.7 ± 0.62
F24S	15.0/Jan	21.3/Sep	17.2 ± 2.23	15.1/Mar	20.4/Sep	16.7 ± 1.89	13.4/May	16.2/Sep	14.[illegible] ± 0.96
F26S	15.1/Jan	21.1/Sep	17.1 ± 2.14	15.1/Mar	20.7/Sep	16.9 ± 1.94	13.5/May	15.7/Sep	14.7 ± 0.78
H2N	14.6/Mar	20.2/Sep	16.4 ± 2.17	14.4/Mar	19.6/Sep	16.3 ± 1.99	12.5/Jul	15.0/Nov ?	13.9 ± 0.88
H0	14.8/Mar	20.1/Sep	16.4 ± 2.17	14.3/May	19.5/Sep	16.2 ± 2.00	12.6/Jul	15.0/Nov ?	13.8 ± 0.83
H2S	14.5/Mar	20.0/Sep	16.5 ± 2.06	14.5/Mar	19.6/Sep	16.1 ± 2.31	12.6/May	15.0/Sep	14.0 ± 0.72
J8N	14.6/Mar	20.0/Sep	16.5 ± 2.00	14.5/Mar	19.7/Sep	16.3 ± 1.98	11.7/Jul	14.4/Jan	13.3 ± 0.90
J4N	14.5/Mar	20.4/Sep	16.5 ± 2.13	14.4/Mar	19.6/Sep	16.3 ± 1.95	12.0/Jul	14.5/Jan	13.1 ± 0.85
J2N	14.5/Mar	20.1/Sep	16.4 ± 2.10	14.2/May	19.3/Sep	16.1 ± 1.99	12.0/May	14.5/Jan	13.0 ± 0.87
J0	14.5/May	19.7/Sep	16.3 ± 1.99	14.3/May	19.4/Sep	16.2 ± 2.32	12.1/May	14.5/Jan	13.2 ± 0.89
J2S	14.4/Mar	20.0/Sep	16.3 ± 2.09	14.3/May	19.6/Sep	16.2 ± 2.03	12.2/May	15.4/Nov ?	13.3 ± 1.17
J4S	14.5/Mar	19.9/Sep	16.4 ± 2.00	14.1/Mar	19.7/Sep	16.1 ± 2.02	12.3/Jul	14.9/Nov ?	13.6 ± 0.97
J6S	14.5/Mar	19.8/Sep	16.4 ± 1.97	14.4/Mar	18.7/Sep	16.1 ± 1.69	12.2/Jul	15.0/Nov ?	13.6 ± 1.01
M8N	14.4/Mar	20.2/Sep	16.6 ± 1.98	14.4/Mar	20.2/Sep	16.4 ± 2.01	11.9/Jul	14.2/Jan	12.3 ± 1.09
M4N	14.5/Mar	19.9/Sep	16.5 ± 1.86	14.4/Mar	19.2/Sep	16.2 ± 1.69	11.8/Jul	14.4/Jan	12.3 ± 1.13
M2N	14.5/Mar	19.6/Sep	16.4 ± 1.85	14.4/Mar	18.2/Sep	16.1 ± 1.51	11.7/Jul	14.4/Jan	12.3 ± 1.09
M0	14.3/May	19.7/Sep	16.3 ± 2.00	14.1/May	19.2/Sep	16.1 ± 1.89	11.8/Jul	14.3/Jan	12.4 ± 1.09
M2S	14.1/May	19.7/Sep	16.1 ± 2.08	13.8/May	19.8/Sep	16.0 ± 2.09	11.7/Jul	14.3/Jan	12.5 ± 0.96
M6S	14.8/Mar	19.8/Sep	16.3 ± 2.01	13.9/May	19.7/Sep	16.1 ± 2.09	11.4/Jul	14.4/Jan	12.5 ± 0.94
M8S	14.5/Mar	19.8/Sep	16.4 ± 1.99	14.4/Mar	19.2/Sep	16.2 ± 1.84	11.5/Jul	14.4/Jan	12.7 ± 0.95

[a] Mid-depth not sampled during every survey; depth less than 4 meters.

Table I-3. Monthly mean temperatures (°C) and standard deviations at continuous temperature stations C22S, C2S, and F2S.

Station C2S

	Surface		Mid-Depth		Bottom	
Month	Mean	S.D.	Mean	S.D.	Mean	S.D.
Jan	14.8	0.75	14.6	0.57	14.7	0.67
Feb	14.4	0.43	13.7	0.32	13.5	0.38
Mar	15.0	0.81	14.7	0.92	14.9[a]	0.45
Apr	15.9	1.11	14.9	1.42	14.3	1.31
May	16.2	1.97	15.1	2.36	14.6	2.34
Jun	19.6[a]	1.11	17.7	1.21	17.1	1.30
Jul	19.1	0.96	17.9	1.46	16.7[a]	1.56
Aug	20.4	1.50	20.3	1.45	17.9	1.90
Sep	19.9	2.01	17.7	2.07	16.7	1.70
Oct	18.2	1.36	16.3	1.31	15.5	1.47
Nov	15.8	0.63	15.5	0.67	14.7[a]	0.51
Dec	15.9	0.48	15.4	0.37	15.1	0.36

Station C22S

	Surface		Mid-Depth		Bottom	
Month	Mean	S.D.	Mean	S.D.	Mean	S.D.
Jan	14.3[a]	0.65	14.5[a]	0.64	14.6	0.62
Feb	13.8[a]	0.32	13.4[a]	0.19	13.6	0.40
Mar	15.3	1.07	a	-	14.6[a]	0.54
Apr	14.9	1.24	14.0[a]	1.72	13.7	1.13
May	15.5	1.95	15.9[a]	2.31	14.6	2.44
Jun	19.0	0.93	17.6	1.23	16.7	1.56
Jul	19.8	0.78	19.2[a]	0.64	15.9	1.68
Aug	20.8	1.45	18.4[a]	1.48	17.0	1.81
Sep	19.9	2.04	16.5[a]	2.05	15.8	1.46
Oct	18.0	1.27	16.4	1.92	13.7[a]	0.32
Nov	15.7	0.66	15.4	0.76	14.6[a]	0.52
Dec	15.2	0.33	15.3	0.35	15.0	0.36

Station F2S

	Surface		15 feet		30 feet		Bottom	
Month	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Jan	14.7	0.61	14.5	0.55	14.3	0.56	14.3	0.62
Feb	13.7	0.34	13.7	0.34	13.5[a]	0.18	13.4	0.37
Mar	14.7	0.69	14.4	1.12	14.3[a]	0.45	13.6	0.93
Apr	15.8	0.87	15.0[a]	1.02	a	-	13.1	1.04
May	16.0[a]	1.77	16.4[a]	1.59	15.2[a]	2.80	13.4	2.14
Jun	18.8[a]	0.83	17.7	1.25	18.2	1.58	15.3	1.53
Jul	19.4	0.81	18.3	1.13	15.8	1.74	14.1	1.15
Aug	20.8	1.24	19.9	1.71	16.9	1.75	15.2	1.31
Sep	20.2	1.79	18.8	1.83	17.5[a]	0.94	16.1	0.82
Oct	18.4	1.43	17.9	1.51	15.5	1.44	14.4	0.92
Nov	16.0	0.64	15.4	0.80	15.0	0.79	14.3	0.86
Dec	15.5	0.47	15.2	0.52	15.2	0.53	14.6	0.61

[a] Gaps in continuous temperature for this month.

Table I-4. **Percent of time that continuous temperature measurements differed by more than 1° C.**

	A1>(B1+1.0)	B1>(A1+1.0)	A2>(B2+1.0)	B2>(A2+1.0)	A3>(B3+1.0)	B3>(A3+1.0)
Jan	4.4	0.0	0.0	0.0	0.0	0.0
Feb	5.5	0.0	0.0	0.0	0.0	0.0
Mar	5.8	22.8	0.0	0.0	9.3	1.5
Apr	37.1	0.0	55.9	1.3	25.0	0.7
May	24.0	0.3	6.1	7.7	5.3	5.4
Jun	52.2	4.1	12.0	6.1	18.6	1.2
Jul	0.0	24.1	14.0	0.0	46.6	0.6
Aug	0.7	11.8	70.0	0.0	47.6	15.2
Sep	8.4	11.0	20.3	13.9	37.7	5.2
Oct	11.0	4.5	22.3	21.5	36.0	0.0
Nov	8.2	3.2	2.4	1.7	0.0	0.0
Dec	20.7	0.0	0.1	0.0	1.6	0.0
Avg	14.8	6.8	16.1	4.3	18.2	2.4

	A1>(C1+1.0)	C1>(A1+1.0)	A2>(C2+1.0)	C2>(A2+1.0)	A3>(C3+1.0)	C3>(A3+1.0)
Jan	7.2	3.8	0.0	0.0	2.0	0.0
Feb	15.2	0.0	0.0	0.1	0.0	0.0
Mar	3.0	0.0	4.7	1.8	7.5	0.0
Apr	3.6	1.1	11.2	9.9	0.0	0.0
May	12.0	0.0	13.0	4.7	18.4	10.5
Jun	61.8	1.2	4.1	8.1	11.8	46.2
Jul	1.8	13.2	4.9	26.5	55.9	1.6
Aug	2.7	21.6	30.1	8.2	45.4	3.0
Sep	4.7	15.2	8.5	52.2	58.3	4.2
Oct	0.3	13.1	0.1	59.6	20.3	19.7
Nov	0.7	6.7	3.8	3.5	3.3	17.6
Dec	5.1	0.0	1.2	0.0	2.3	0.3
Avg	9.8	6.3	9.3	14.5	18.7	7.7

Where: A1 = C2S Surface, A2 = C2S Mid-depth, A3 = C2S Bottom
B1 = C22S Surface, B2 = C22S Mid-depth, B3 = C22S Bottom
C1 = F2S Surface, C2 = F2S 4.5 m, C3 = F2S, 9 m

Table I-5. Comparison of monthly mean and standard deviation of intake, discharge, and surface ambient temperatures (°C).

Month	Intake	Discharge	Surface Ambient (C22S)	Discharge Minus Intake	Intake Minus Surface Ambient	Discharge Minus Surface Ambient	Intake Exceeded Surface Ambient By More Than 1.0 C (%)	Surface Ambient Exceeded Intake By More Than 1.0 C (%)	Available Data For Comparison (%)
Jan	15.6 ± 0.6	27.3 ± 0.6	14.3 ± 0.6	11.7	1.3	13.0	78.9	0.0	30.5
Feb	15.0 ± 2.4	26.4 ± 1.1	13.8 ± 0.3	11.4	1.2	12.6	51.7	0.0	67.4
Mar	15.5 ± 0.7	26.8 ± 0.8	15.3 ± 1.1	11.3	0.2	11.5	11.1	10.5	99.0
Apr	15.8 ± 2.3	26.1 ± 3.7	14.9 ± 1.2	10.3[a]	0.9	11.2[a]	38.3	6.0	95.1
May	16.0 ± 2.9	27.7 ± 2.4	15.5 ± 2.0	11.7	-0.1	11.4	27.4	3.8	98.3
Jun	18.7 ± 2.2	24.3 ± 6.1	19.0 ± 0.9	5.6[a]	-0.1	5.3[a]	1.4	22.5	97.0
Jul	19.0 ± 1.4	31.0 ± 1.5	19.8 ± 0.8	12.0	-0.8	11.2	1.3	40.6	99.9
Aug	20.0 ± 2.8	31.7 ± 1.9	20.9 ± 1.4	11.7	-0.8	10.9	2.9	46.3	96.5
Sep	19.4 ± 2.6	26.9 ± 5.9	19.9 ± 2.0	7.5[a]	-0.5	7.0[a]	2.8	59.3	88.3
Oct	17.9 ± 2.1	29.9 ± 1.6	18.0 ± 1.3	12.0	-0.1	11.9	6.9	18.0	99.5
Nov	16.7 ± 2.0	26.7 ± 4.4	15.7 ± 0.7	10.0[a]	1.0	11.0[a]	36.6	0.1	94.9
Dec	16.5 ± 0.3	29.2 ± 1.6	15.2 ± 0.3	12.7[b]	1.3	14.0[b]	82.7	0.0	98.8

[a] Plant not at full operation during this period.
[b] Heat treatment accounts for high values.

APPENDIX I - TEMPERATURE

FIGURES

Figure I-1. Surface isotherms from temperature profiles, 11 January 1979.

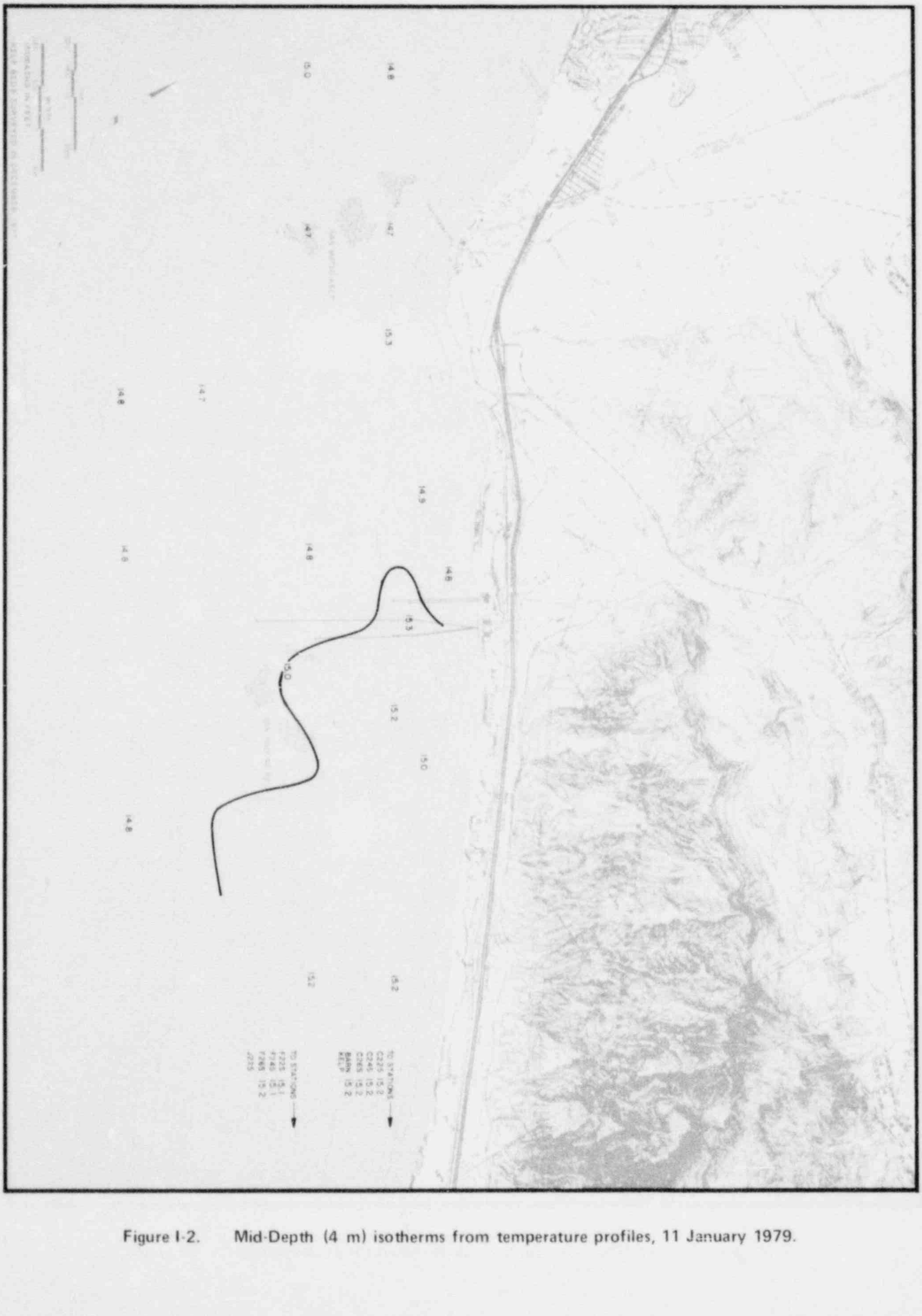

Figure I-2. Mid-Depth (4 m) isotherms from temperature profiles, 11 January 1979.

Figure I-3. Bottom isotherms from temperature profiles, 11 January 1979.

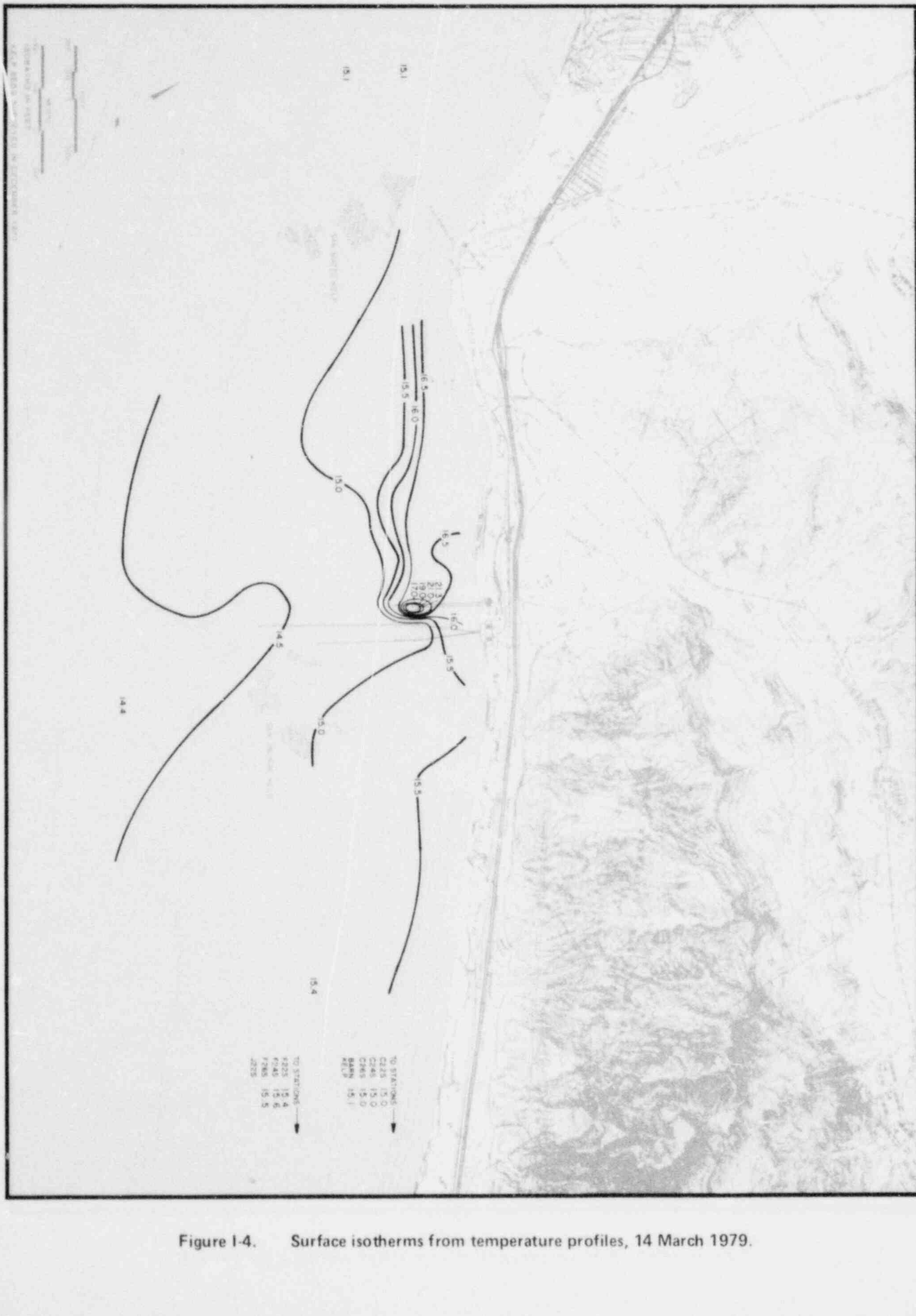

Figure I-4. Surface isotherms from temperature profiles, 14 March 1979.

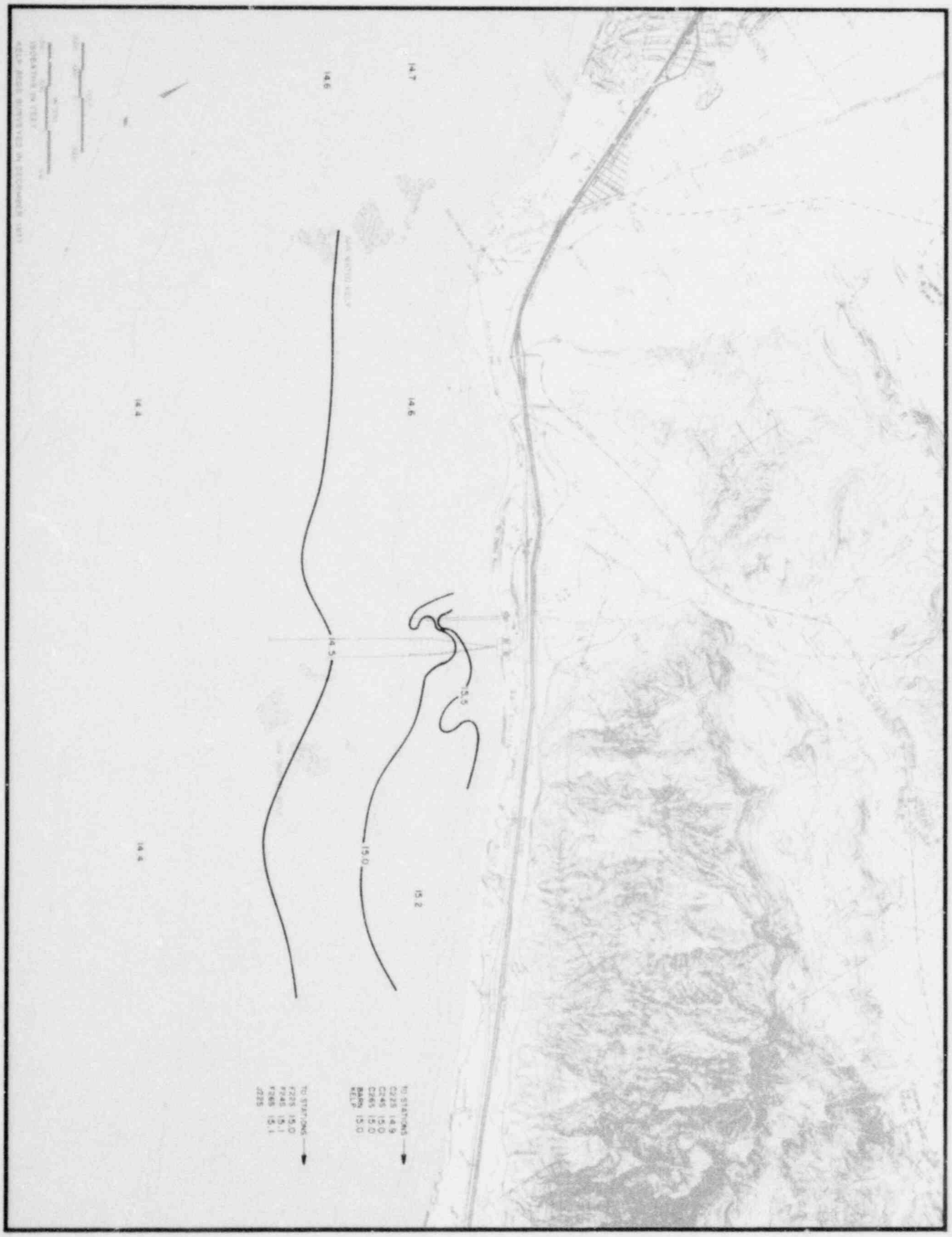

Figure I-5. Mid-Depth (4 m) isotherms from temperature profiles, 14 March 1979.

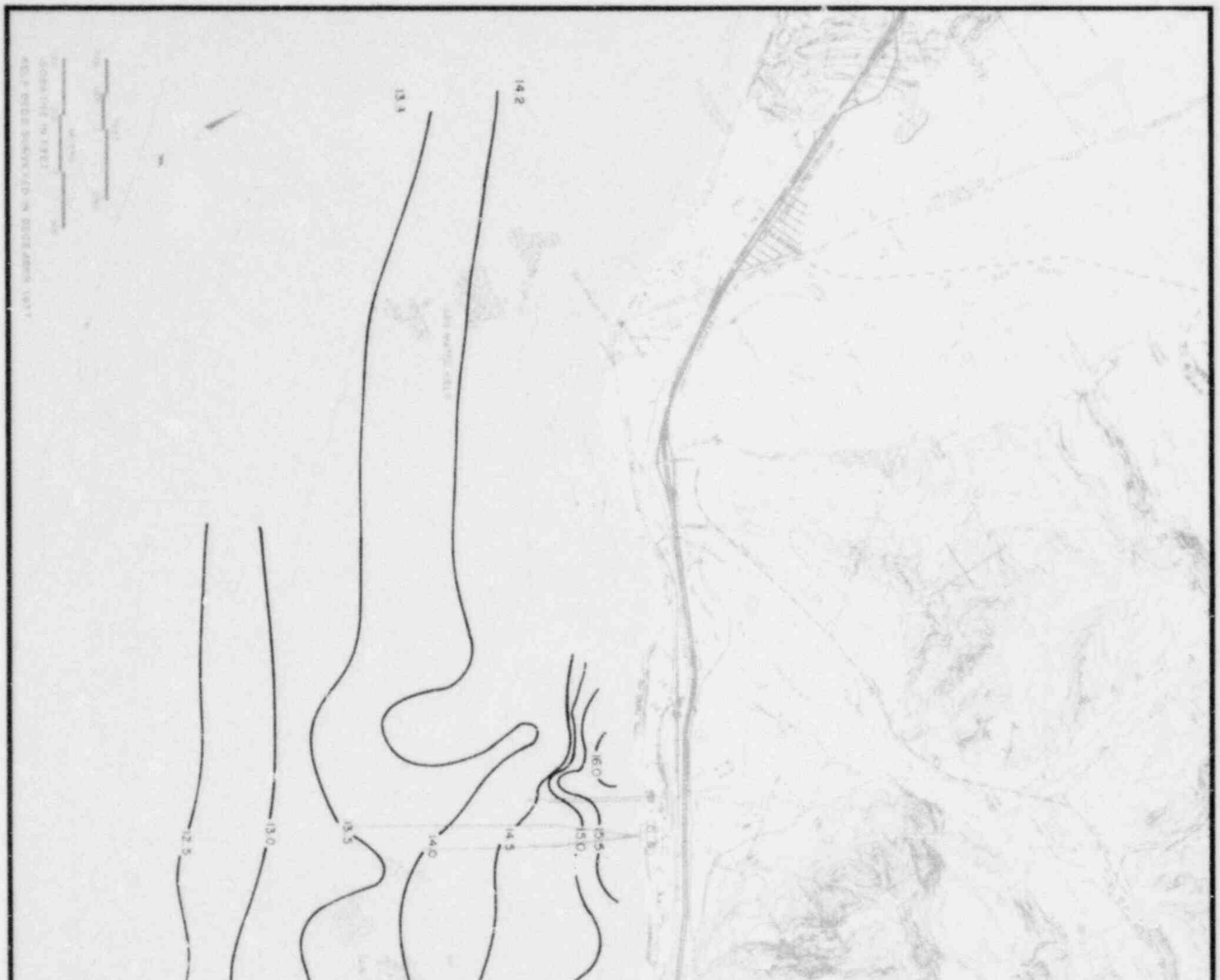

Figure I-6. Bottom isotherms from temperature profiles, 14 March 1979.

Figure I-7. Surface isotherms from temperature profiles, 16 May 1979.

Figure I-8. Mid-Depth (4 m) isotherms from temperature profiles, 16 May 1979.

Figure I-9. Bottom isotherms from temperature profiles, 16 May 1979.

Figure I-10. Surface isotherms from temperature profiles, 11 July 1979.

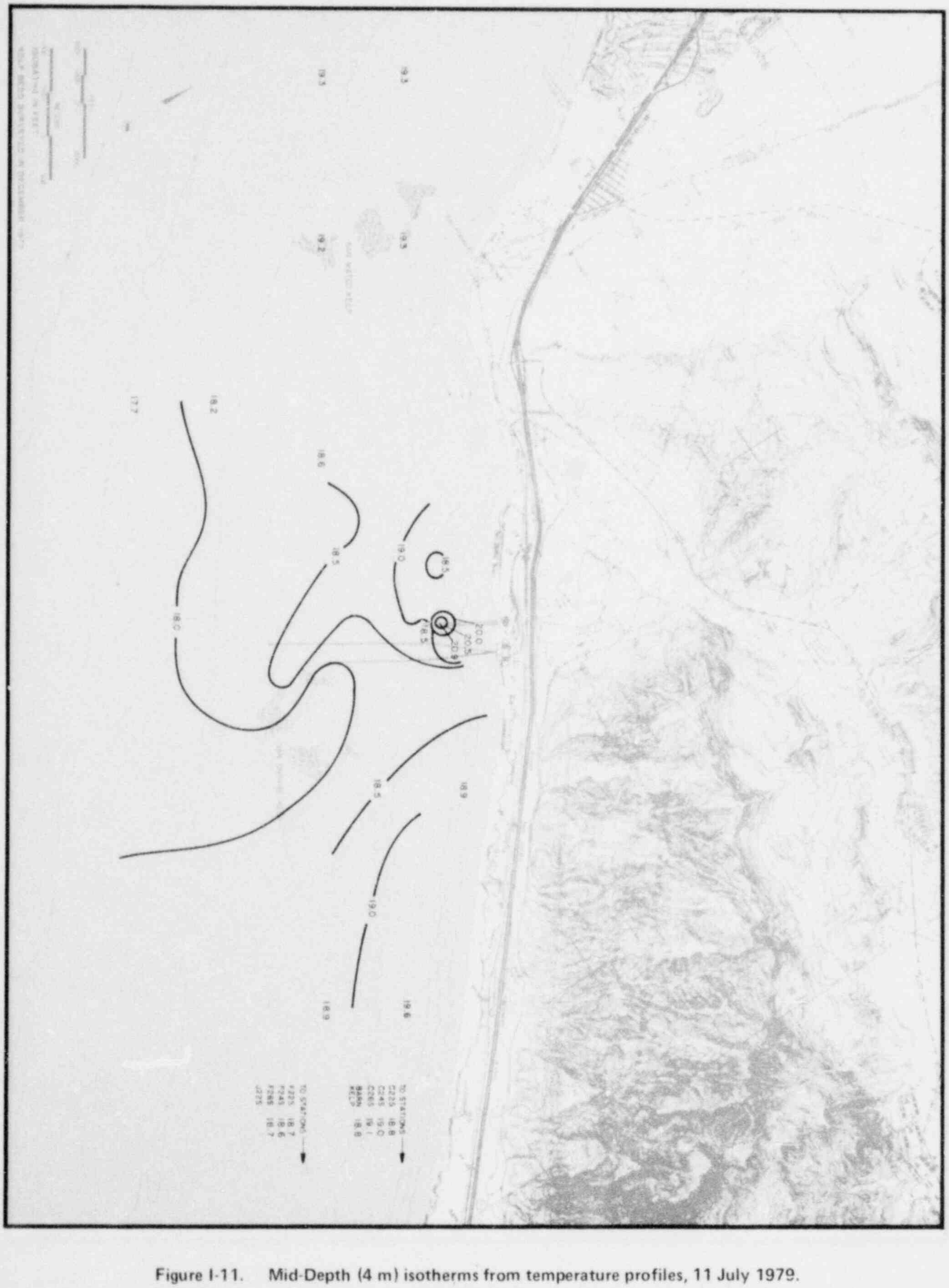

Figure I-11. Mid-Depth (4 m) isotherms from temperature profiles, 11 July 1979.

Figure I-12. Bottom isotherms from temperature profiles, 11 July 1979.

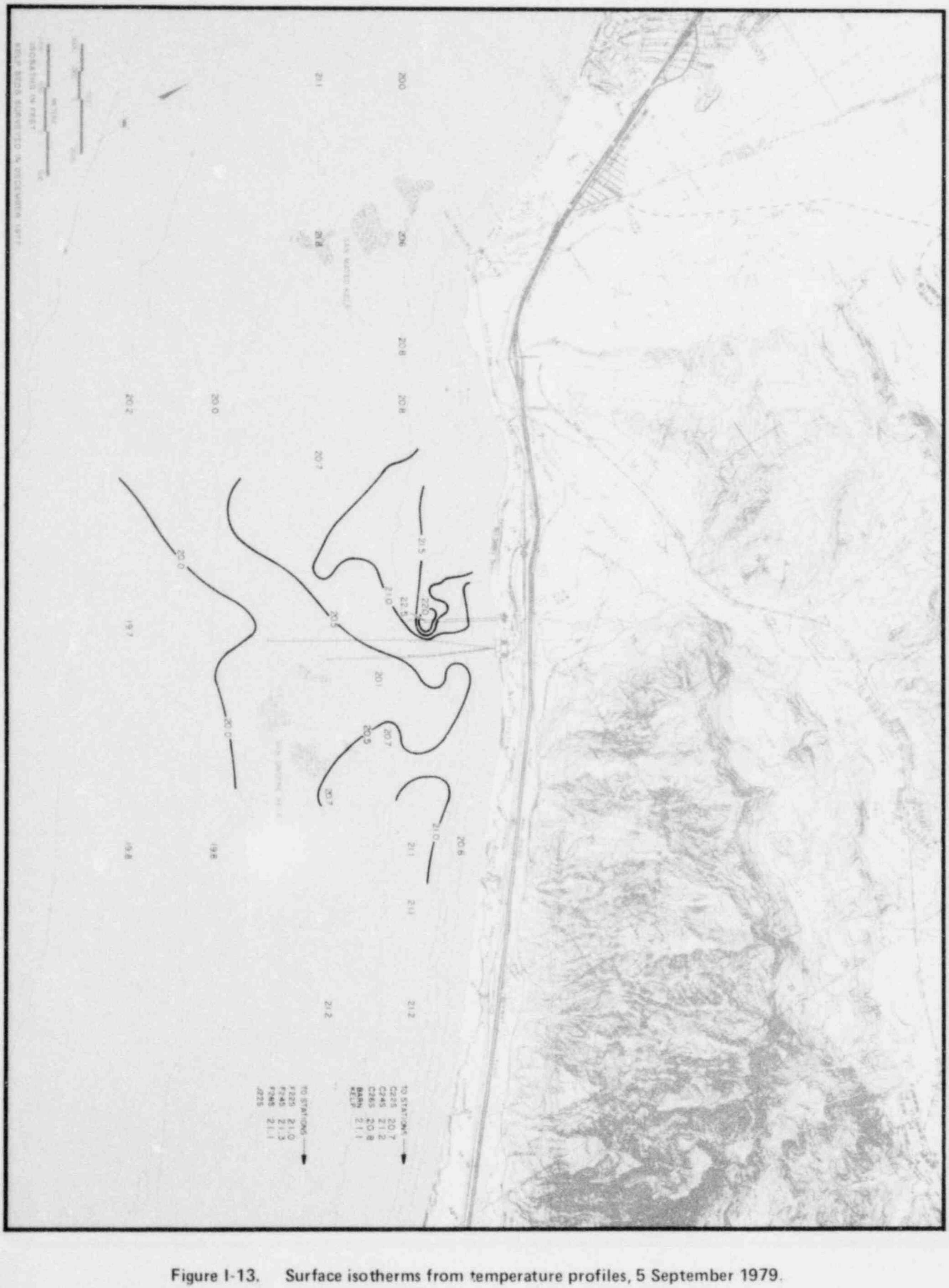

Figure I-13. Surface isotherms from temperature profiles, 5 September 1979.

Figure I-14. Mid-Depth (4 m) isotherms from temperature profiles, 5 September 1979.

Figure I-15. Bottom isotherms from temperature profiles, 5 September 1979.

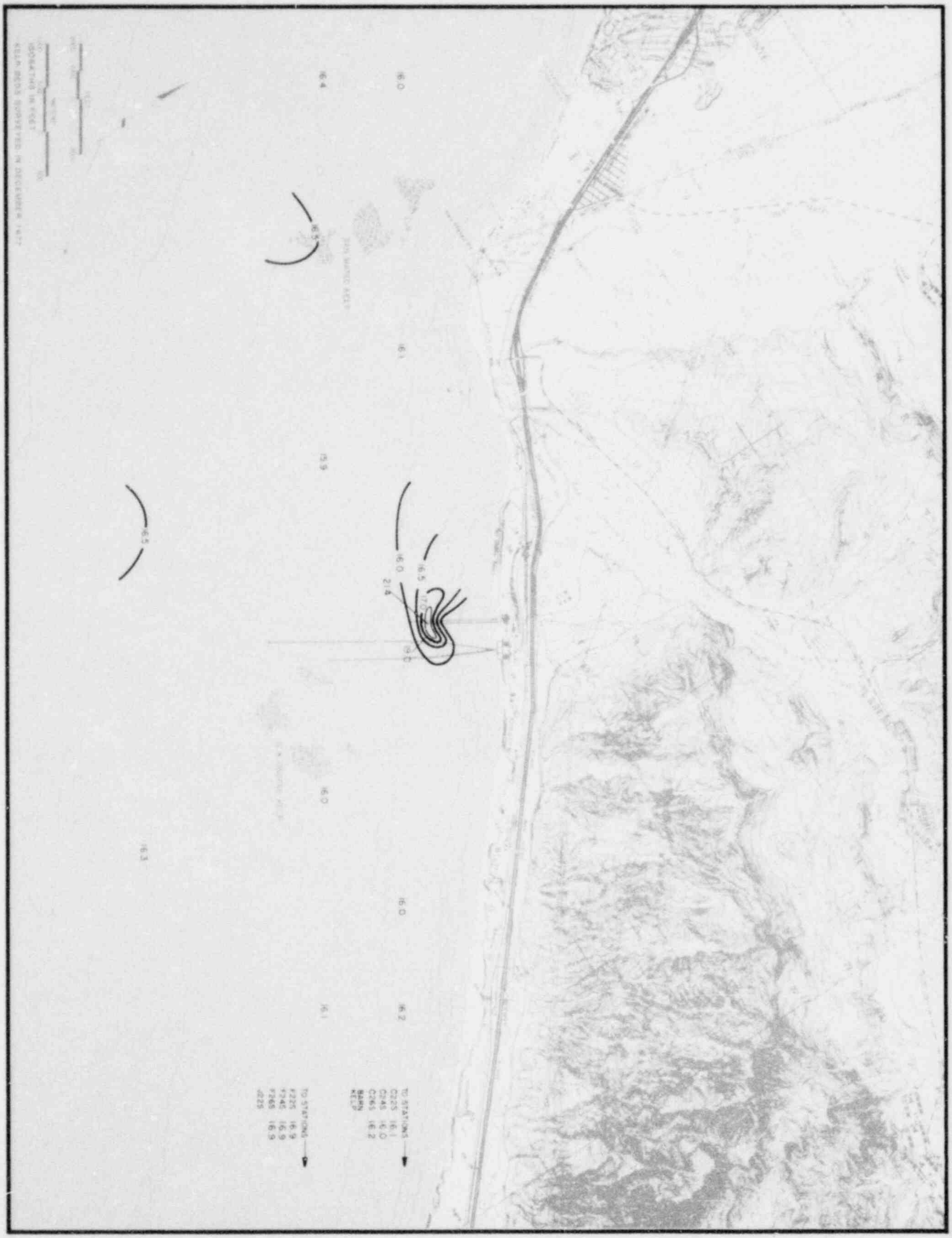

Figure I-16. Surface isotherms from temperature profiles, 7 November 1979.

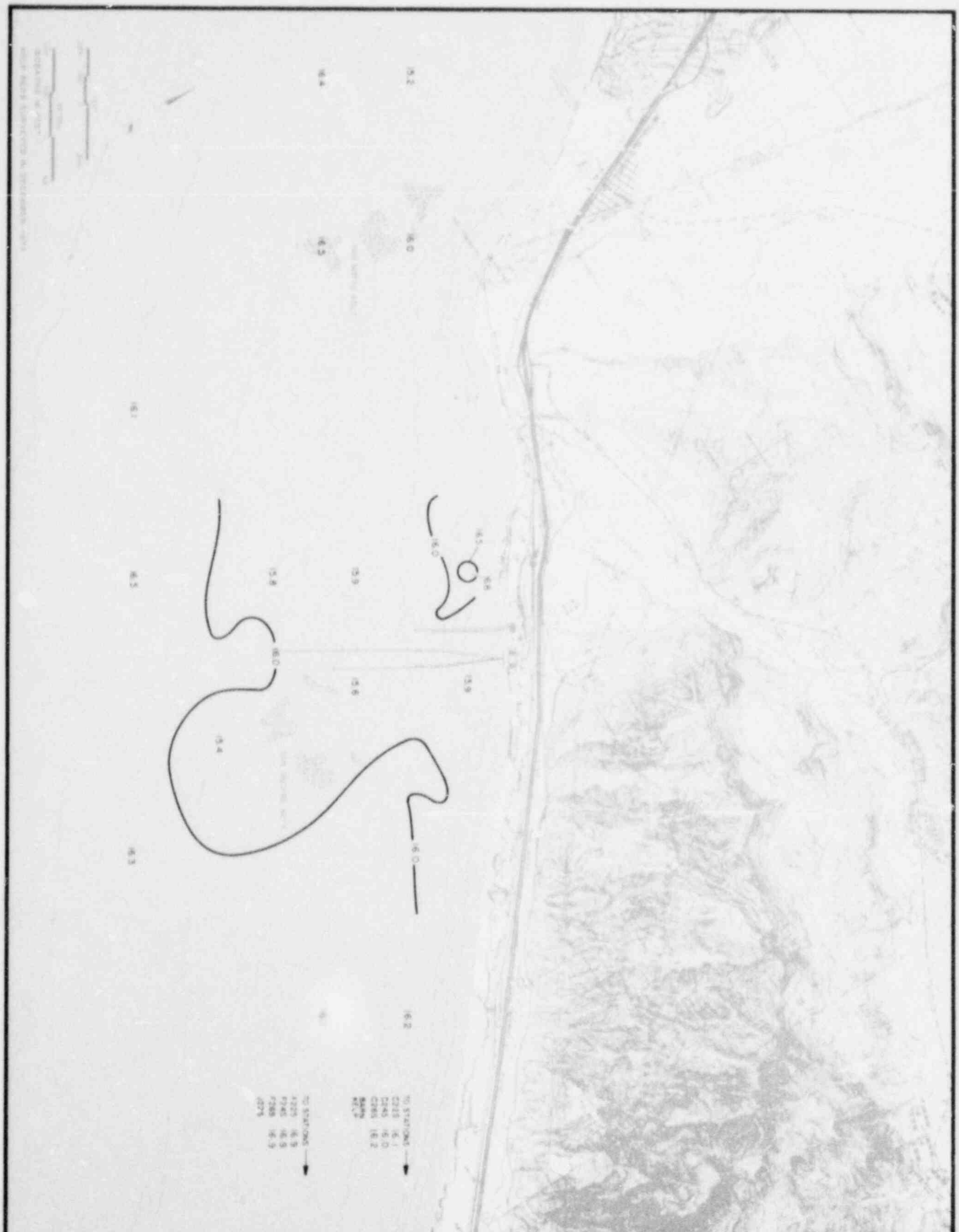

Figure I-17. Mid-Depth (4 m) Isotherms fron. temperature profiles, 7 November 1979.

Figure I-18. Bottom isotherms from temperature profiles, 7 November 1979.

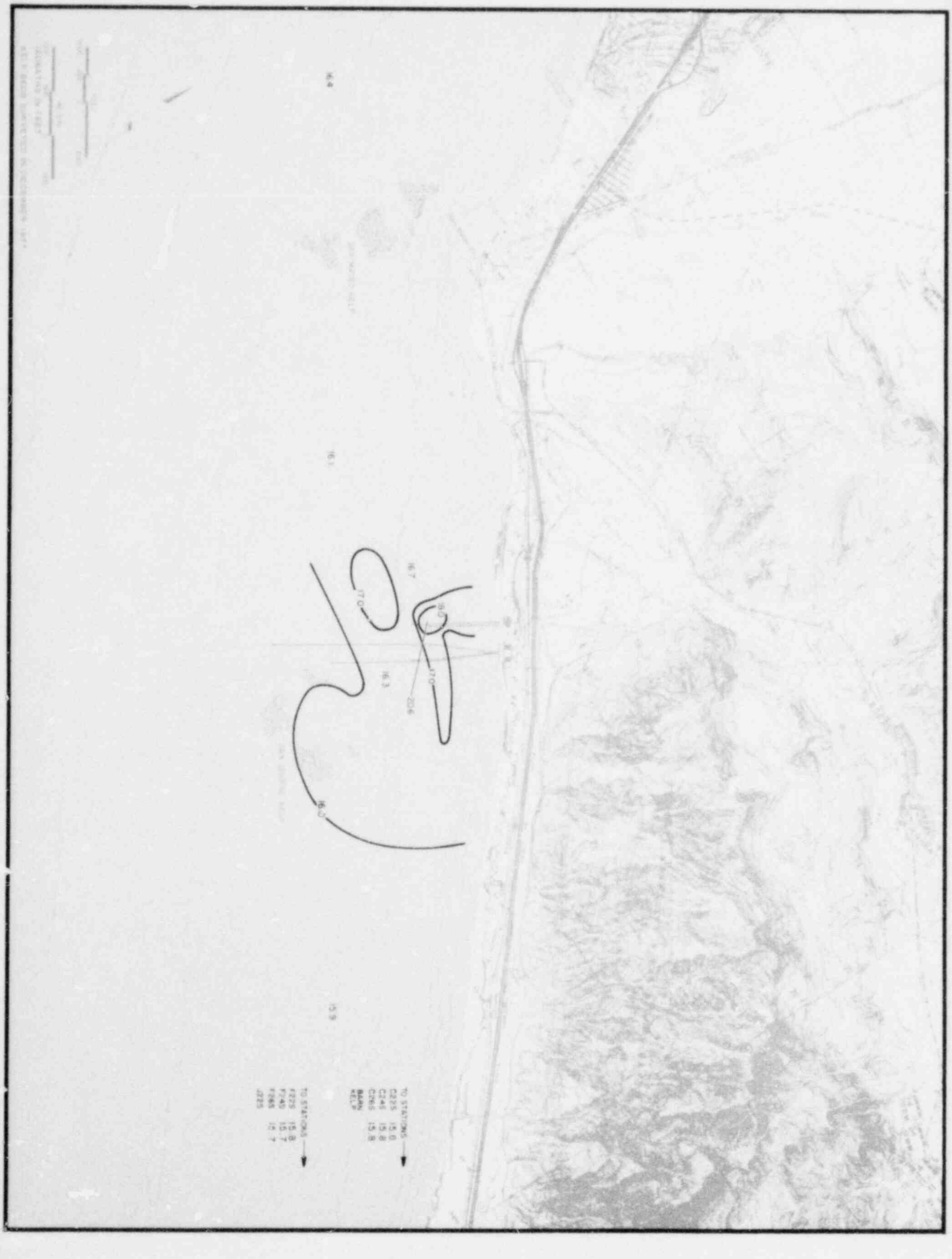

Figure I-19. Surface isotherms from temperature profiles, 27 November 1979.

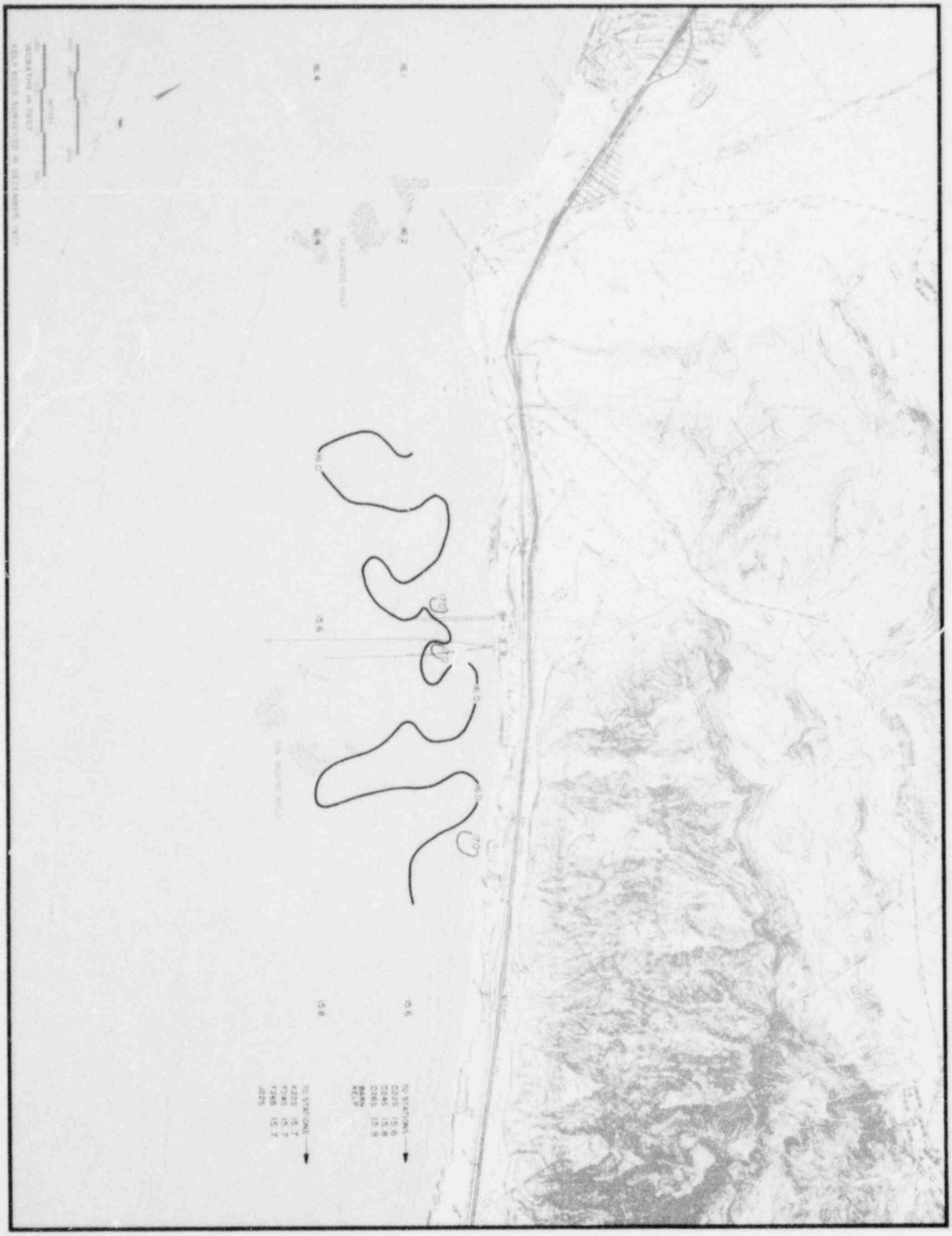

Figure I-20. Mid-Depth (4 m) isotherms from temperature profiles, 27 November 1979.

Figure I-21. Bottom isotherms from temperature profiles, 27 November 1979.

Figure I-22. Isometric vertical cross-sections of temperature, 11 January 1979.

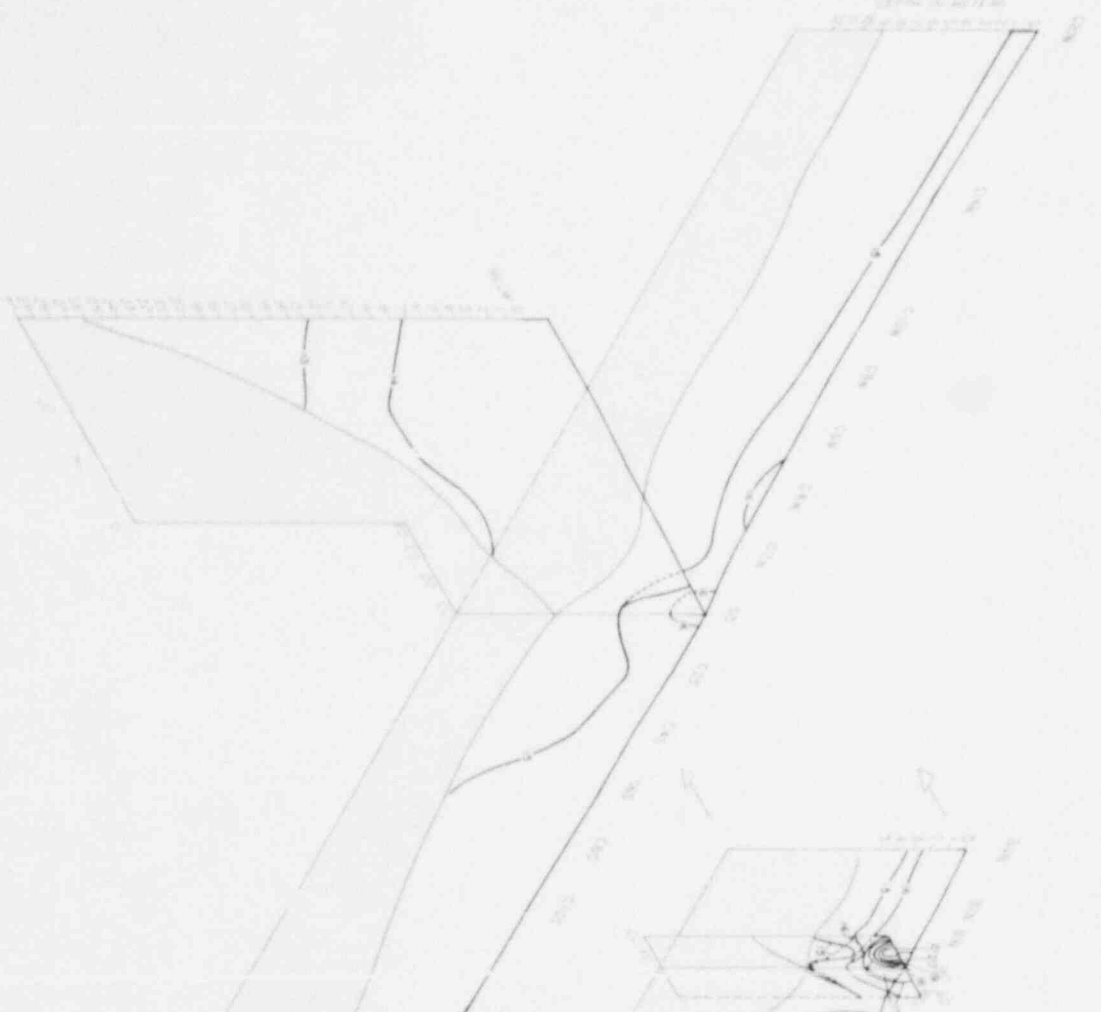

Figure I-23. Isometric vertical cross-sections of temperature, 14 March 1979

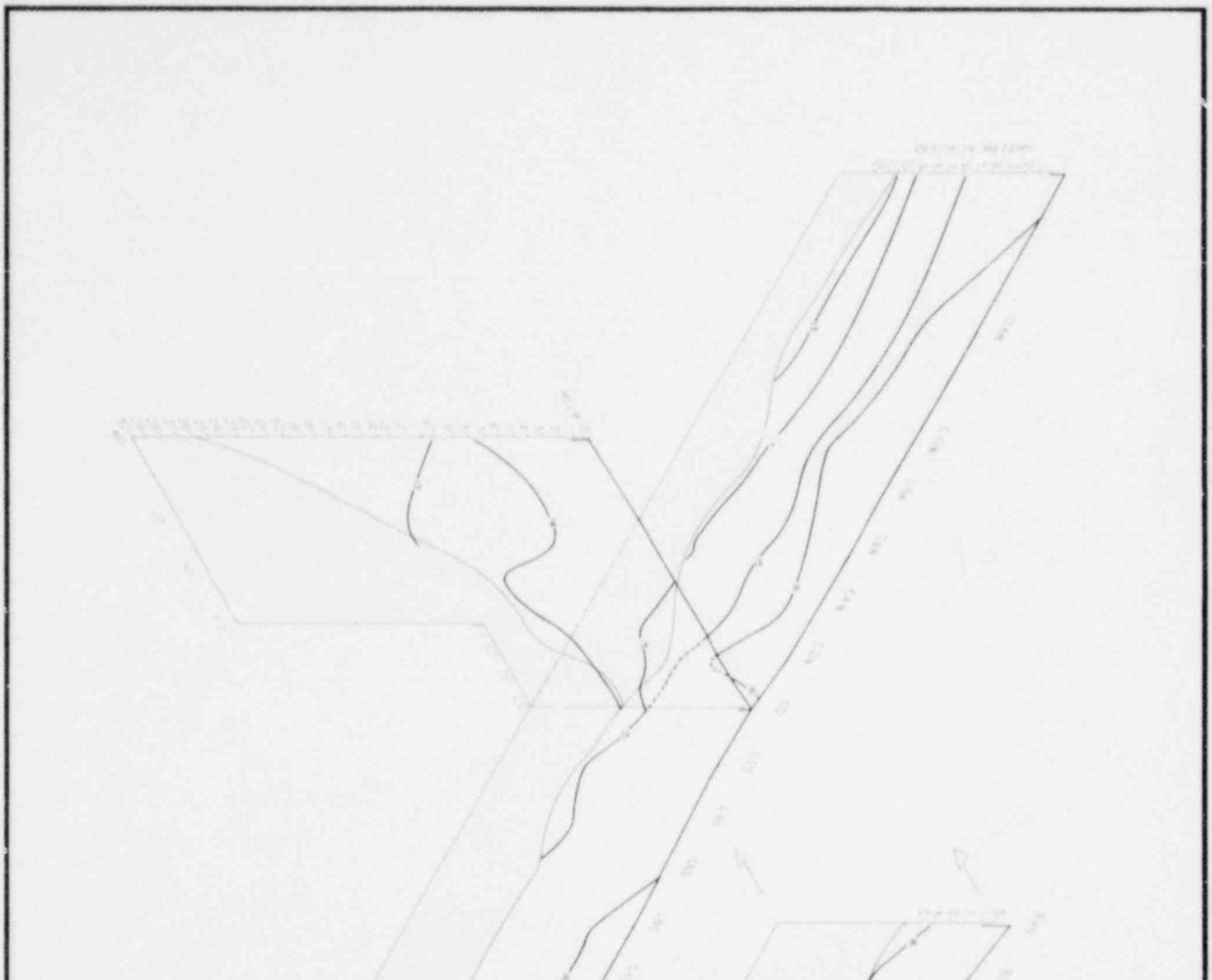

Figure I-24. Isometric vertical cross-sections of temperature, 16 May 1979.

Figure I-25. Isometric vertical cross-sections of temperature, 11 July 1979.

Figure I-26. Isometric vertical cross-sections of temperature, 5 September 1979.

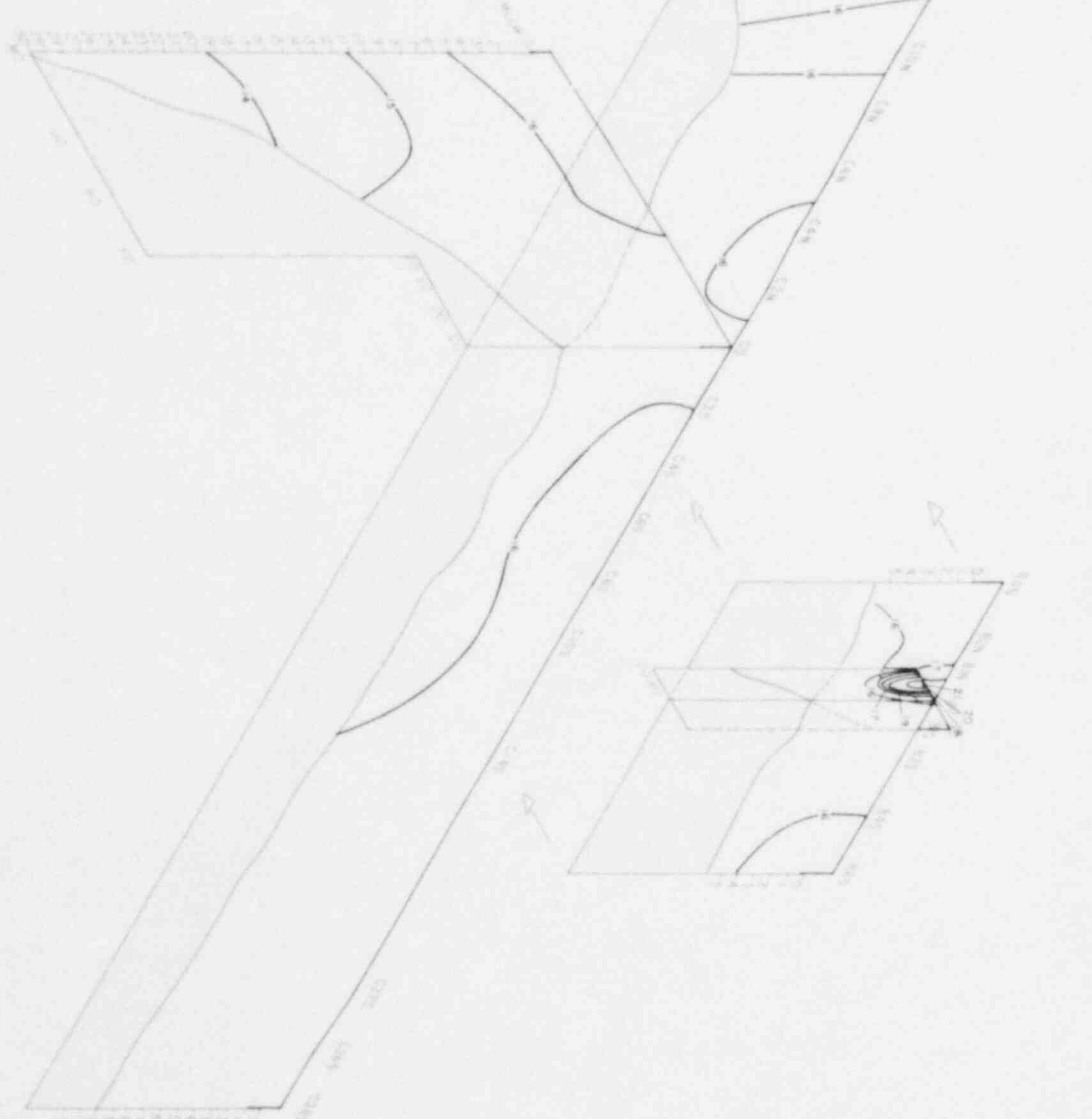

Figure I-27. Isometric vertical cross-sections of temperature, 7 November 1979.

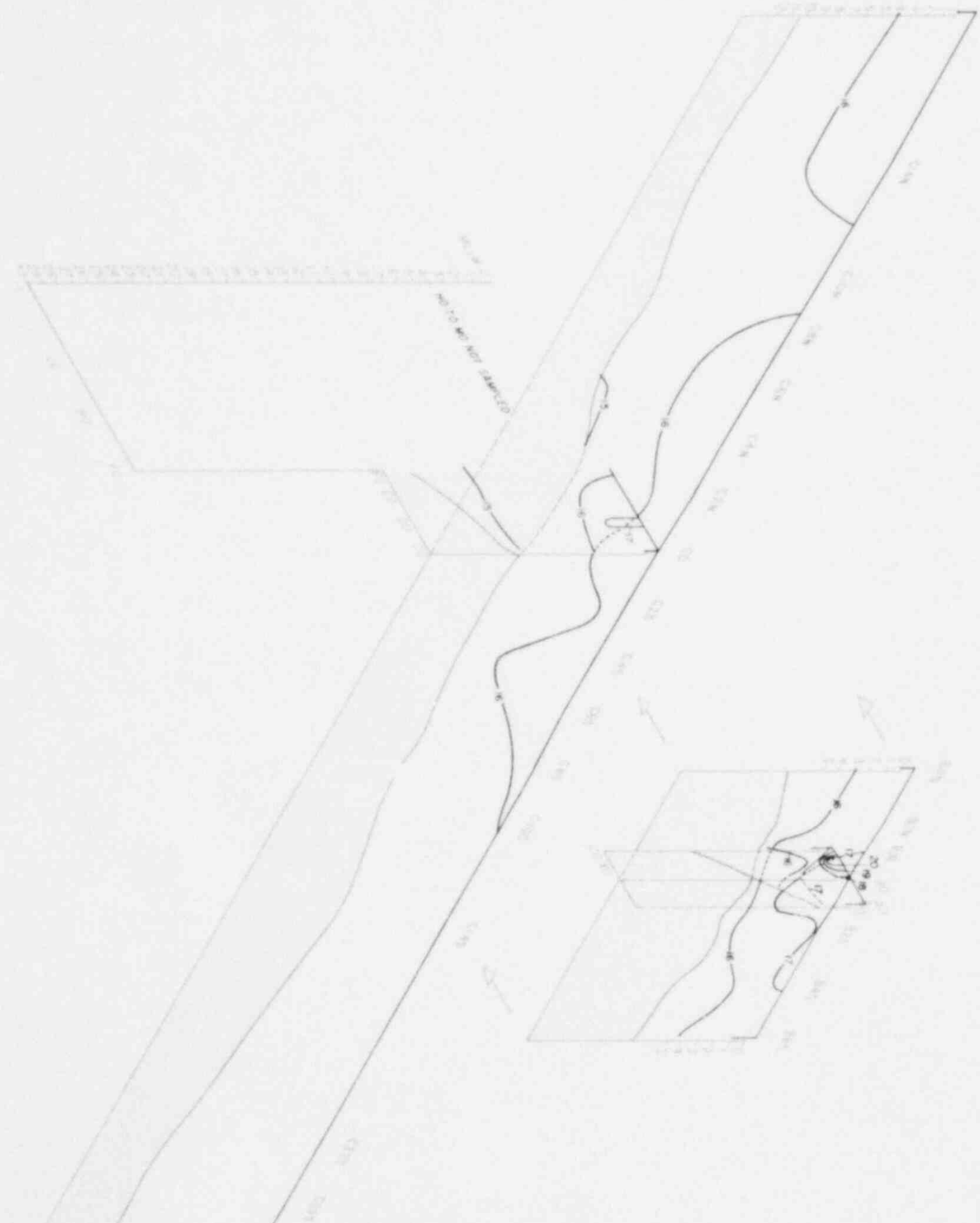

Figure I-28. Isometric vertical cross-sections of temperature, 27 November 1979.

Figure I-29. Surface isotherms from infrared radiometer measurements, Flight 1, 1023-1101 PST, 11 January 1979.

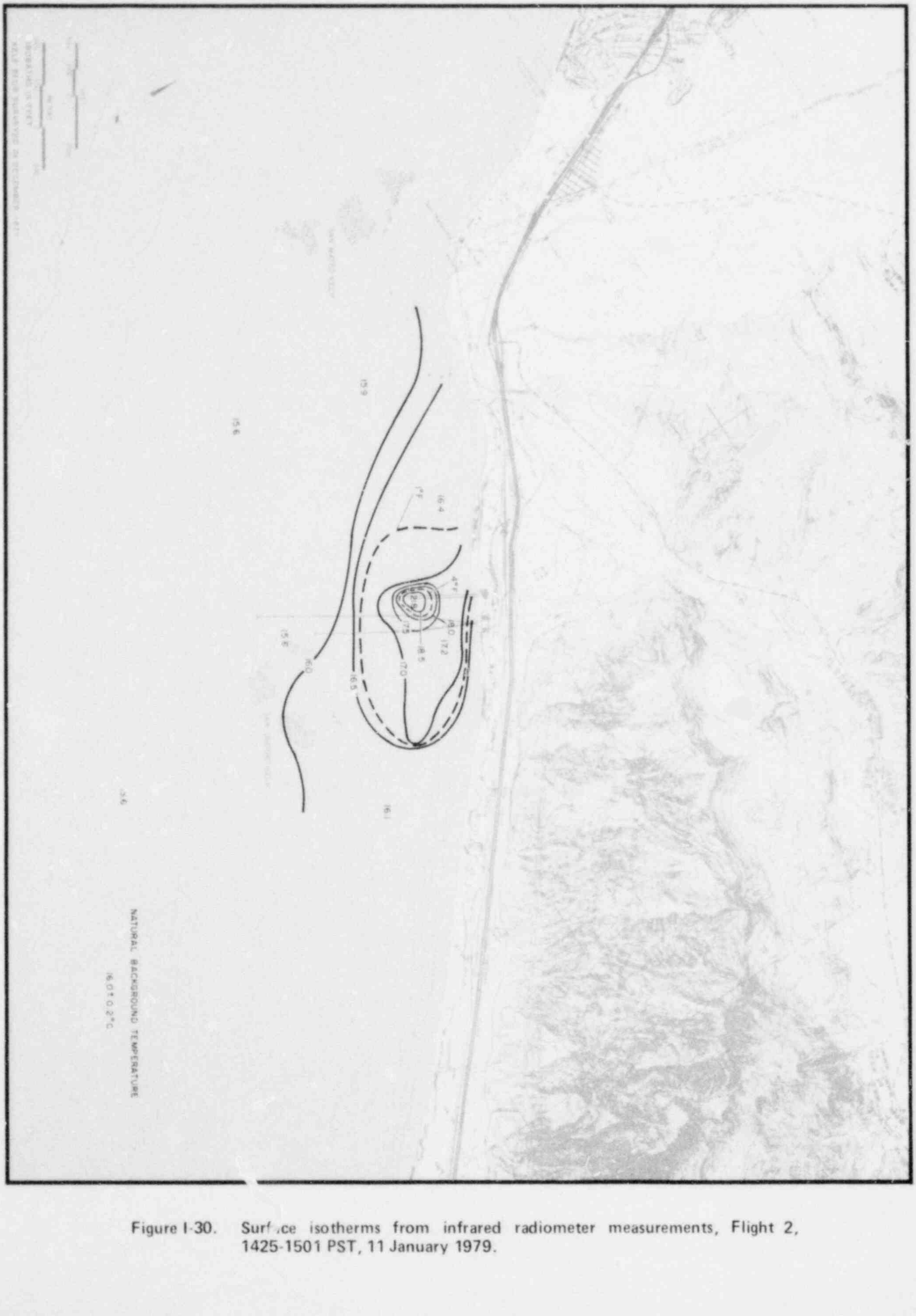

Figure I-30. Surface isotherms from infrared radiometer measurements, Flight 2, 1425-1501 PST, 11 January 1979.

Figure I-31. Surface isotherms from infrared radiometer measurements, Flight 1, 0915-1000 PST, 14 March 1979.

Figure I-32. Surface isotherms from infrared radiometer measurements, Flight 2, 1217-1257 PST, 14 March 1979.

Figure I-33. Surface isotherms from infrared radiometer measurements, Flight 3, 1514-1550 PST, 14 March 1979.

Figure I-34. Surface isotherms from infrared radiometer measurements, 1209-1250 PST, 1 June 1979 special survey.

Figure I-35. Surface isotherms from infrared radiometer measurements, Flight 1, 0801-0847 PST, 11 July 1979.

Figure I-36. Surface isotherms from infrared radiometer measurements, Flight 2, 1114-1150 PST, 11 July 1979.

Figure I-37. Surface isotherms from infrared radiometer measurements, Flight 3, 1310-1340 PST, 11 July 1979.

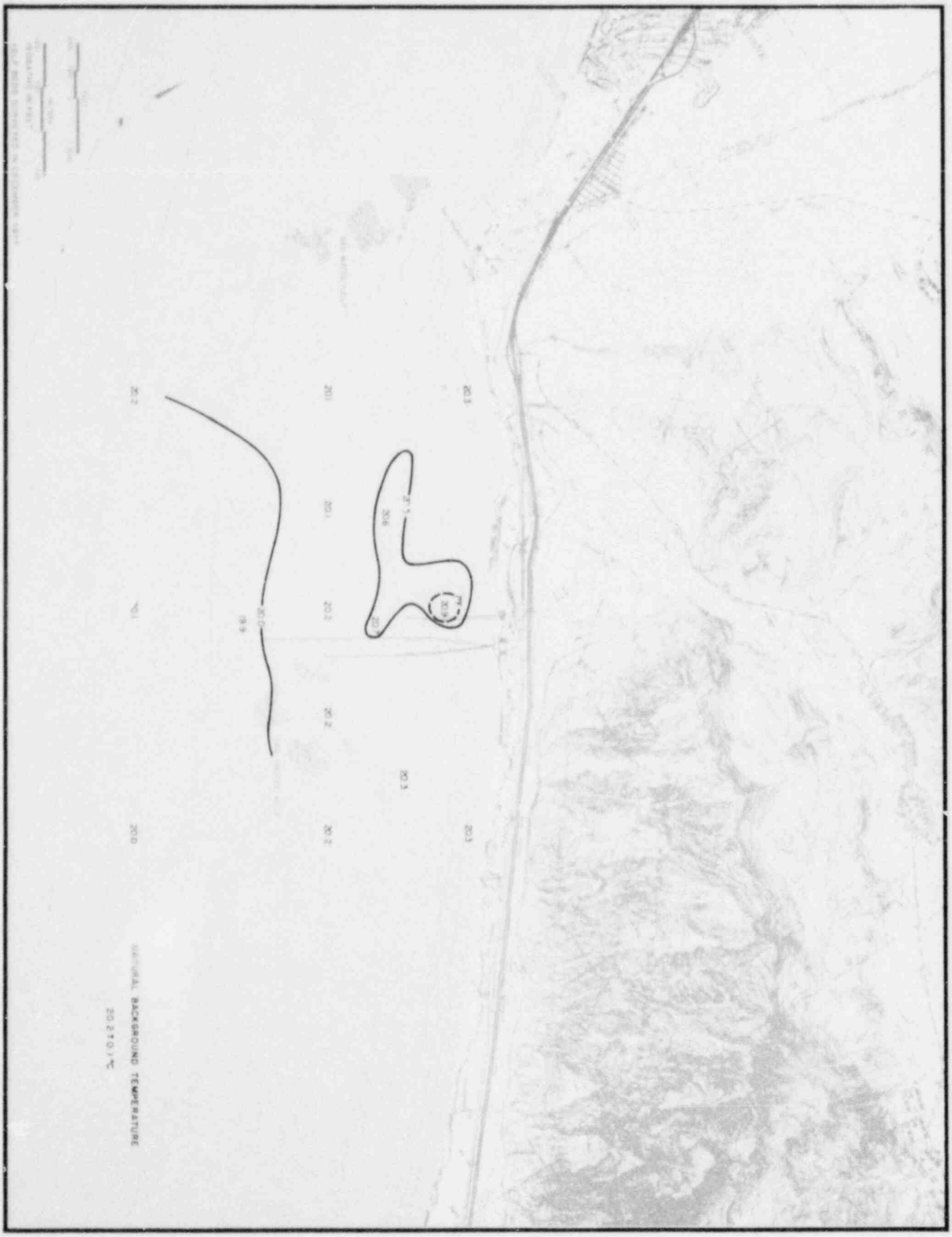

Figure I-38. Surface isotherms from infrared radiometer measurements, Flight 1, 0957-1035 PST, 5 September 1979.

Figure I-39. Surface isotherms from infrared radiometer measurements, Flight 2, 1303-1339 PST, 5 September 1979.

Figure I-40. Surface isotherms from infrared radiometer measurements, Flight 1, 0757-0841 PST, 7 November 1979.

Figure I 41. Surface isotherms from infrared radiometer measurements, Flight 2, 1300-1346 PST, 7 November 1979

Figure I-42. Surface isotherms from infrared radiometer measurements, Flight 1, 1150-1233 PST, 27 November 1979.

Figure I-43. Surface isotherms from infrared radiometer measurements, Flight 2, 1440-1515 PST, 27 November 1979.

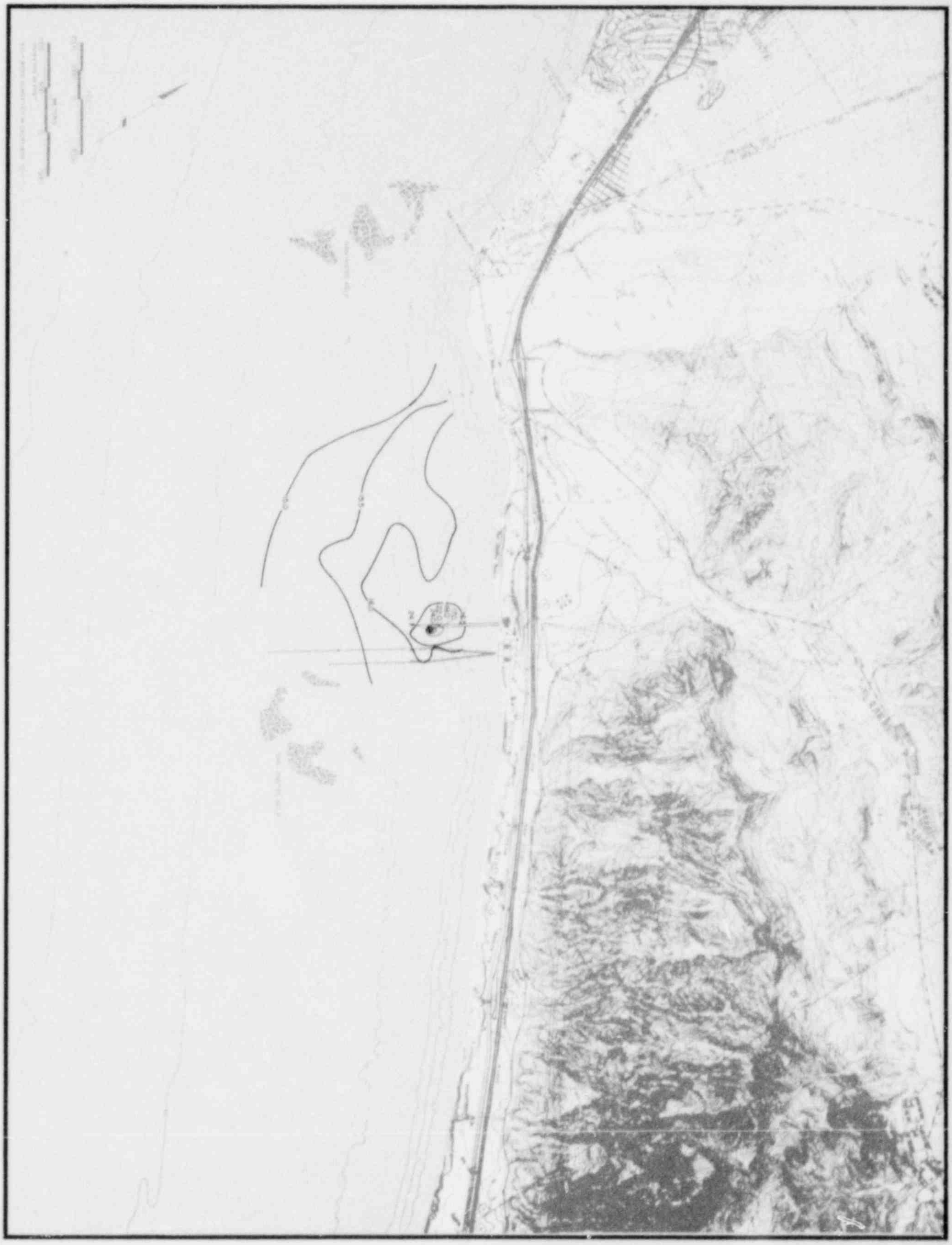

Figure I-44. Surface isotherms from temperature dispersion measurements by Survey Vessel, Run 1, 0951-1105 PST, 11 January 1979.

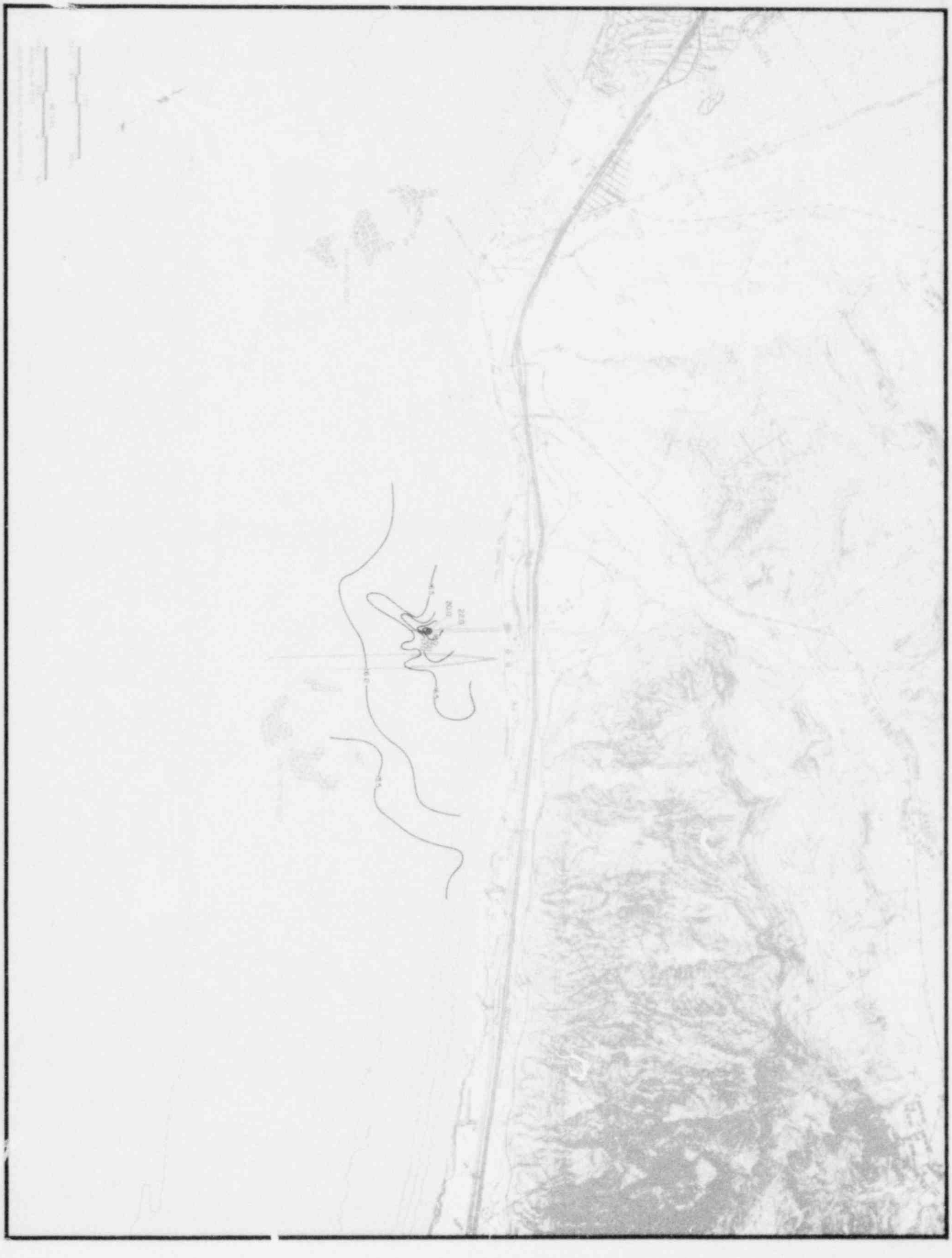

Figure I-45. Surface isotherms from temperature dispersion measurements by Survey Vessel, Run 2, 1430-1527 PST, 11 January 1979.

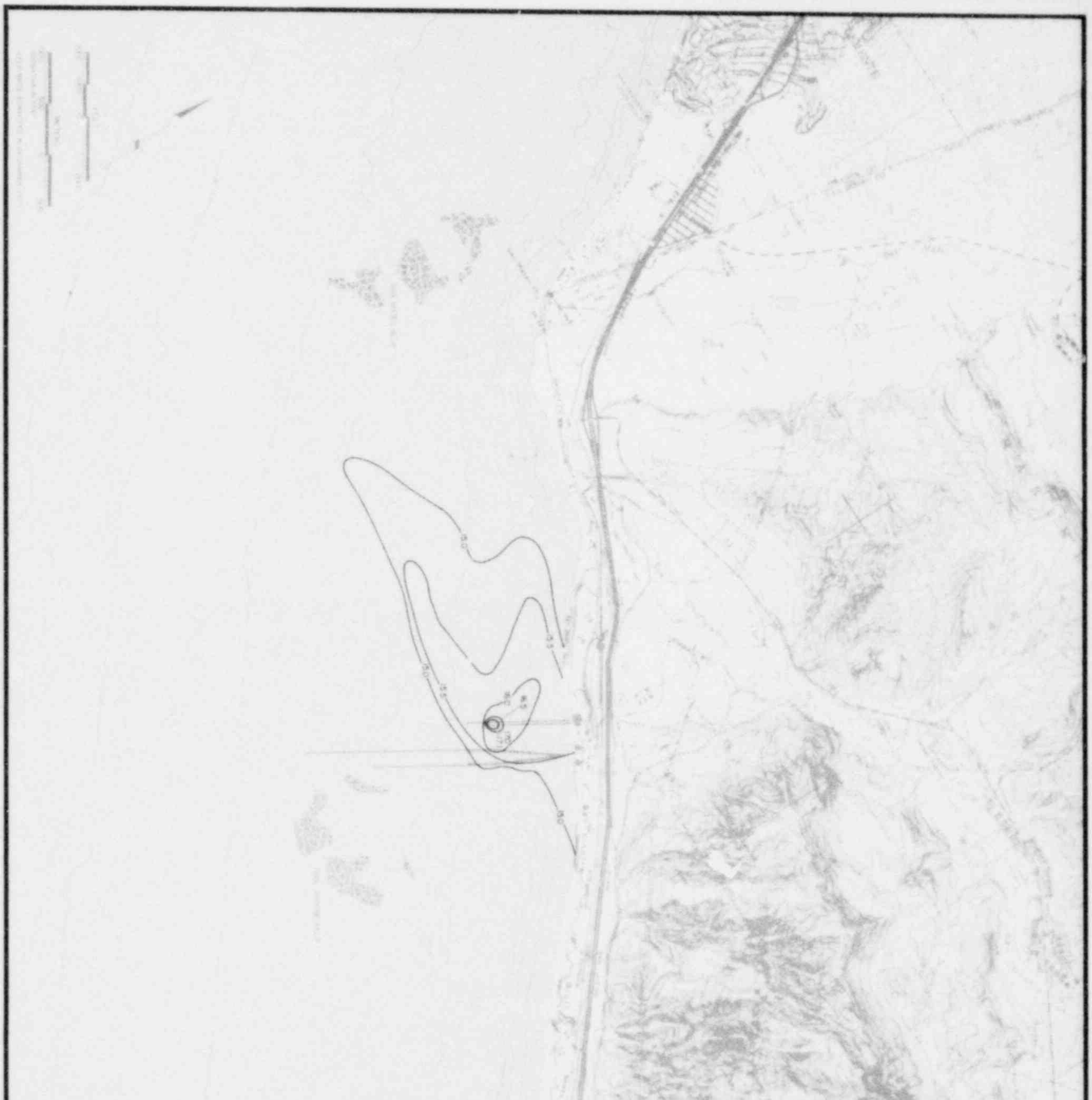

Figure I-46. Surface isotherms from temperature dispersion measurements by Survey Vessel, 0910-1032 PST, 14 March 1979.

Figure I-47. Surface isotherms from temperature dispersion measurements by Survey Vessel, Run 1, 0755-0901 PST, 16 May 1979.

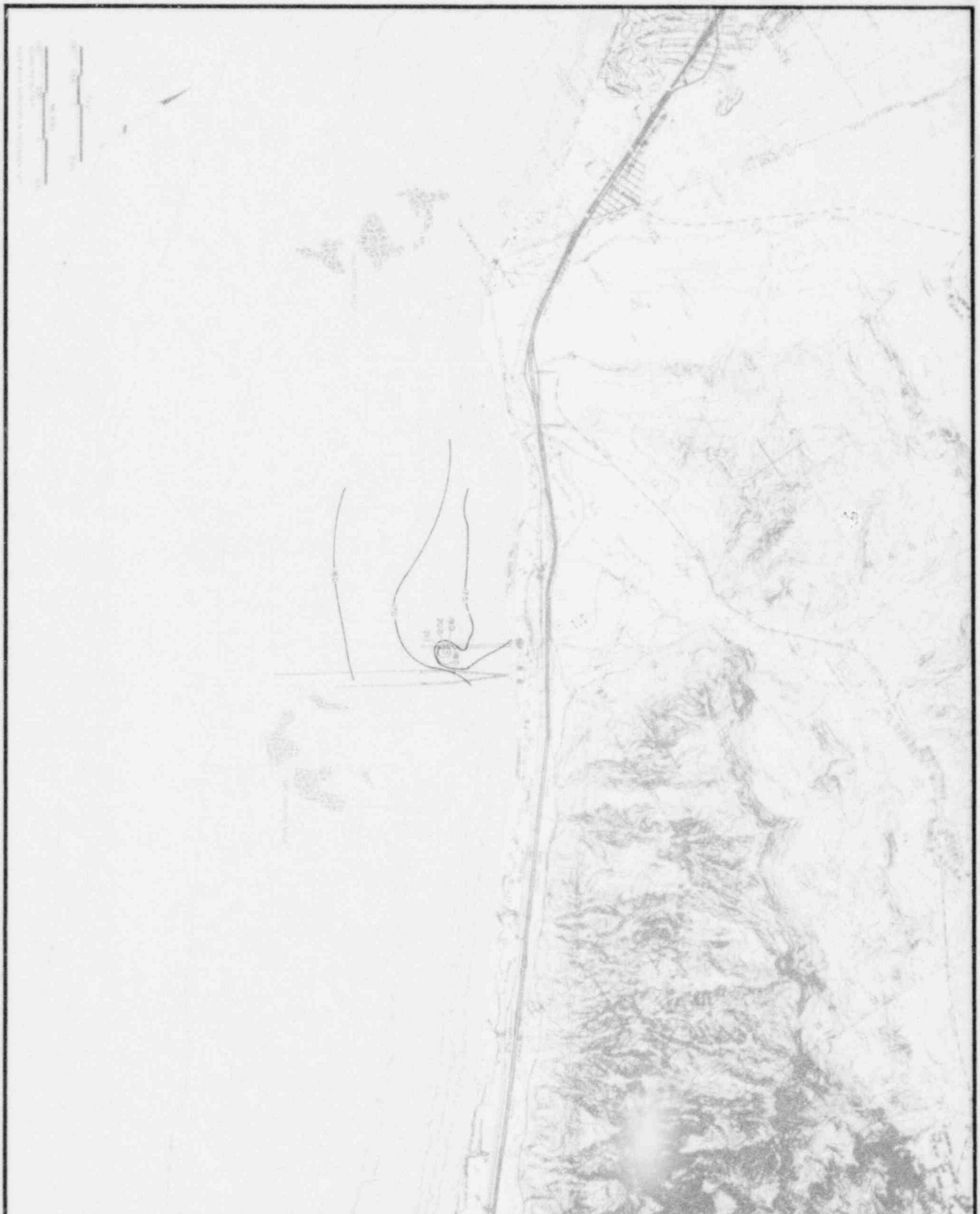

Figure I-48. Surface isotherms from temperature dispersion measurements by Survey Vessel, Run 2, 1407-1426 PST, 16 May 1979.

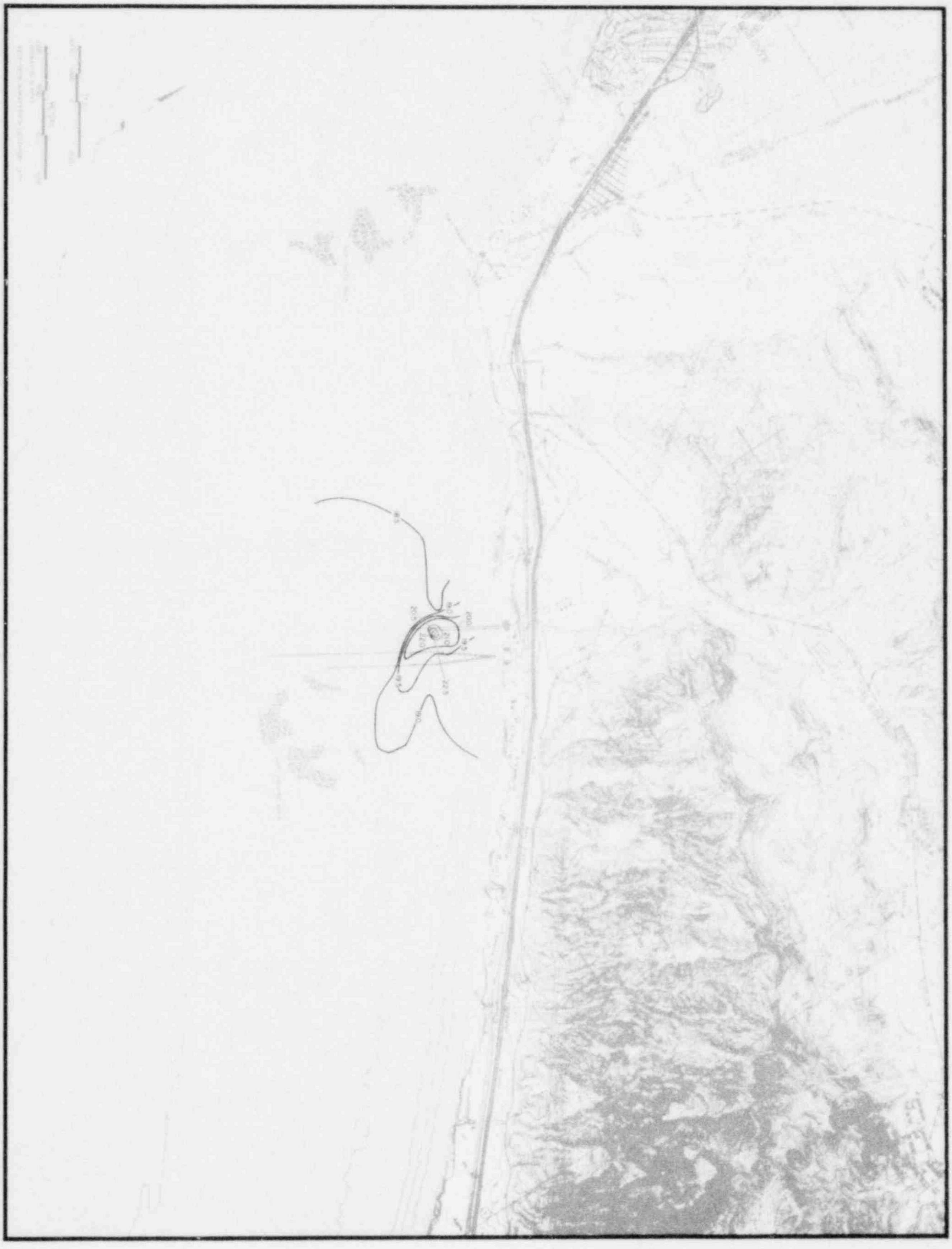

Figure I-49. Surface isotherms from temperature dispersion measurements by Survey Vessel, 1212-1325 PST, 1 June 1979.

Figure I-50. Surface isotherms from temperature dispersion measurements by Survey Vessel, 0837-0906 PST, 5 September 1979.

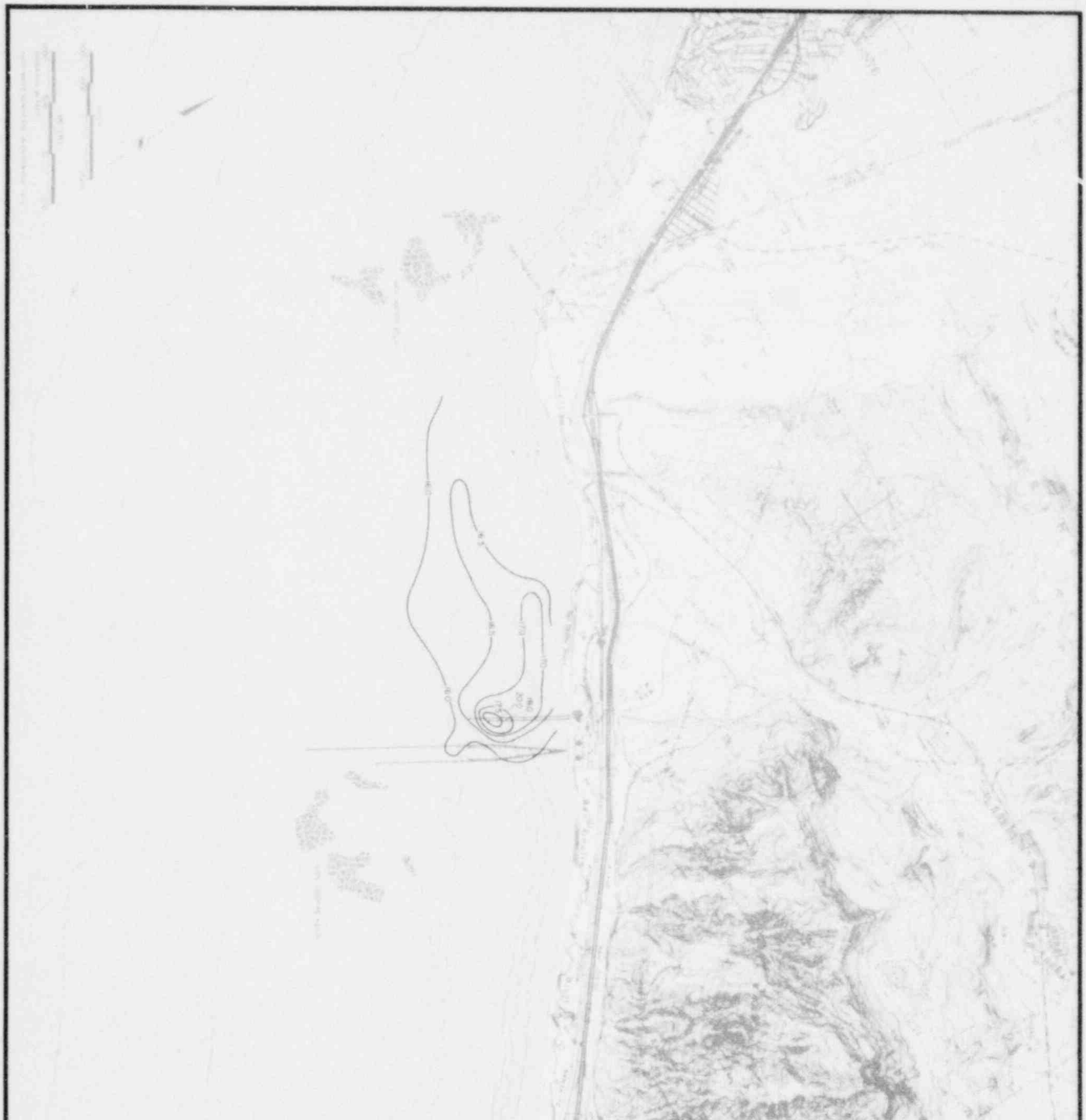

Figure I-51. Surface isotherms from temperature dispersio· measurements by Survey Vessel, 0814-0856 PST, 7 November 1979.

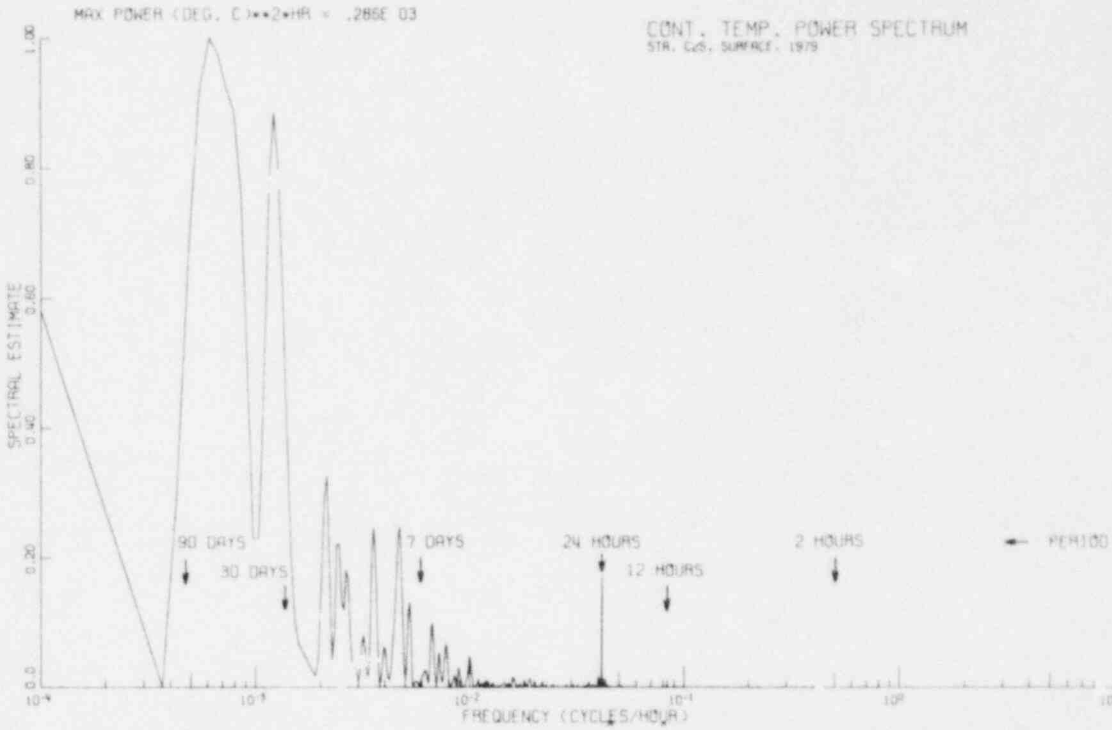

Figure I-52. Continuous temperature power spectrum for Station C2S, Surface, 1979.

Figure I-53. Continuous temperature power spectrum for Station C2S, mid-depth, 1979.

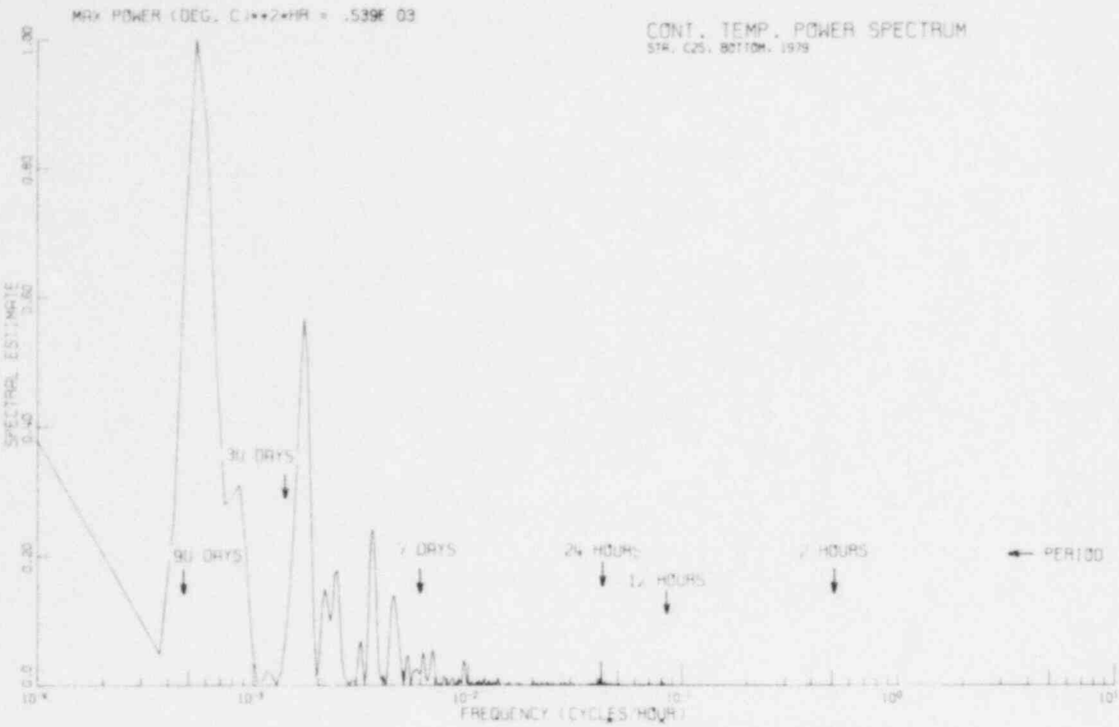

Figure I-54. Continuous temperature power spectrum for Station C2S, Bottom, 1979.

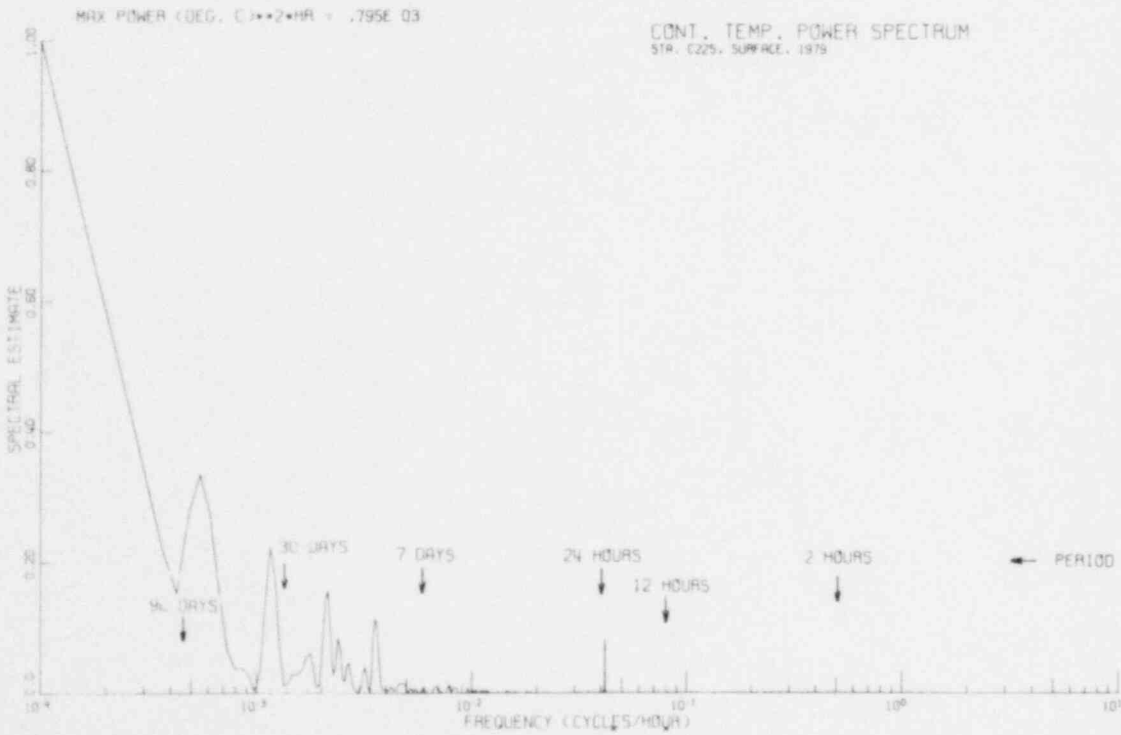

Figure I-55. Continuous temperature power spectrum for Station C22S, Surface, 1979.

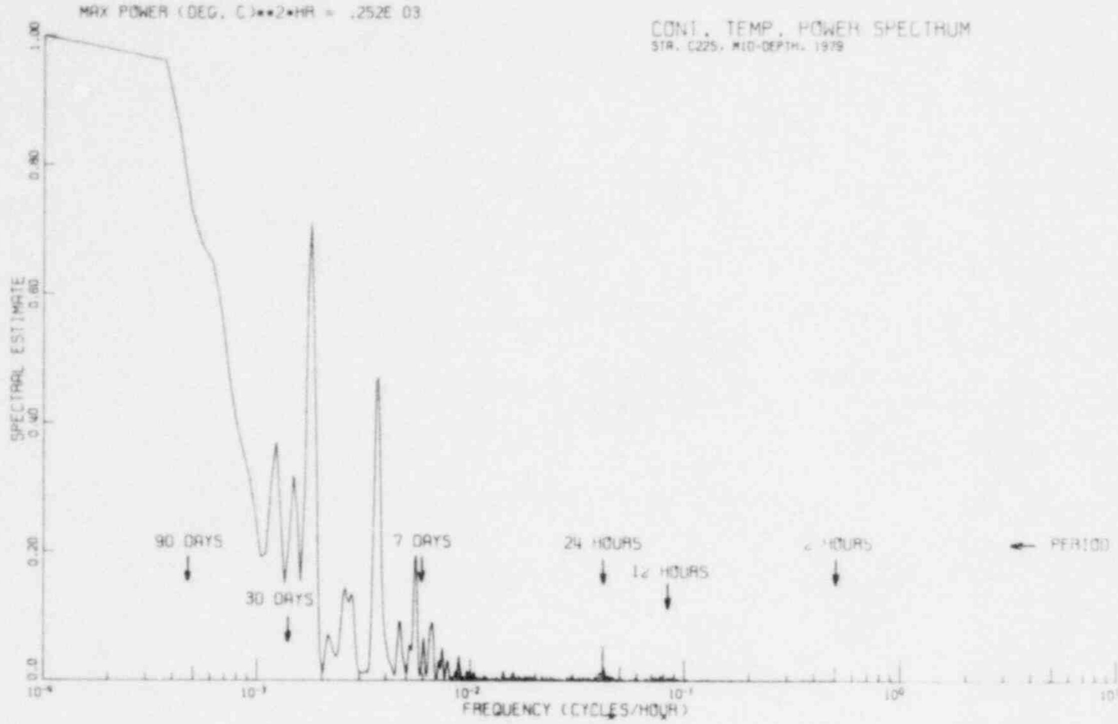

Figure I-56. Continuous temperature power spectrum for Station C22S, Mid-Depth, 1979.

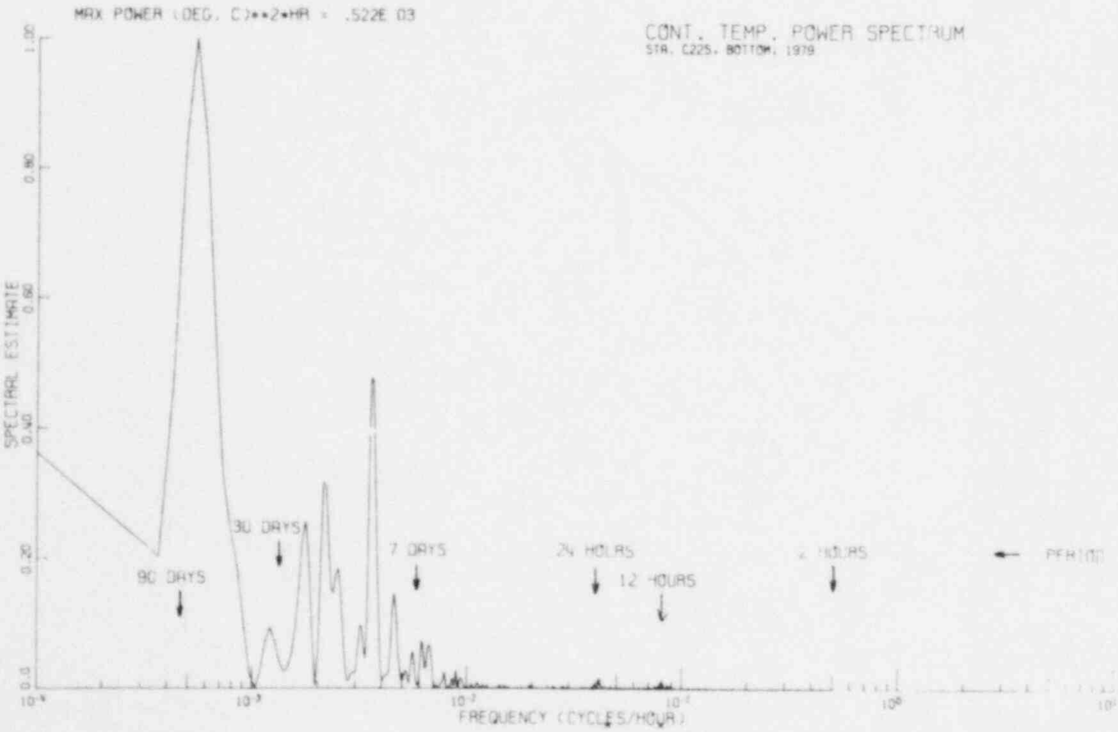

Figure I-57. Continuous temperature power spectrum for Station C22S, Bottom, 1979.

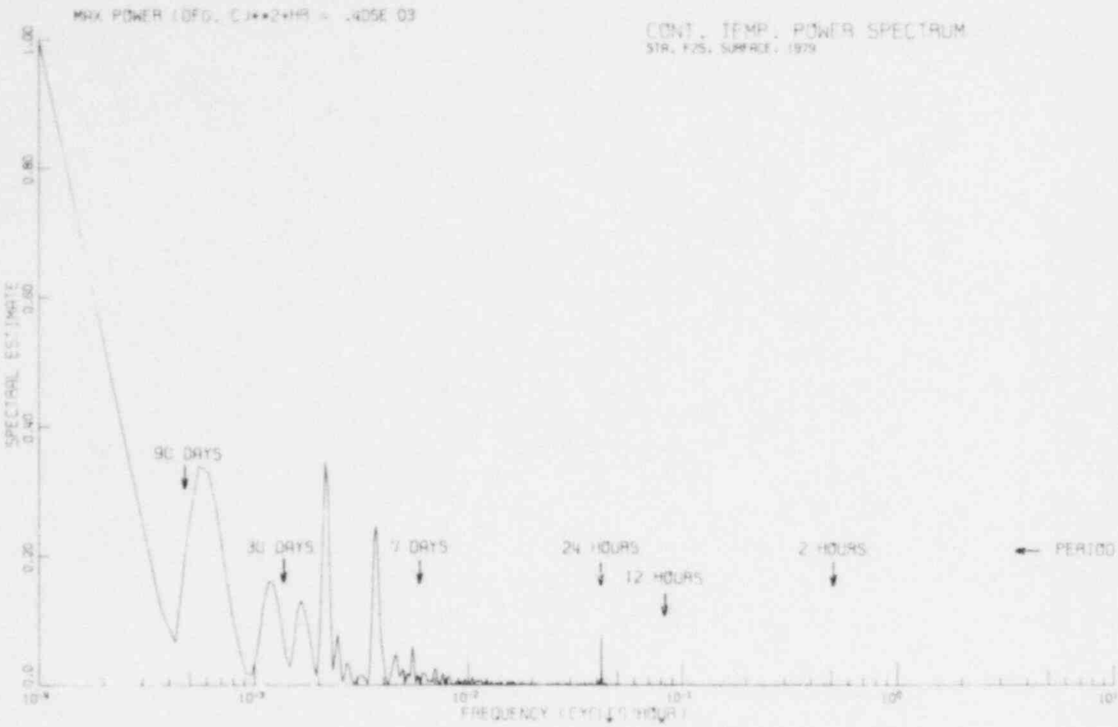

Figure I-58. Continuous temperature power spectrum for Station F2S, Surface, 1979.

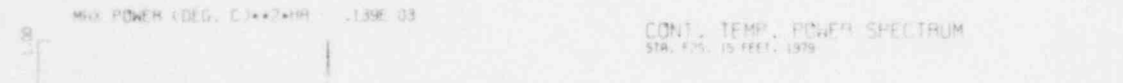

Figure I-59. Continuous temperature power spectrum for Station F2S, 4.5 m of depth, 1979.

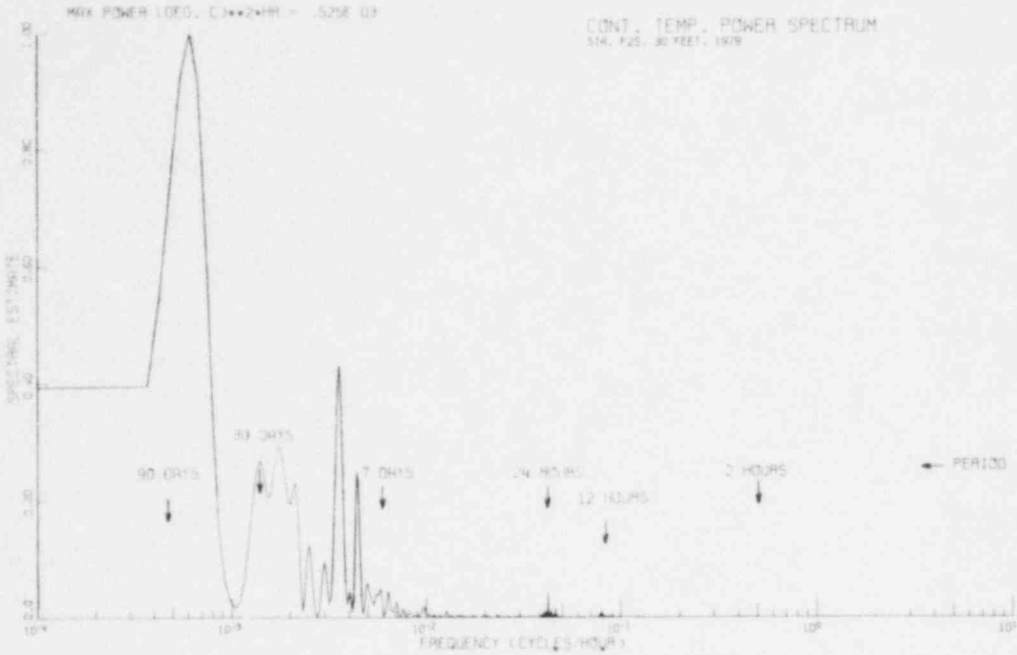

Figure I-60. Continuous temperature power spectrum for Station F2S, 9 m of depth, 1979.

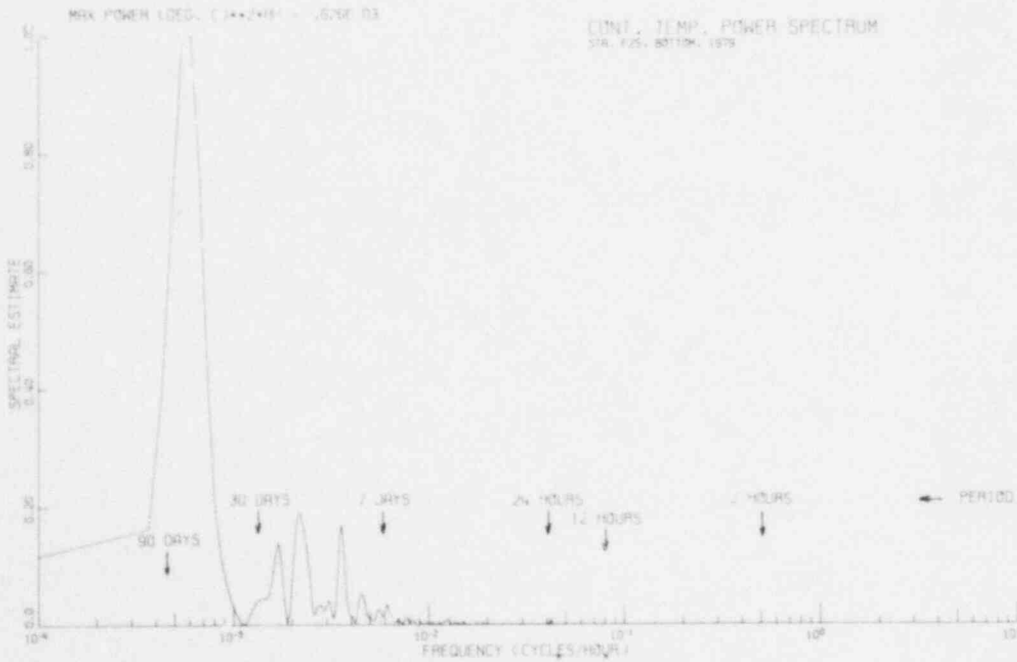

Figure I-61. Continuous temperature power spectrum for Station F2S, Bottom, 1979.

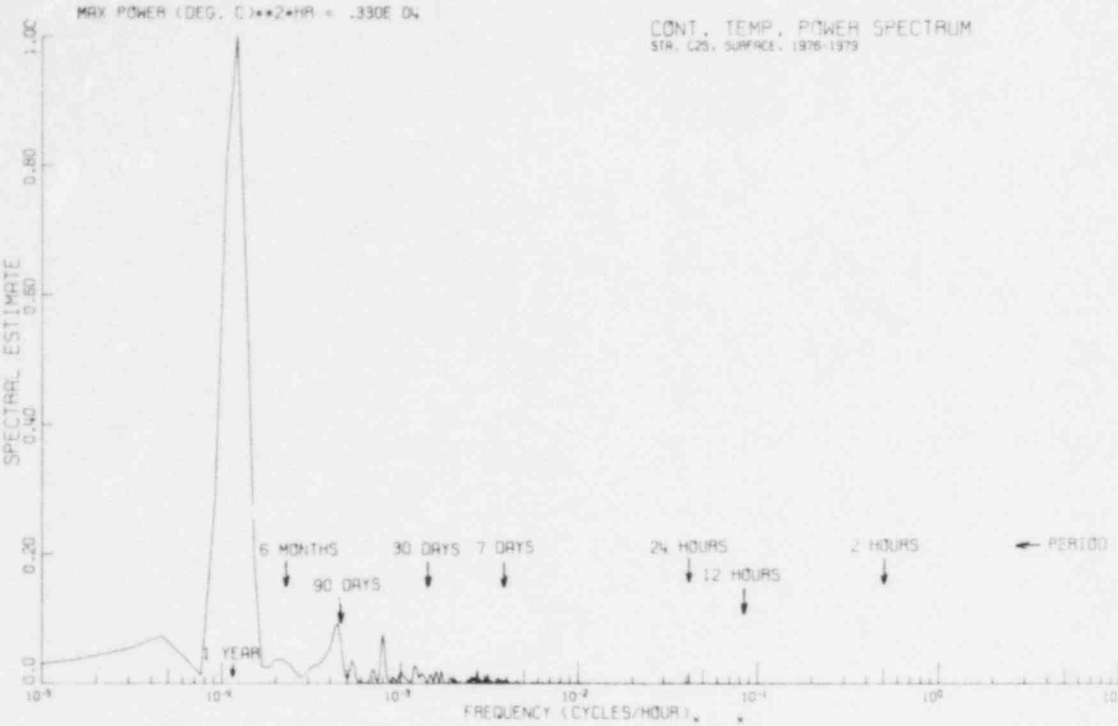

Figure I-62. Continuous temperature power spectrum for Station C2S, Surface, 1976-1979.

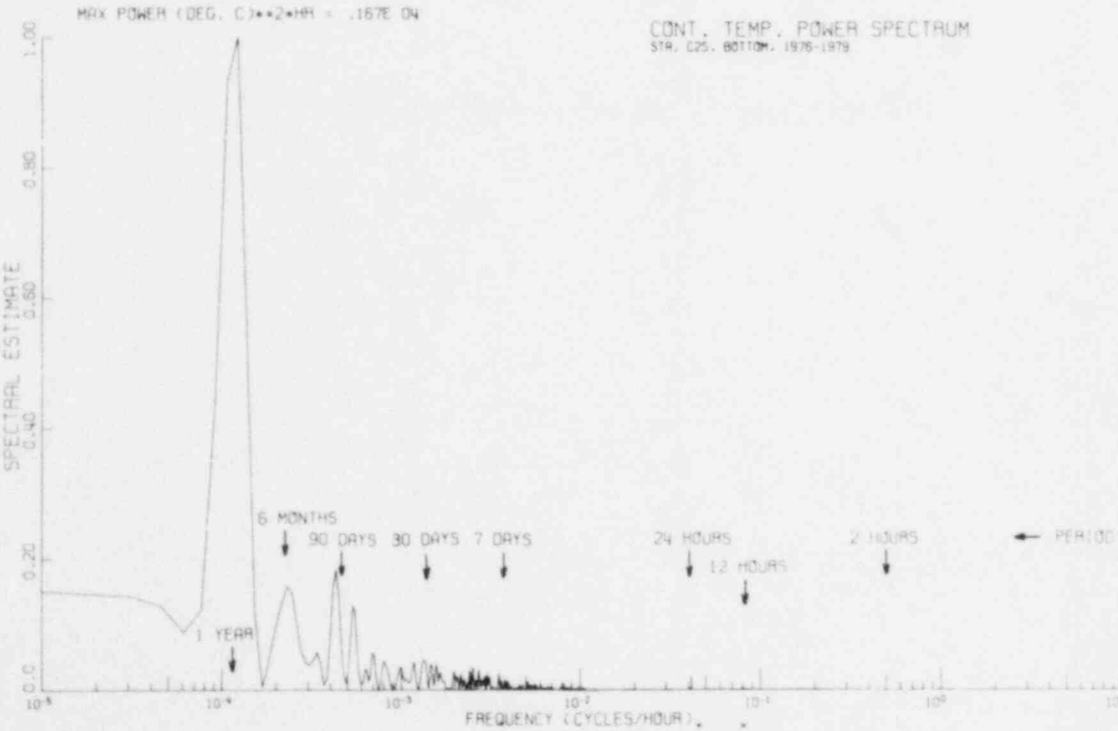

Figure I-63. Continuous temperature power spectrum for Station C2S, Bottom 1976-1979.

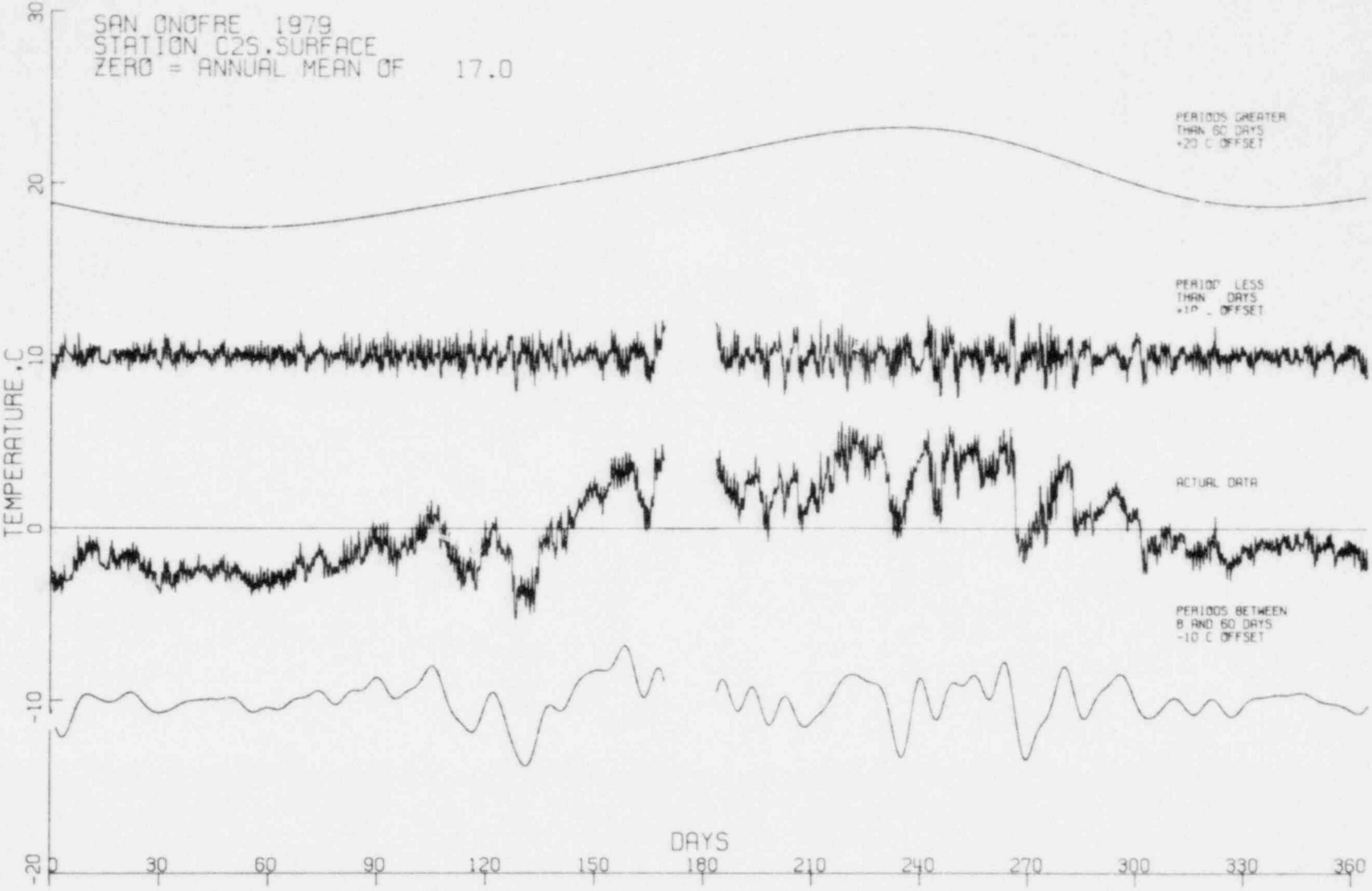

Figure I-64. Continuous temperature filtered into frequency bands for Station C2S, Surface, 1979.

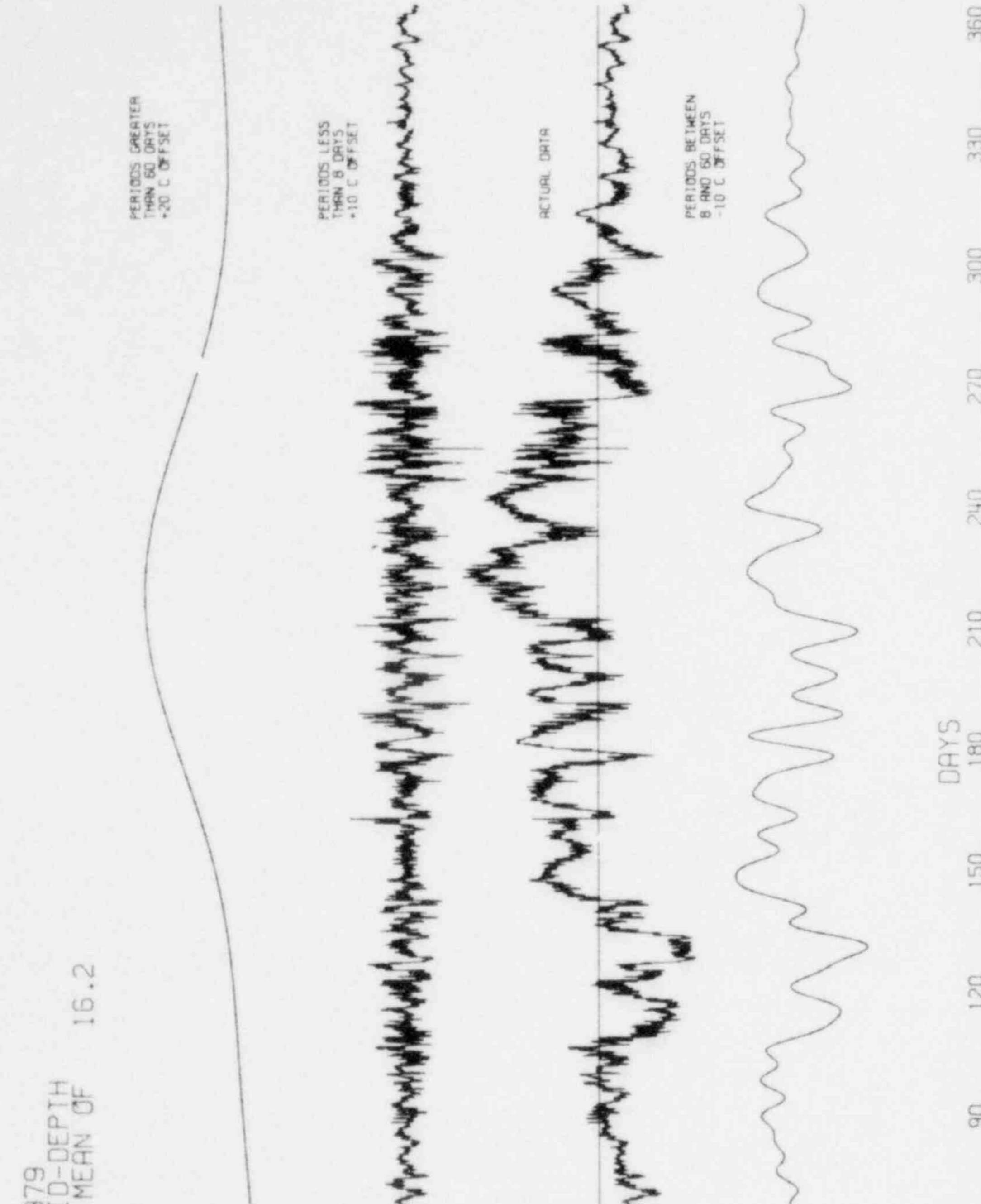

Figure I-65. Continuous temperature filtered into frequency bands for Station C2S, Mid-Depth, 1979.

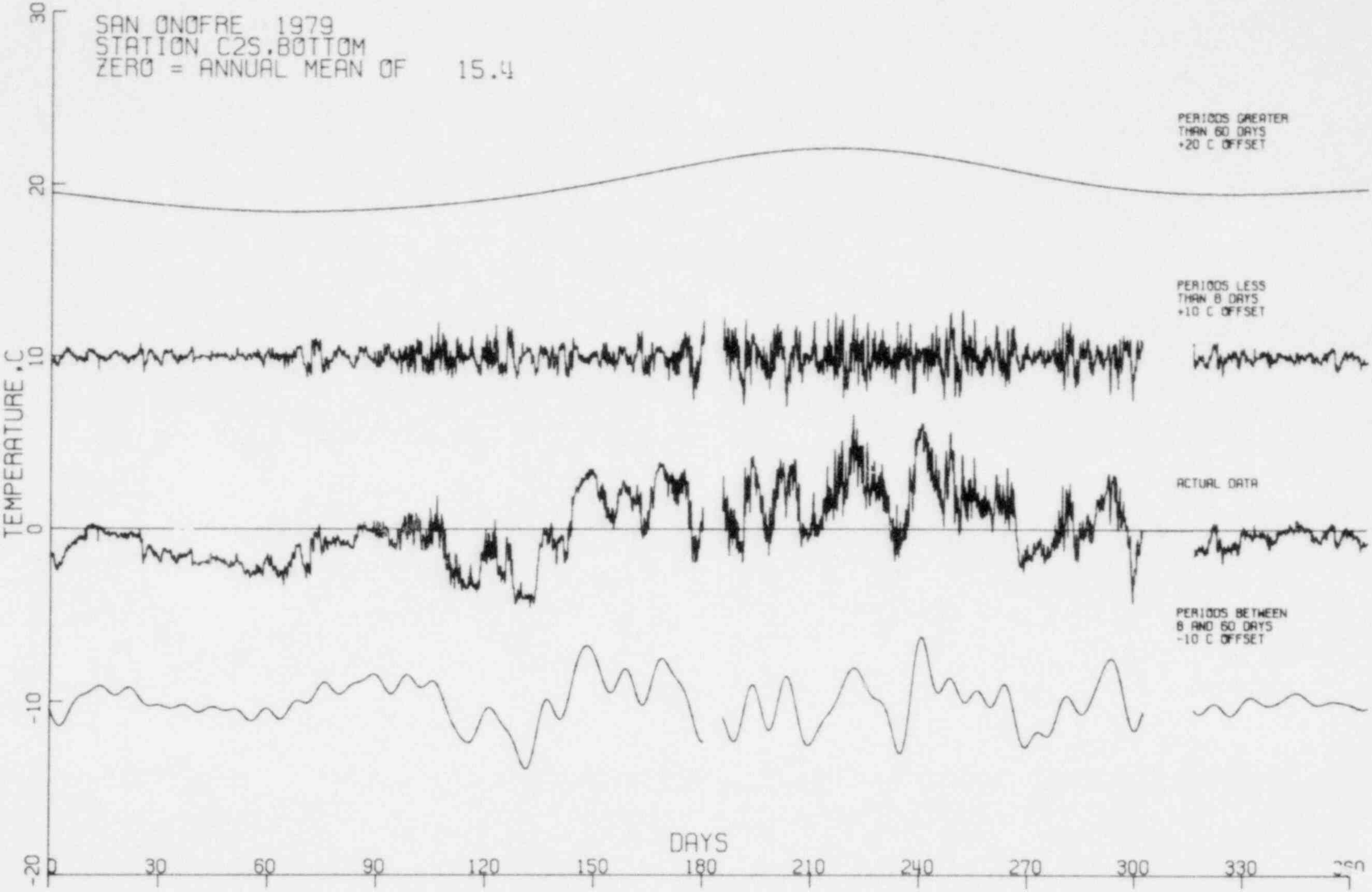

Figure I-66. Continuous temperature filtered into frequency bands for Station C2S, Bottom, 1979.

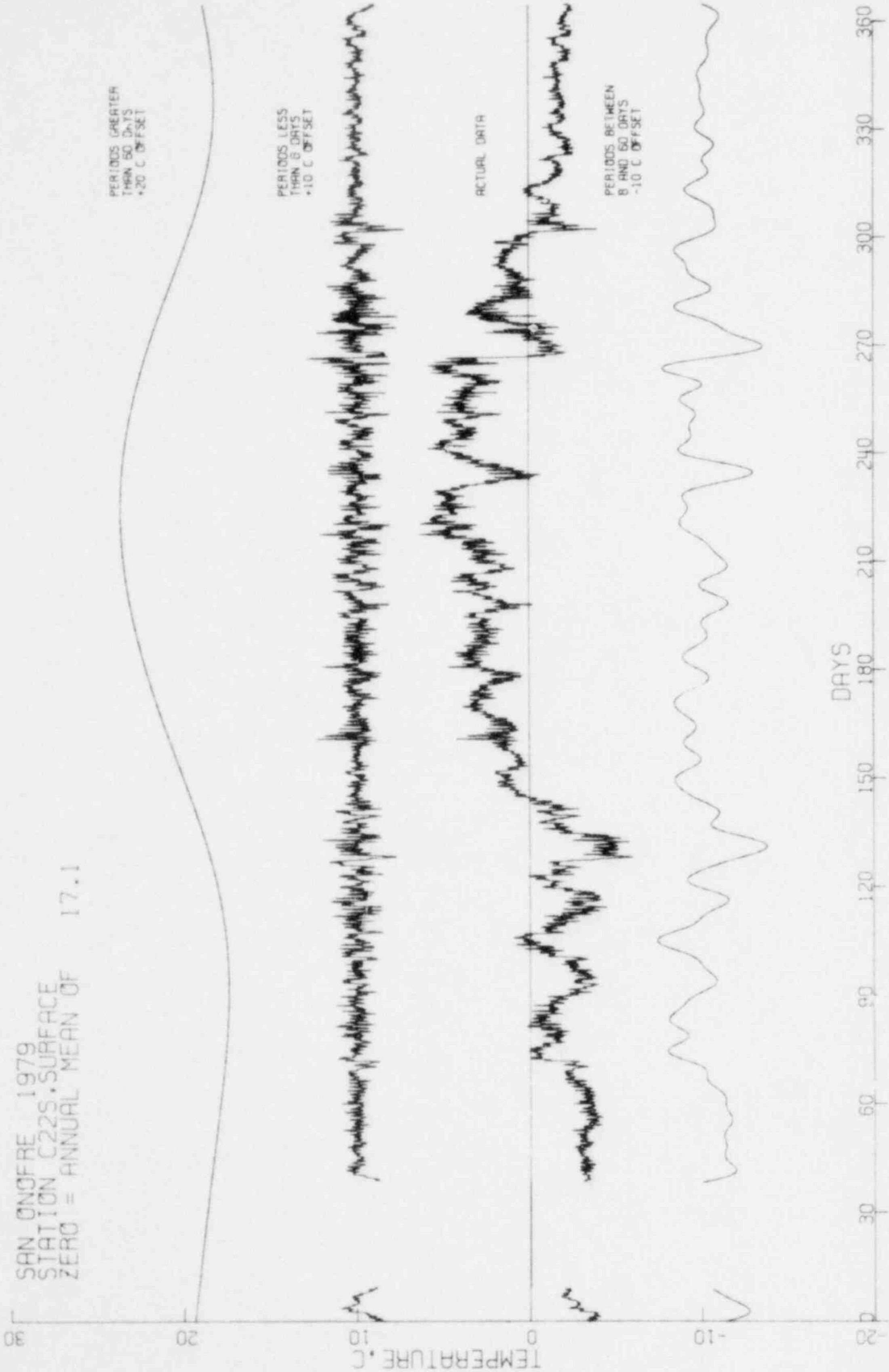

Figure I-67. Continuous temperature filtered into frequency bands for Station C22S, Surface 1979.

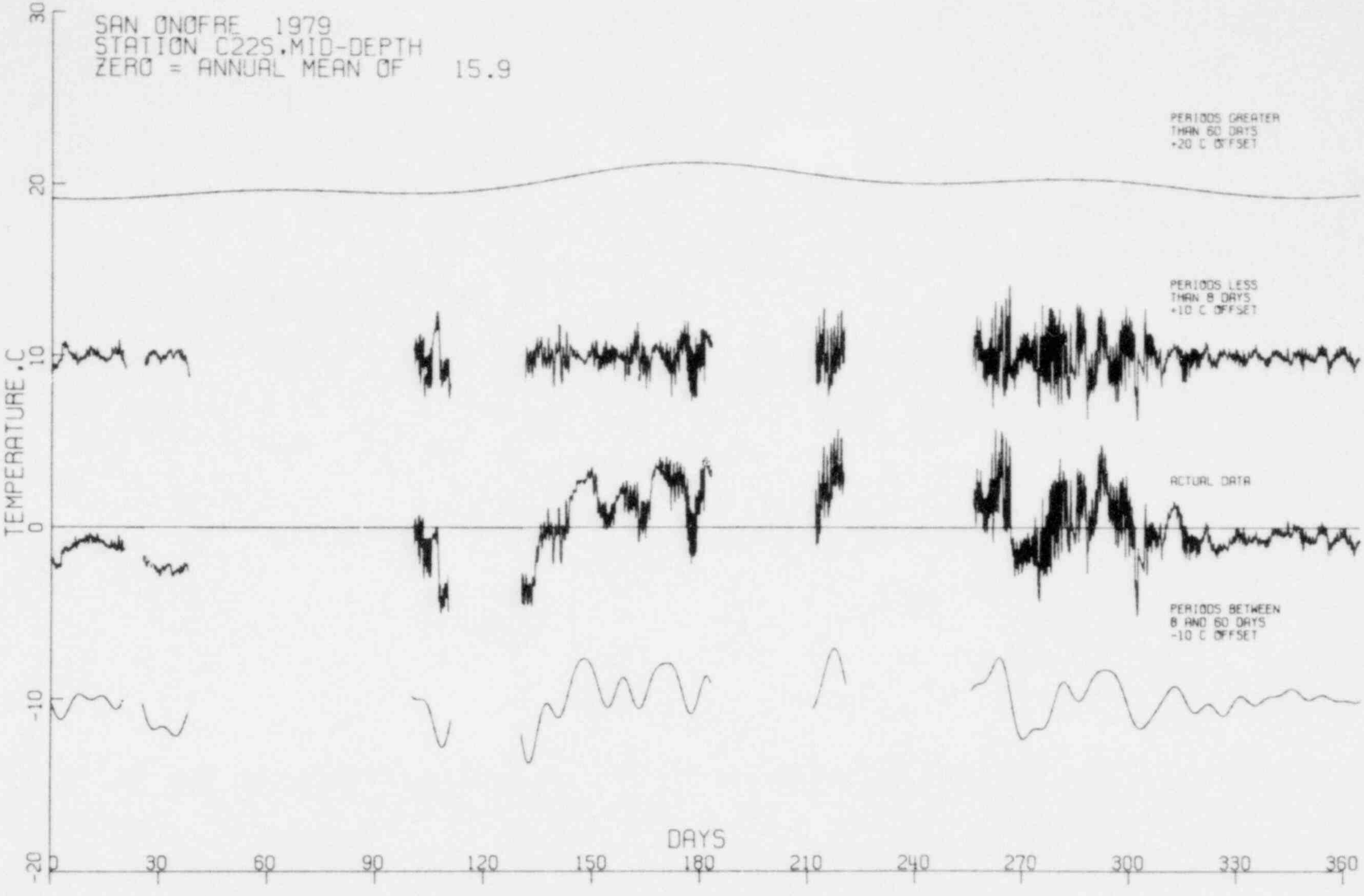

Figure I-68. Continuous temperature filtered into frequency bands for Station C22S, mid-depth, 1979.

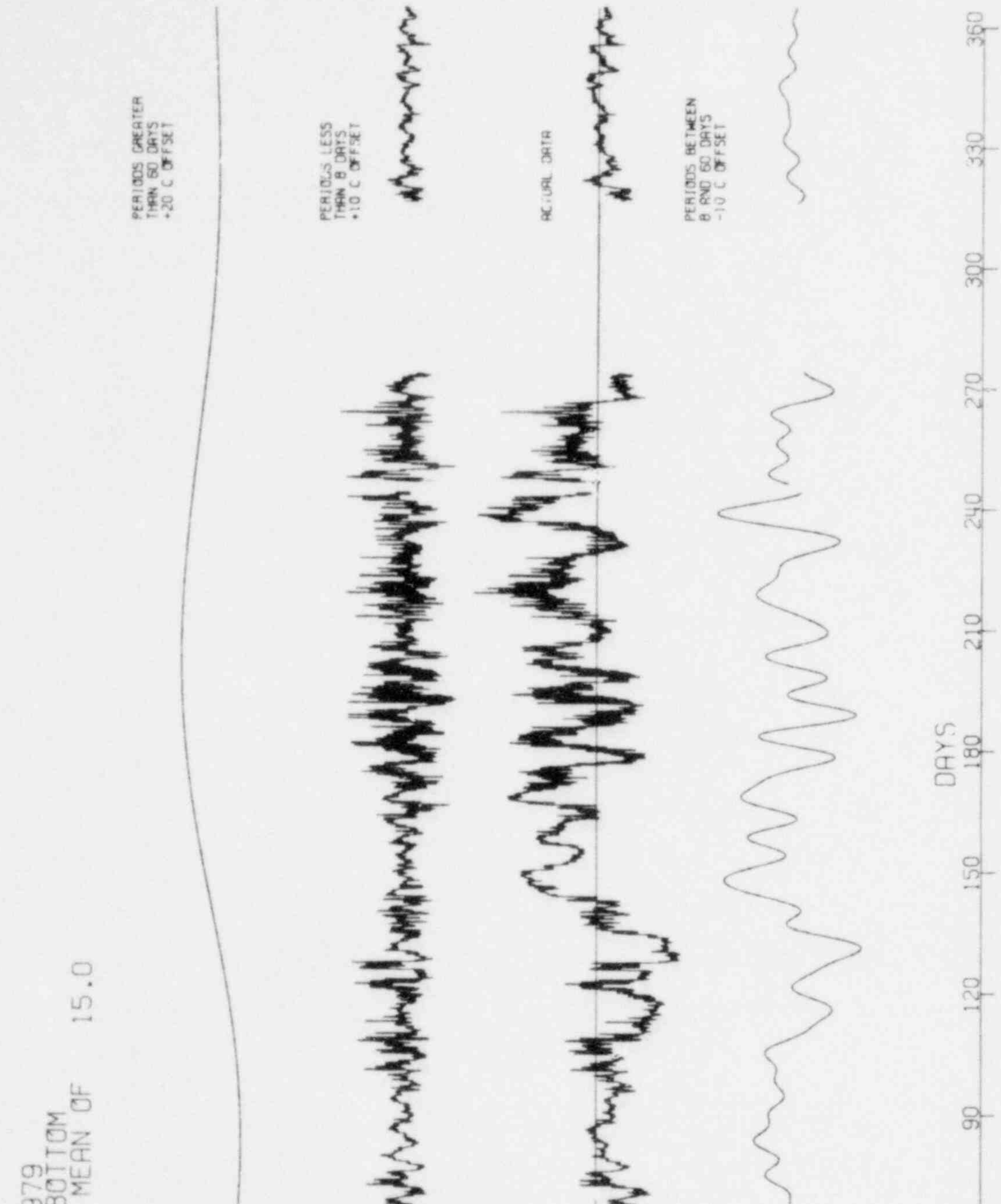

Figure I-69. Continuous temperature filtered into frequency bands for Station C22S, Bottom, 1979.

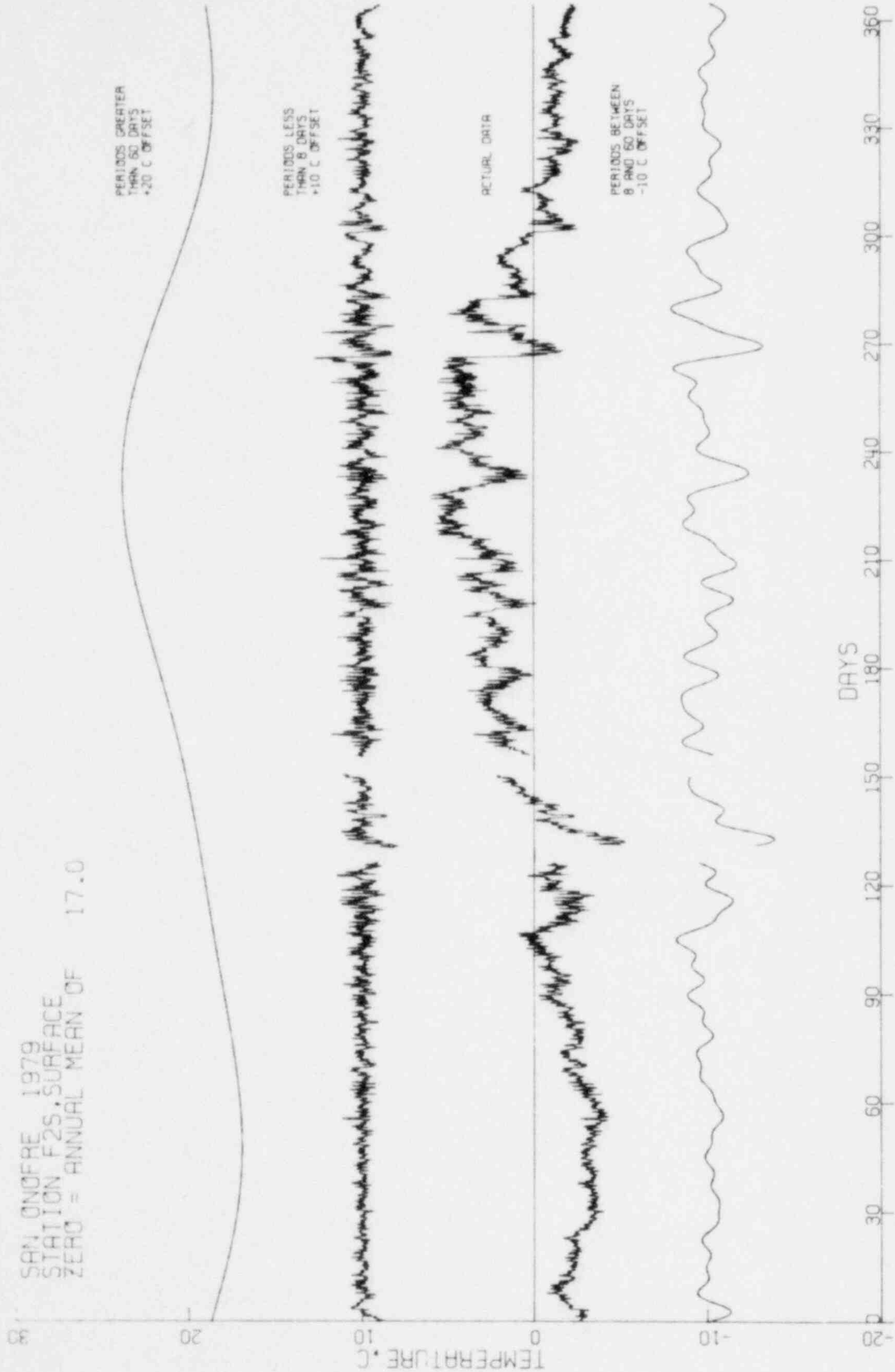

Figure I-70. Continuous temperature filtered into frequency bands for Station F2S, Surface, 1979.

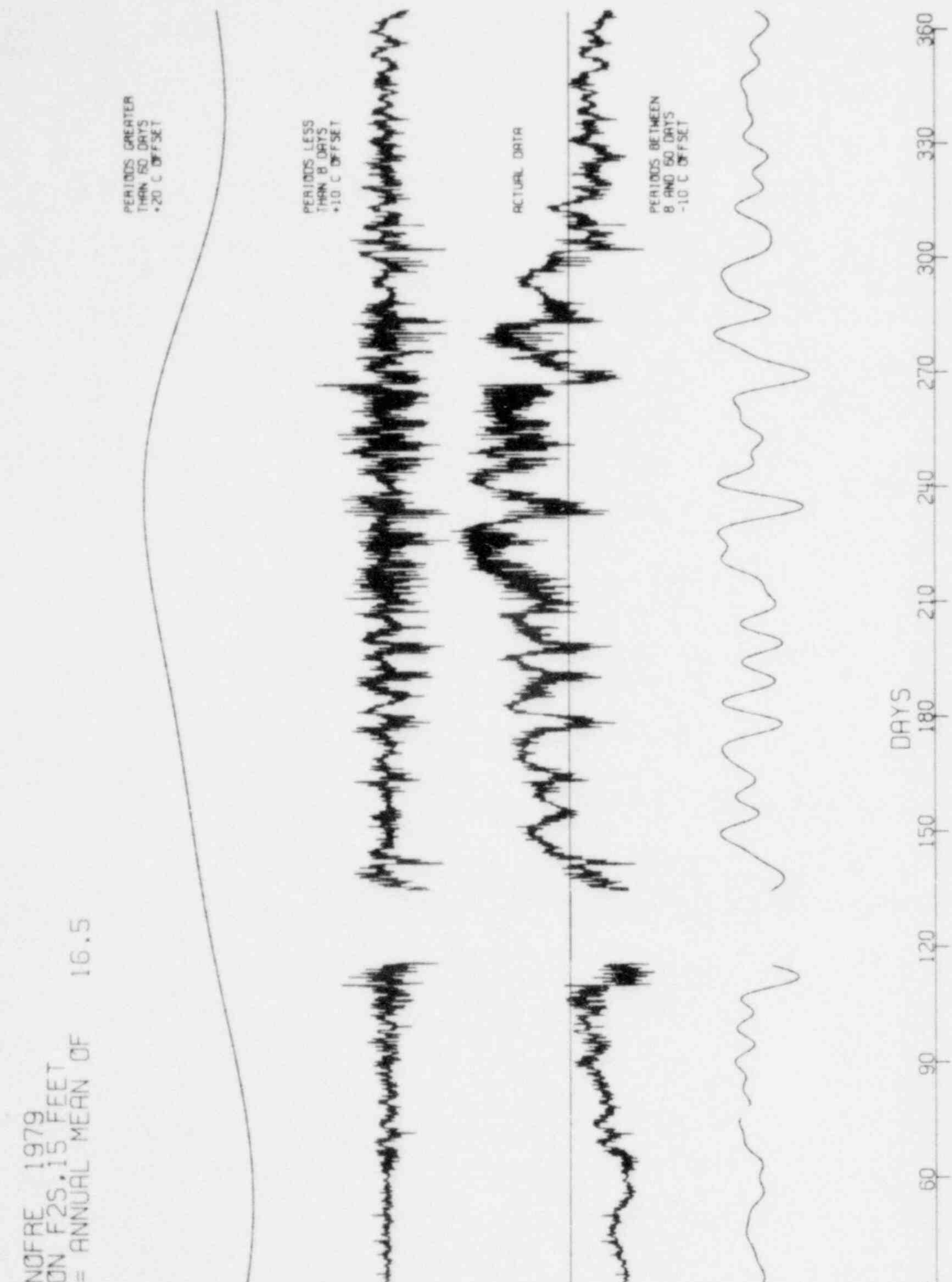

Figure I-71. Continuous temperature filtered into frequency bands for Station F2S, 4.5 m of depth, 1979.

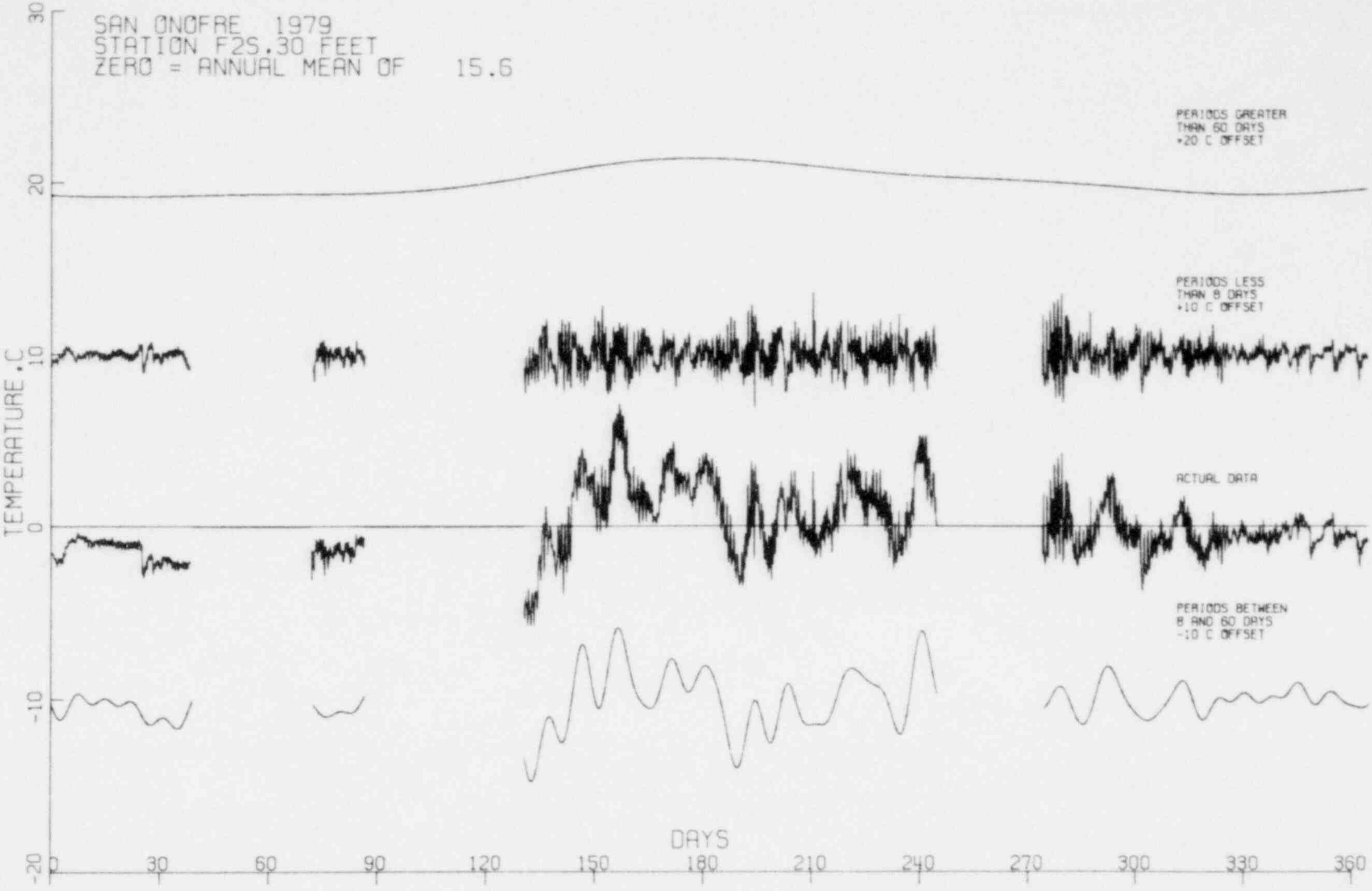

Figure I-72. Continuous temperature filtered into frequency bands for Station F2S, 9 m of depth, 1979.

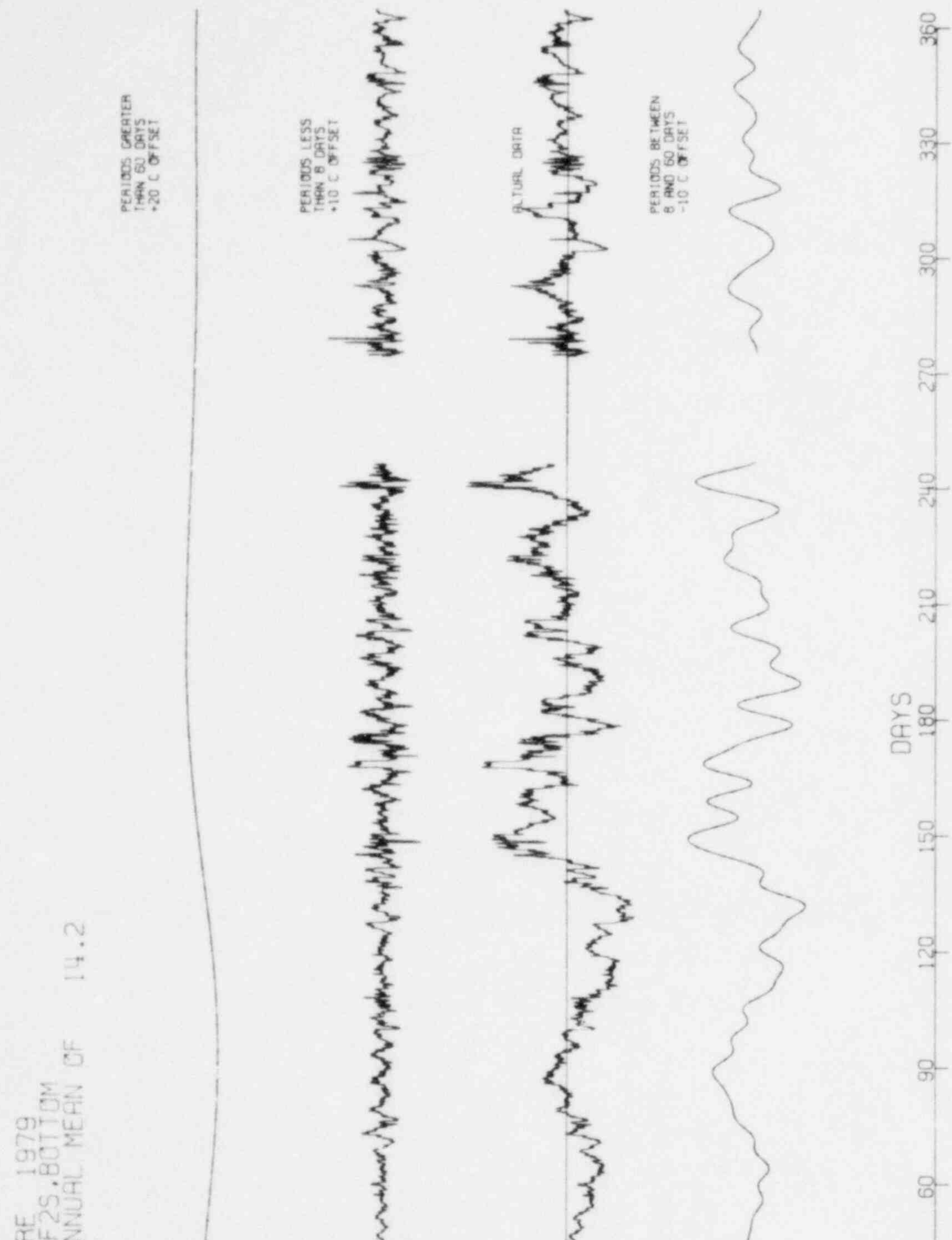

Figure I-73. Continuous temperature filtered into frequency bands for Station F2S, Bottom, 1979.

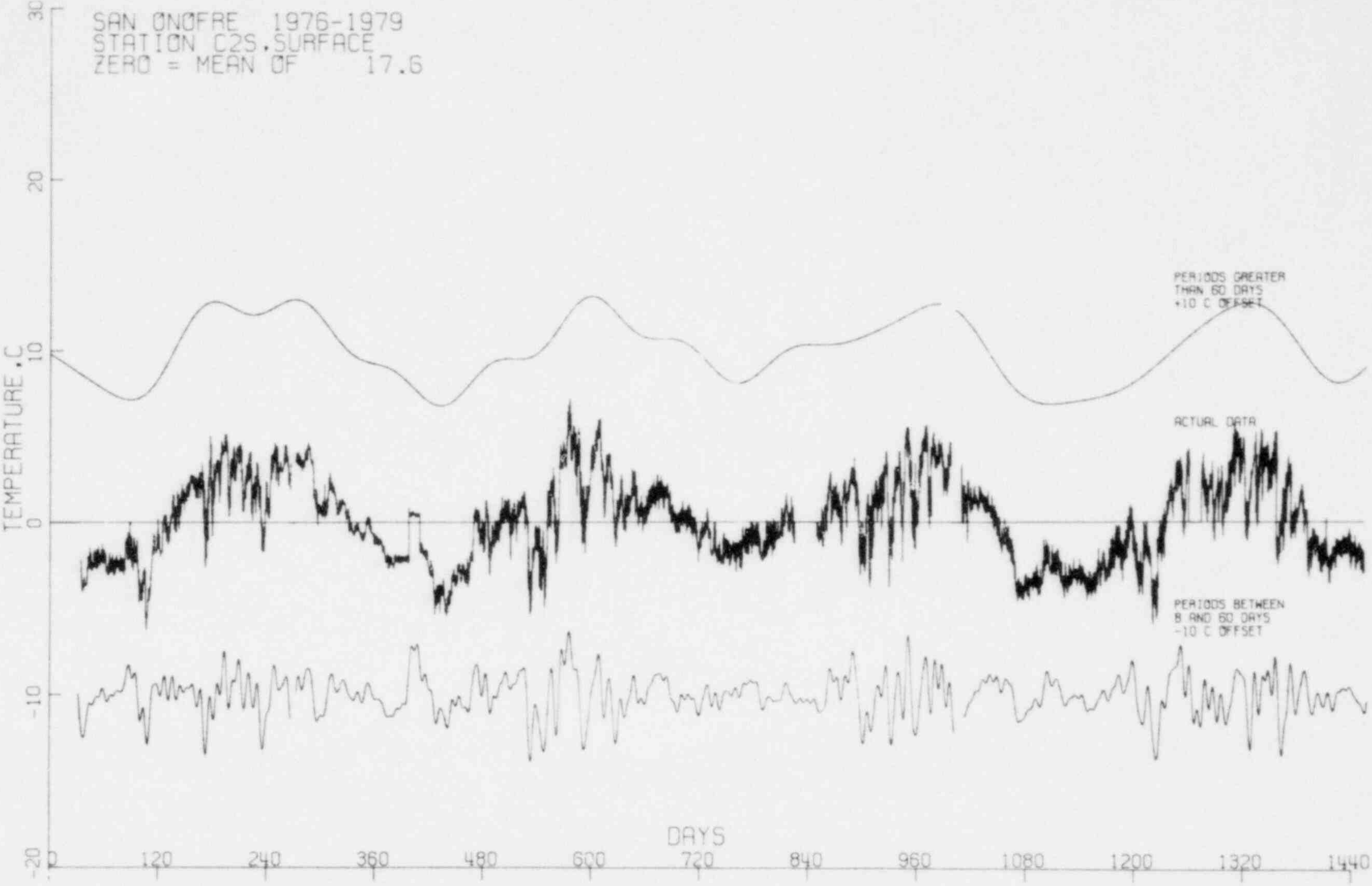

Figure I-74. Continuous temperature filtered into frequency bands for Station C2S, Surface, 1976-1979.

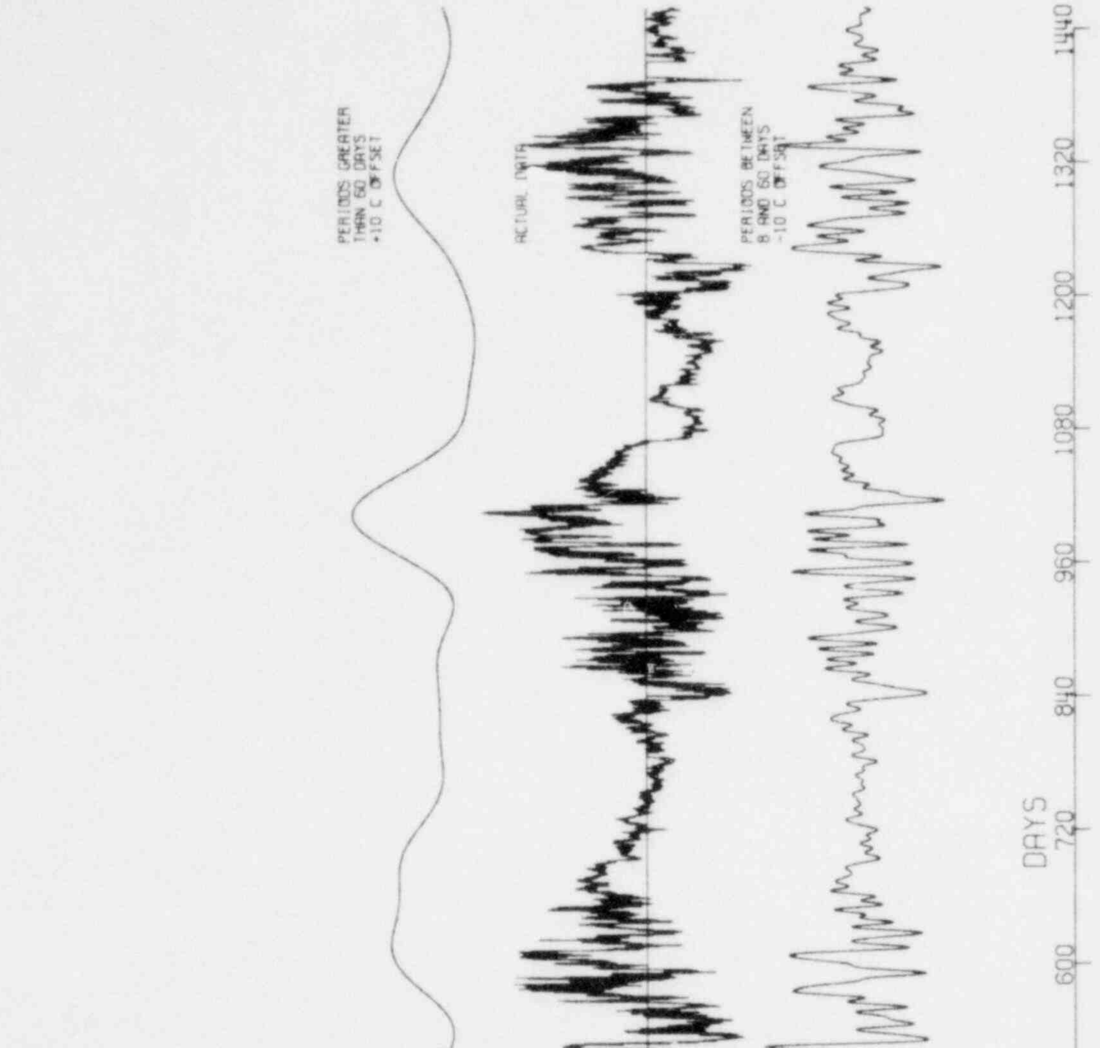

Figure I-75. Continuous temperature filtered into frequency bands for Station C26, Bottom, 1976-1979.

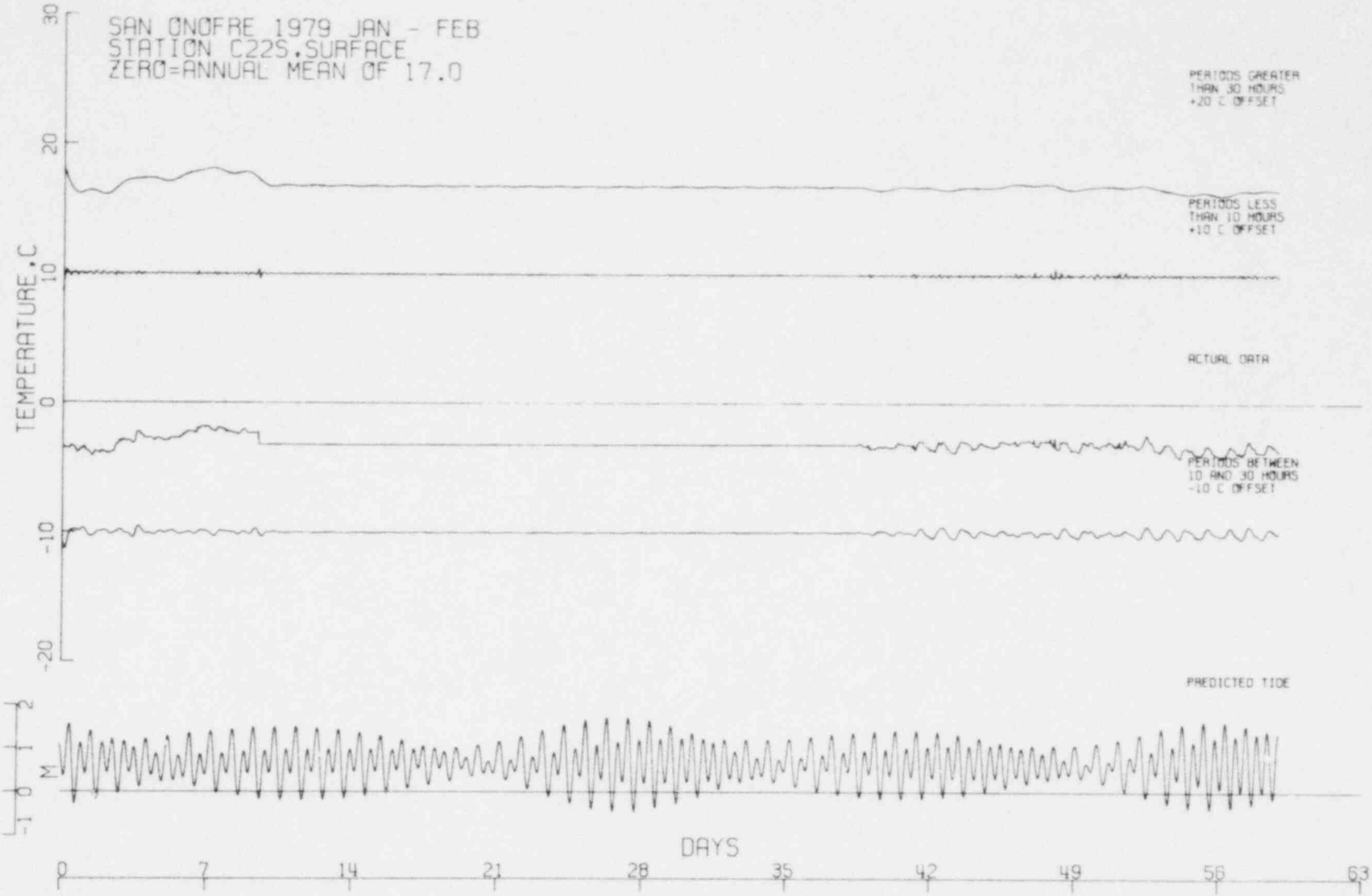

Figure I-76. Continuous temperature filtered into frequency bands for Station C22S, Surface, January and February 1979.

Figure I-77. Continuous temperature filtered into frequency bands for Station C22S, Surface, July and August 1979.

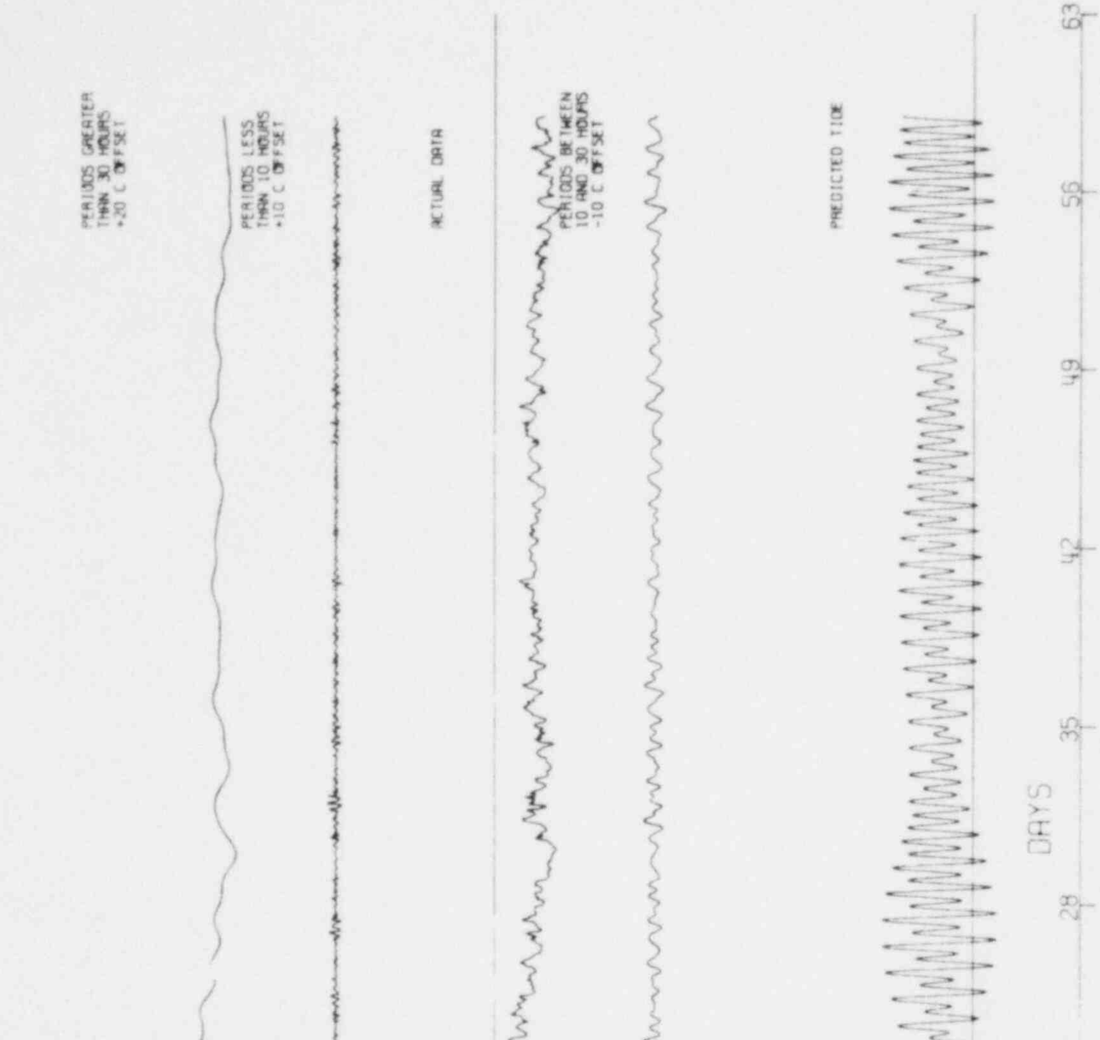

Figure I-78. Continuous temperature filtered into frequency bands for Station C2S, Surface, January and February 1979.

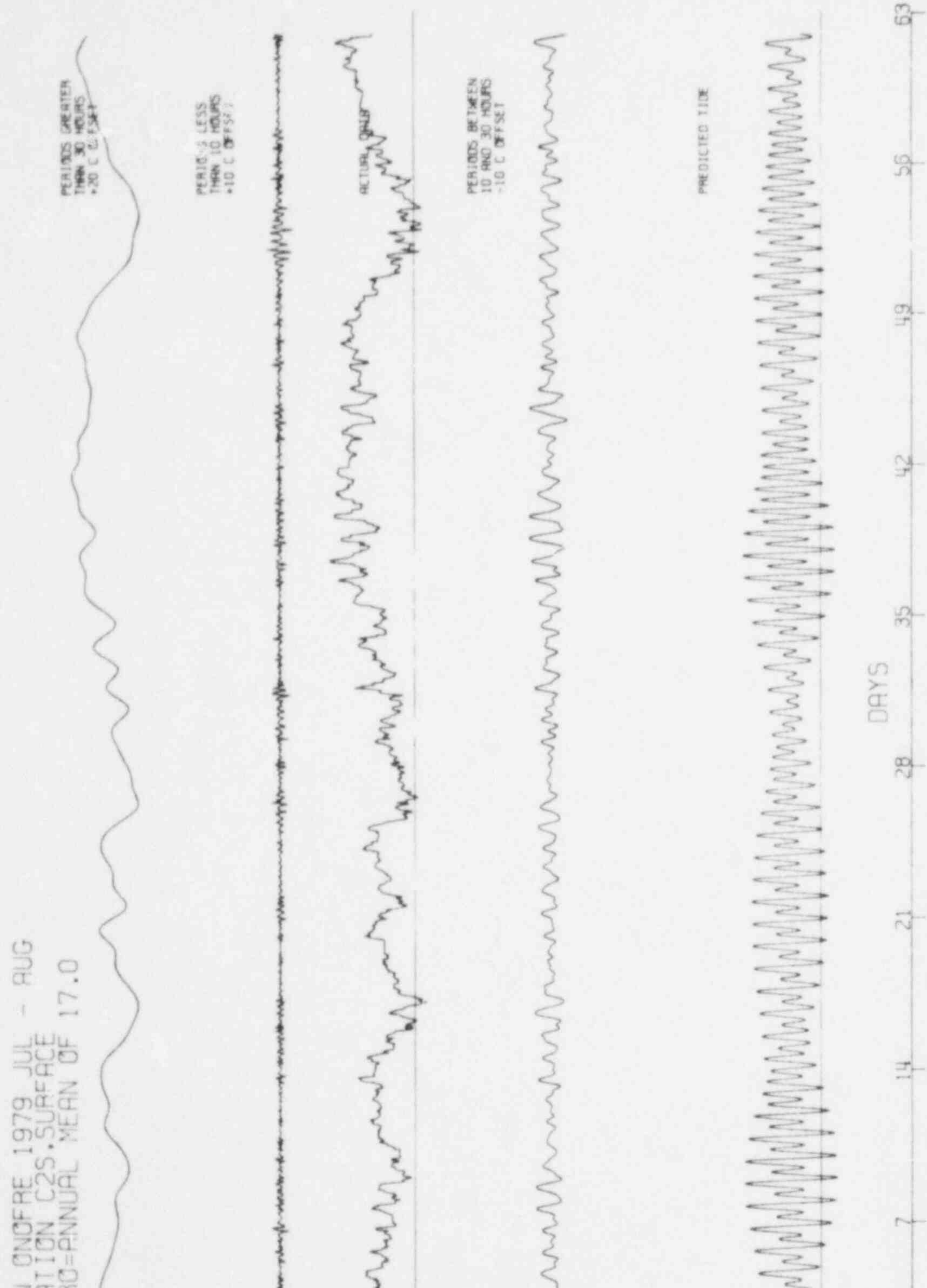

Figure I-79. Continuous temperature filtered into frequency bands for Station C2S, Surface, July and August 1979.

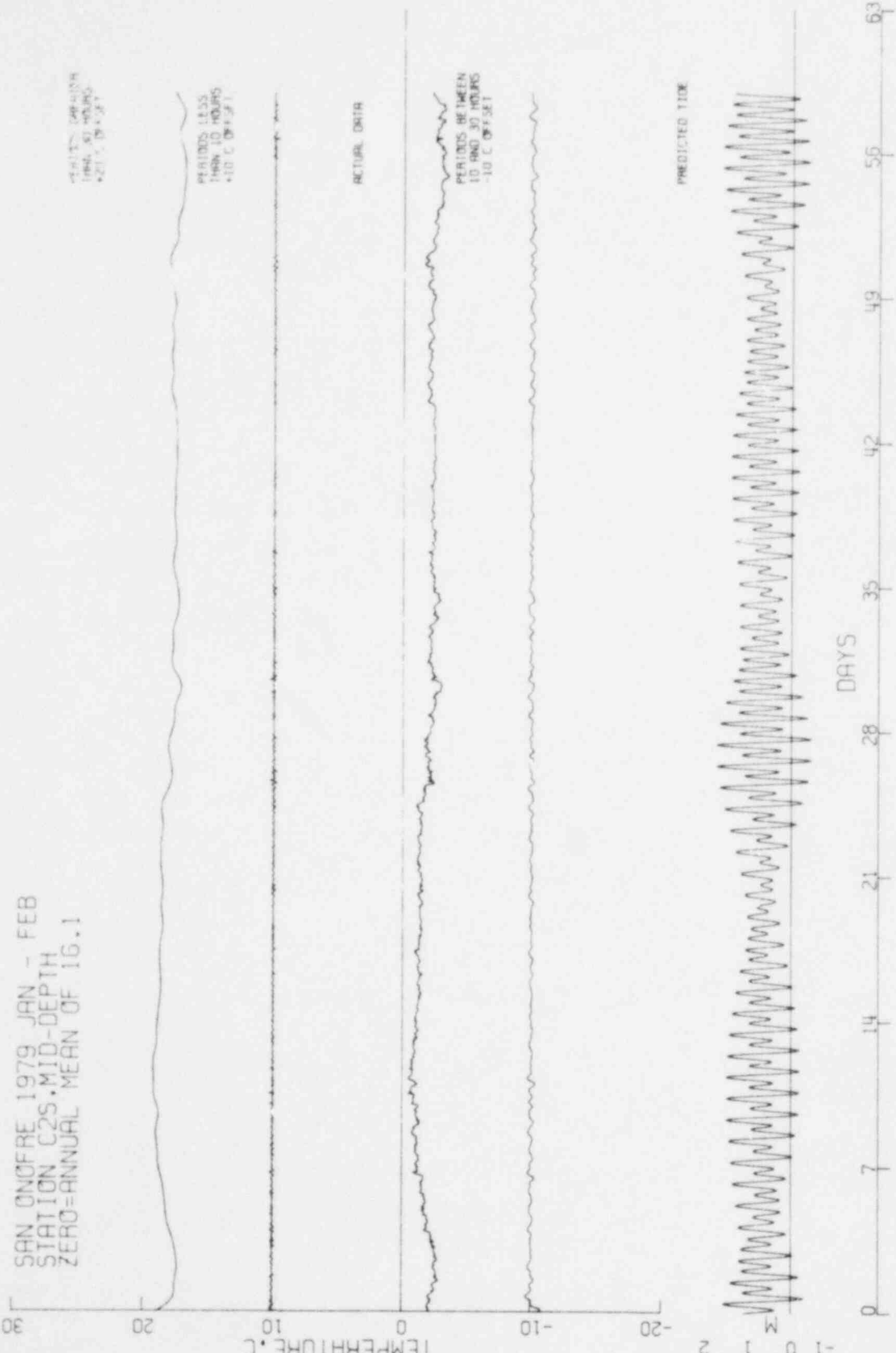

Figure I-80. **Continuous temperature filtered into frequency bands for Station C2S, Mid-Depth, January and February 1979.**

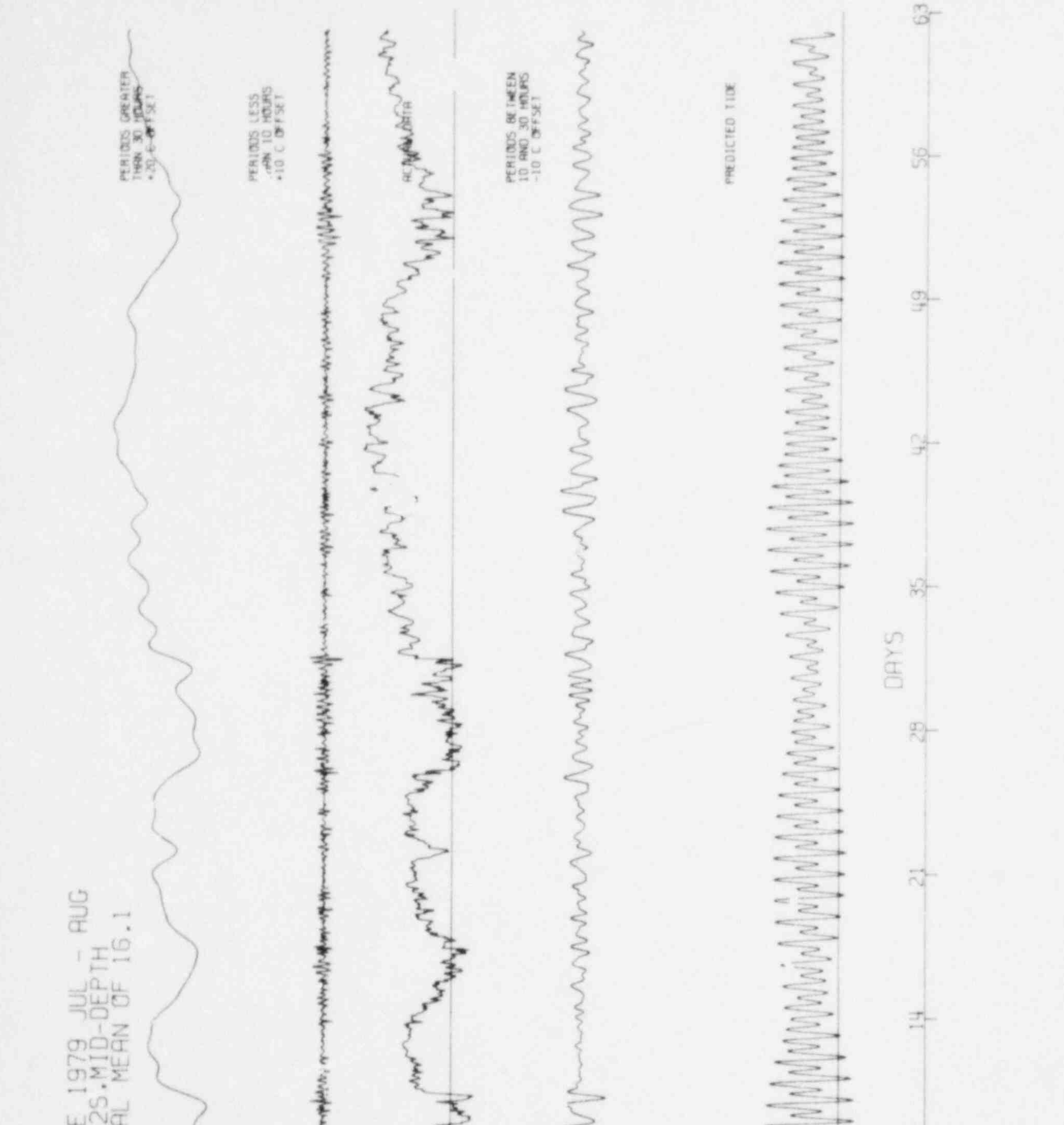

Figure I-81. Continuous temperature filtered into f·equency bands for Station C2S, Mid-Depth, July and August 1979.

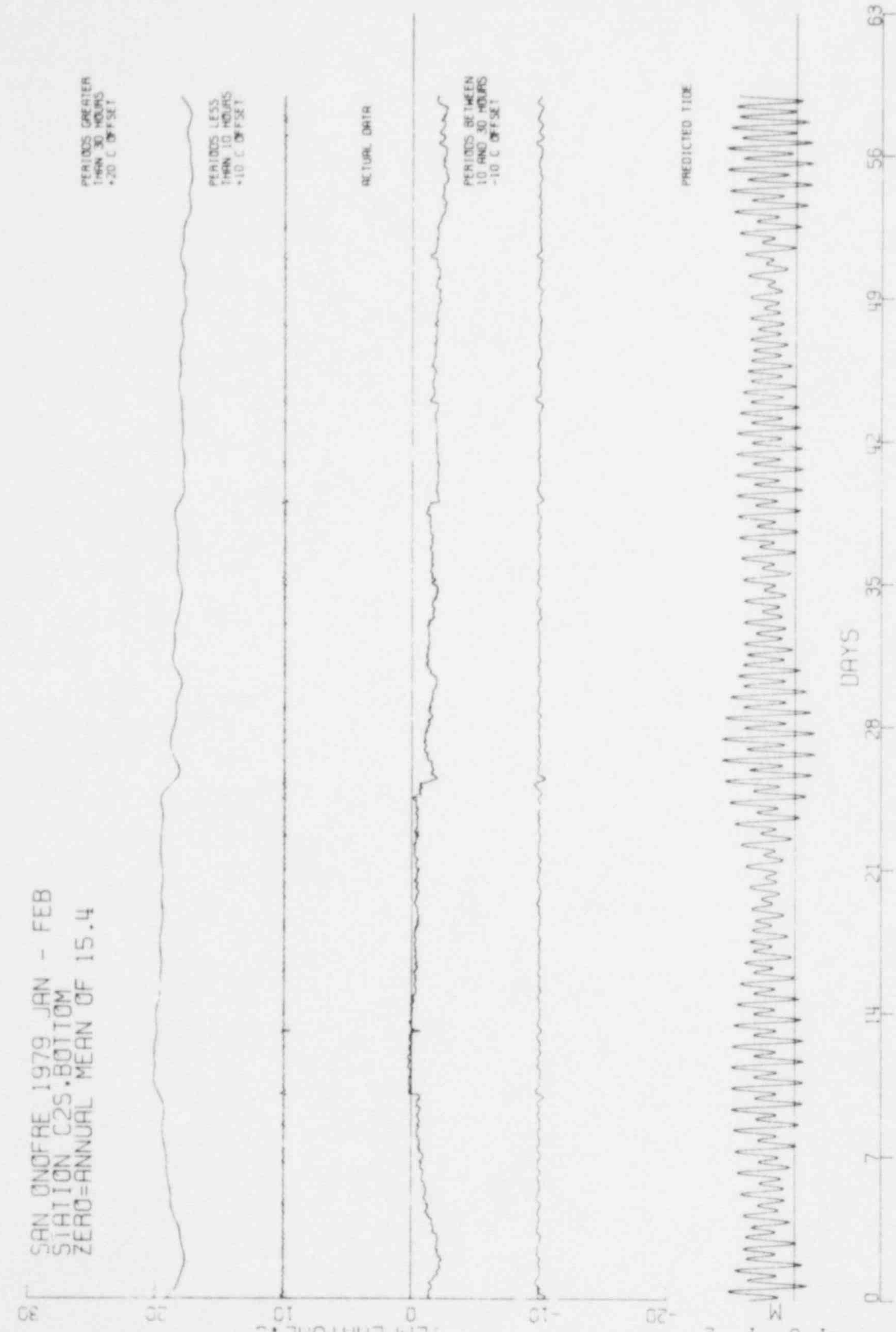

Figure I-82. Continuous temperature filtered into frequency bands for Station C2S, Bottom, January and February 1979.

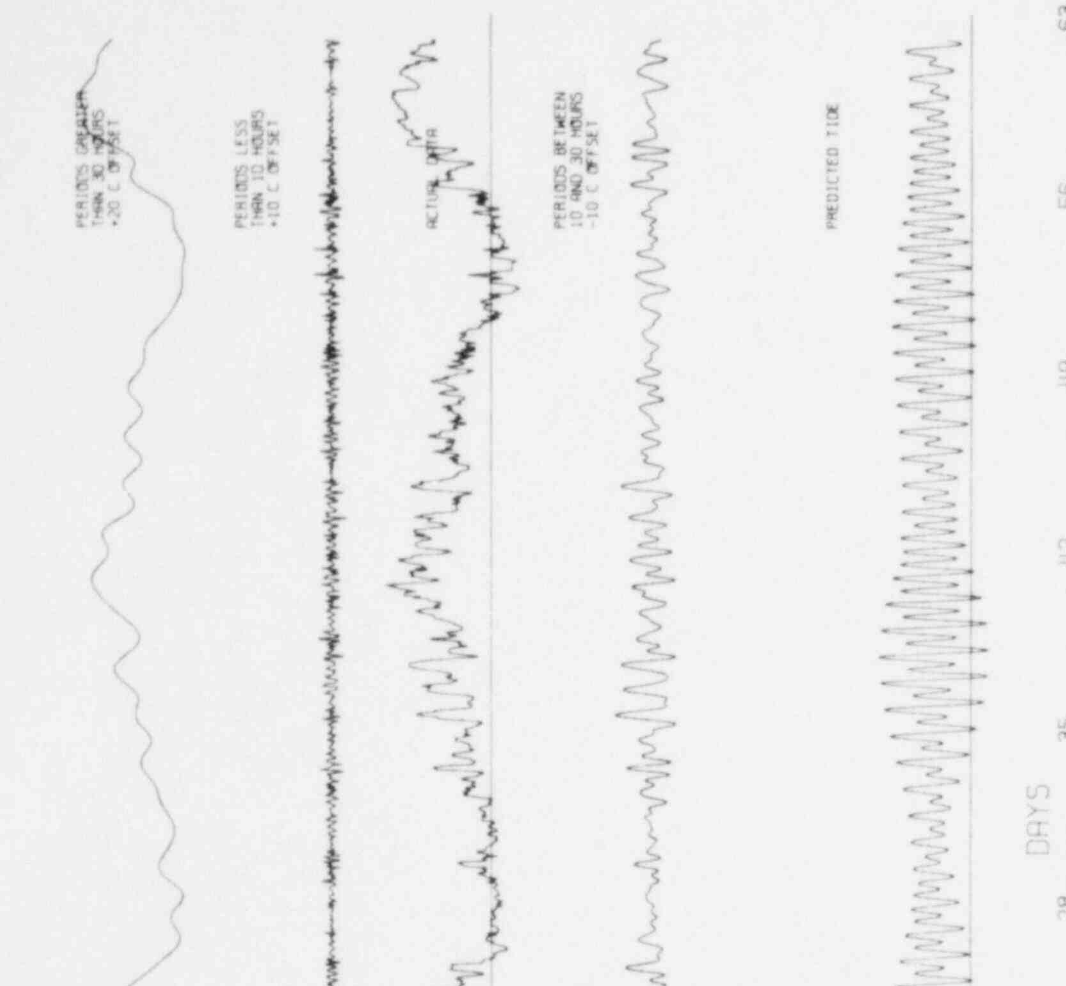

Figure I-83. Continuous temperature filtered into frequency bands for Station C2S, Bottom, July and August 1979.

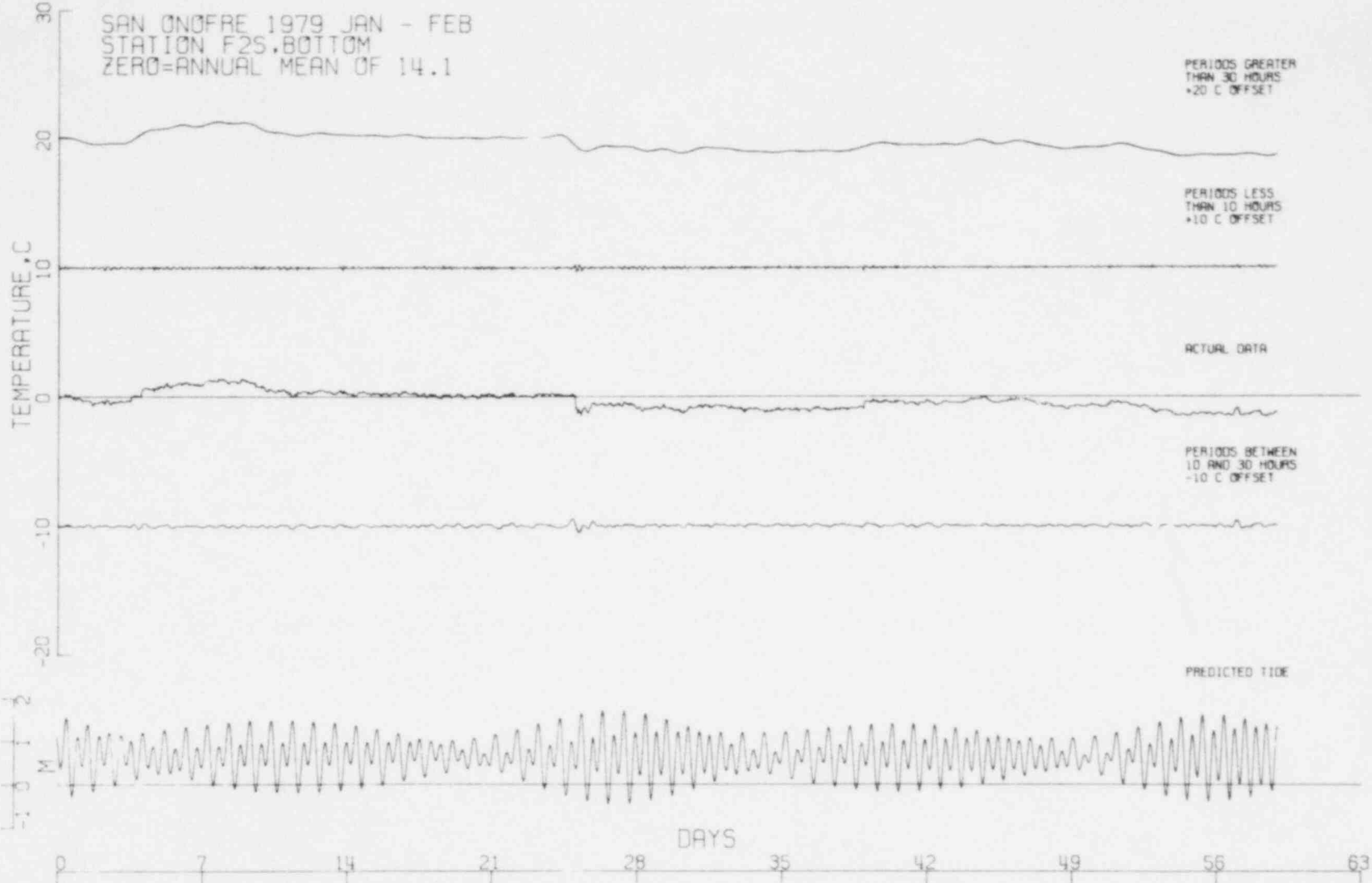

Figure I-84. Continuous temperature filtered into frequency bands for Station F2S, Bottom, January and February 1979.

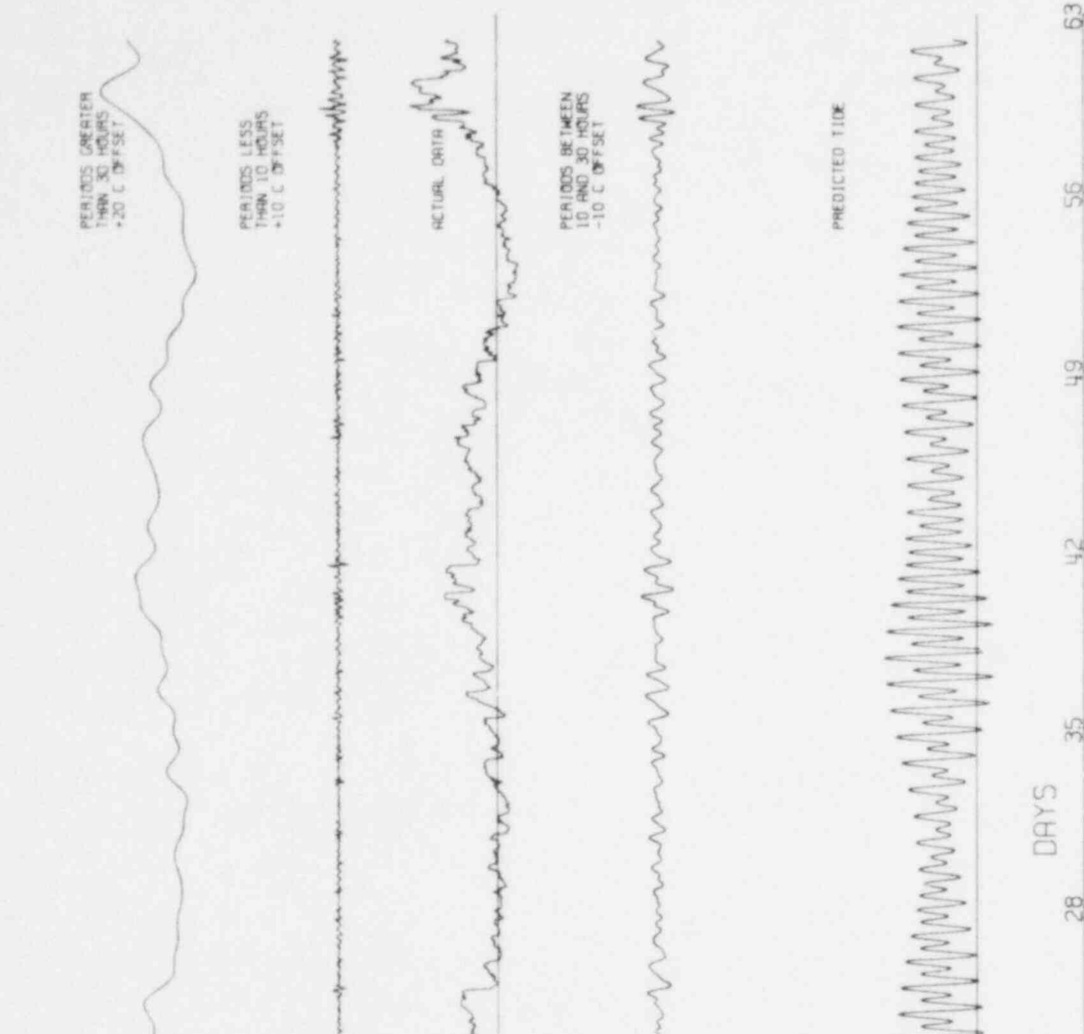

Figure I-85. Continuous temperature filtered into frequency bands for Station F2S, Bottom, July and August 1979.

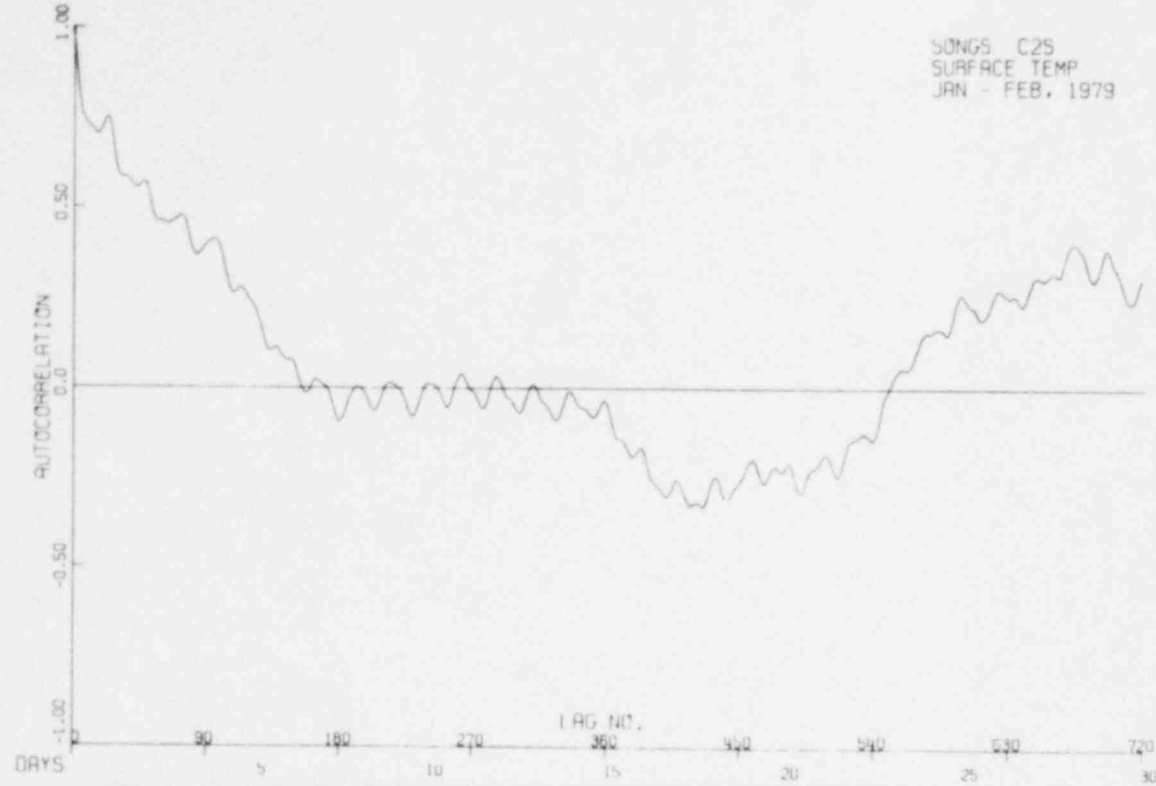

Figure I-86. **Autocorrelation of surface temperature at Station C2S during January and February 1979.**

Figure I-87. **Autocorrelation of surface temperature at Station C2S during July and August 1979.**

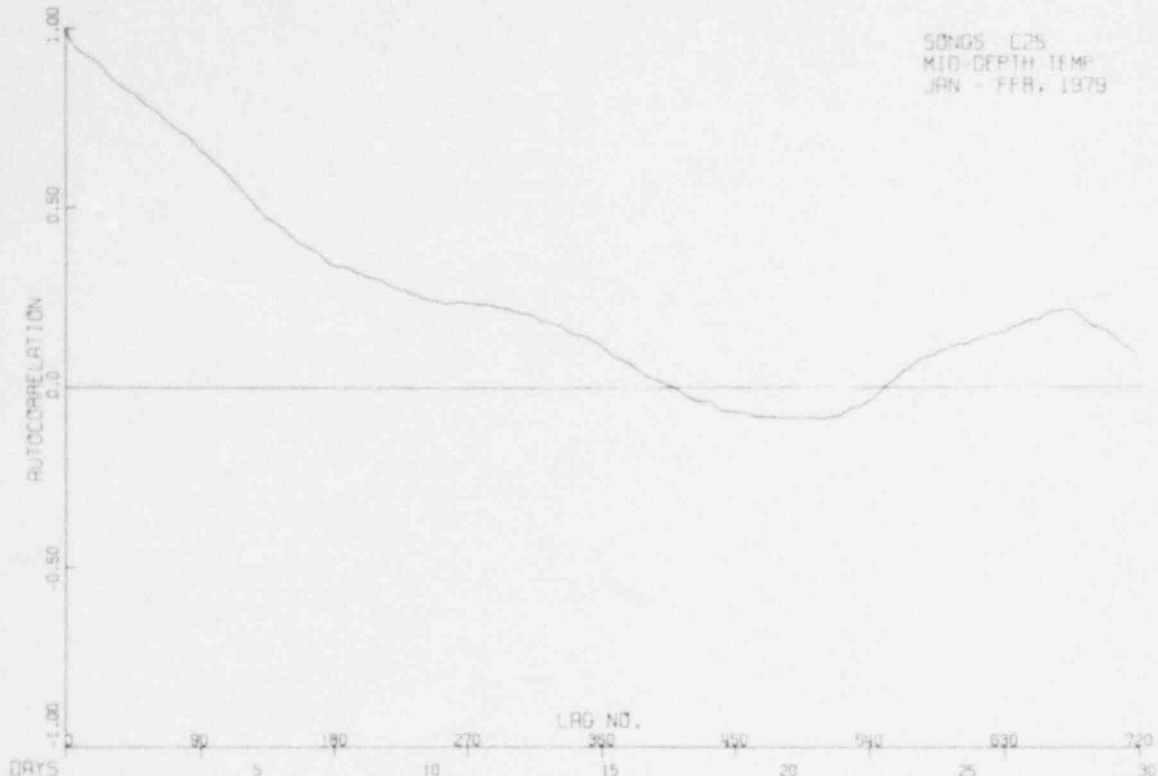

Figure I-88. Autocorrelation of mid-depth temperature at Station C2S during January and February 1979.

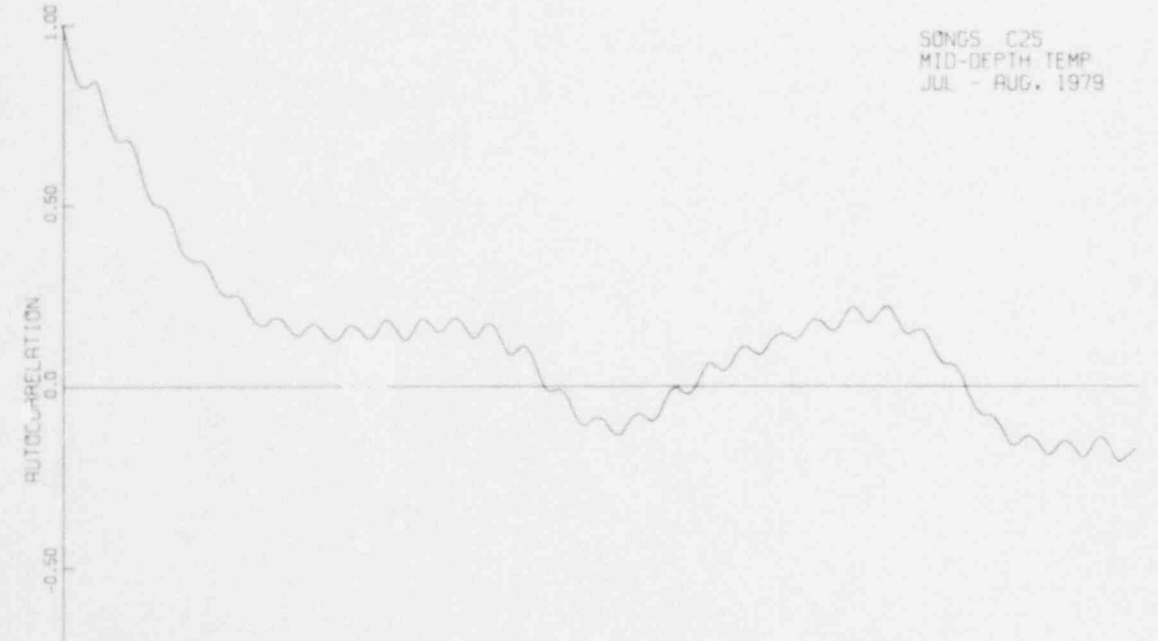

Figure I-89. Autocorrelation of mid-depth temperature at Station C2S during July and August 1979.

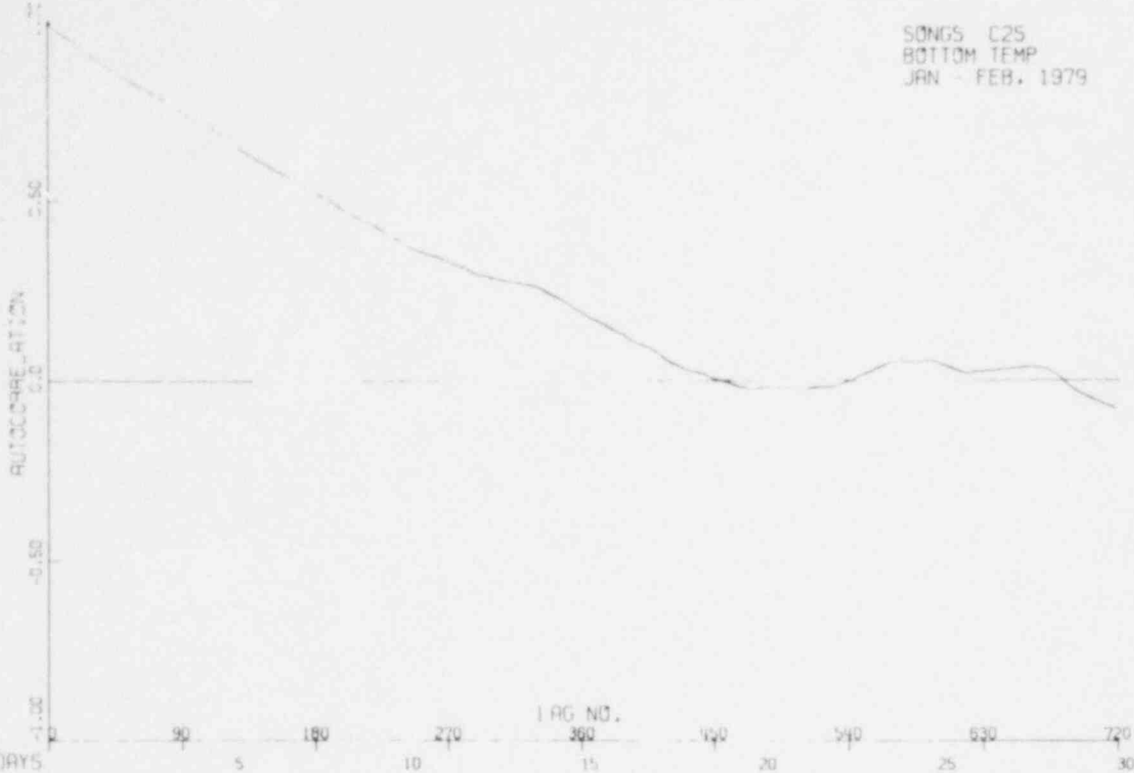

Figure I-90. Autocorrelation of bottom temperature at Station C2S during January and February 1979.

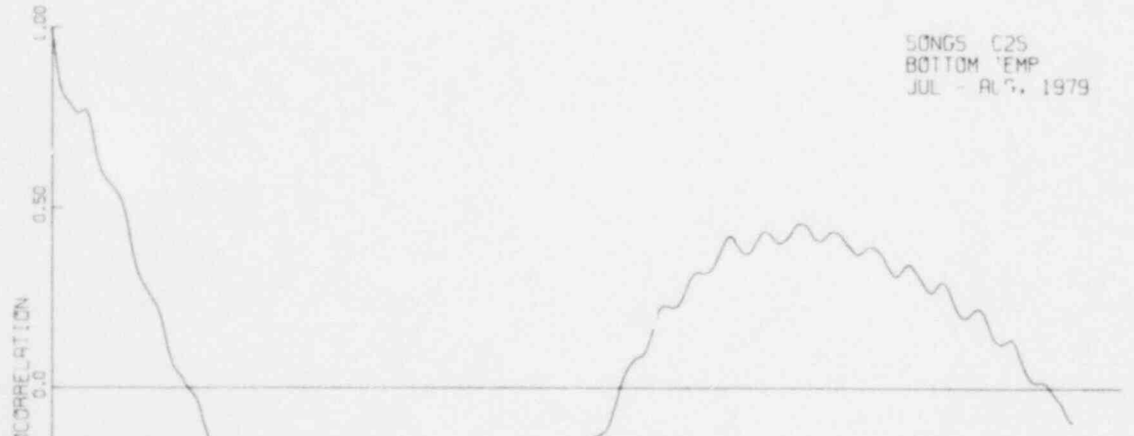

Figure I-91. Autocorrelation of bottom temperature at Station C2S during July and August 1979.

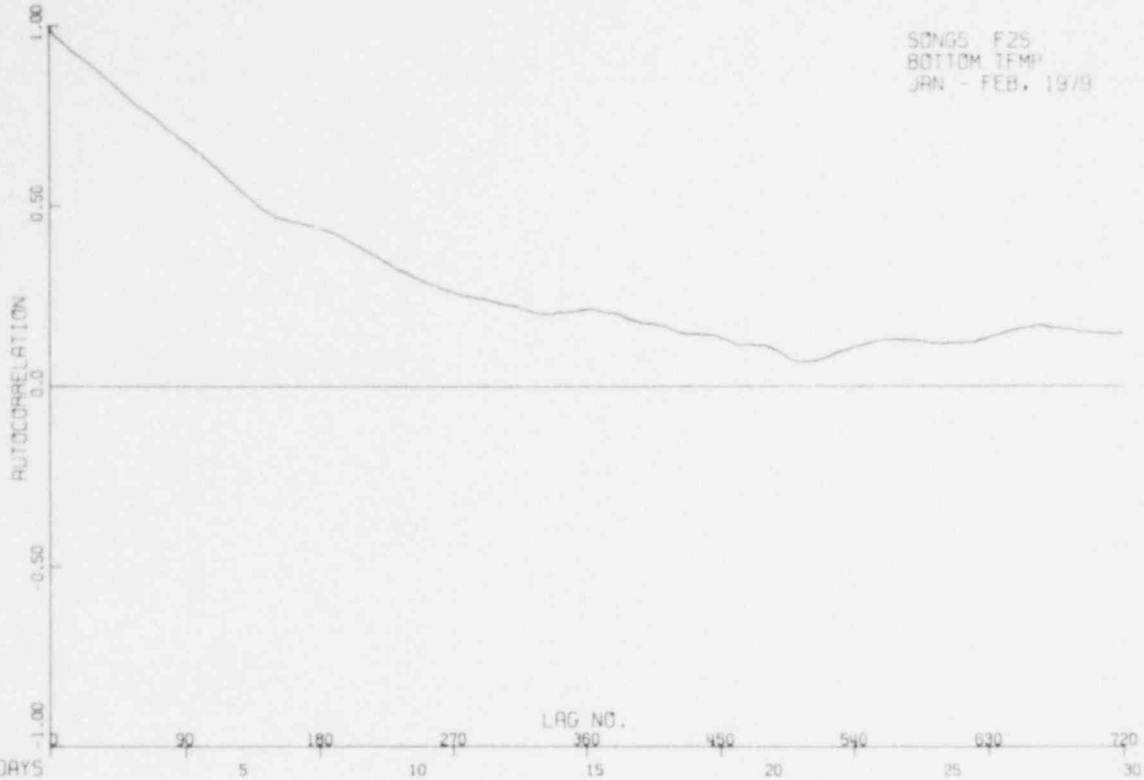

Figure I-92. Autocorrelation of bottom temperature at Station F2S during January and February 1979.

Figure I-93. Autocorrelation of bottom temperature at Station F2S during July and August 1979.

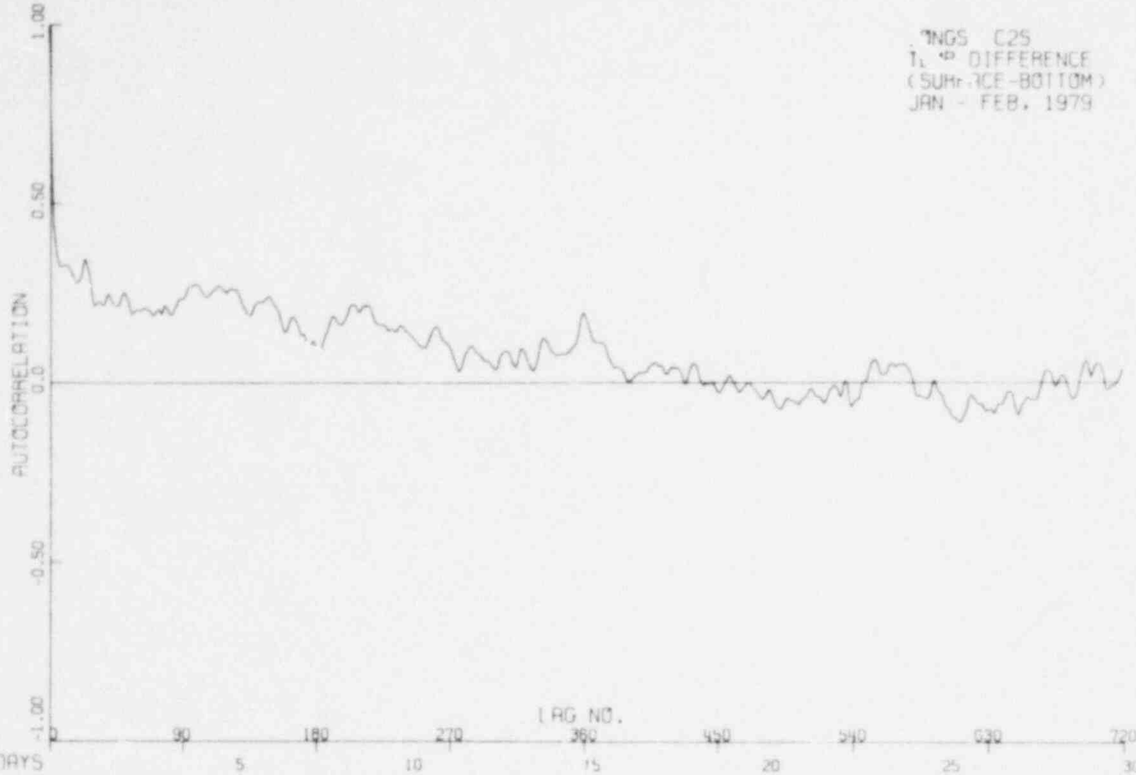

Figure I-94. Autocorrelation of surface to bottom temperature difference at Station C2S during January and February 1979.

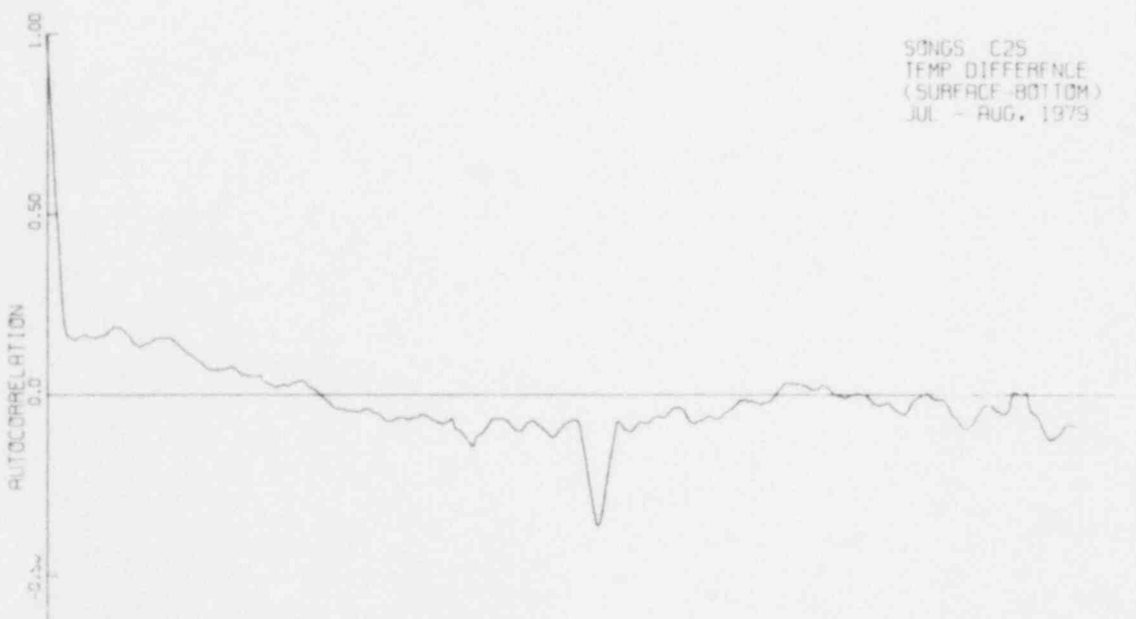

Figure I-95. Autocorrelation of surface to bottom temperature difference at Station C2S during July and August 1979.

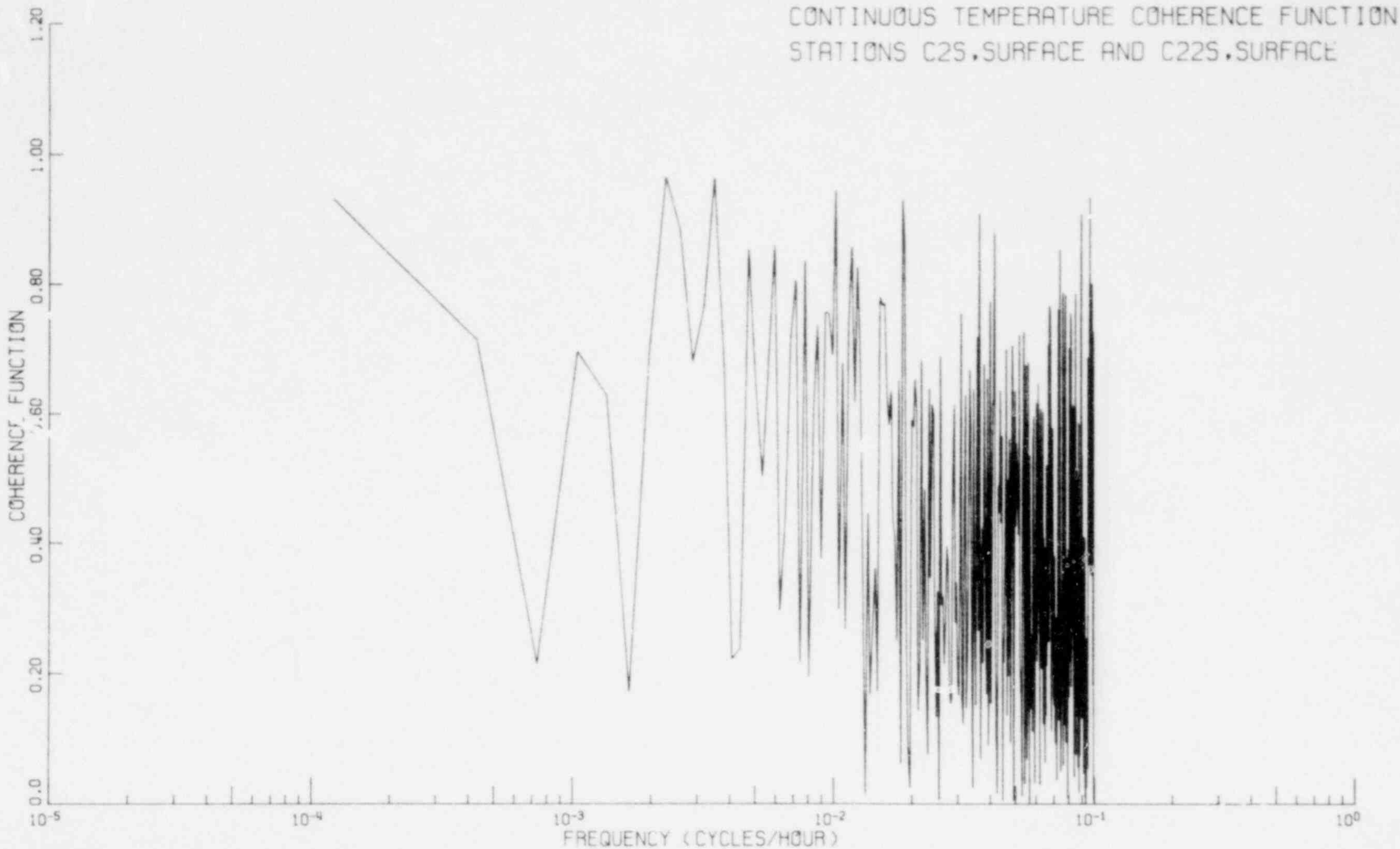

Figure I-96. Coherency as a function of the frequency of surface temperature fluctuations at Stations C2S and C22S during 1979.

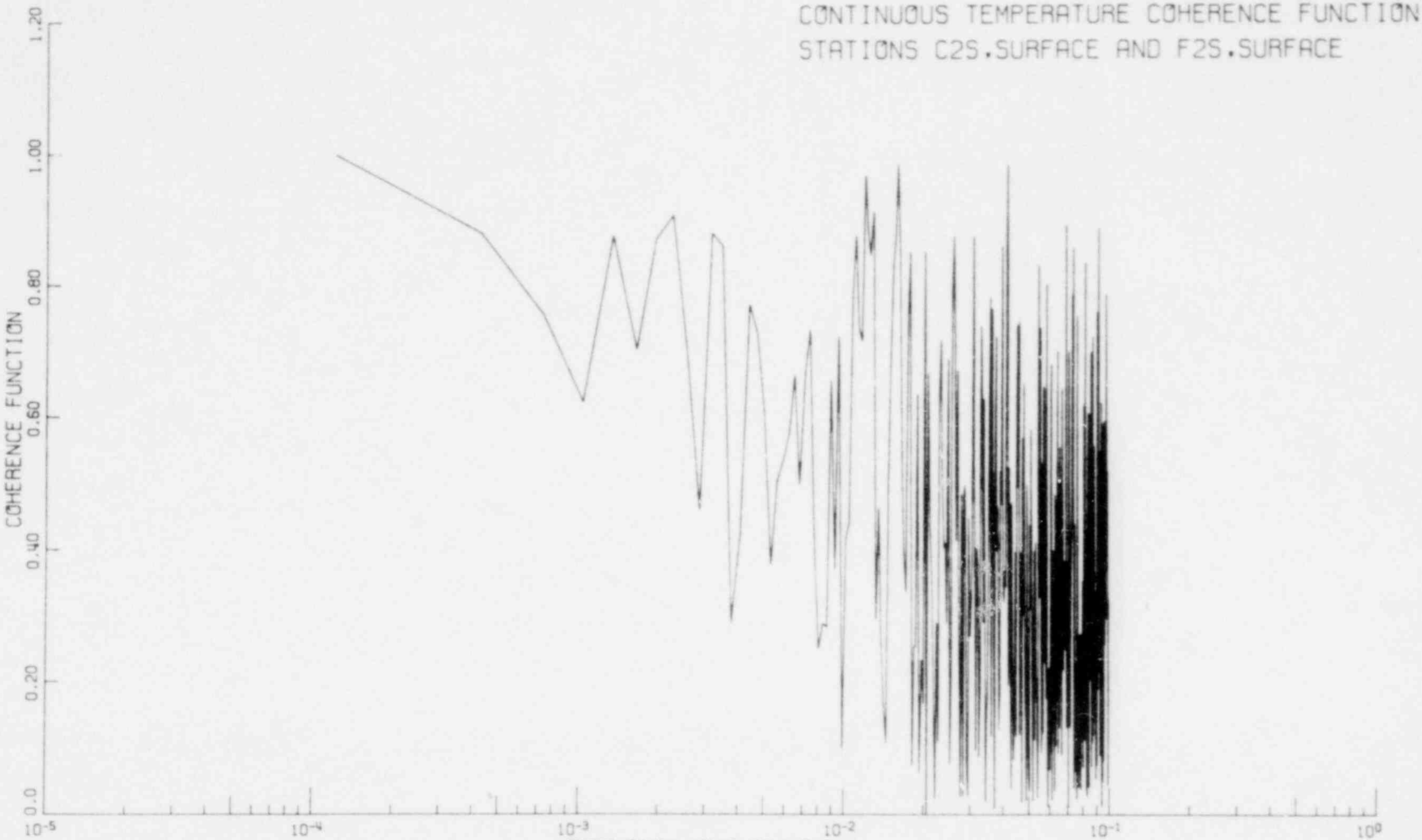

Figure I-97. Coherency as a function of the frequency of surface temperature fluctuations at Stations C2S and F2S during 1979.

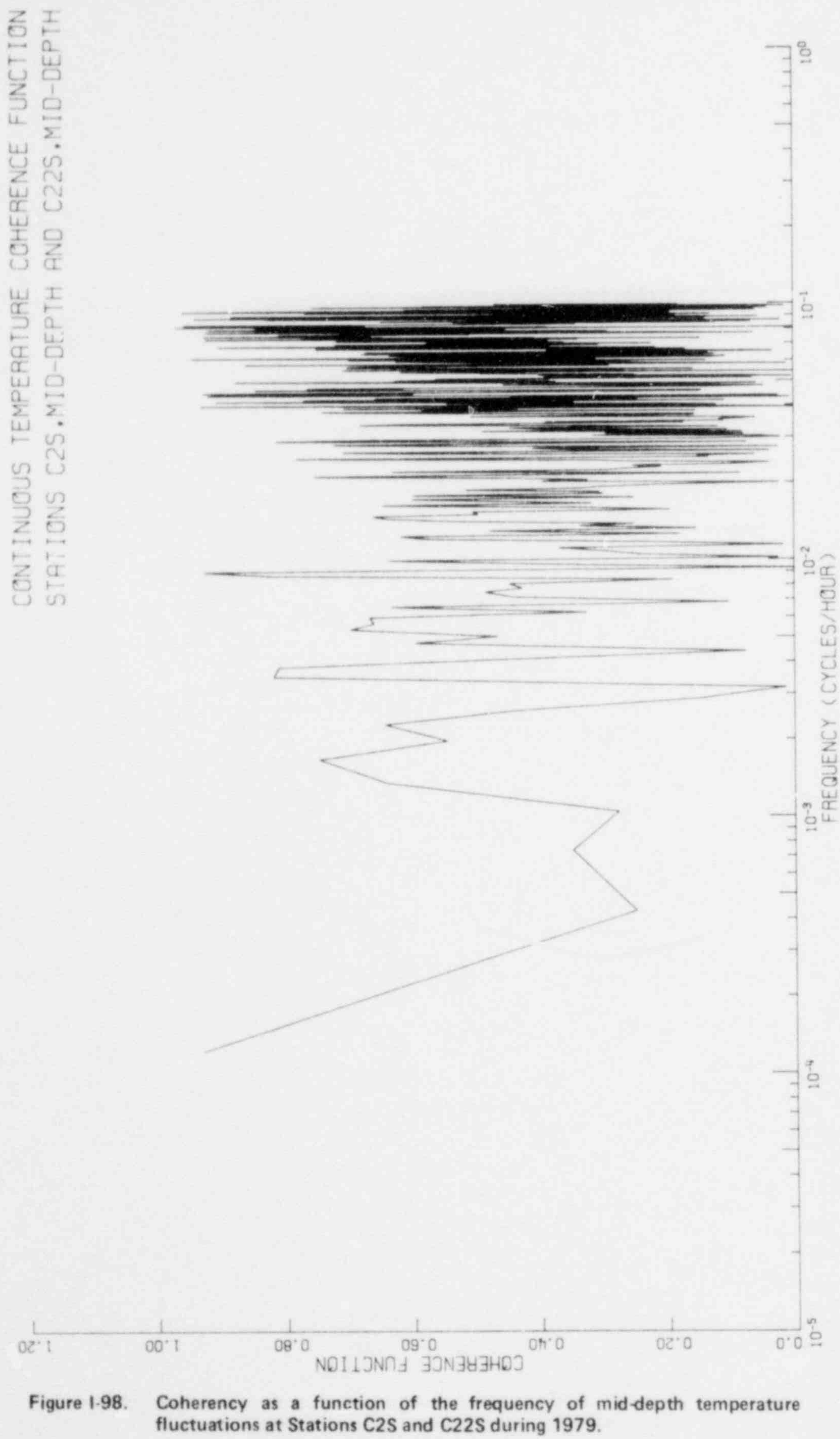

Figure I-98. Coherency as a function of the frequency of mid-depth temperature fluctuations at Stations C2S and C22S during 1979.

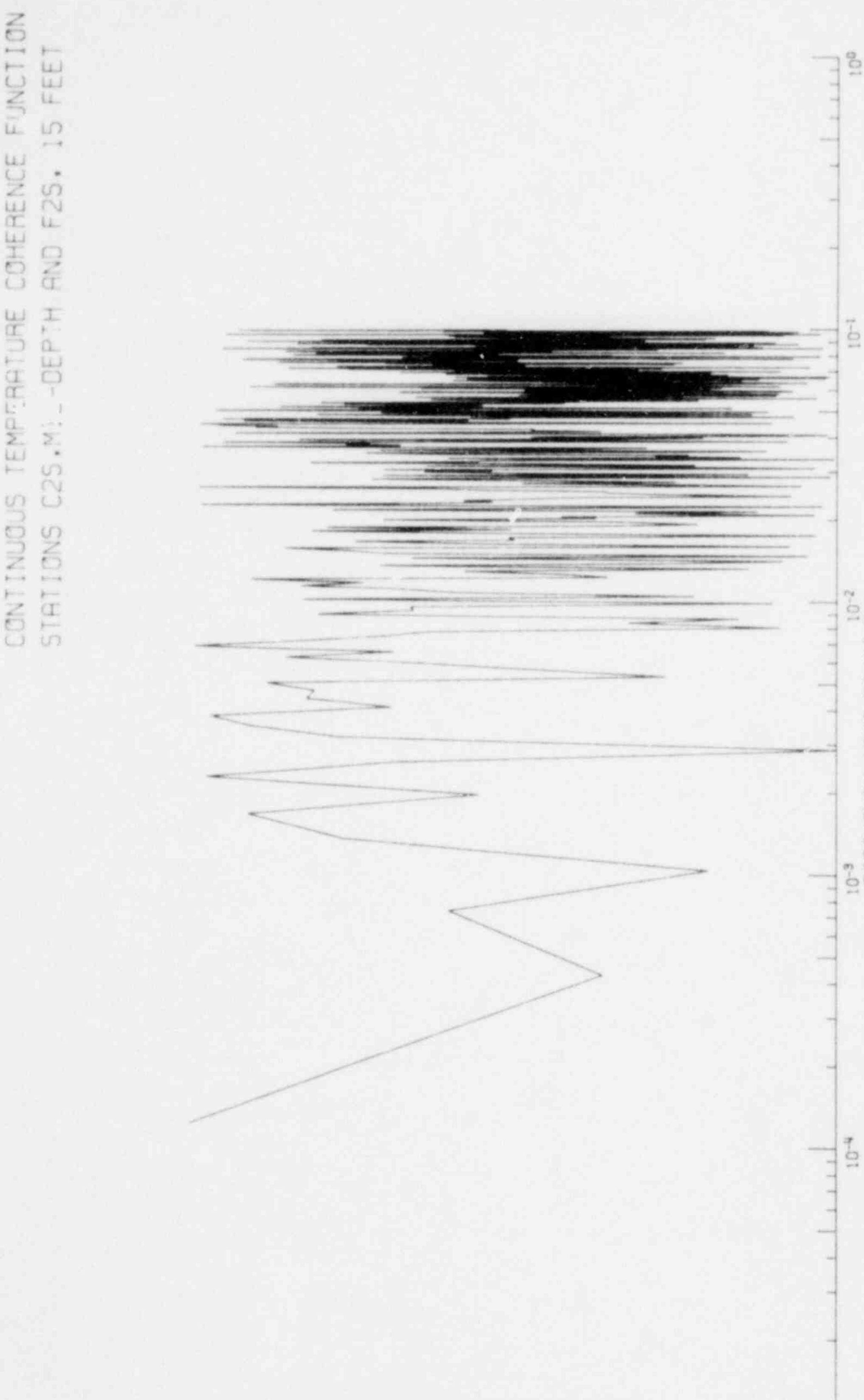

Figure I-99. Coherency as a function of the frequency of 4.5 m depth temperature fluctuations at Stations C2S and F2S during 1979.

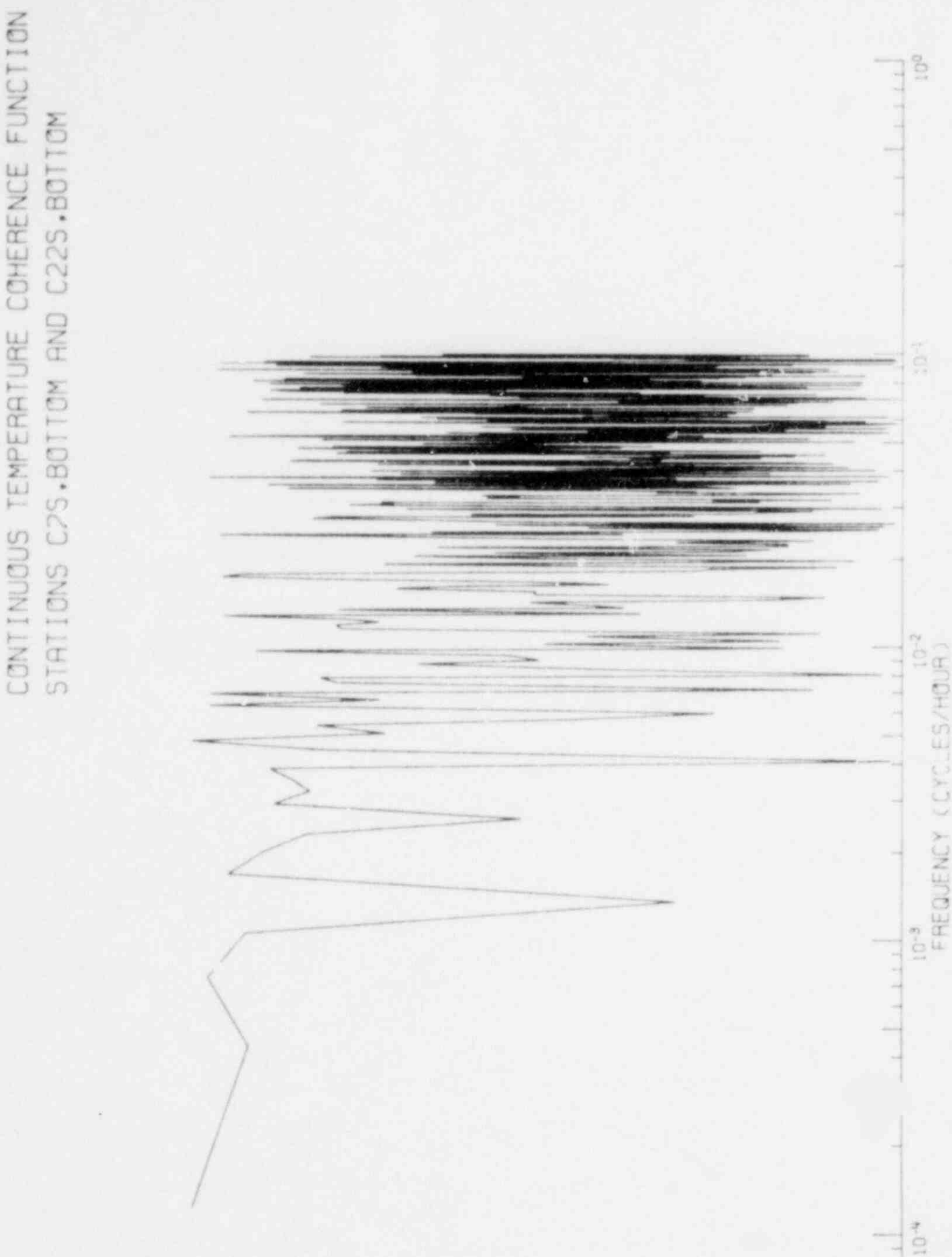

Figure I-100. Coherency as a function of the frequency of bottom temperature fluctuations at Stations C2S and C22S during 1979.

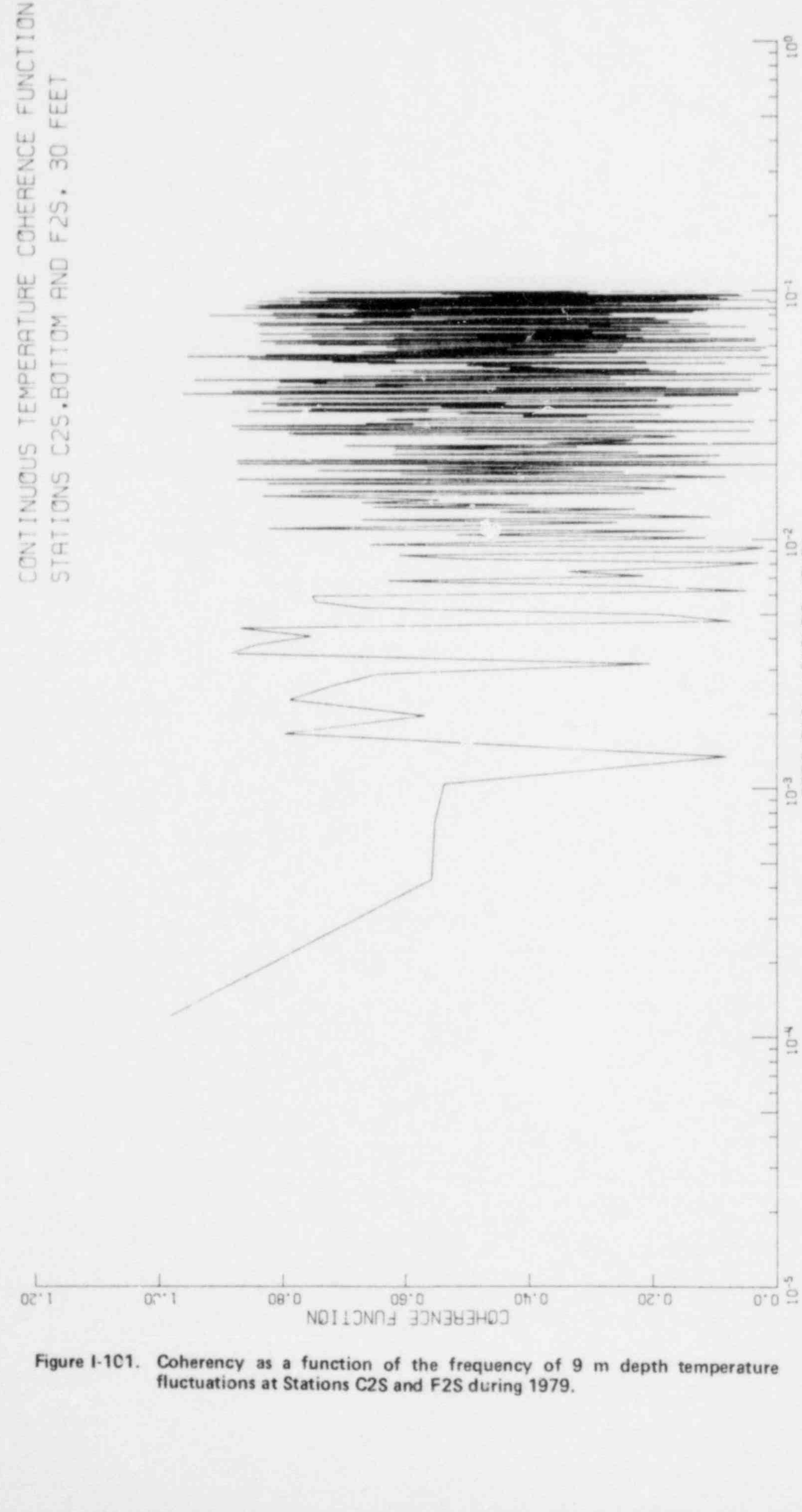

Figure I-101. Coherency as a function of the frequency of 9 m depth temperature fluctuations at Stations C2S and F2S during 1979.

Figure I-102. Coherency as a function of the frequency of bottom temperature fluctuations at Stations C2S and F2S during 1979.

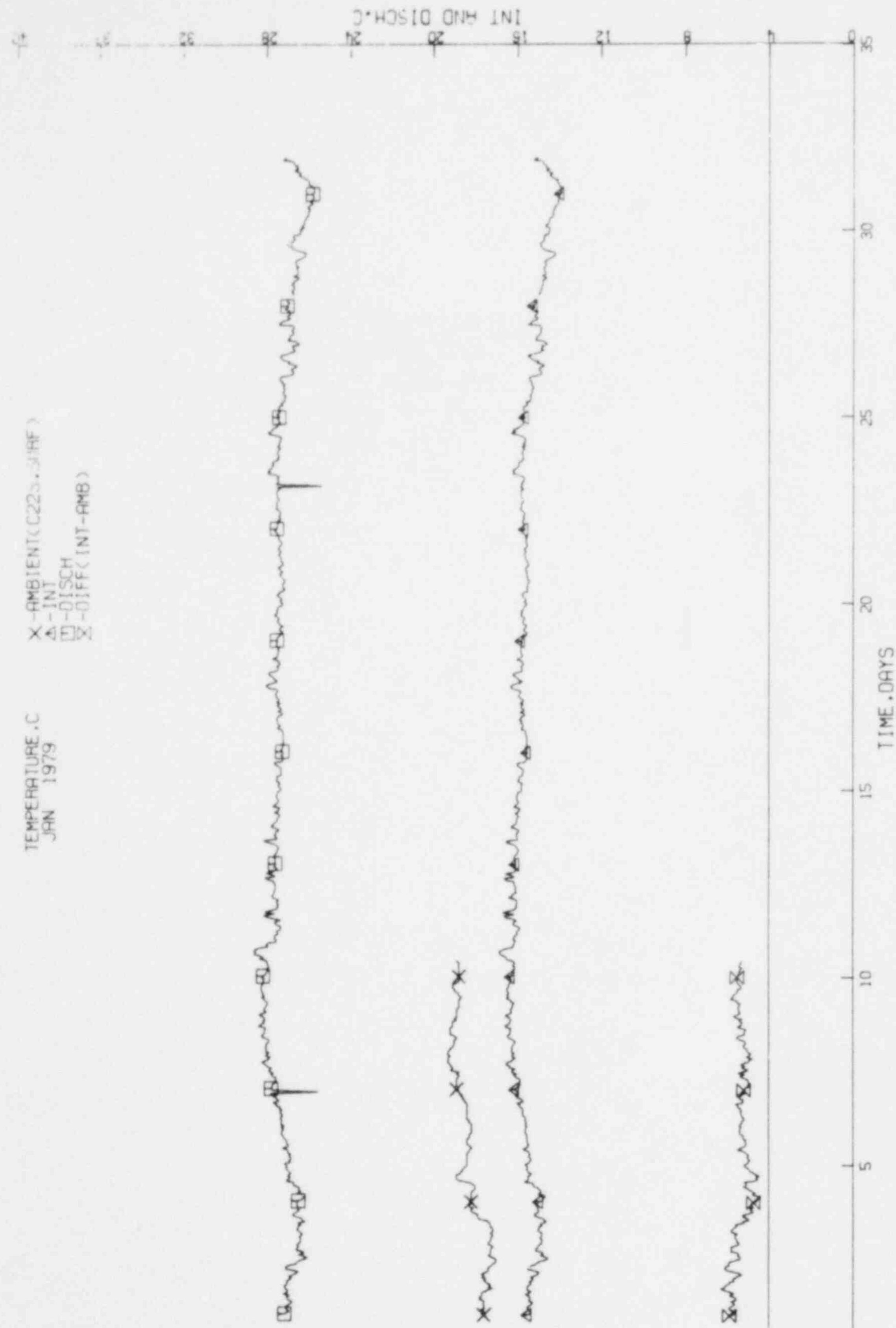

Figure I-103. Comparison of intake, discharge, and ocean surface ambient temperatures during January 1979.

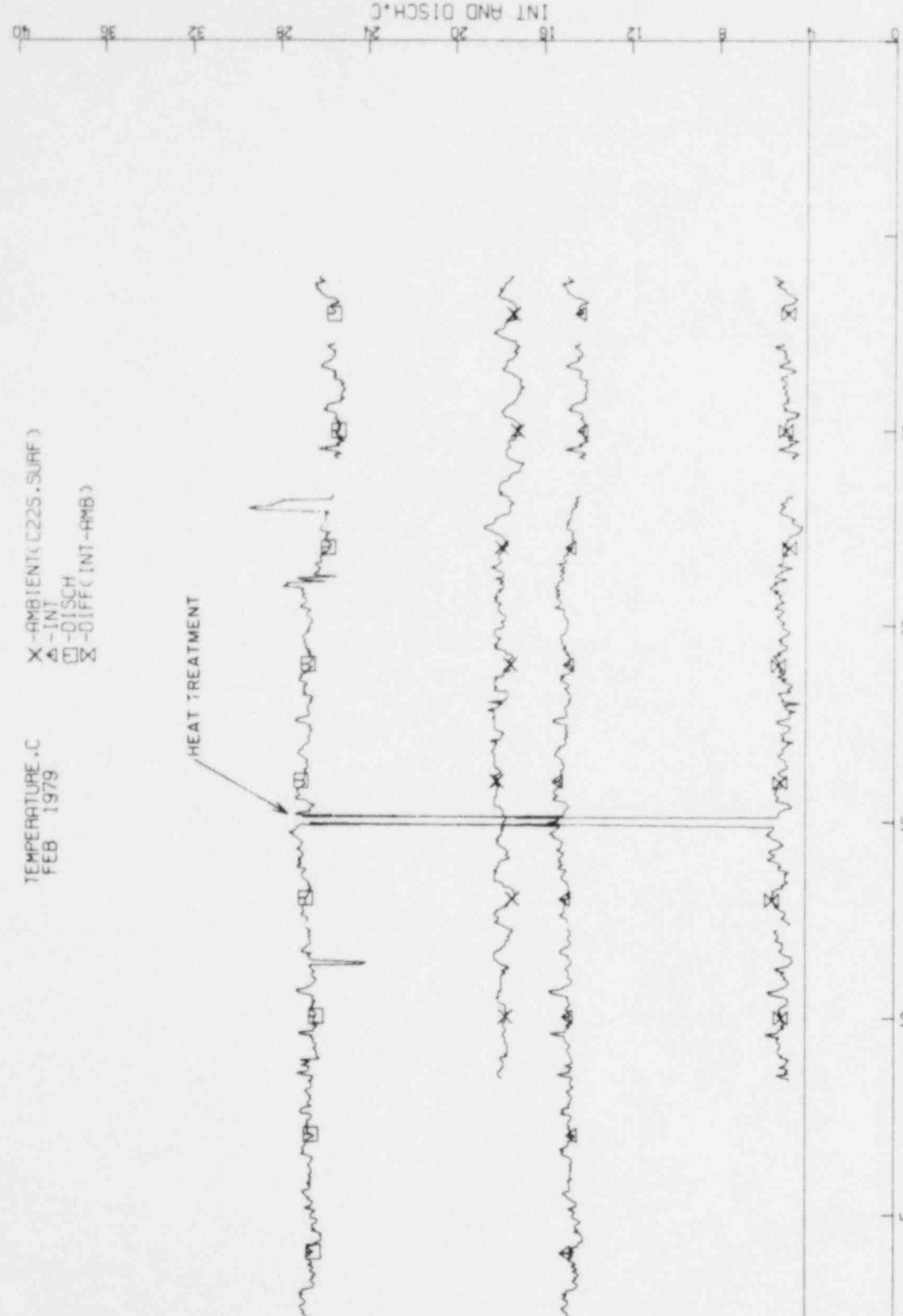

Figure I-104. Comparison of intake, discharge, and ocean surface ambient temperatures during February 1979.

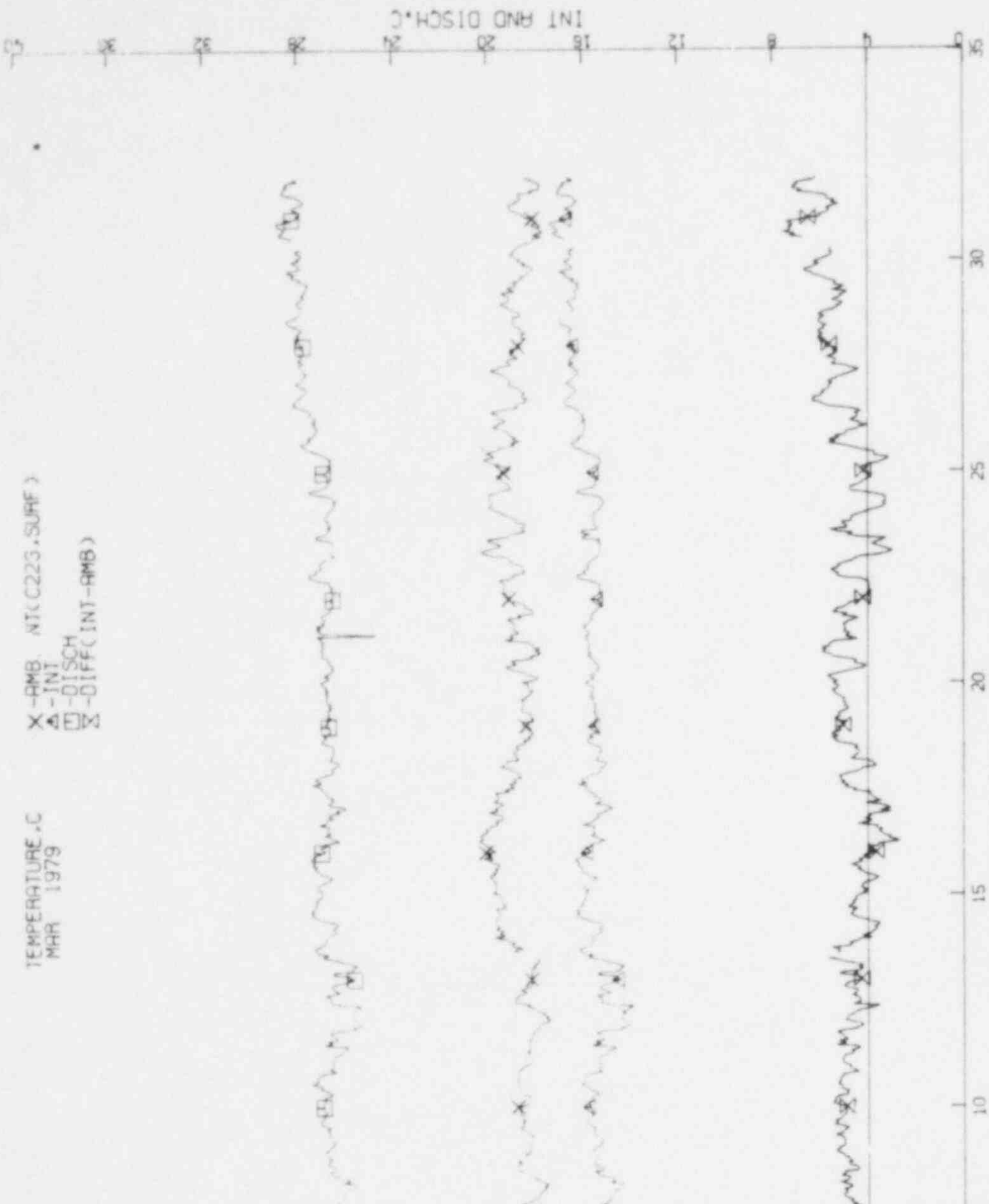

Figure I-105. Comparison of intake, discharge, and ocean surface ambient temperatures during March 1979.

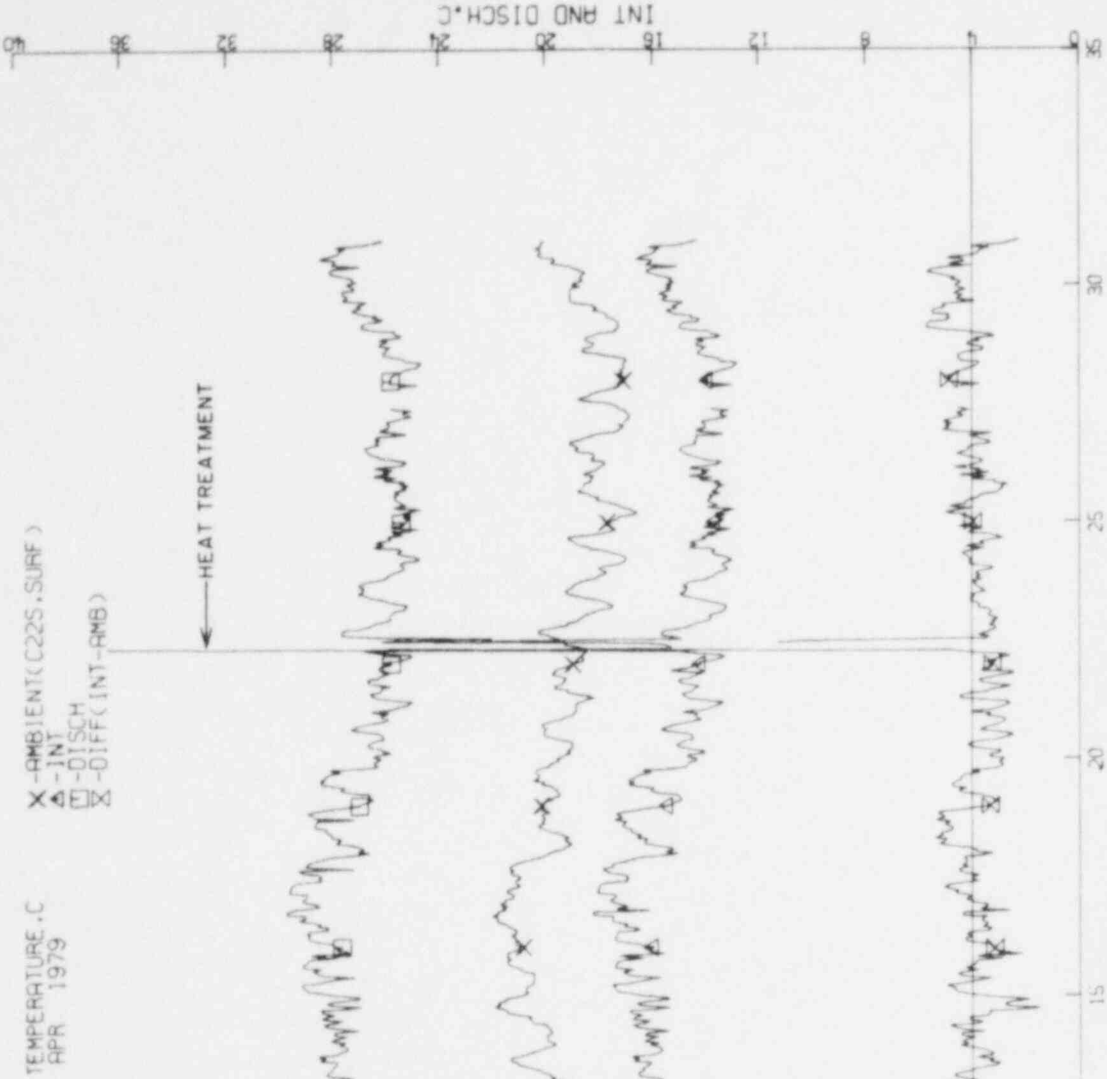

Figure I-106. Comparison of intake, discharge, and ocean surface ambient temperatures during April 1979.

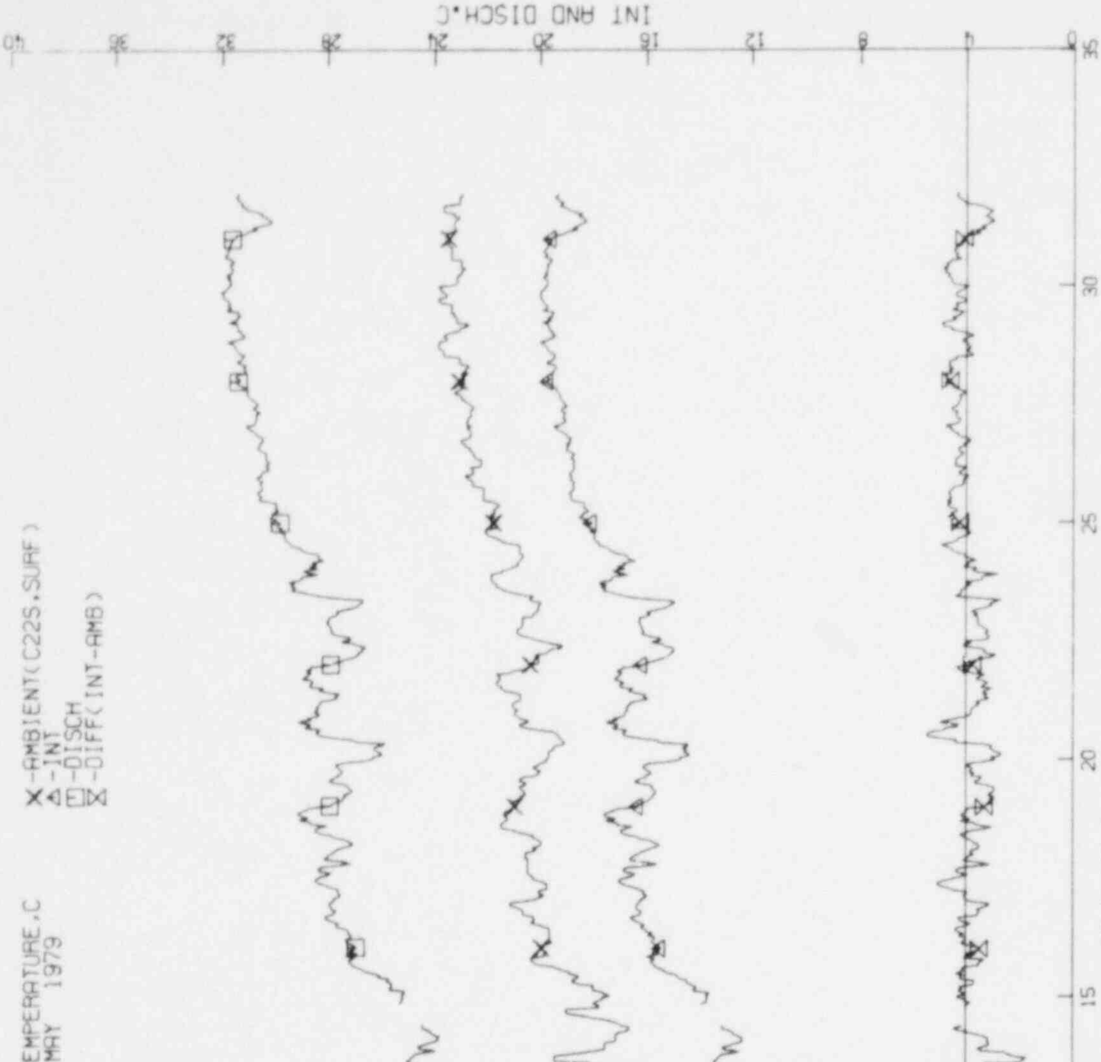

Figure I-107. Comparison of intake, discharge, and ocean surface ambient temperatures during May 1979.

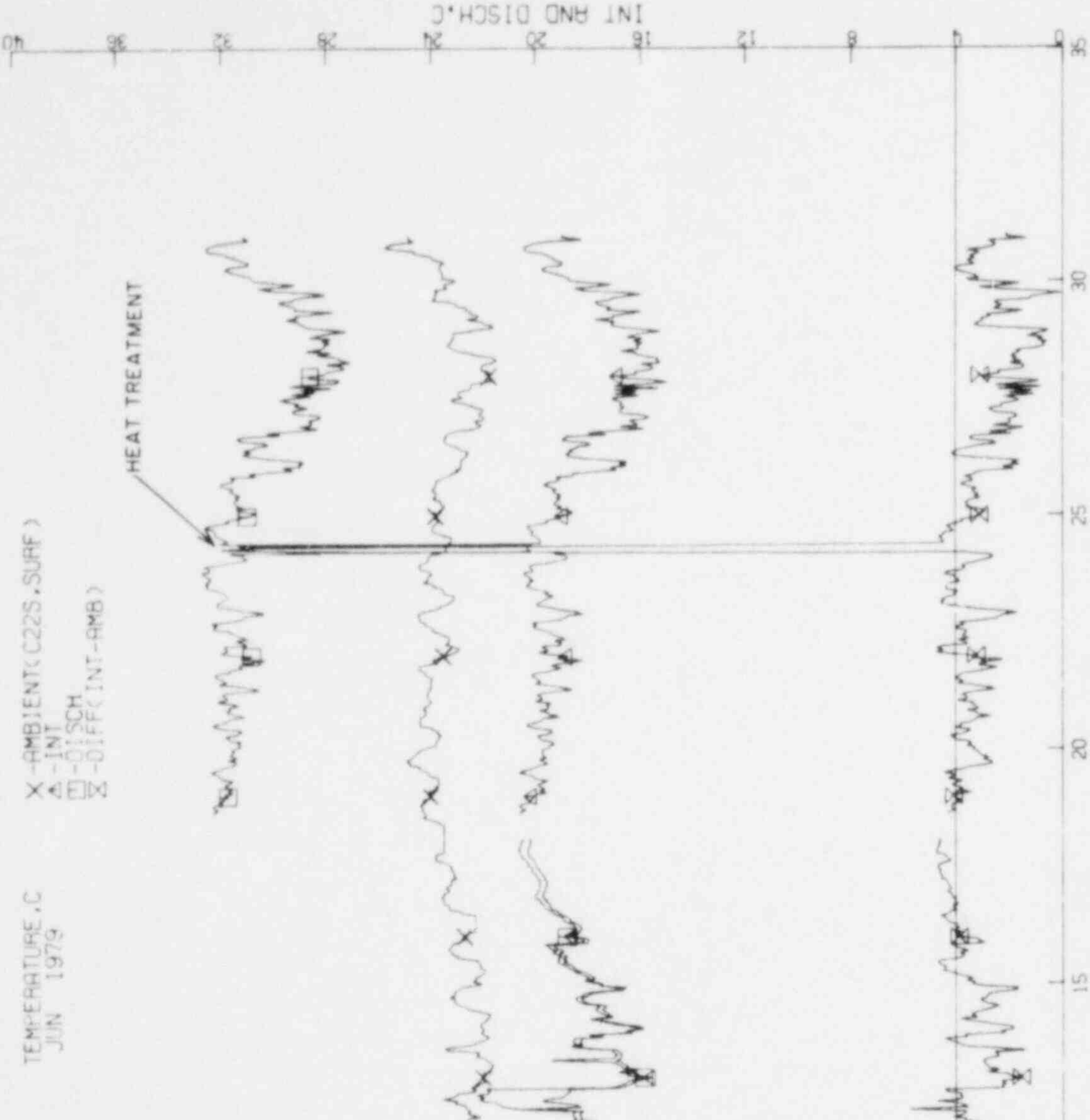

Figure I-108. Comparison of intake, discharge, and ocean surface ambient temperatures during June 1979.

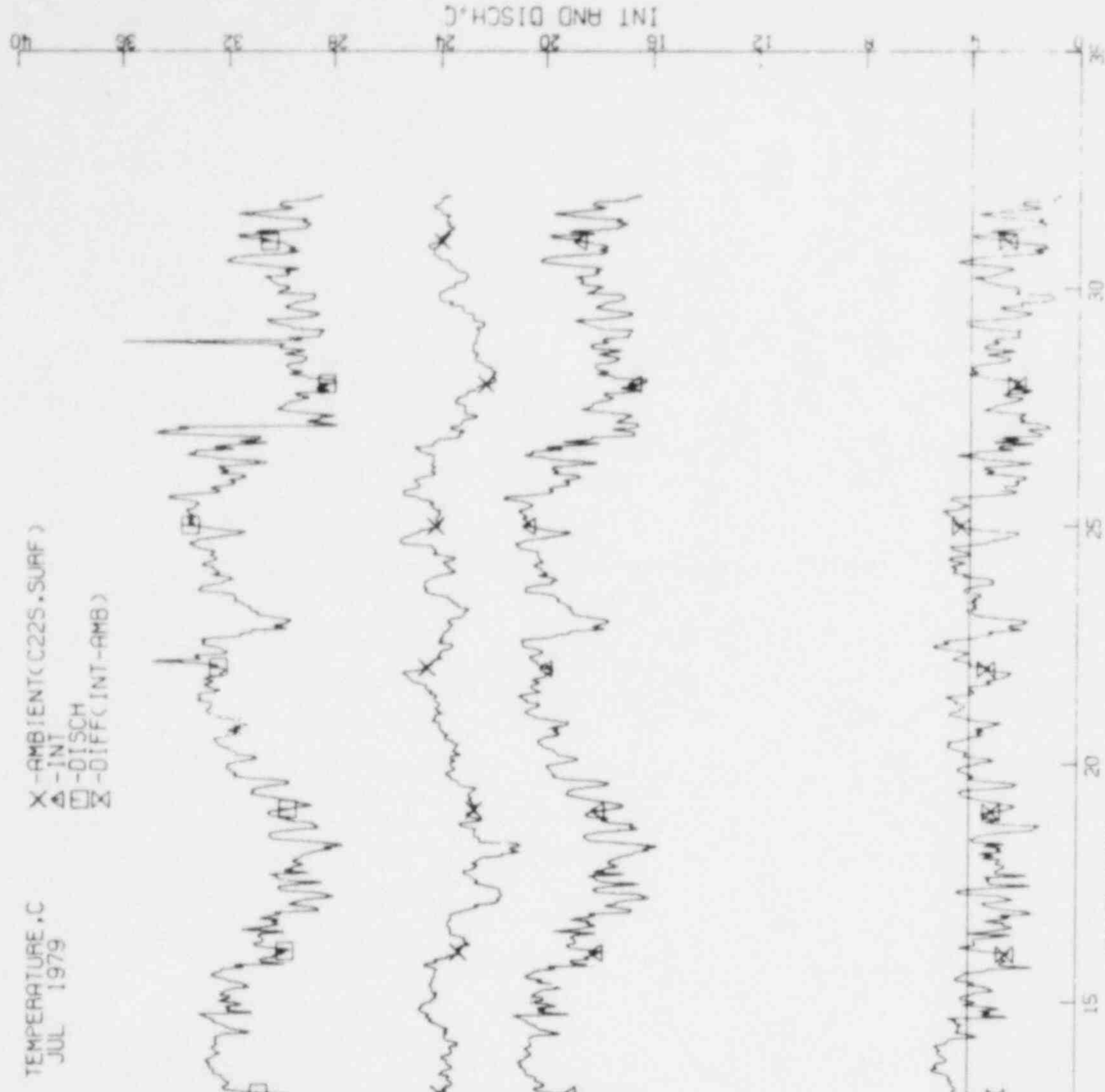

Figure I-109. Comparison of intake, discharge, and ocean surface ambient temperatures during July 1979.

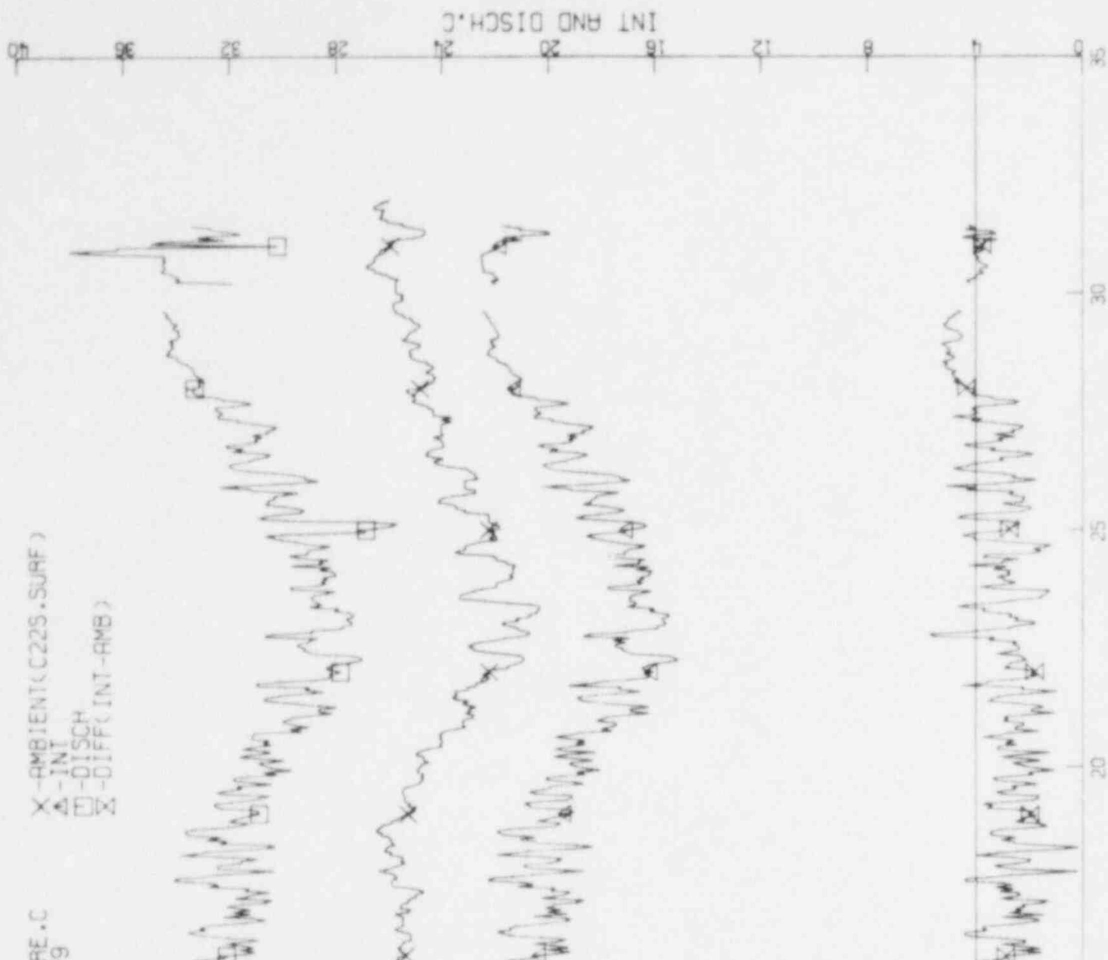

Figure I-110. **Comparison of intake, discharge, and ocean surface ambient temperatures during August 1979.**

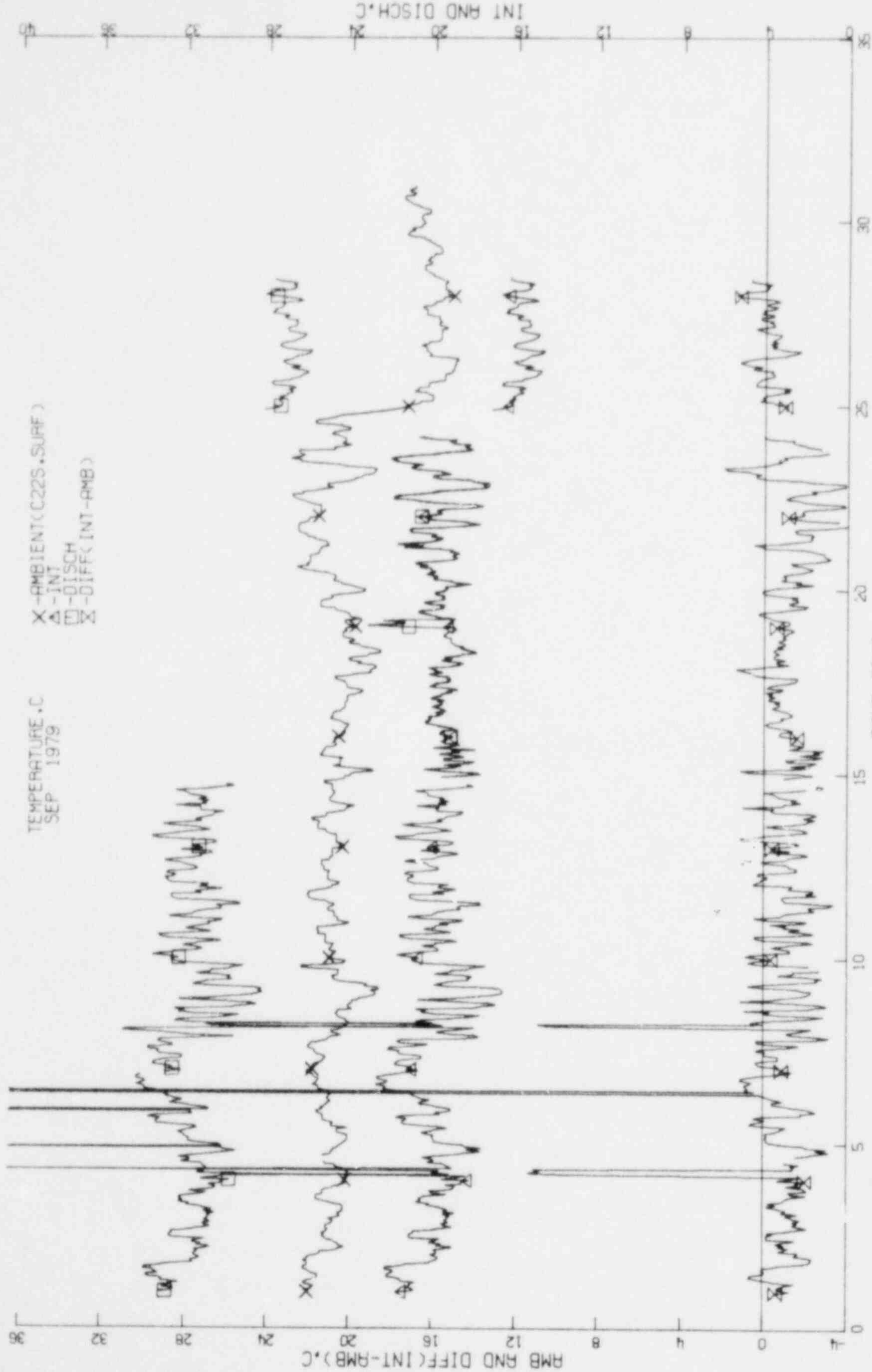

Figure I-111. Comparison of intake, discharge, and ocean surface ambient temperatures during September 1979.

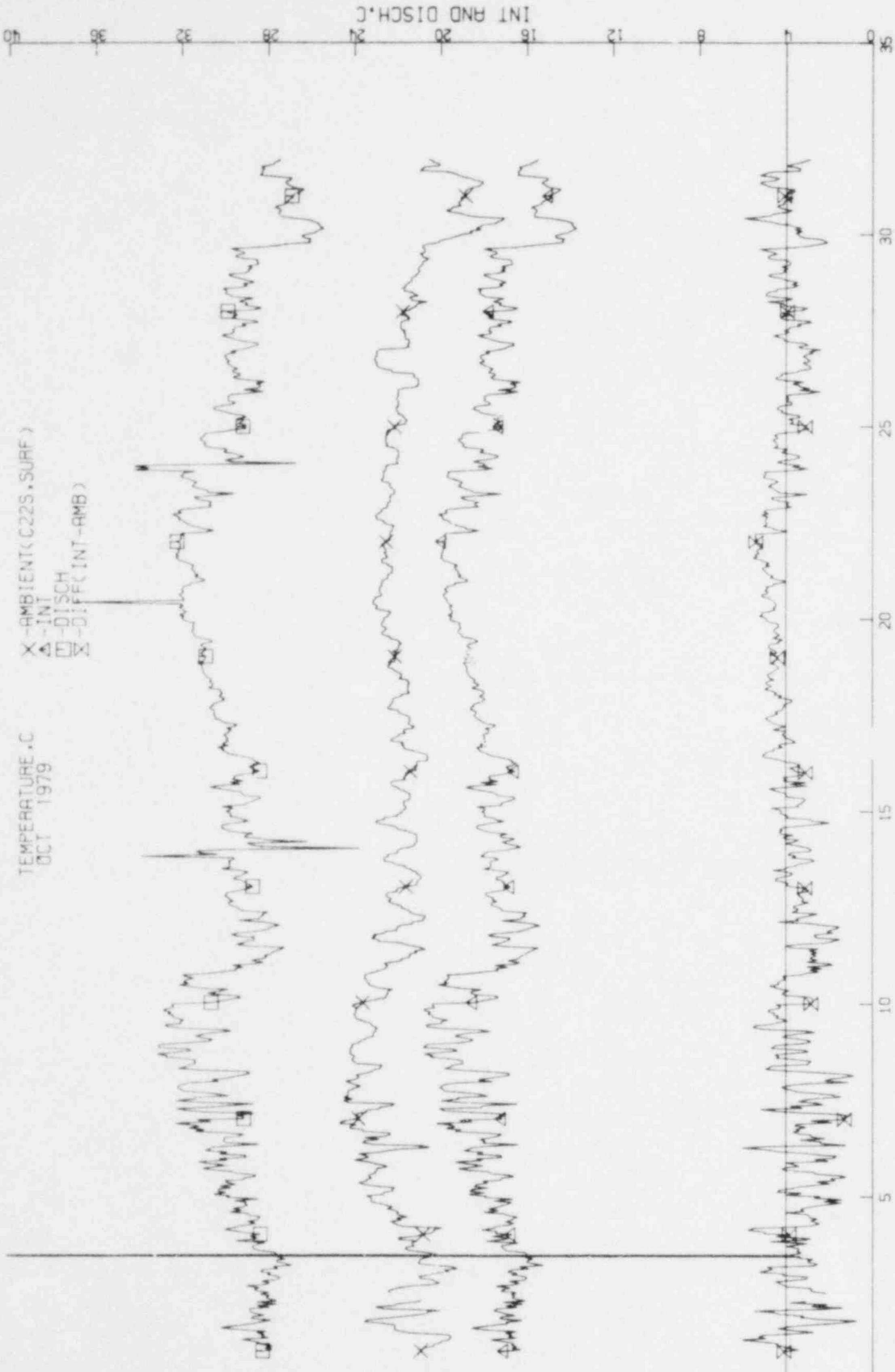

Figure I-112. Comparison of intake, discharge, and ocean surface ambient temperatures during October 1979.

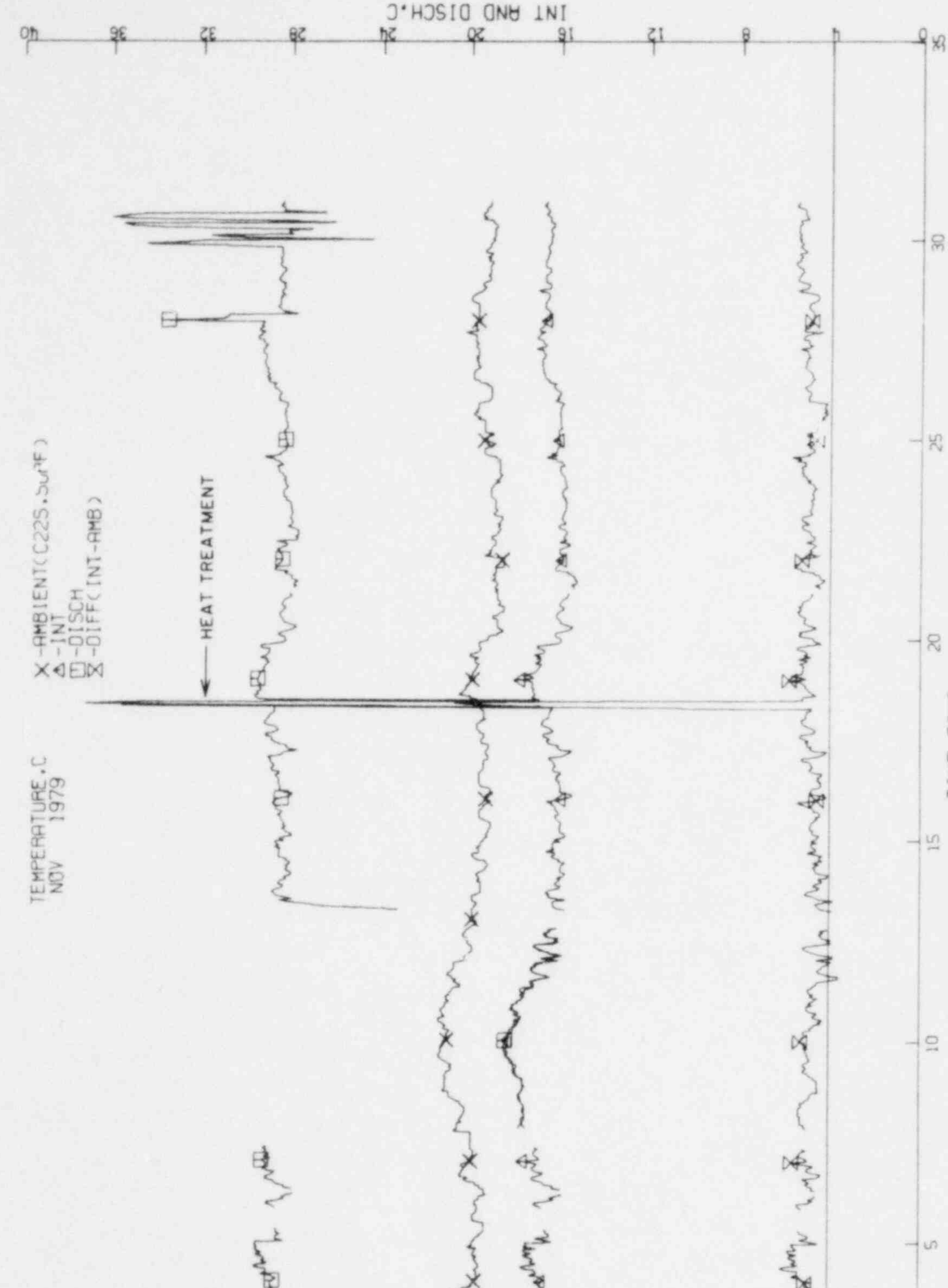

Figure I-113. Comparison of intake, discharge, and ocean surface ambient temperatures during November 1979.

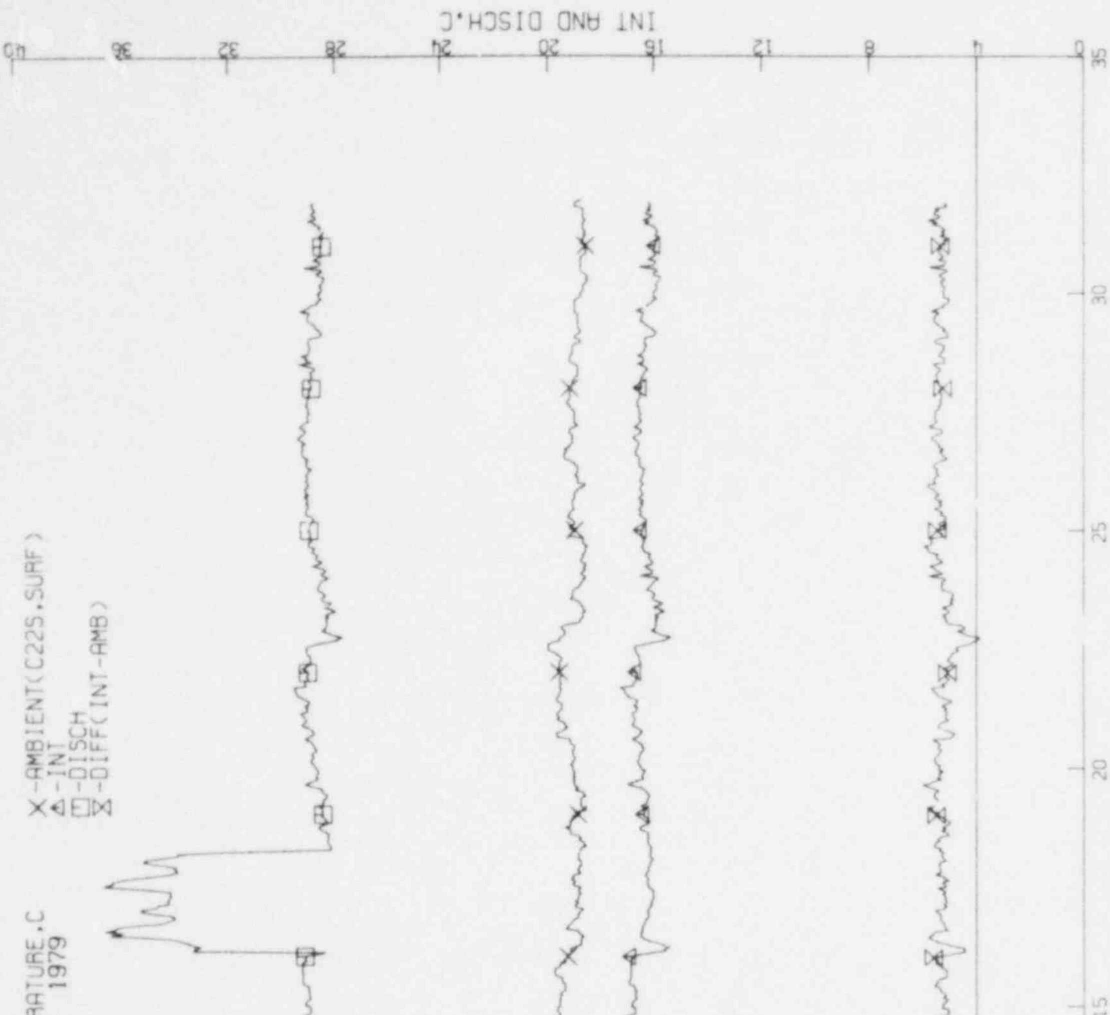

Figure I-114. Comparison of intake, discharge, and ocean surface ambient temperatures during December 1979.

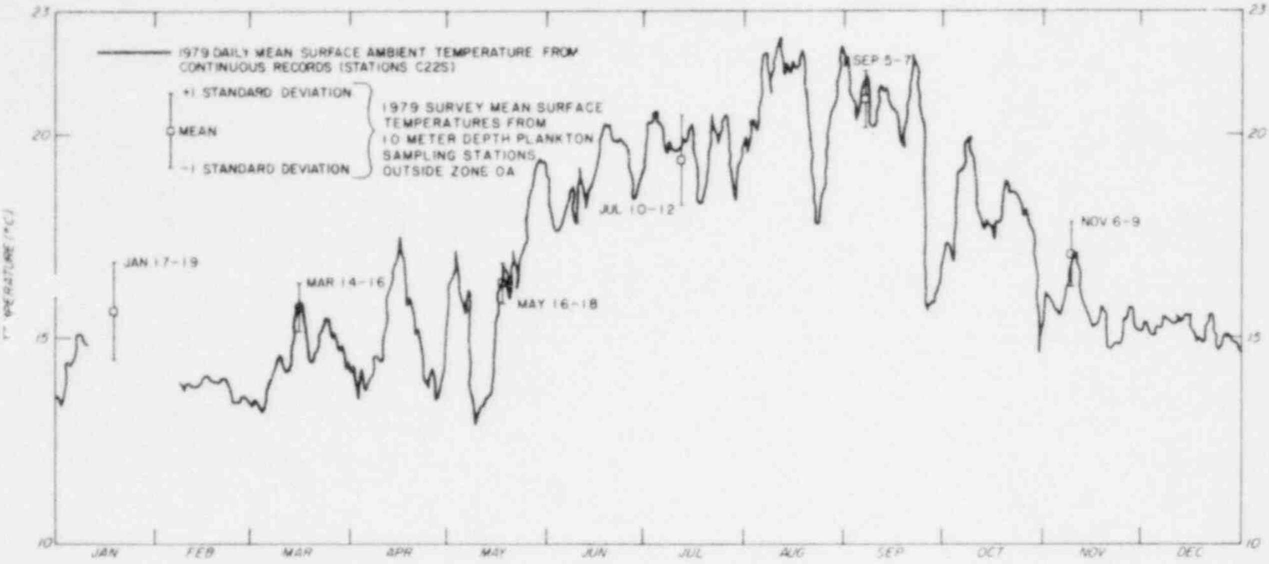

Figure I-115. Representativeness of temperature conditions during plankton sampling.

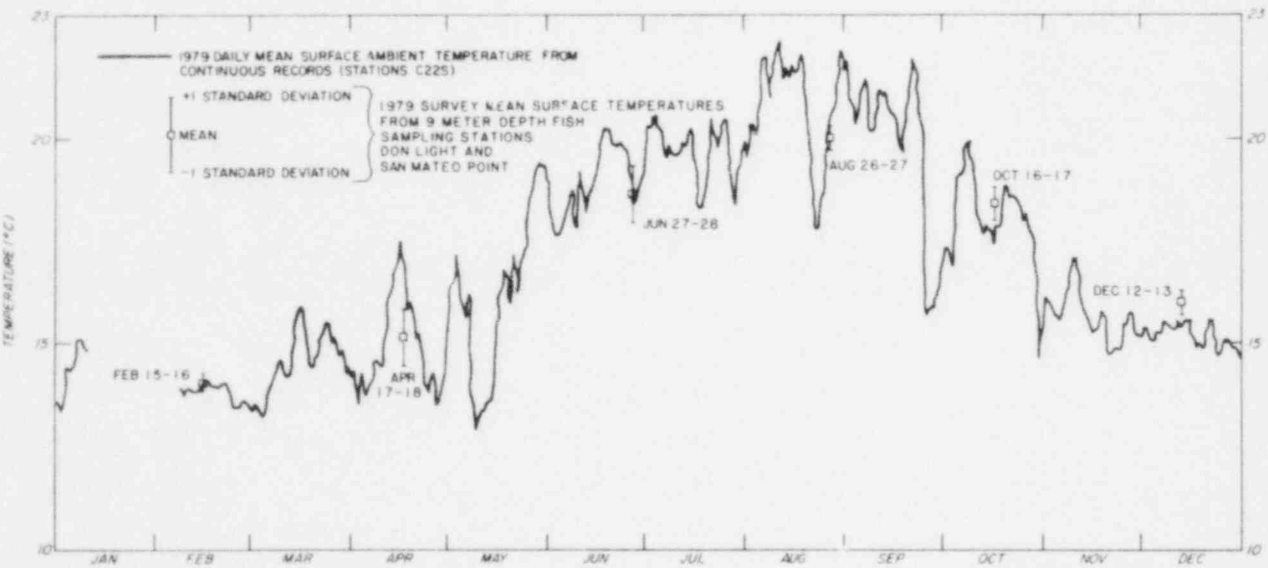

Figure I-116. Representativeness of temperature conditions during fish sampling.

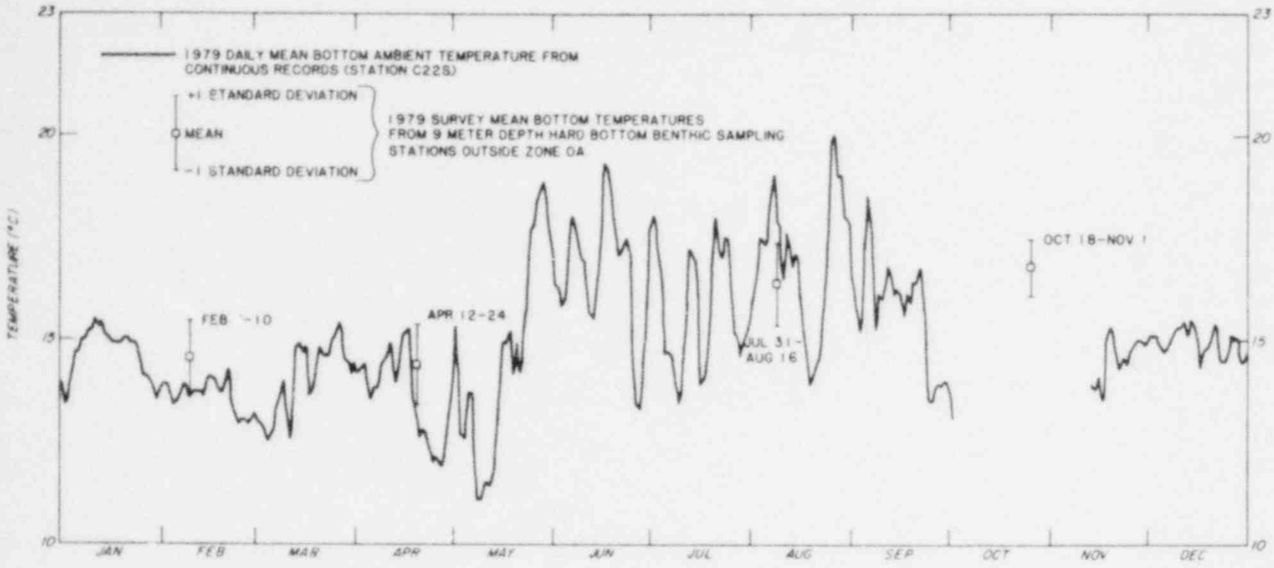

Figure I-117. Representativeness of temperature conditions during hard bottom benthic sampling.

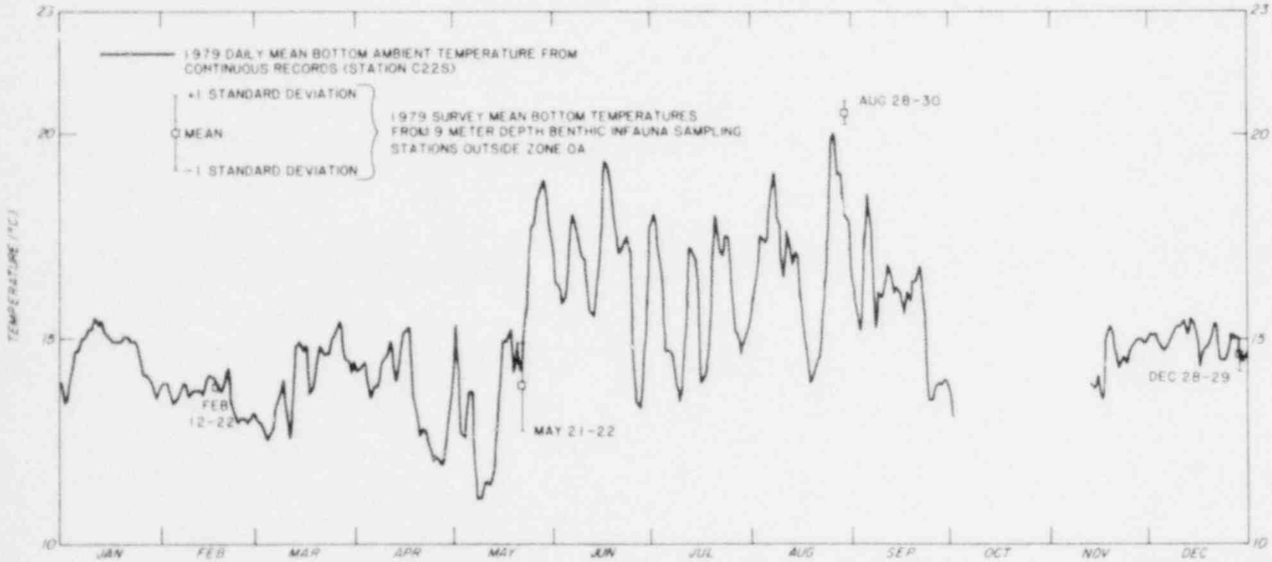

Figure I-118. Representativeness of temperature conditions during benthic infauna sampling.

APPENDIX II - TURBIDITY

TABLES

Table II-1. Mean and range of surface and mid-depth (4 m) percent light transmittance during 1979 bimonthly surveys.

	Depth	Item	Jan 11	Mar 14	May 16	Jul 11	Sep 5	Nov 7	Nov 27	Year
Operational Stations	Surface	Min/Sta[a]	00/X0[b]	02/X0[b]	01/X0	02/X0[b]	02/X0	02/X0	01/X0	00/X0[b]
		Max/Sta[a]	44/F14S	72/F14N	50/F14N	64/C14N	59/F14N	80/F14N	84/F6S	84/F6S
		Mean Std Dev	8 10.4	41 22.3	16 14.2	26 14.2	33 13.8	39 19.5	41 21.5	29 16.6
	Mid-Depth	Min/Sta	00/X0[b]	01/X0	00/X0	01/X0[b]	02/X0	01/A1N	00/X0[b]	00/X0[b]
		Max/Sta	42/F14S	76/F14N	46/F6S	68/F14N	49/F14N	80/F14N	84/F14N	84/F14N
		Mean Std Dev	9 10.5	38 18.0	18 14.3	21 13.1	26 13.2	36 19.6	49 20.0	22 15.5
Preoperational Stations	Surface	Min/Sta	08/J8N	45/F20N	33/F26S	17/F2N	44/F2N	61/F2S	45/F2N	08/J8N
		Max/Sta	54/M4S	80/J8N	63/F20N	60/M4N	52/J4N	82/F20N[b]	85/F20N	85/F20N
		Mean Std Dev	32 13.1	70 7.9	43 6.3	46 10.2	47 2.2	74 5.8	70 12.5	55 8.3
	Mid-Depth	Min/Sta	06/J8N	41/F20N	24/F26S	07/F2N	09/F2N	57/J4S	47/F2N	06/J8N
		Max/Sta	65/M2S	79/J8N	65/F20N	62/M2N	48/M8S	80/F20N[b]	85/F20N	85/F20N
		Mean Std Dev	36 15.4	70 8.9	42 7.6	46 11.8	43 7.4	72 6.4	72 12.1	54 9.9

[a] Minimum or maximum percent light transmittance and station where measured.
[b] Minimum or maximum observed at more than one station; measurement closest to discharge presented.

Table II-2. Mean and range of Secchi disc depths of visibility (m) during 1979 bimonthly surveys.

	Item	Jan 11	Mar 14	May 16	Jul 11
Operational Stations	Min/Sta[a]	1.0/B.5N[b]	1.5/A8S	1.5/X0[b]	1.8/A0
	Max/Sta[a]	7.0/Barn Kelp	11.0/E0	6.0/D4S	7.0/C14N
	Mean	2.6	6.1	3.3	4.6
	Std Dev	1.39	2.76	1.40	4.47
Preoperational Stations	Min/Sta	1.9/F14N	6.5/F14S	4.0/F26S	3.5/F2N
	Max/Sta	13.0/M8S	17.0/M4N	10.7/F20N	10.0/F14N
	Mean	6.0	13.2	6.3	7.4
	Std Dev	2.71	3.09	1.21	1.26
	Item	**Sep 5**	**Nov 7**	**Nov 27**	**Year**
Operational Stations	Min/Sta[a]	1.5/X0	2.3/X0	1.5/X0	1.0/B.5N[b]
	Max/Sta[a]	8.0/C10N[b]	9.5/E2N[b]	11.0/E2S[b]	11.0/E0[b]
	Mean	5.4	5.8	6.7	5.1
	Std Dev	1.83	2.45	2.85	4.61
Preoperational Stations	Min/Sta	4.7/F2N	7.0/F14S	7.5/F2N[c]	1.9/F14N
	Max/Sta	10.5/F14N	14.5/F20N	16.9/F14N[c]	17.0/M4N
	Mean	8.2	11.2	11.3[c]	8.8
	Std Dev	1.21	1.57	2.09[c]	3.28

[a] Minimum or maximum Secchi disc value and stations where measured.
[b] Minimum or maximum observed at more than one station; value closest to discharge presented.
[c] Based on data from stations along the F-line only.

Table II-3. Mean and range of surface and mid-depth (4 m) suspended solids concentration (mg/ℓ) during 1979 bimonthly surveys.

	Depth	Item	Jan 11	Mar 14	May 16	Jul 11	Sep 5	Nov 7	Year
Operational Stations	Surface	Min/Sta[a]	0.1/B2N&S	0.4/E2N	0.2/F6S	0.6/C2N	0.0/D2S	0.2/E0[b]	0.0/D2S
		Max/Sta[a]	12.8/F6N	13.2/D0	21.6/A0	19.7/A0	21.8/C20N	19.0/D0	21.8/C20N
		Mean	2.6	3.7	4.2	4.6	2.2	3.6	3.5
		Std Dev	2.88	3.26	4.06	4.62	4.01	4.19	3.97
	Mid-Depth	Min/Sta	0.1/C6N	0.4/C2N	0.4/C6S	0.4/C0[b]	0.2/C0[b]	0.4/F0[b]	0.1/C6N
		Max/Sta	61.2/A2N	12.6/A2N	411.8/A2N	316.2/A2N	817.6/A0	25.2/A0	817.6/A0
		Mean	6.6	3.5	29.7	13.9	53.9	4.1	18.6
		Std Dev	14.82	3.09	97.54	55.28	198.96	5.08	95.21
Preoperational Stations	Surface	Min/Sta	0.2/F22S	0.2/H2N[b]	0.2/H0	0.4/H0[b]	0.2/M0[b]	0.2/H2S[b]	0.2/H0[b]
		Max/Sta	11.2/F20N	10.8/F20N	2.4/H2N	11.0/M8N	19.8/J8N	1.2/M8S	19.8/J8N
		Mean	2.5	2.2	1.2	2.9	3.7	0.4	2.1
		Std Dev	3.15	3.43	0.68	3.78	5.86	0.28	3.61
	Mid-Depth	Min/Sta	0.1/H2S	0.2/H0[b]	0.2/H0[b]	0.6/H2N	0.0/J8N	0.2/J0[b]	0.0/J8N
		Max/Sta	8.0/J8S	11.2/J8N	5.2/F20N	13.2/M8N	0.8/J0[b]	2.2/H0	13.2/M8N
		Mean	3.1	2.7	1.3	3.8	0.4	0.8	2.0
		Std Dev	2.60	3.21	1.37	3.50	0.25	0.62	2.62

[a] Minimum or maximum concentration and station where measured.
[b] Minimum or maximum observed at more than one station; concentration closest to discharge presented.

Table II-4 Mean and range of surface and mid-depth (4 m) settleable solids concentration (mg/ℓ/hr) during 1979 bimonthly surveys.

	Depth	Item	Jan 11[a]	Mar 14	May 16	Jul 11	Sep 5	Nov 7	Year
Operational Stations	Surface	Min/Sta[b]	<0.1/X0[c]	0.0/C0[c]	0.0/C2N[c]	0.0/B0[c]	0.0/C0[c]	0.0/B0[c]	0.0/B0[c]
		Max/Sta[b]	<0.1/X0[c]	23.0/X0	50.0/X0	21.0/A0[c]	58.0/A0	22.0/A2N	58.0/A0
		Mean	<0.1	3.2	8.5	4.5	6.2	4.5	<4.5
		Std Dev	0.00	4.71	11.28	5.78	12.23	7.01	<8.38
	Mid-Depth	Min/Sta	<0.1/X0[c]	0.0/B0[c]	0.0/D0[c]	0.0/D0[c]	0.0/B0[c]	0.0/B25[c]	0.0/B0[c]
		Max/Sta	0.2/A0[c]	1527.0/A0	1501.0/A2N	510.0/A2N	4177.0/A0	187.0/A0	4177.0/A0
		Mean	<0.1	57.6	92.2	21.9	251.0	14.1	72.8
		Std Dev	<0.00	269.96	309.59	89.46	954.93	41.35	434.74
Preoperational Stations	Surface	Min/Sta	<0.1/H0[c]	0.0/H2N[c]	0.0/H0[c]	0.0/H0[c]	0.0/H0[c]	0.0/H2N[c]	0.0/H0[c]
		Max/Sta	<0.1/H0[c]	23.0/F22S	17.0/M0	13.0/F22S	11.0/F20N	2.0/F20N	23.0/F22S
		Mean	<0.1	3.5	5.3	2.1	1.1	0.5	2.1
		Std Dev	0.00	6.34	6.33	3.70	3.15	0.66	4.54
	Mid-Depth	Min/Sta	<0.1/H0[c]	0.0/H2N,H2S	0.0/H0[c]	0.0/H0[c]	0.0/H0[c]	0.0/H2S[c]	0.0/H0[c]
		Max/Sta	<0.1/H0[c]	20.0/F22S	14.0/M0	24.0/F22S	19.0/J8S	2.0/H0[c]	24.0/F22S
		Mean	<0.1	3.3	5.0	3.2	4.3	0.6	2.7
		Std Dev	0.00	5.85	5.36	6.67	6.92	0.77	5.43

[a] January 11 concentrations were determined by volume (ml/ℓ/hr).
[b] Minimum or maximum concentration and station where measured.
[c] Minimum or maximum observed at more than one station; concentration closest to discharge presented.

Table II-5. Comparison of surface percent light transmittance at similar fish, plankton, and turbidity sampling stations during 1979.

Fish													SO9	SO14	SM9	SM14	DL9	DL14
Plankton	1	2	3	4	5	7	9	11	13	14	15	16						
Turbidity	C8N	D4N	D2N	D2S	D4S	C22S	C20N	F2S	F22S	F20N	M2N	M4S	C2N	F0	C14N	F14N	C26S	F26S
Survey Date																		
Jan 11	3	2	1	20	9	38	8	12	43	15	40	54	0	7	1	1	42	43
Jan 17	2	2	3	2	4	2	4	19	5	22	56	52						
Jan 18	29	-	-	7	-	3	8	9	16	7	66	13						
Jan 19	32	-	-	24	-	48	27	50	52	38	74	78						
Feb 15													15	31	8	19	20	36
Feb 16													12	38	15	17	30	30
Mar 14[a]	61/33	60/74	56/71	56/80	56/71	59/78	43/46	58/82	62/87	45/60	78/-	74/-	29	64	41	72	58	66
Mar 15	44	-	-	70	-	67	-	66	76	-	-	-						
Mar 16	20	-	-	30	-	58	36	42	-	-	-	-						
Apr 17													4	13	5	10	18	26
Apr 18													1	38	18	30	34	30
May 16[a]	8/22	8/21	12/38	32/48	34/44	30/41	17/20	14/54	39/43	63/54	35/40	46/57	7	35	13	50	27	33
May 17	13	-	-	23	-	44	38	31	42	58	37	44						
May 18	30	-	-	29	-	37	22	31	35	26	35	32						
Jun 27													27	28	28	29	29	45
Jun 28													21	28	46	45	29	41
Jul 10	18	46	46	48	48	47	32	48	54	46	54	54						
Jul 11[a]	24/41	33	21	28/39	33	37/44	47/32	42/43	38/45	57/50	56/64	57/71	17	41	64	62	39	14
Jul 12	58	-	-	33	-	28	46	35	38	30	76	75						
Aug 26													15	45	50	55	37	48
Aug 27													26	43	54	44	49	53
Sep 5[a]	42	40	35	35	41	49	39/44	45/48	47	45	46	41	21	42	43	59	42	48
Sep 6	-	-	-	-	-	-	-	55	48	-	-	-						
Sep 7	-	-	-	-	-	-	-	70	62	-	-	-						
Oct 16													64	71	73	73	60	72
Oct 17													20	64	22	40	38	50
Nov 6	-	-	-	-	-	-	-	77	45									
Nov 7	26	43	47	63	59	62	48	61	80	82	79	78	29	63	34	56	57	82
Nov 8								80	56									
Nov 9								70	68									
Nov 27	43	47	25	47	33	75	79	67	68	85	-	-	28	59	82	81	76	77
Dec 12													64	77	33	71	71	80
Dec 13													60	85	67	70	56	90

[a] Bimonthly physical/chemical and plankton surveys on the same day.

Table II-6. Integrated ($\int\alpha$) and normalized ($\bar{\alpha}$/m) volume attenuation coefficients (m^{-1}) at each station during 1979 bimonthly surveys[a]

Survey Date	Jan 11		Mar 14		May 16		Jul 11		Sep 5		Nov 7		Nov 27[b]	
Station	$\int\alpha$	$\bar{\alpha}$/m	$\int\alpha$	$\bar{\alpha}$/m	$\int\alpha$	$\bar{\alpha}$/m	$\int\alpha$	$\bar{\alpha}$/m	$\int\alpha$	$\bar{\alpha}$/m	$\int\alpha$	$\bar{\alpha}$/m	$\int\alpha$	$\bar{\alpha}$/m
A2N	21.7	4.72	12.2	3.58	11.4	3.44	c	c	6.65	2.89	10.6	2.47	9.95	2.69
A1N	16.0	4.72	11.4	3.44	12.6	3.60	c	c	9.96	3.83	12.6	2.87	7.92	2.03
A0	18.4	4.72	14.0	4.24	13.3	4.15	12.4	4.58	9.45	3.78	9.76	2.27	8.28	2.67
S2S	17.7	3.76	13.4	2.73	17.6	4.01	15.0	3.26	8.68	1.67	11.6	1.96	13.9	2.63
A4S	27.1	4.51	12.1	1.83	28.2	4.40	17.0	2.74	13.5	1.93	20.3	2.74	12.2	2.11
A6A	20.0	4.72	12.3	2.57	14.9	3.64	13.3	2.89	10.6	1.92	12.0	2.03	9.45	2.10
A8S	15.6	4.59	10.4	2.97	c	c	c	c	8.37	2.79	10.2	3.10	6.97	1.99
B4N	27.2	4.39	12.3	2.05	22.4	3.30	24.2	3.14	16.6	2.41	14.2	2.26	12.6	1.56
B2N	20.8	4.72	14.8	2.47	20.9	3.25	17.5	2.92	14.2	2.29	17.6	2.44	9.03	1.29
B1N	27.8	4.72	16.9	2.86	28.2	4.03	19.7	2.85	16.1	2.73	16.4	2.10	11.3	1.61
B.5N	30.7	4.72	15.6	3.05	31.2	4.33	21.4	3.06	13.3	2.46	10.4	1.38	7.30	1.09
B0	30.0	4.68	11.9	2.09	23.6	3.69	22.5	3.31	12.3	2.08	13.3	1.68	13.6	2.16
B.5S	30.0	4.69	12.1	1.70	26.0	3.66	11.5	1.77	16.9	2.29	13.3	1.64	9.45	1.35
B1S	27.3	4.14	8.84	1.55	23.5	3.31	12.5	1.84	13.6	2.09	12.6	1.62	10.2	1.48
B2S	18.7	2.75	11.2	1.49	25.7	3.95	15.6	2.11	20.4	2.65	12.7	1.57	8.26	1.27
B4S	24.3	3.29	12.2	1.47	25.1	3.22	21.0	2.69	23.9	2.65	10.7	1.26	8.25	1.10
B6S	32.6	4.46	9.56	1.31	21.2	2.82	17.9	2.30	16.0	2.05	10.7	1.24	11.7	1.44
C20N	33.0	2.48	13.9	1.58	21.8	2.02	15.8	1.48	19.2	2.04	13.4	0.97	5.42	0.48
C14N	47.6	4.67	8.67	1.07	21.6	1.86	11.7	1.15	12.1	1.15	13.1	1.14	5.97	0.51
C10N	38.1	4.38	16.7	2.14	21.6	2.20	18.6	1.98	9.48	1.09	14.3	1.42	6.28	0.61
C8N	40.2	4.42	7.62	0.99	22.2	2.24	16.4	1.74	12.1	1.33	16.4	1.52	7.67	0.73
C6N	32.2	3.62	7.85	1.02	25.0	2.40	22.3	2.32	10.4	1.18	15.6	1.46	16.3	1.57
C4N	32.2	3.54	8.98	1.34	27.3	2.90	18.2	2.17	20.6	2.34	23.9	2.19	13.1	1.51
C2N	31.7	3.87	10.1	1.68	23.9	3.02	15.4	2.16	14.4	2.09	22.2	2.34	10.0	1.18
X0	34.3	4.70	28.5	3.85	34.7	4.56	33.6	4.60	28.1	4.01	27.6	3.10	31.2	4.28
C0	40.2	4.68	13.9	1.72	27.3	3.25	15.8	2.16	25.9	2.94	31.0	3.16	11.5	1.29
C2S	23.0	2.55	11.4	1.21	21.4	2.46	19.7	2.16	29.2	3.11	12.4	1.28	8.81	0.99
C4S	19.6	2.20	10.8	1.17	22.2	2.39	23.7	2.61	23.5	2.37	13.7	1.37	10.3	1.16
C6S	19.0	2.37	10.4	1.19	15.2	1.79	18.3	2.13	17.4	1.96	13.2	1.37	10.1	1.19
C8S	29.9	3.54	8.86	1.08	17.6	2.07	15.4	1.88	15.4	1.67	13.0	1.37	14.4	1.66
C10S	22.5	3.46	8.42	1.04	17.8	2.07	15.7	1.96	14.0	1.61	14.7	1.61	11.6	1.41
C14S	24.7	3.21	7.09	1.09	19.8	2.75	12.7	1.72	11.8	1.55	6.40	0.82	14.4	1.87
C22S	21.9	2.41	10.4	1.12	21.0	2.16	13.9	1.50	14.3	1.42	7.78	0.72	18.5	1.83
C24S	30.1	3.24	9.92	1.09	21.6	2.51	18.3	1.93	12.0	1.46	8.47	0.83	9.39	0.93
C26S	18.1	1.91	8.38	1.01	15.4	1.92	15.2	1.71	13.9	1.70	6.98	0.72	21.4	1.91
Barn Kelp	11.8	0.84	8.82	0.63	c	c	21.4	2.10	20.4	1.46	c	c	c	c
D6N	34.6	3.46	8.12	0.99	18.6	2.00	21.8	2.08	15.9	1.59	10.4	0.87	14.6	1.28
D4N	33.5	3.45	8.80	1.10	20.6	1.91	17.5	1.94	17.9	1.81	11.5	0.96	13.2	1.22
D2N	30.5	3.08	9.12	1.14	24.7	2.40	19.1	2.30	16.3	1.89	9.88	0.89	15.5	1.55
D0	35.4	3.34	9.31	0.99	19.8	2.36	23.8	2.27	23.5	2.26	11.9	1.00	9.80	0.97
D2S	17.0	1.76	9.21	0.94	20.8	2.04	23.9	2.26	25.7	2.36	15.0	1.36	11.4	1.13
D4S	18.1	1.89	10.4	1.04	16.2	1.67	28.7	2.76	19.3	1.77	13.4	1.23	12.0	1.26
E4N	24.6	2.34	10.6	1.19	17.1	1.45	15.0	1.97	20.7	1.95	11.8	0.92	14.4	1.18
E2N	34.2	2.90	8.64	0.96	22.9	1.85	16.3	2.51	25.0	2.45	10.2	0.79	18.8	1.50
E0	26.0	2.36	10.6	0.98	19.8	2.36	20.6	2.26	19.6	1.77	11.3	0.90	12.7	1.14
E2S	17.7	1.64	9.50	0.99	17.5	1.59	18.3	1.65	19.0	1.60	11.2	0.95	5.99	0.54
F20N	36.7	2.06	14.3	0.98	17.0	0.90	14.6	0.93	16.8	1.17	7.64	0.40	3.05	0.21
F14N	60.6	4.21	6.21	0.54	17.6	1.12	16.9	1.12	14.2	1.01	8.15	0.50	3.57	0.23
F6N	34.7	2.80	8.92	0.92	25.9	2.01	24.9	1.98	18.3	1.51	11.0	0.79	7.26	0.53
F2N	26.9	2.19	8.63	0.89	21.2	1.58	35.2	2.84	29.3	2.50	10.1	0.74	17.6	1.33
F0	23.4	1.97	10.5	0.95	21.2	1.80	20.0	1.80	21.0	1.72	9.36	0.72	13.2	1.08
F2S	18.8	1.66	9.77	0.93	18.3	1.66	18.7	1.42	19.2	1.57	9.88	0.81	6.60	0.55
F6S	15.8	1.44	10.1	0.91	17.2	1.59	16.9	1.51	14.5	1.23	7.87	0.69	9.92	0.91
F14S	9.14	0.87	9.79	0.95	17.7	1.62	25.3	2.34	15.9	1.37	11.7	1.01	9.64	0.81
F22S	8.78	0.75	11.1	0.96	23.1	1.76	20.6	1.82	14.0	1.14	6.52	0.49	8.71	0.72
F24S	14.0	1.22	13.1	1.17	20.4	1.59	25.8	2.24	13.2	1.14	6.55	0.50	8.19	0.64
F26S	12.0	1.01	10.6	0.96	21.6	1.80	21.8	2.06	16.4	1.24	5.95	0.41	6.90	0.54
H2N	17.9	1.20	7.67	0.59	14.6	1.03	18.8	1.29	18.6	1.31	8.37	0.52	c	c
H0	14.3	0.98	8.19	0.64	17.4	1.33	20.4	1.35	17.8	1.23	8.37	0.52	c	c
H2S	12.6	0.92	13.6	1.00	21.6	[illegible]	14.7	1.11	15.6	1.12	8.06	0.53	c	c
J8N	40.0	1.93	13.6	0.66	20.1	1.00	21.6	1.09	23.5	1.17	11.4	0.57	c	c
J4N	21.7	1.15	17.6	1.04	27.5	1.51	18.5	1.12	21.0	1.18	11.6	0.60	c	c
J2N	17.2	0.93	18.2	1.03	35.3	1.95	19.2	1.11	20.3	1.12	9.65	0.50	c	c
J0	14.0	0.75	14.4	0.83	26.5	1.48	19.0	1.05	18.2	1.06	9.54	0.51	c	c
J2S	12.0	0.65	11.6	0.66	23.2	1.31	17.2	0.98	18.5	1.07	9.02	0.48	c	c
J4S	10.5	0.61	8.02	0.48	16.8	1.25	17.7	1.06	15.9	0.97	10.3	0.57	c	c
J8S	8.75	0.53	12.0	0.81	17.2	1.10	25.4	1.59	15.6	0.98	11.1	0.64	c	c
M8N	26.9	0.71	25.0	0.65	24.9	0.74	24.3	0.73	24.7	0.74	17.0	0.48	c	c
M4N	17.7	0.57	19.8	0.65	32.7	1.13	23.1	0.79	24.5	0.80	14.3	0.47	c	c
M2N	17.9	0.61	20.6	0.72	31.9	1.14	21.4	0.77	25.1	0.87	13.9	0.48	c	c
M0	14.9	0.53	23.2	0.85	30.5	1.15	24.2	0.92	23.4	0.86	14.7	0.53	c	c
M2S	11.0	0.42	18.8	0.73	39.6	1.54	22.2	0.87	21.6	0.84	14.6	0.54	c	c
M4S	10.4	0.40	17.1	0.68	35.4	1.41	20.7	0.83	20.9	0.85	14.0	0.53	c	c
M8S	8.92	0.37	20.7	0.87	22.5	1.01	21.0	0.90	18.4	0.80	12.1	0.50	c	c

[a] For a one meter transmissometer pathlength the attenuation coefficient (α) is equal to the negative natural logarithum of the light transmittance (T) ($\alpha = -\ln T$). Integrated alpha (/-) is the cumulative light attenuation coefficient at the bottom of each station location w. .e normalized alpha ($\bar{\alpha}$) is $\int\alpha$ divided by the depth of the water column. $\bar{\alpha}$ is reported as having a maximum value of 4.72 because this value exceeds the lower limit of the transmissometer readout by 0.1.

[b] Additional survey for Unit 1 stations due to unscheduled plant outage during 7 November 1979 survey.

[c] Station not sampled during this survey.

APPENDIX II - TURBIDITY

FIGURES

Figure II-1. Surface light transmittance contours for 11 January 1979.

Figure II-2. Mid-Depth (4 m) light transmittance contours for 11 January 1979.

Figure II-3. Surface light transmittance contours for 14 March 1979.

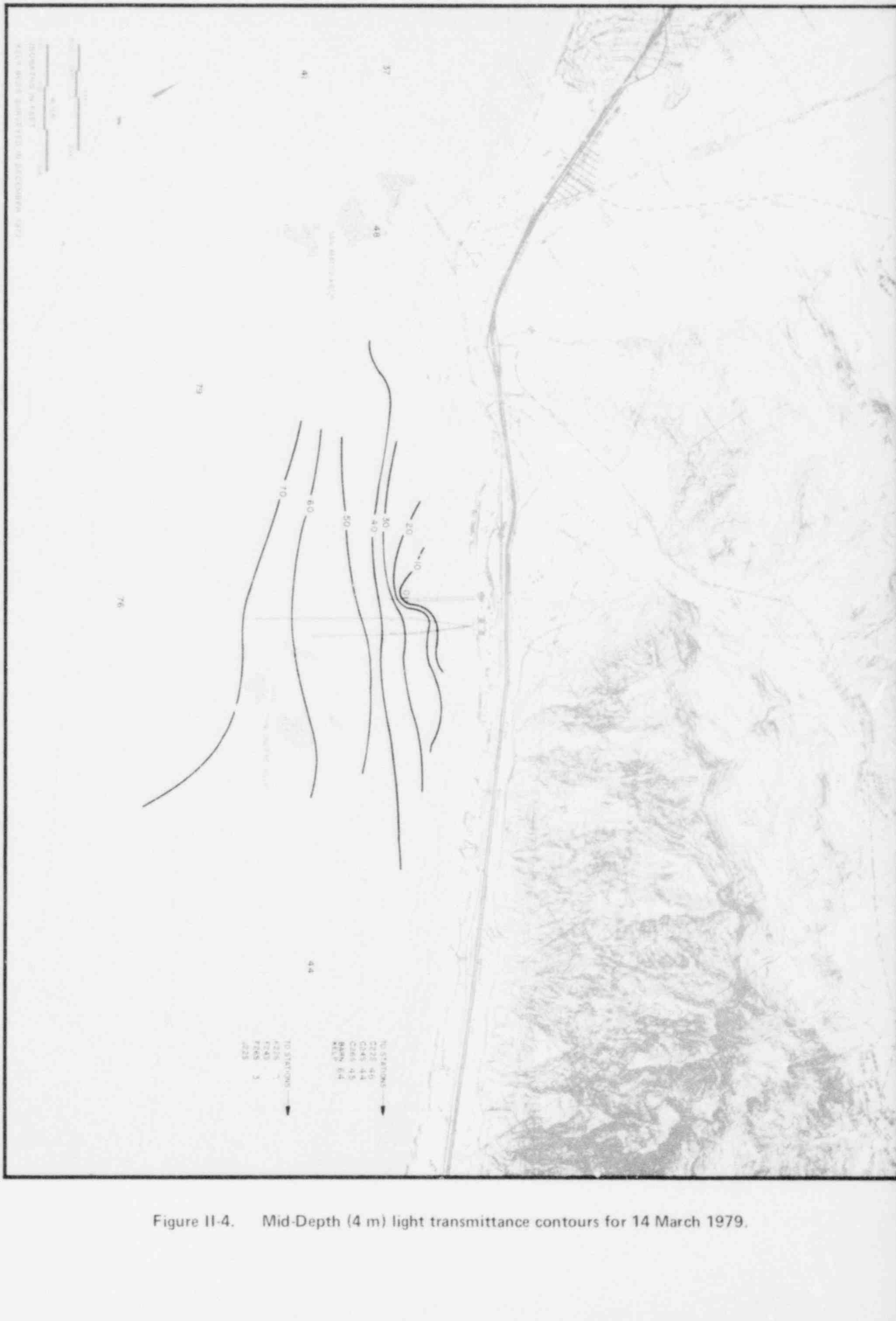

Figure II-4. Mid-Depth (4 m) light transmittance contours for 14 March 1979.

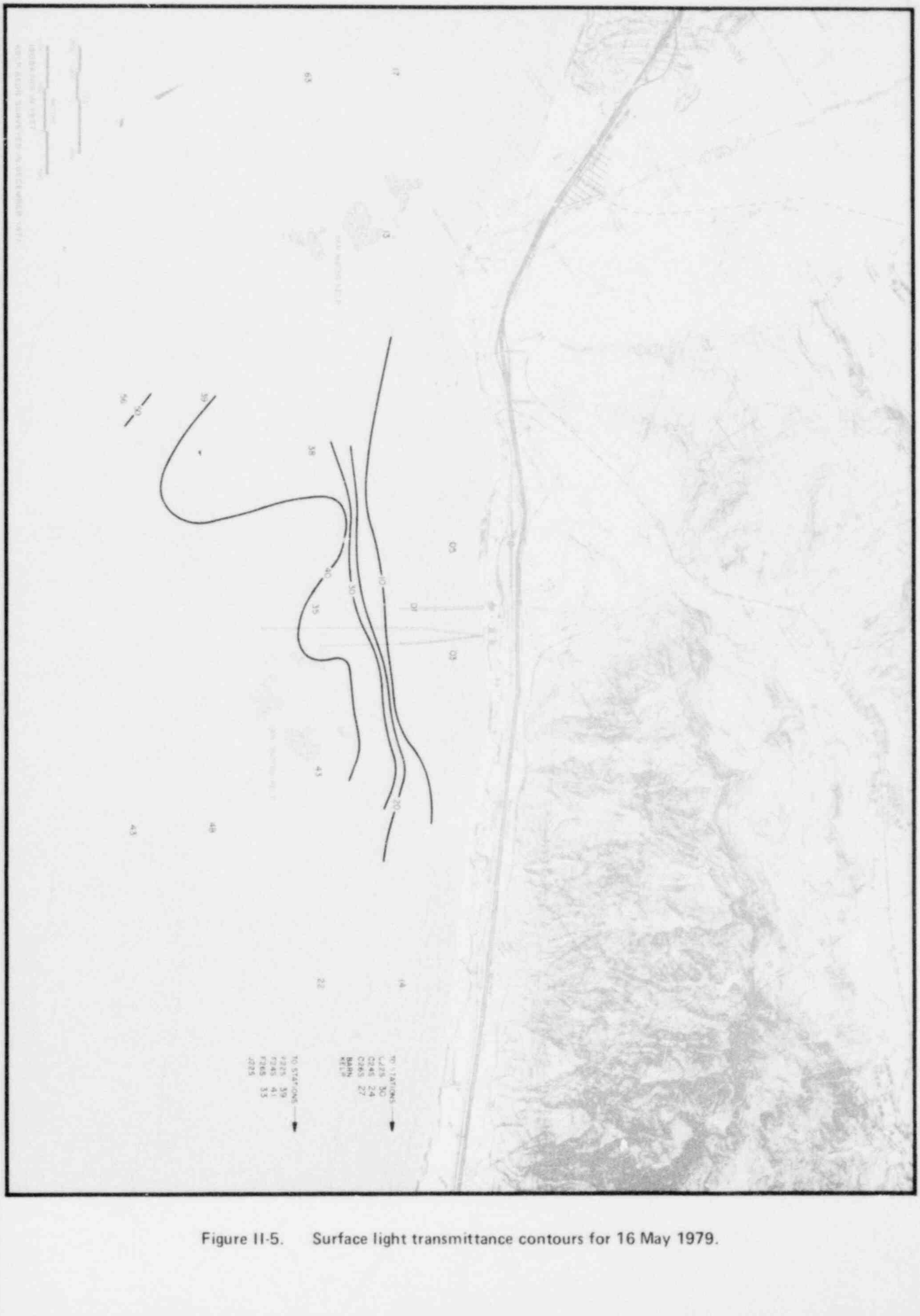

Figure II-5. Surface light transmittance contours for 16 May 1979.

Figure II-6. Mid-Depth (4 m) light transmittance contours for 16 May 1979.

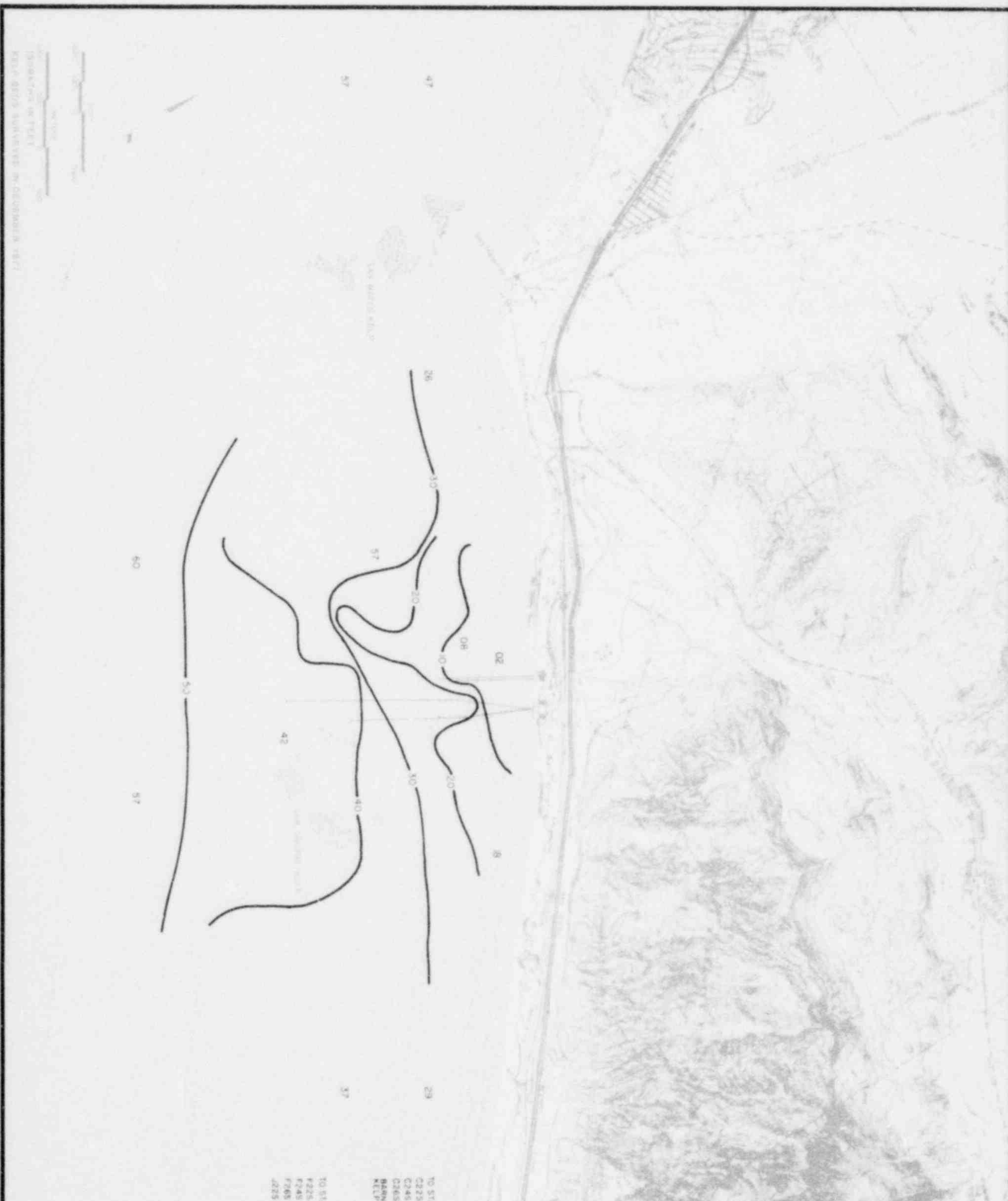

Figure II-7. Surface light transmittance contours for 11 July 1979.

Figure II-8. Mid-Depth (4 m) light transmittance contours for 11 July 1979.

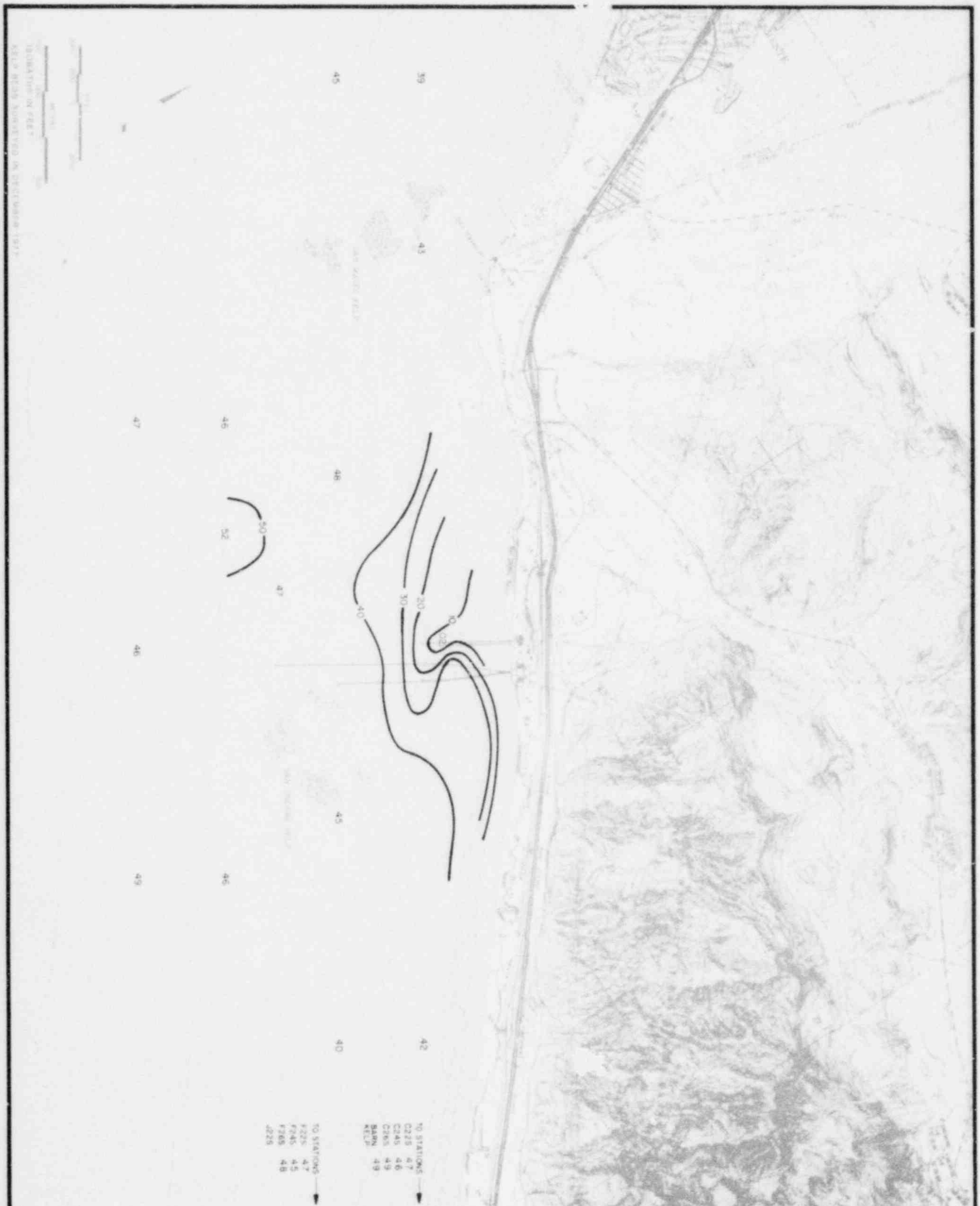

Figure II-9. Surface light transmittance contours for 5 September 1979.

Figure II-10. Mid-Depth (4 m) light transmittance contours for 5 September 1979.

Figure II-11. Surface light transmittance contours for 7 November 1979.

Figure II-12. Mid-Depth (4 m) light transmittance contours for 7 November 1979.

Figure II-13. Surface light transmittance contours for 27 November 1979.

Figure II-14. Mid-Depth (4 m) light transmittance contours for 27 November 1[illegible]79.

Figure II-15. Secchi disc depth of visibility contours (m) for 11 January 1979.

Figure II-16. Secch disc depth of visibility contours (m) for 14 March 1979.

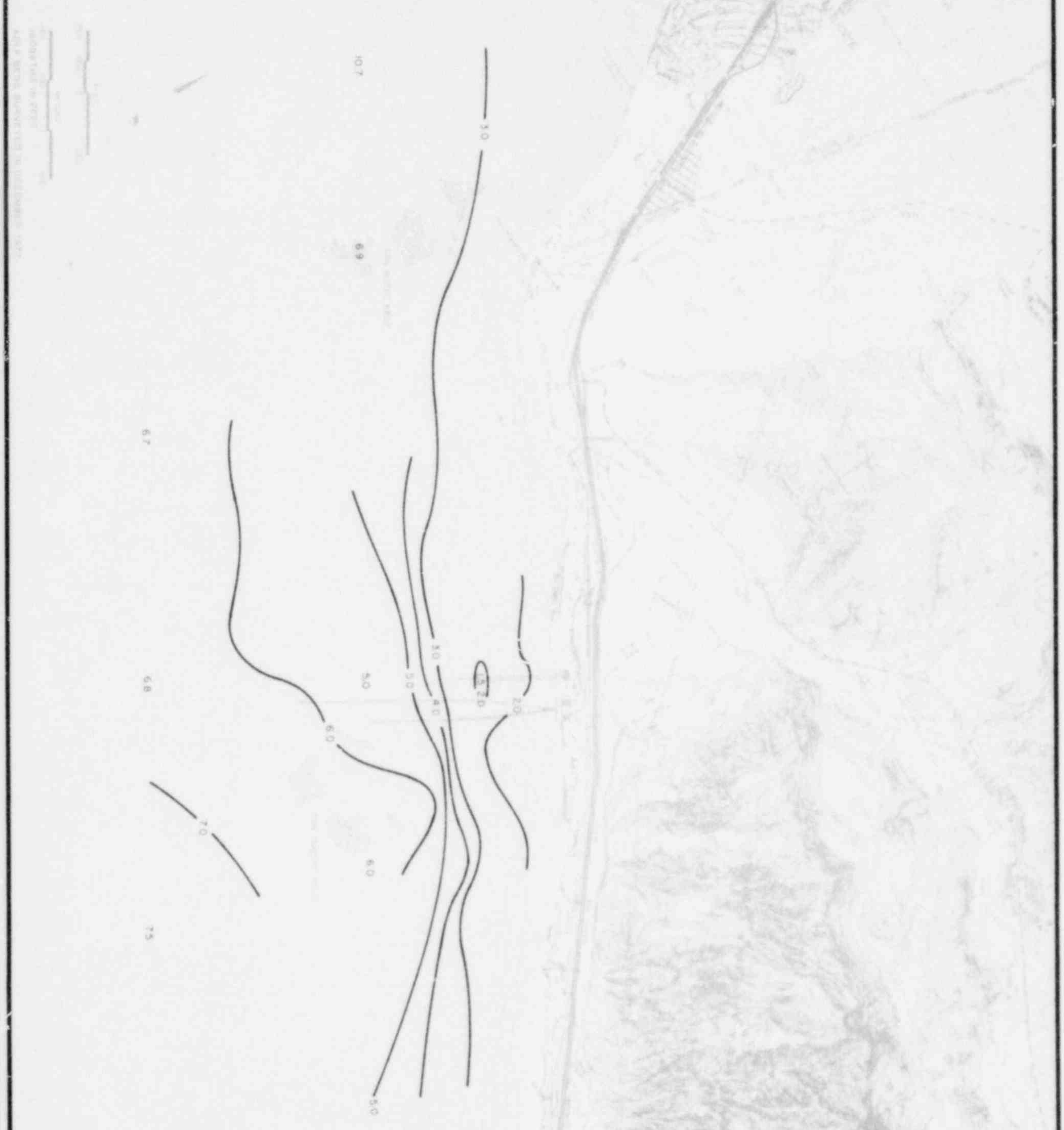

Figure II-17. Secchi disc depth of visibility contours (m) for 16 May 1979.

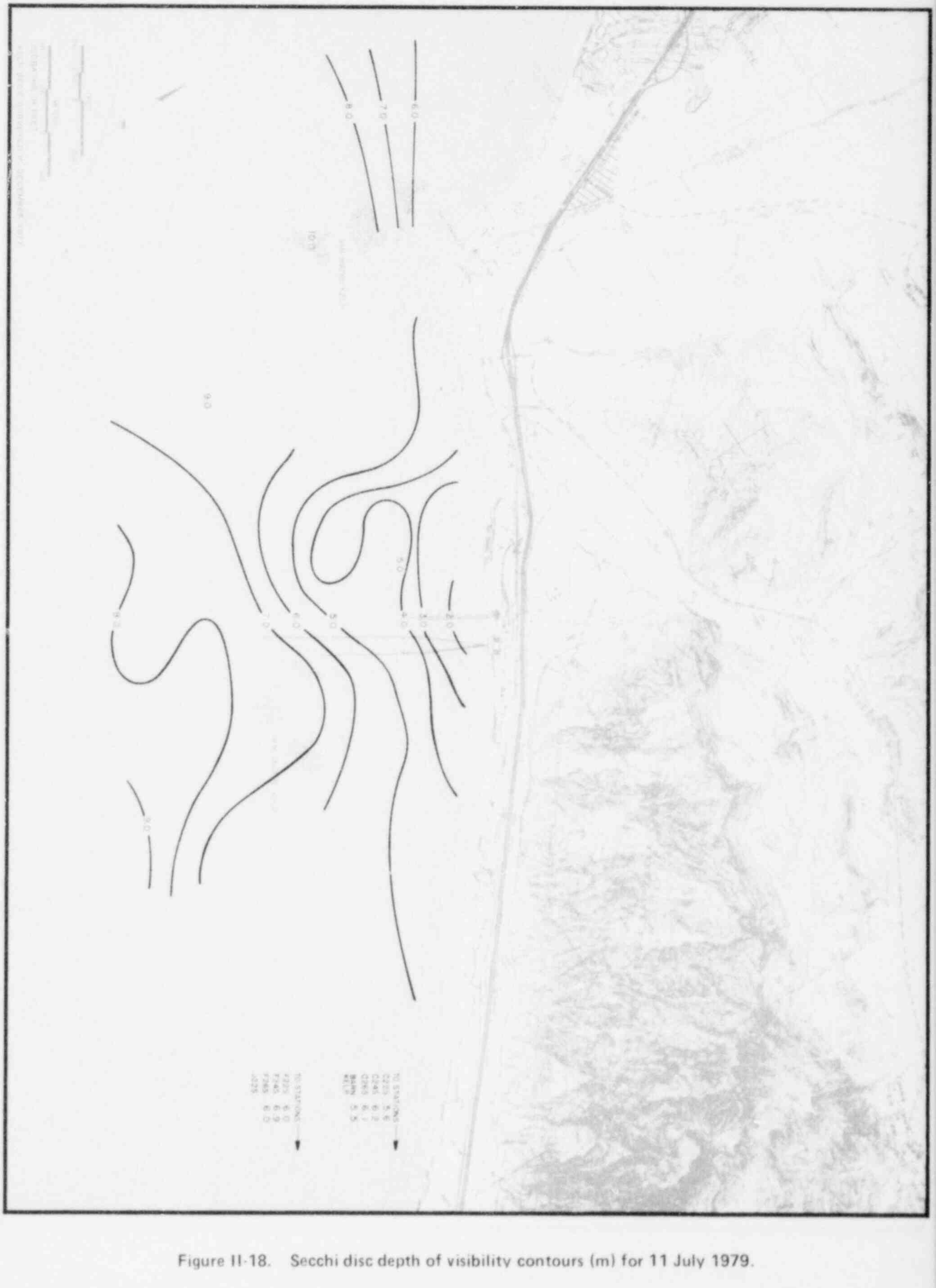

Figure II-18. Secchi disc depth of visibility contours (m) for 11 July 1979.

Figure II-19. Secchi disc depth of visibility contours (m) for 5 September 1979.

Figure II-20. Secchi disc depth of visibility contours (m) for 7 November 1979.

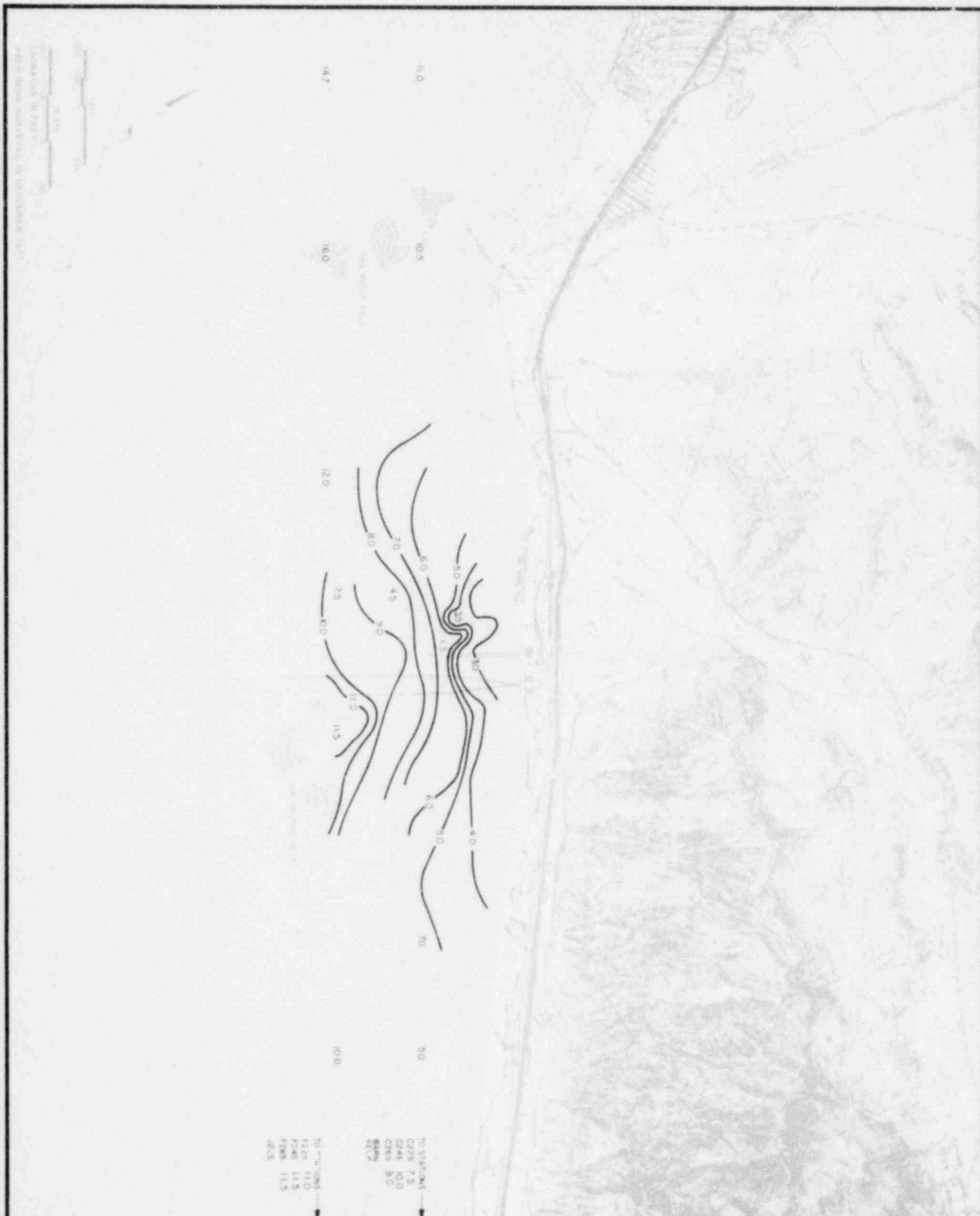

Figure II-21. Secchi disc depth of visibility contours (m) for 27 November 1979.

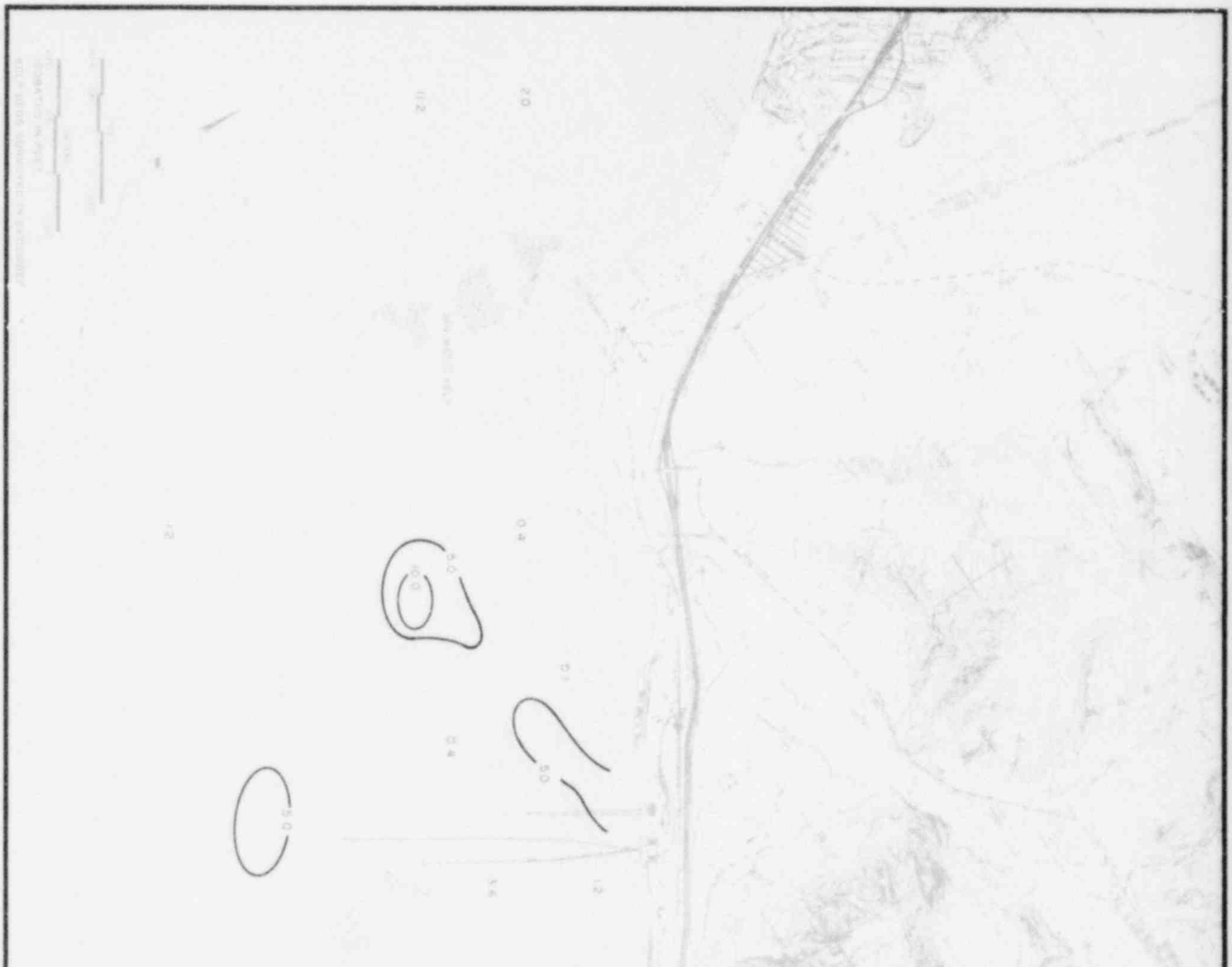

Figure II-22. Surface suspended solids concentration contours (mg/ℓ) for 11 January 1979.

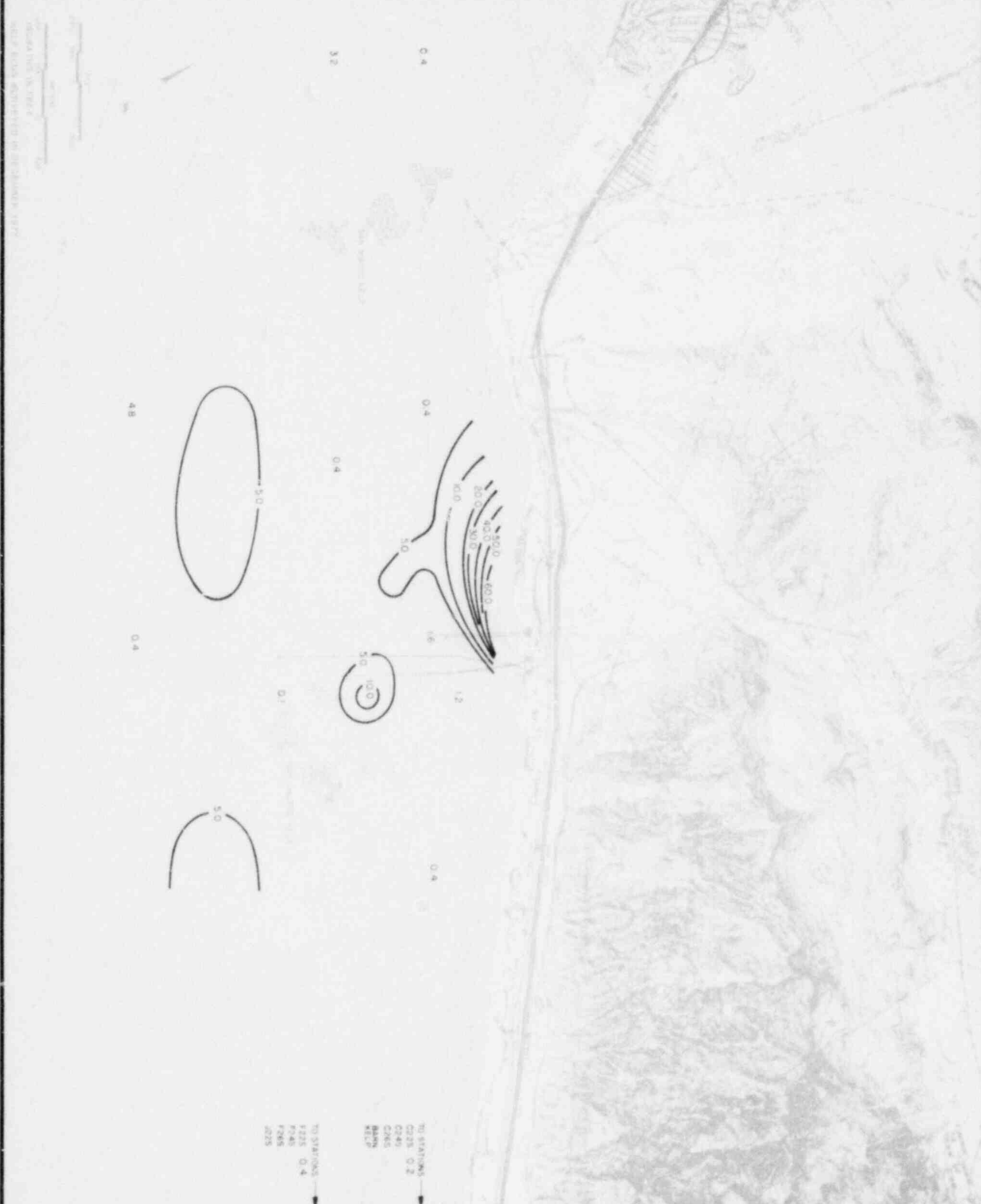

Figure II-23. Mid-Depth (4 m) suspended solids concentration contours (mg/ℓ) for 11 January 1979.

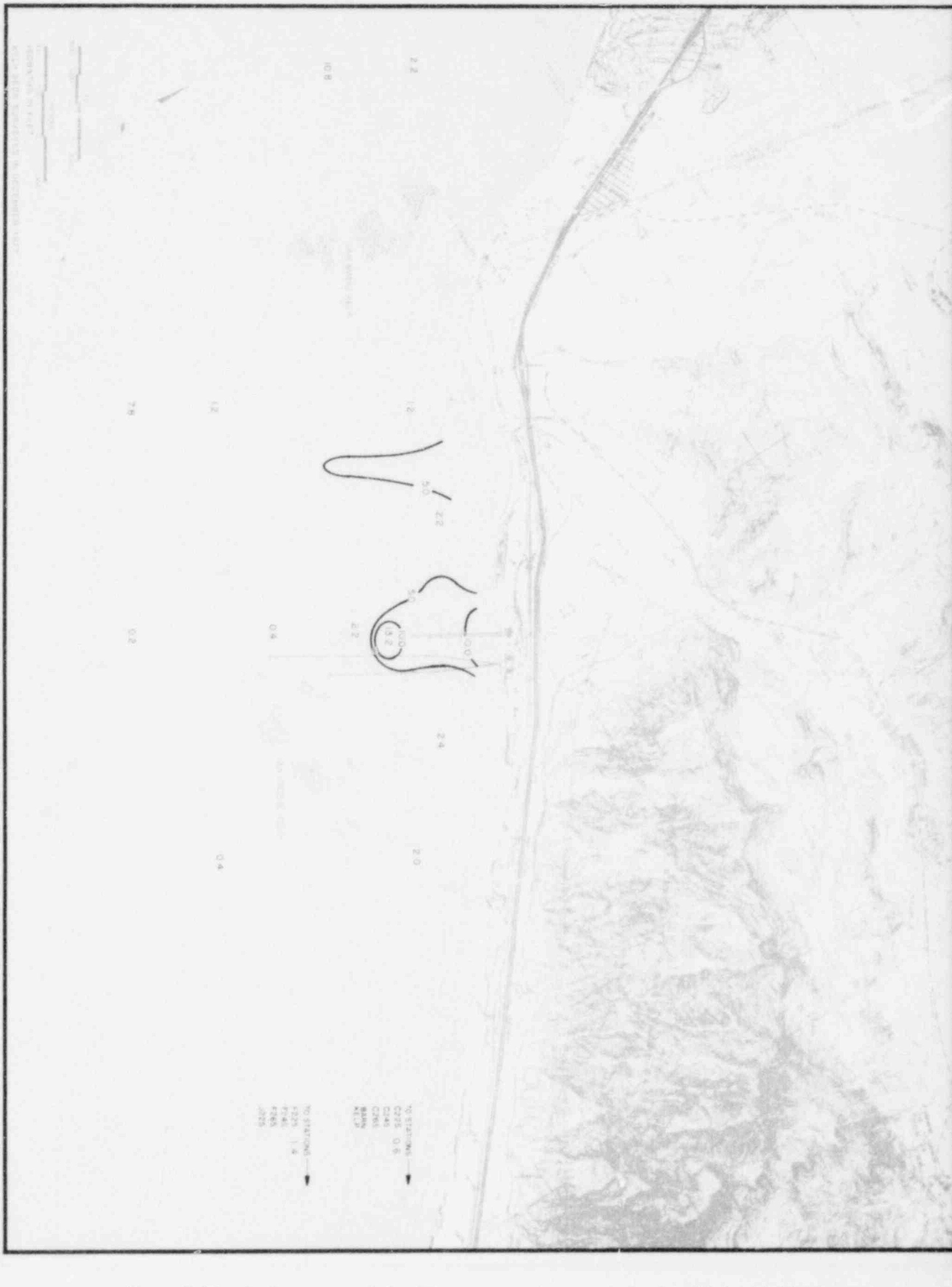

Figure II-24. Surface suspended solids concentration contours (mg/ℓ) for 14 March 1979.

Figure II-25. Mid-Depth (4 m) suspended solids concentration contours (mg/ℓ) for 14 March 1979.

Figure II-26. Surface suspended solids concentration contours (mg/ℓ) for 16 May 1979.

Figure II-27. Mid-Depth (4 m) suspended solids concentration contours (mg/ℓ) for 16 May 1979.

Figure II-28. Surface suspended solids concentration contours (mg/ℓ) for 11 July 1979.

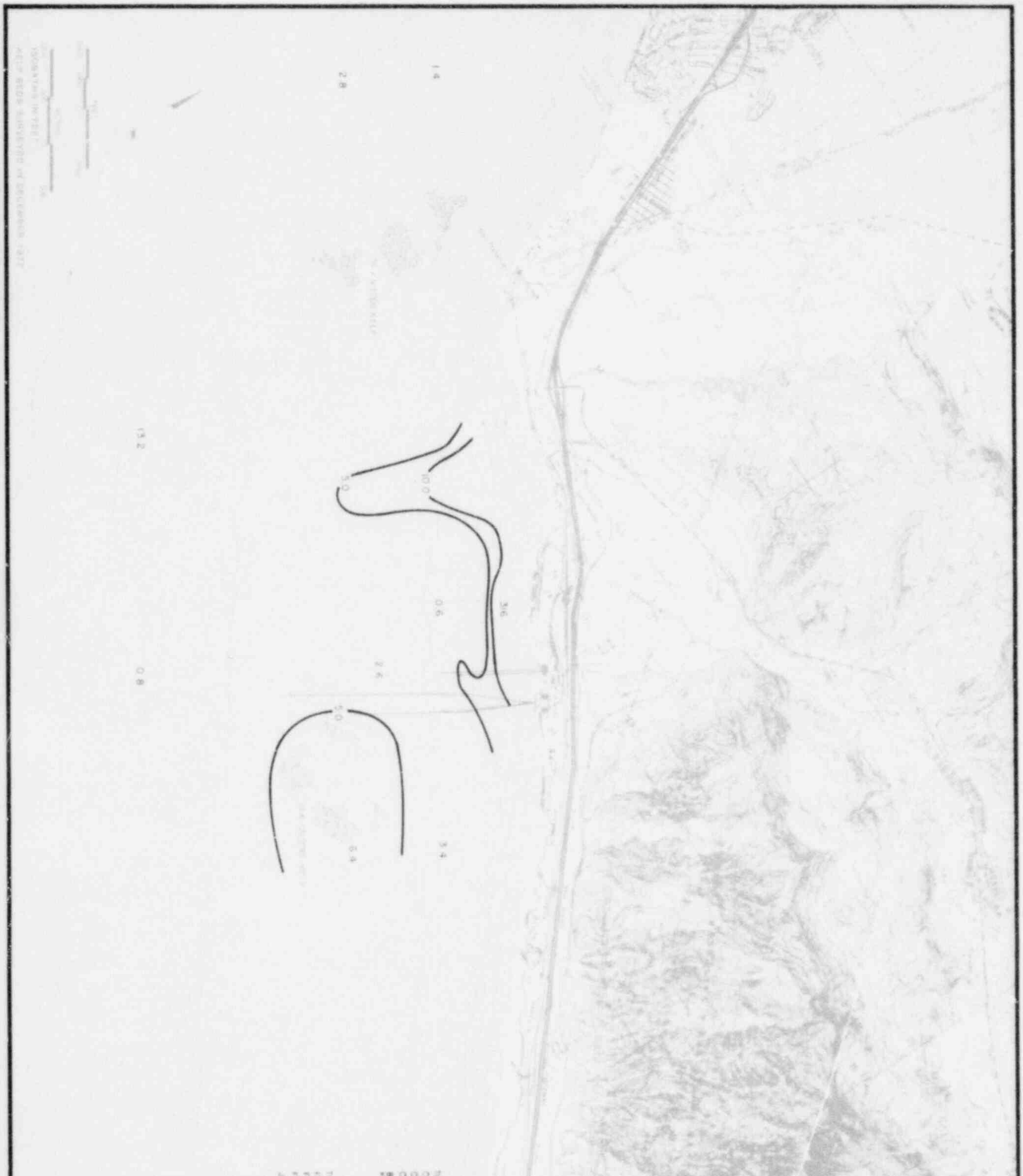

Figure II-29. Mid-Depth (4 m) suspended solids concentration contours (mg/ℓ) for 11 July 1979.

Figure II-30. Surface suspended solids concentration contours (mg/ℓ) for 5 September 1979.

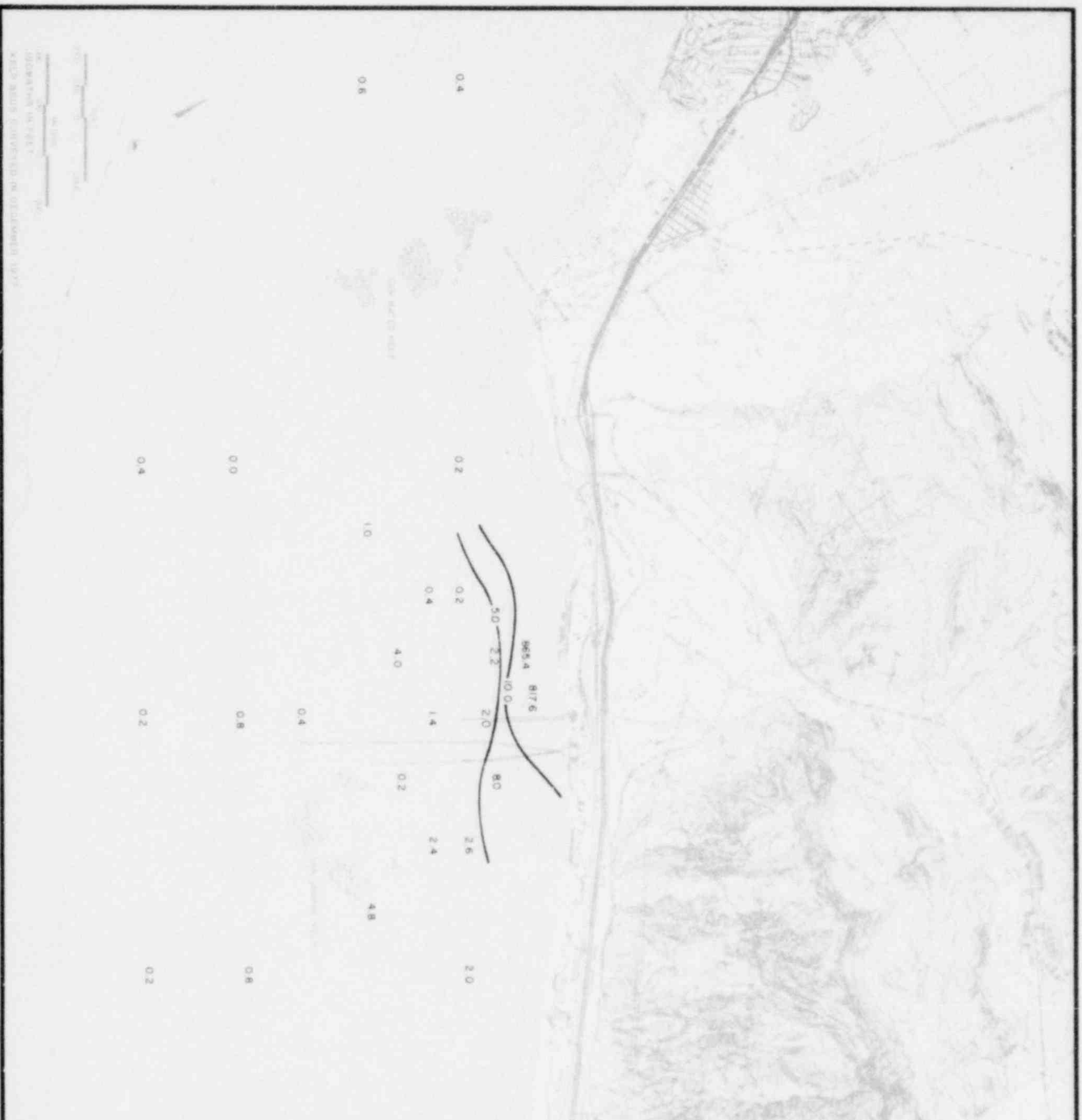

Figure II-31. Mid-Depth (4 m) suspended solids concentration contours (mg/ℓ) for 5 September 1979.

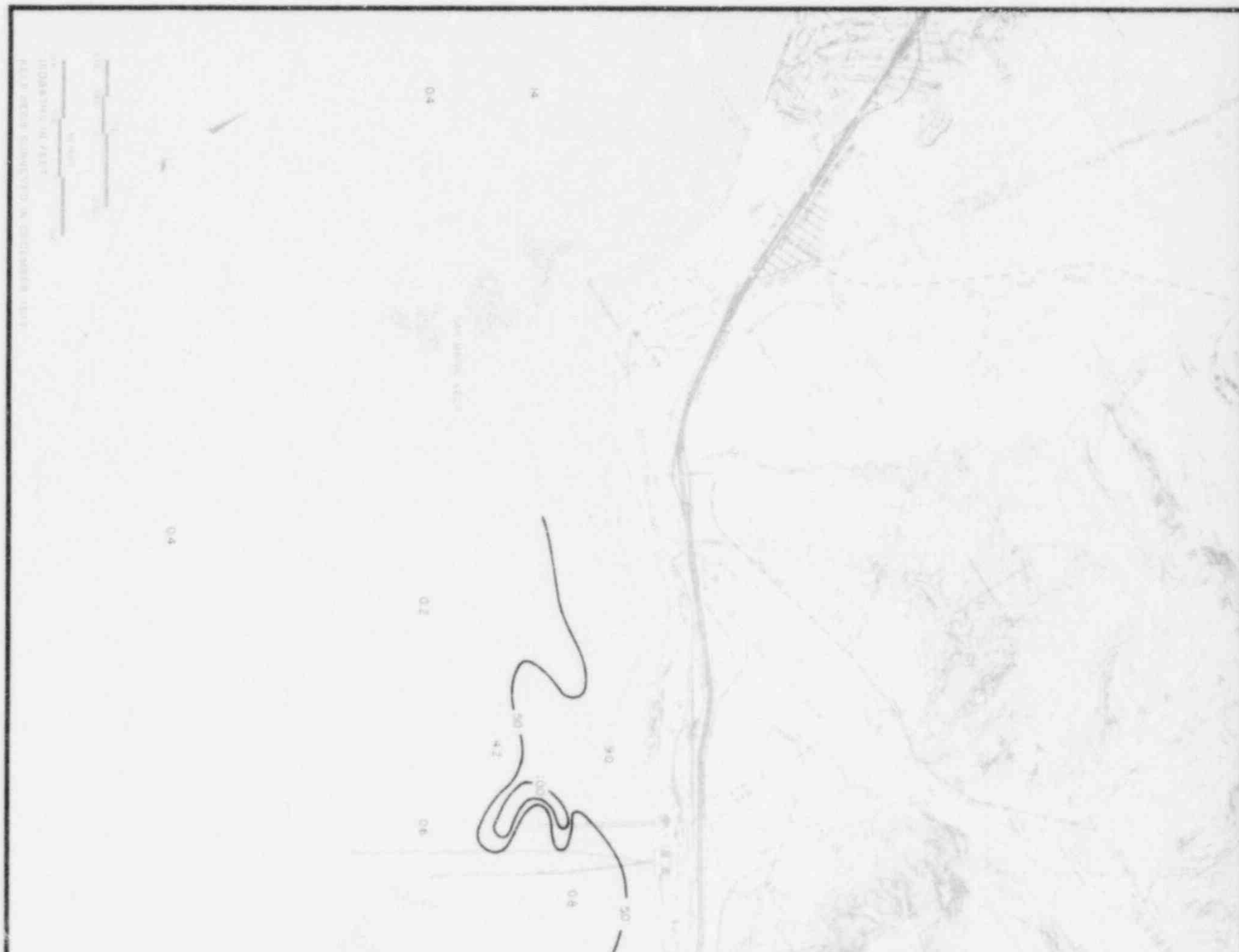

Figure II-32. Surface suspended solids concentration contours (mg/ℓ) for 7 November 1979.

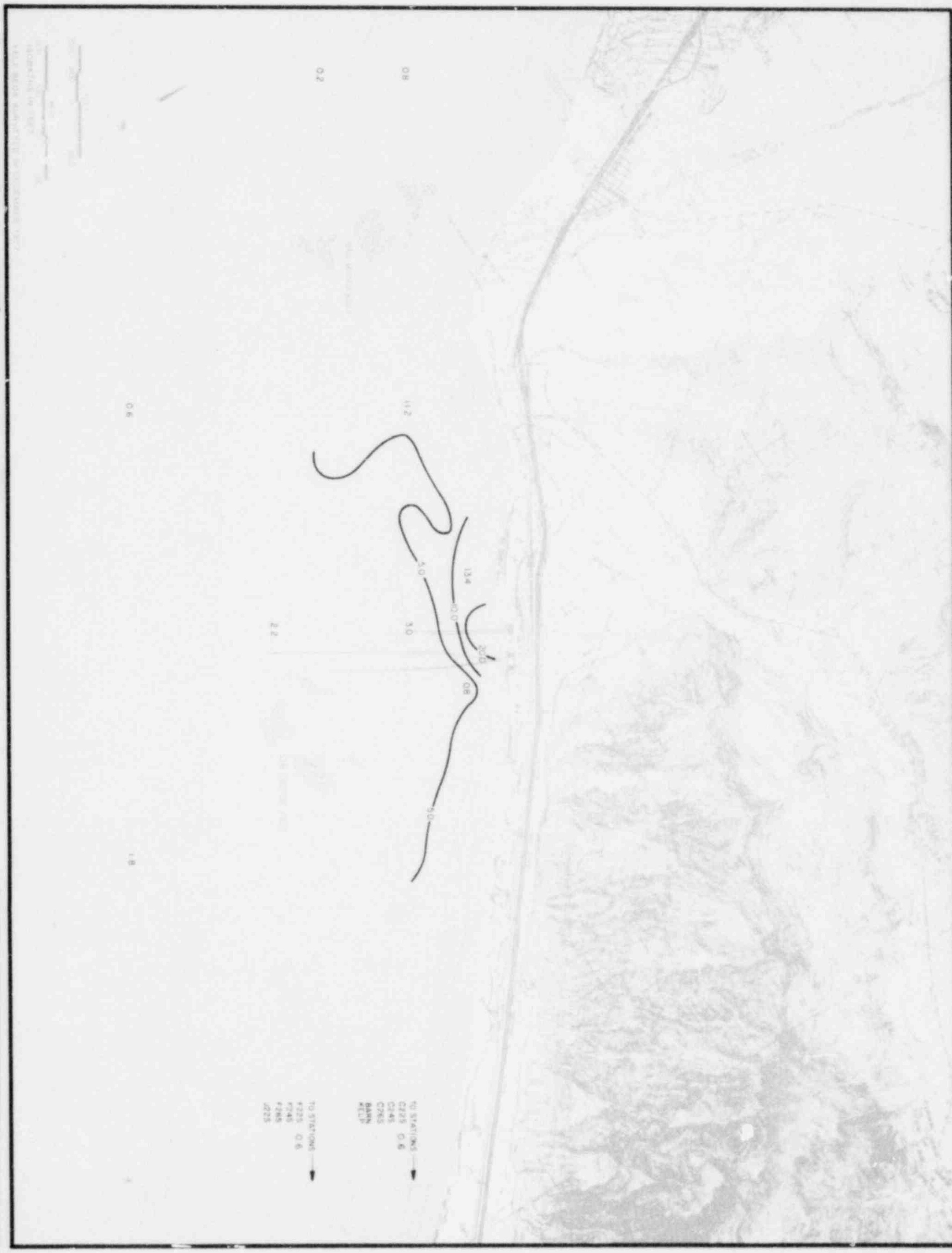

Figure II-33. Mid-Depth (4 m) suspended solids concentration contours (mg/ℓ) for 7 November 1979.

Figure II-34. Surface settleable solids concentration contours (mg/ℓ/hr) for 11 January 1979.

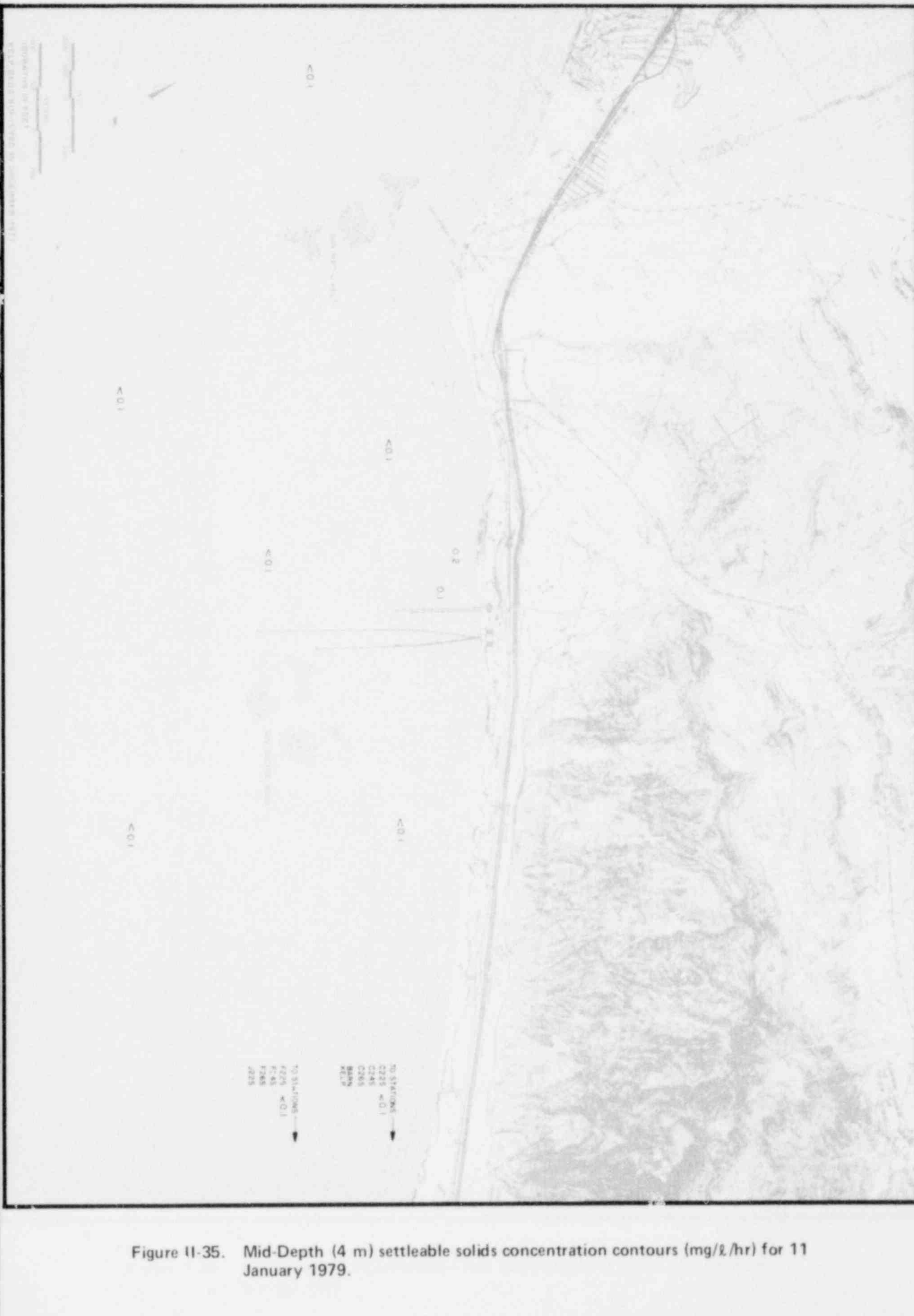

Figure II-35. Mid-Depth (4 m) settleable solids concentration contours (mg/ℓ/hr) for 11 January 1979.

Figure II-36. Surface settleable solids concentration contours (mg/ℓ/hr) for 14 March 1979.

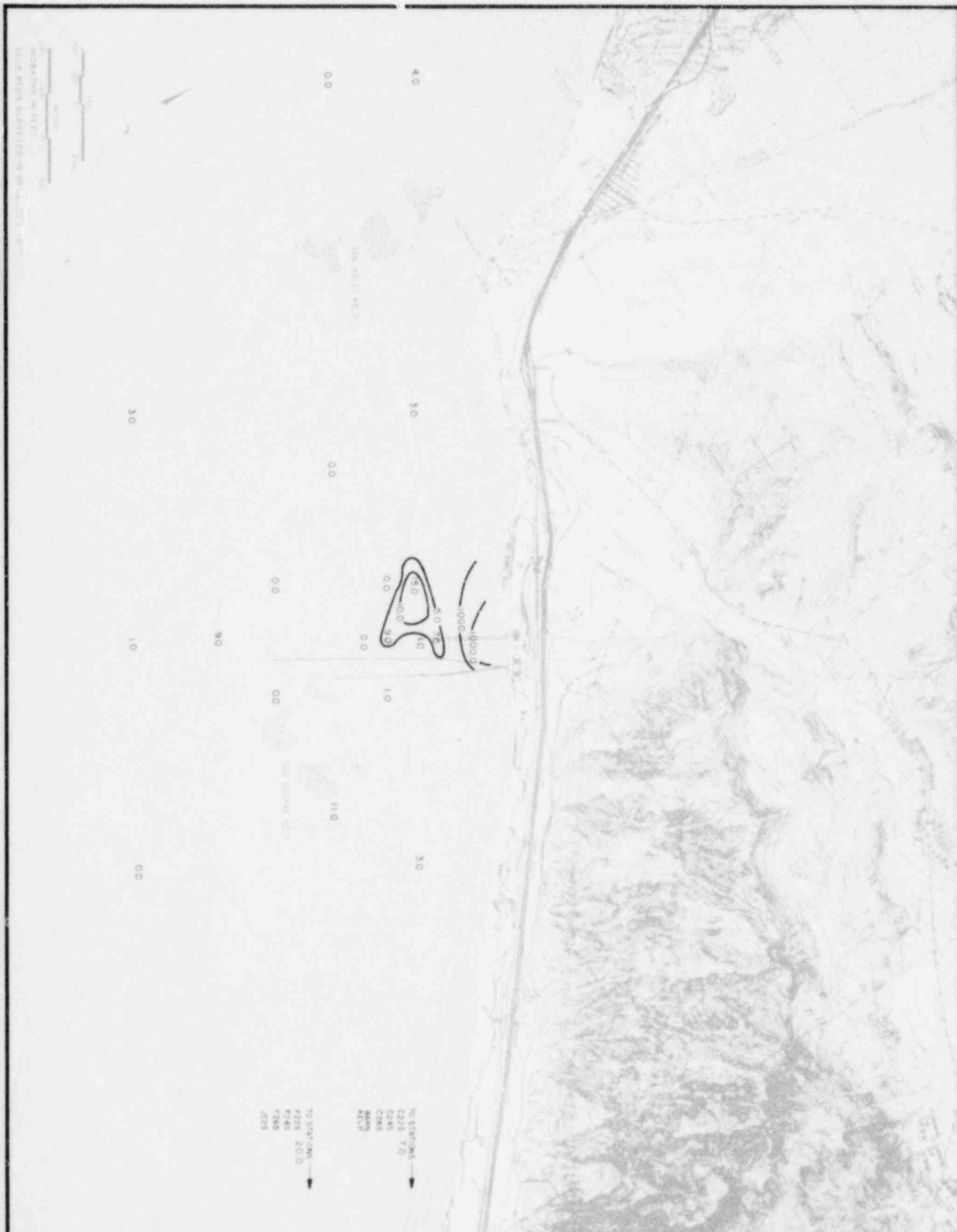

Figure II-37. Mid-Depth (4 m) settleable solids concentration contours (mg/ℓ/hr) for 14 March 1979.

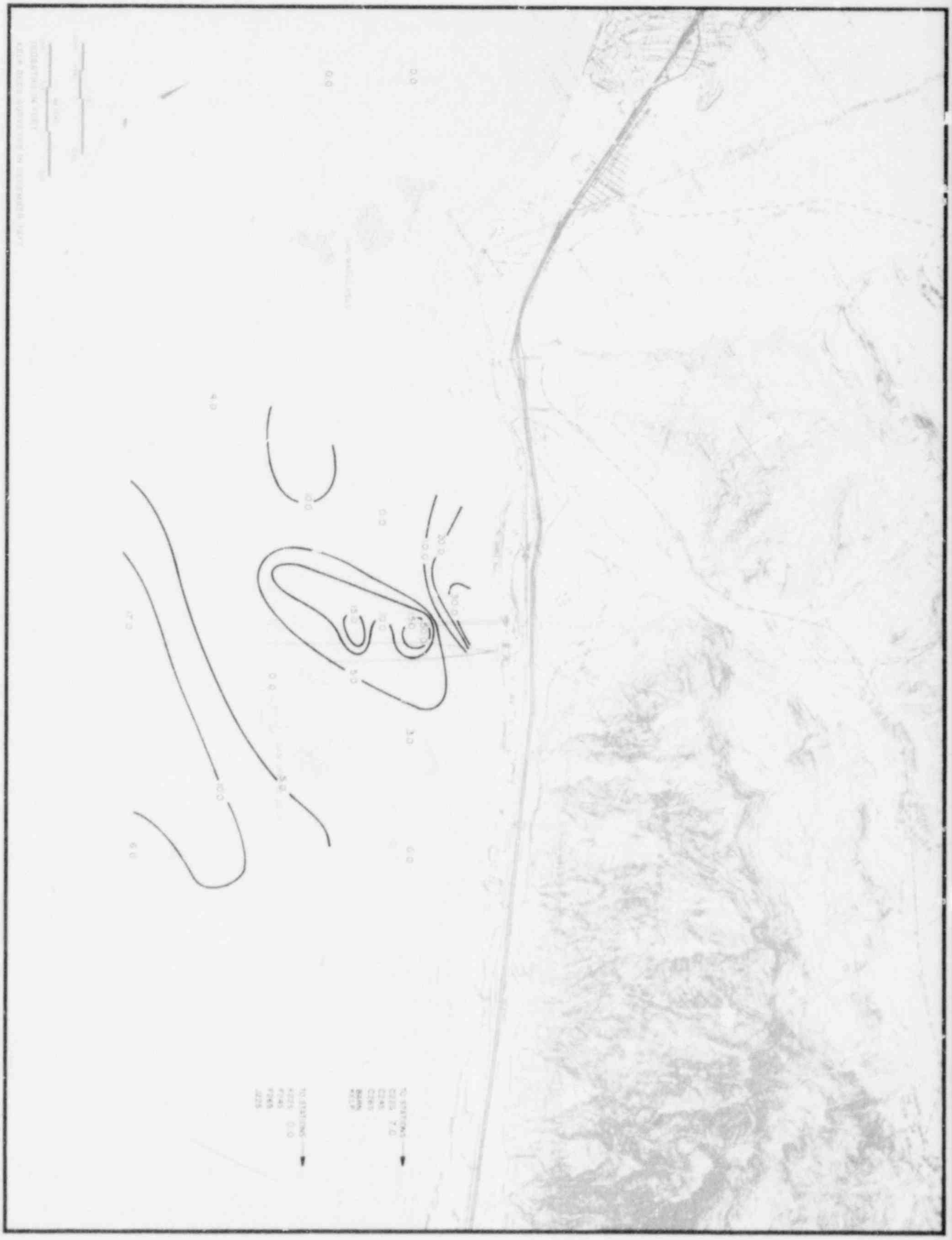

Figure II-38. Surface settleable solids concentration contours (mg/ℓ/hr) for 16 May 1979.

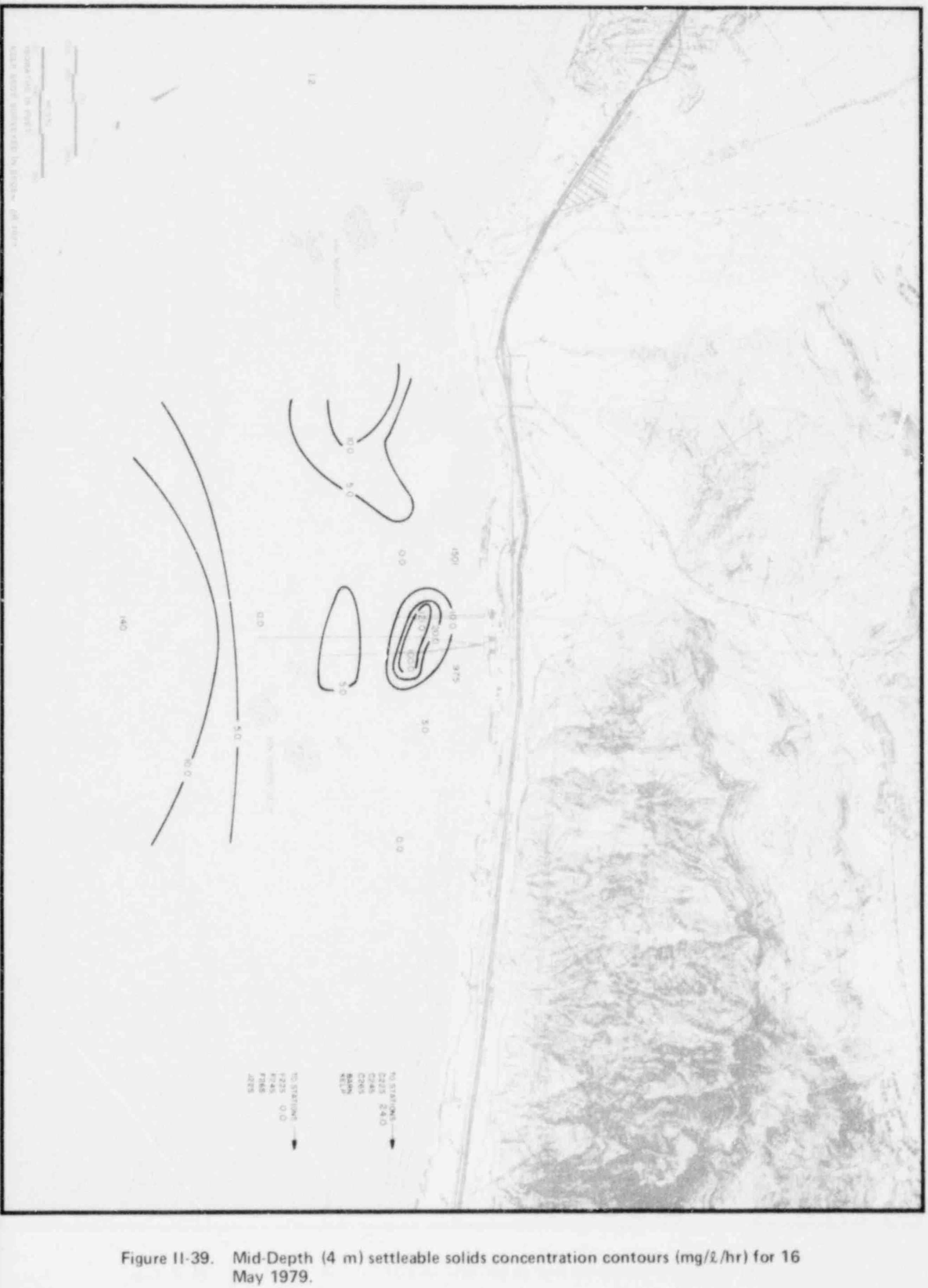

Figure II-39. Mid-Depth (4 m) settleable solids concentration contours (mg/ℓ/hr) for 16 May 1979.

Figure II-40. Surface settleable solids concentration contours (mg/ℓ/hr) for 11 July 1979.

Figure II-41. Mid-Depth (4 m) settleable solids concentration contours (mg/ℓ/hr) for 11 July 1979.

Figure II-42. Surface settleable solids concentration contours (mg/ℓ/hr) for 5 September 1979.

Figure II-43. Mid-Depth (4 m) settleable solids concentration contours (mg/ℓ/hr) for 5 September 1979.

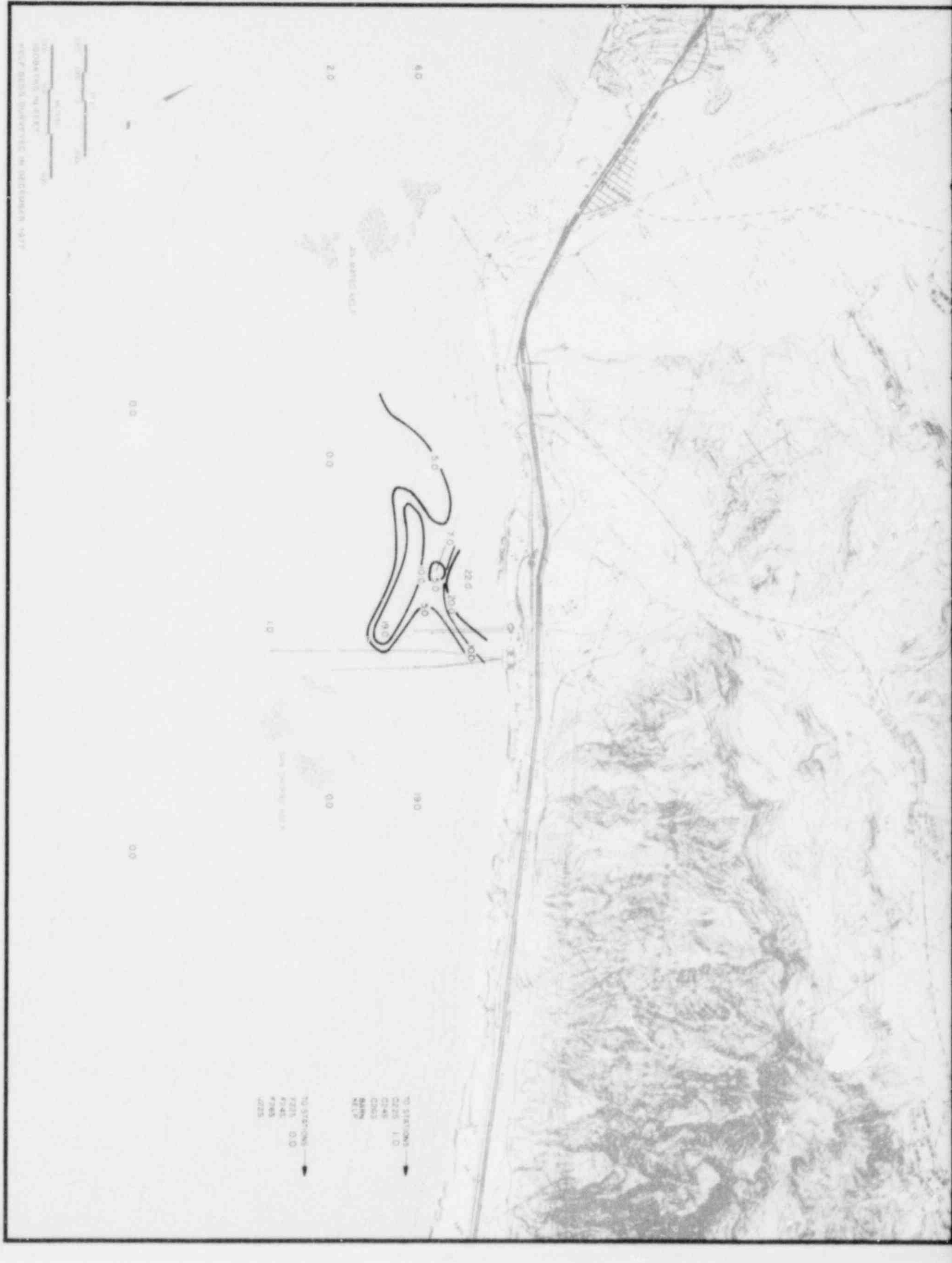

Figure II-44. Surface settleable solids concentration contours (mg/ℓ/hr) for 7 November 1979.

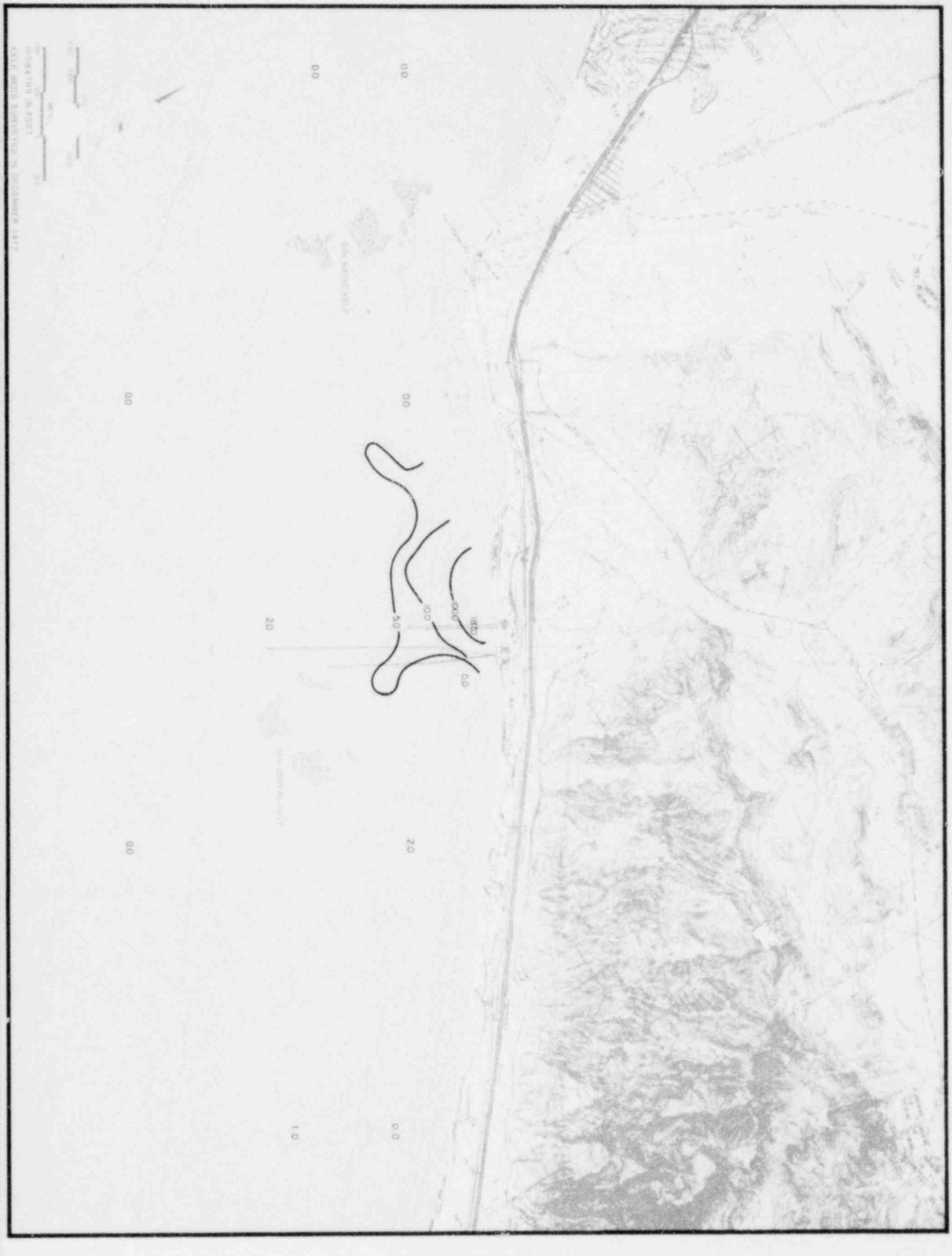

Figure II-45. Mid-Depth (4 m) settleable solids concentration contours (mg/ℓ/hr) for 7 November 1979.

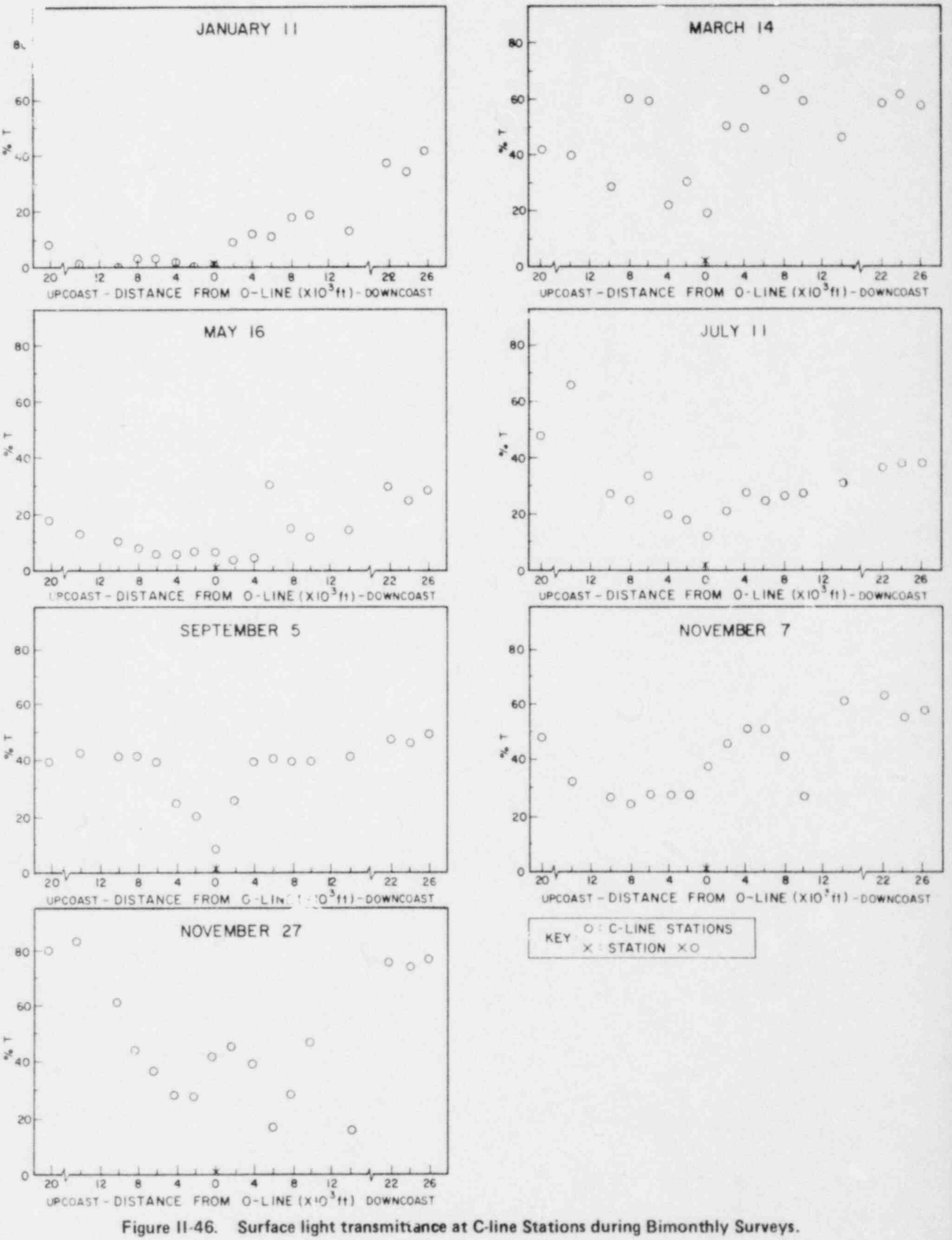

Figure II-46. Surface light transmittance at C-line Stations during Bimonthly Surveys.

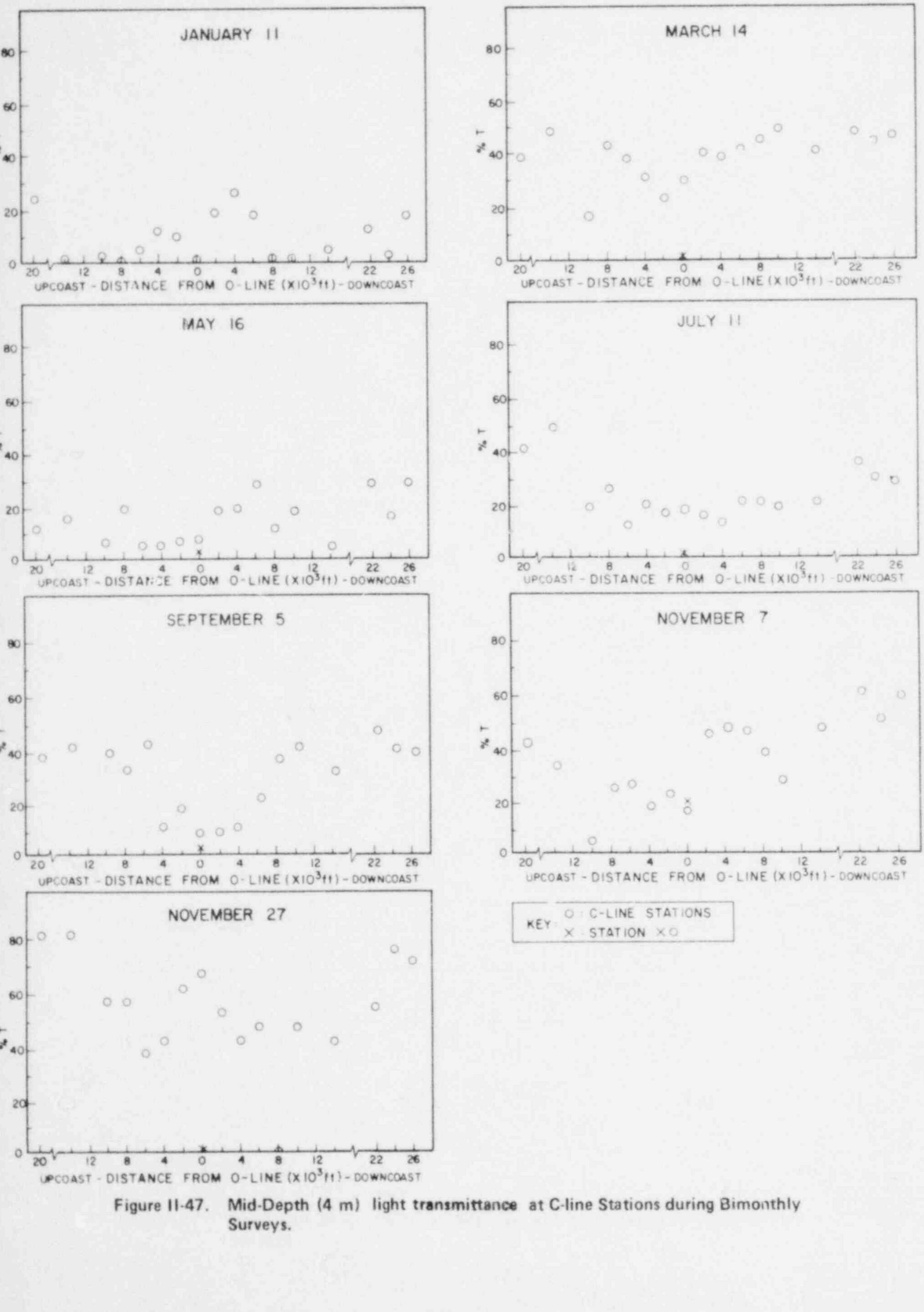

Figure II-47. Mid-Depth (4 m) light transmittance at C-line Stations during Bimonthly Surveys.

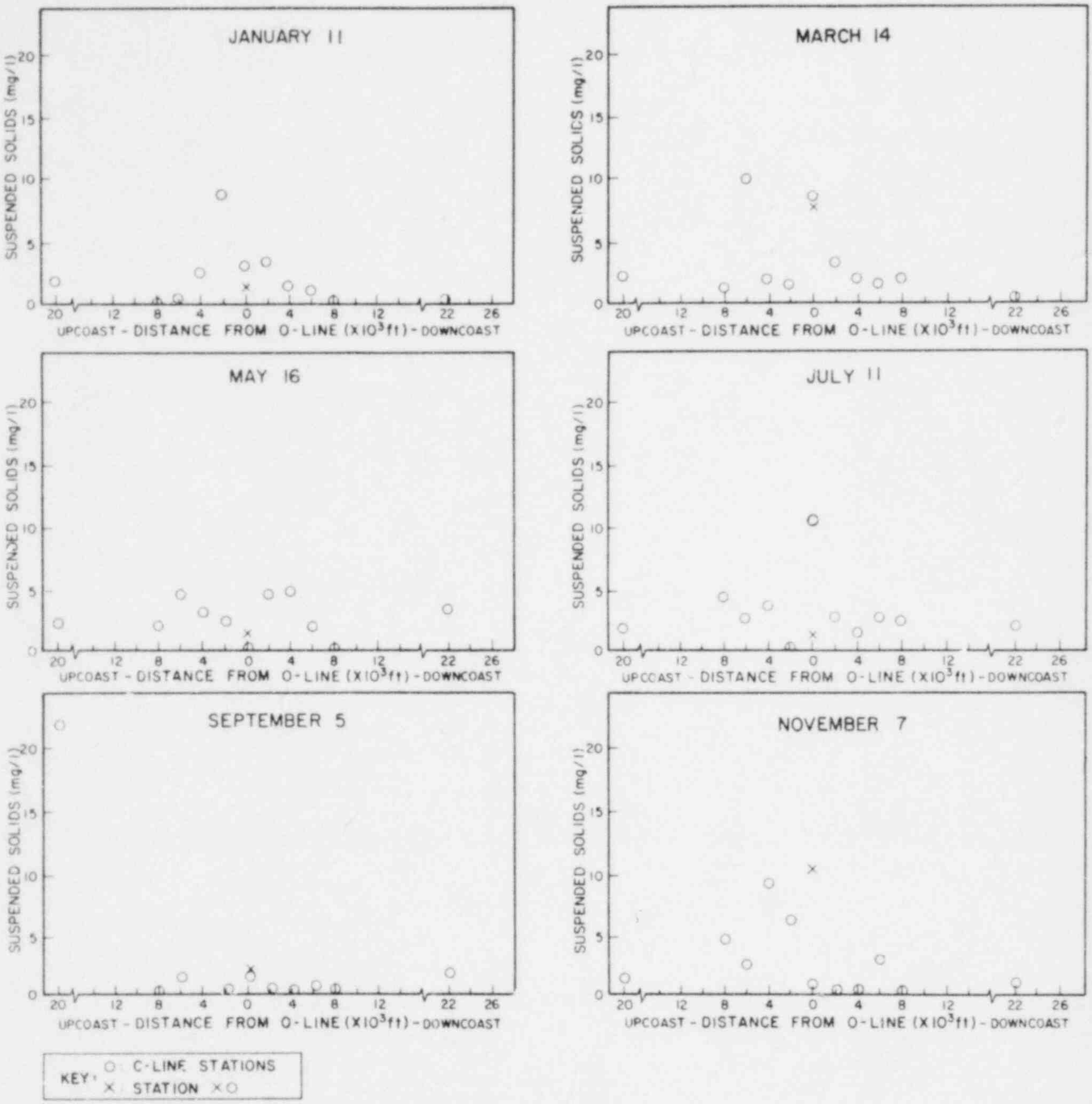

Figure II-48. Surface suspended solids concentrations at C-line Stations during Bimonthly Surveys.

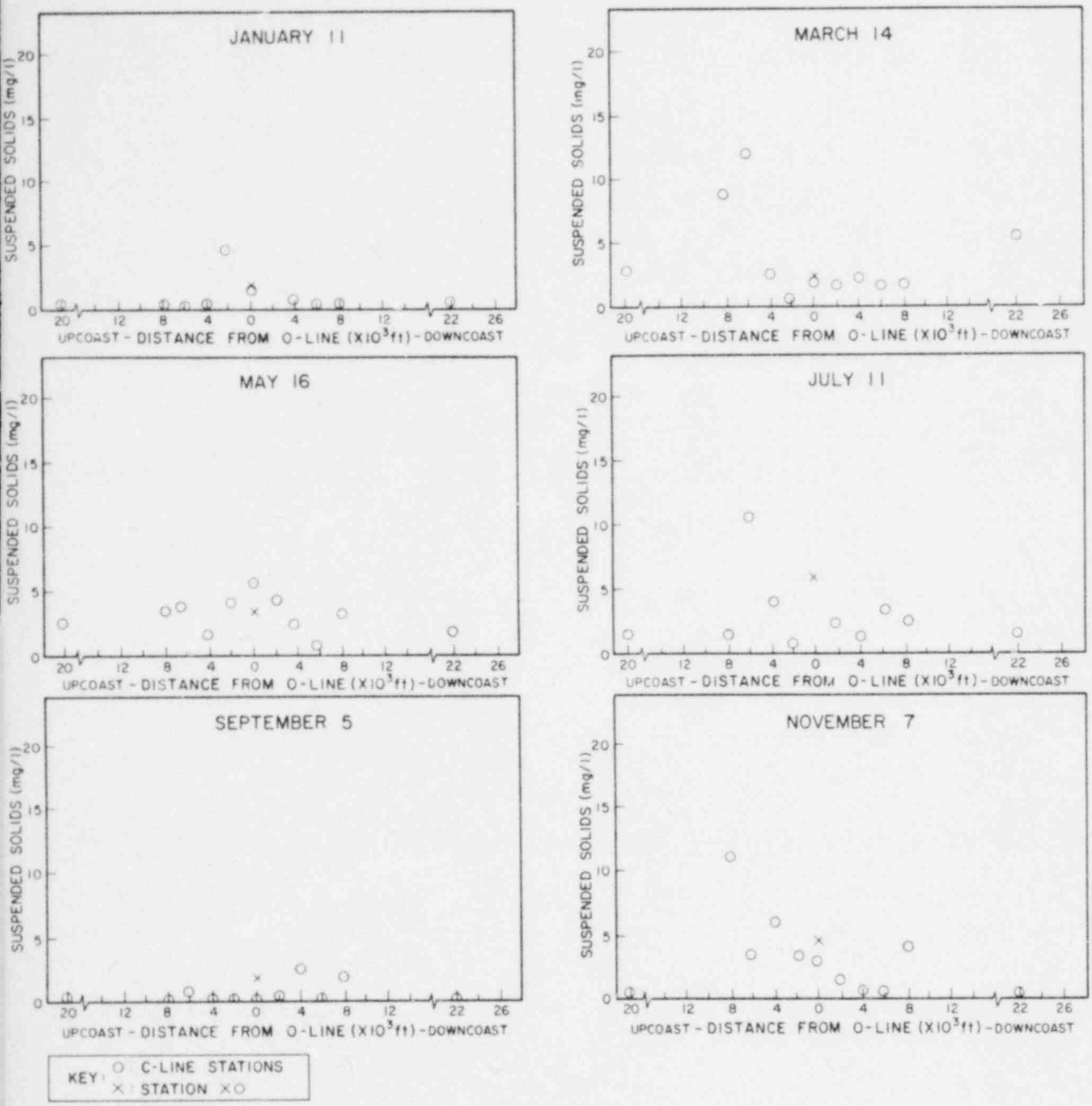

Figure II-49. Mid-Depth (4 m) suspended solids concentrations at C-line Stations during Bimonthly Surveys.

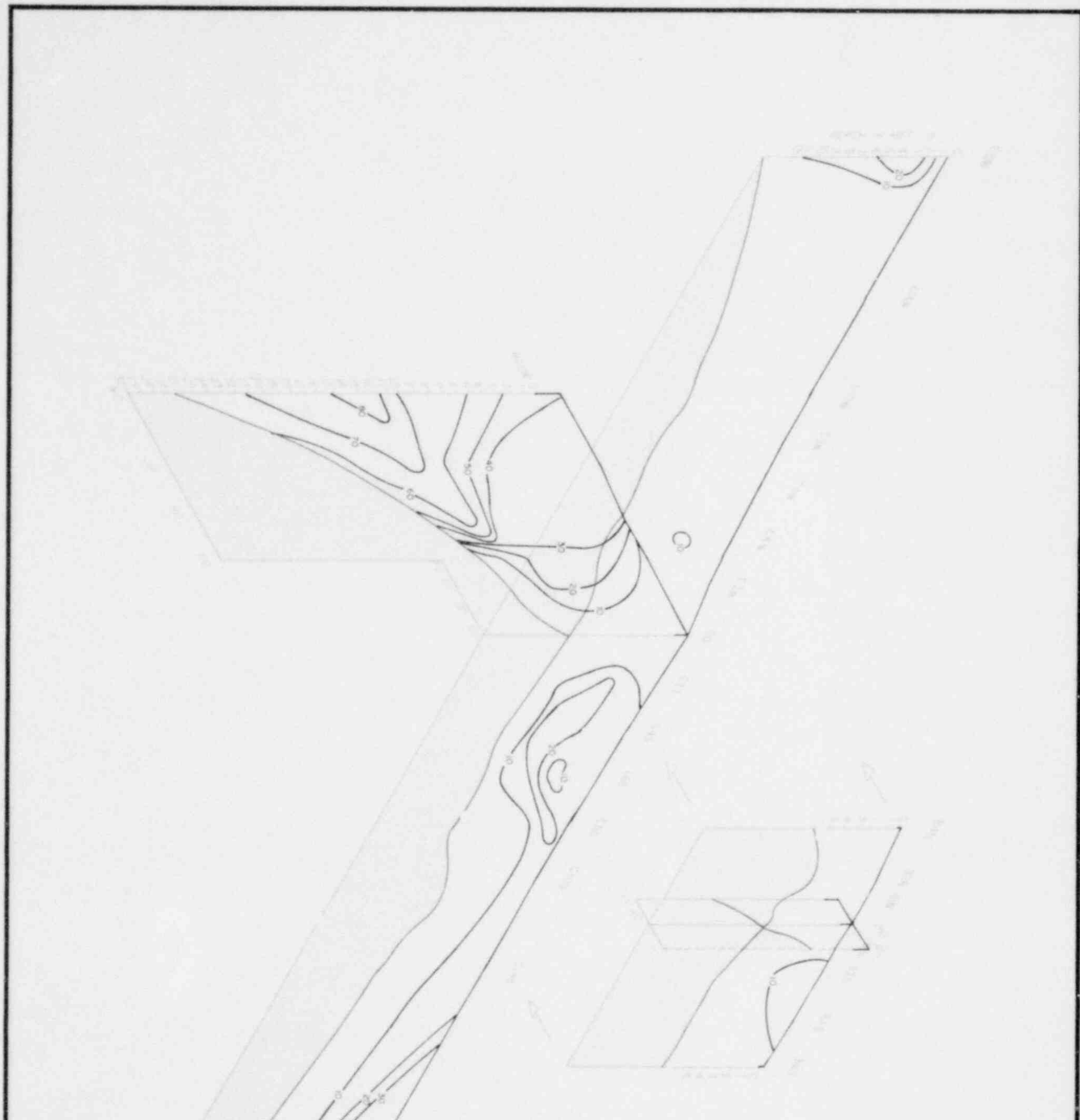

Figure II-50. Isometric vertical cross-sections of percent light transmittance for 11 January 1979.

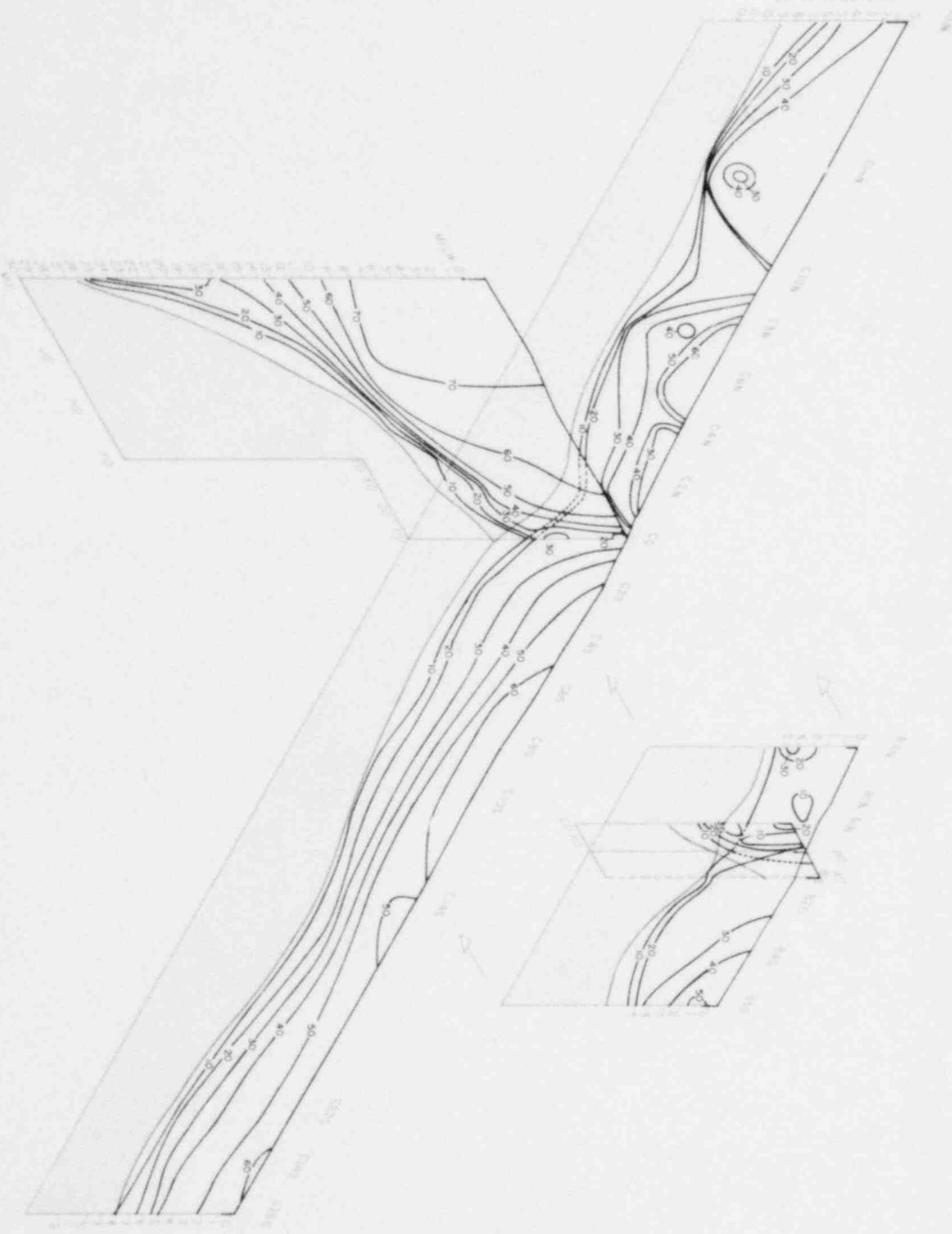

Figure II-51. Isometric vertical cross-sections of percent light transmittance for 14 March 1979.

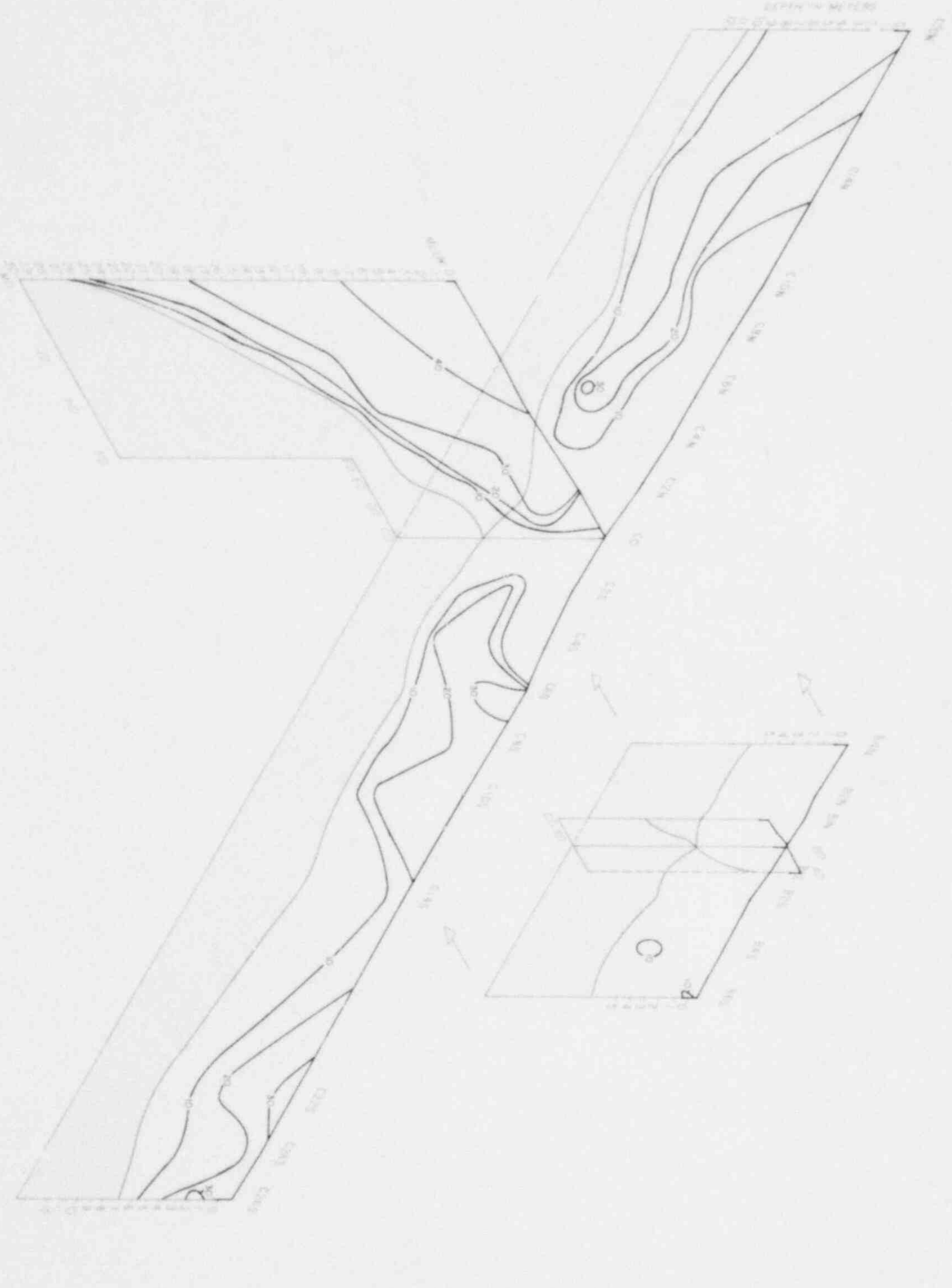

Figure II-52. Isometric vertical cross-sections of percent light transmittance for 16 May 1979.

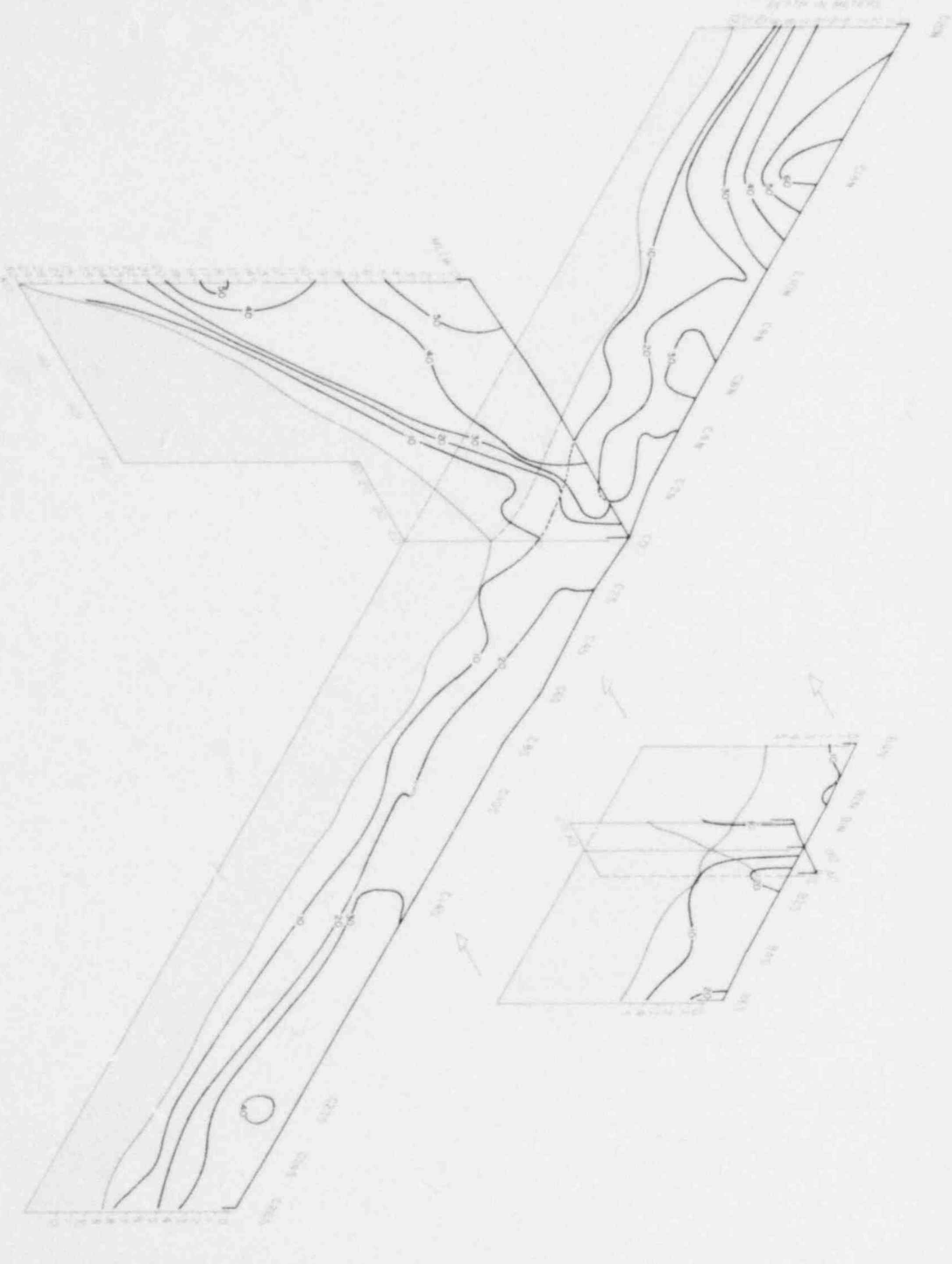

Figure II-53. Isometric vertical cross-sections of percent light transmittance for 11 July 1979.

Figure II-54. Isometric vertical cross-sections of percent light transmittance for 5 September 1979.

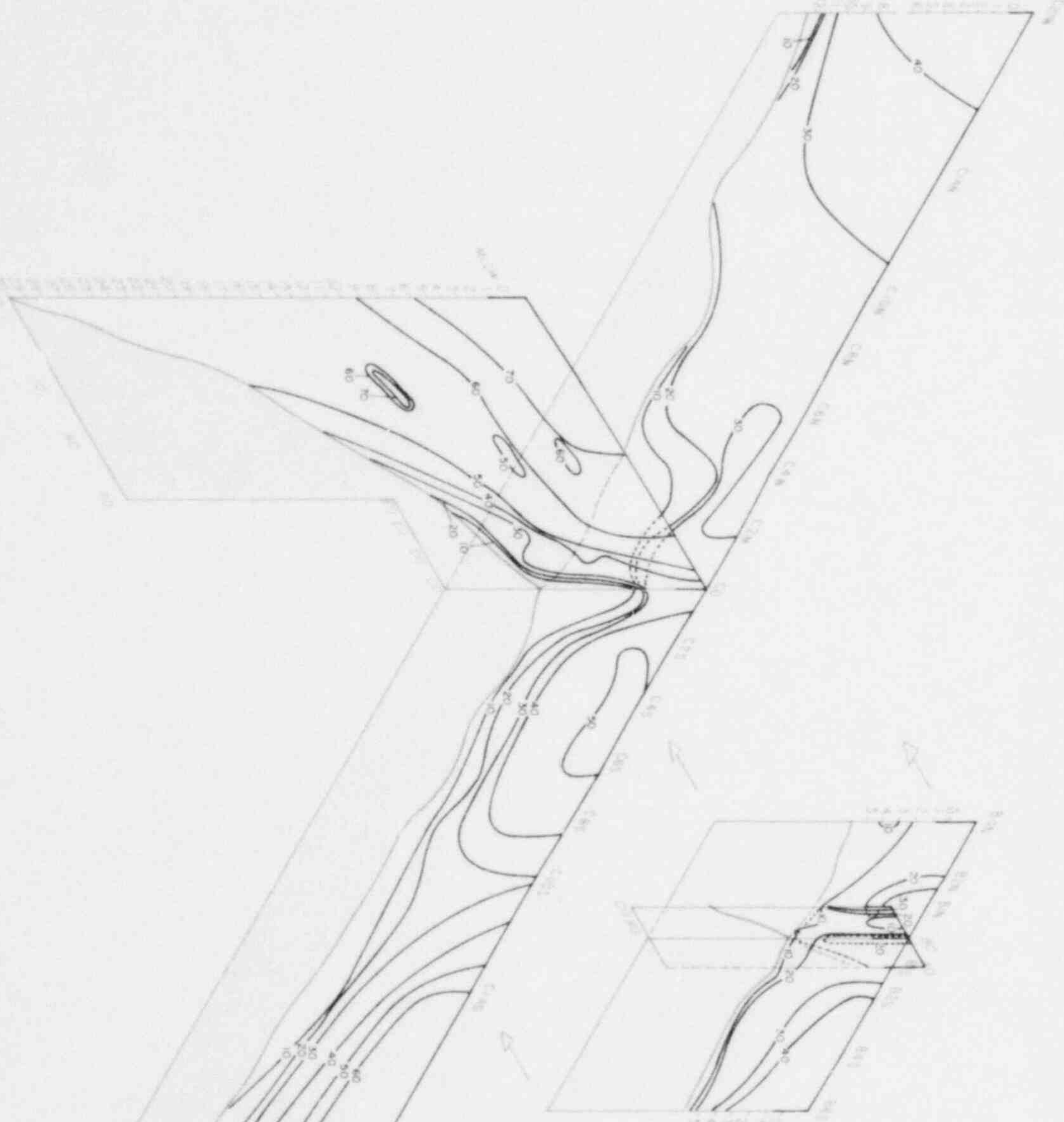

Figure II-55. Isometric vertical cross-sections of percent light transmittance for 7 November 1979.

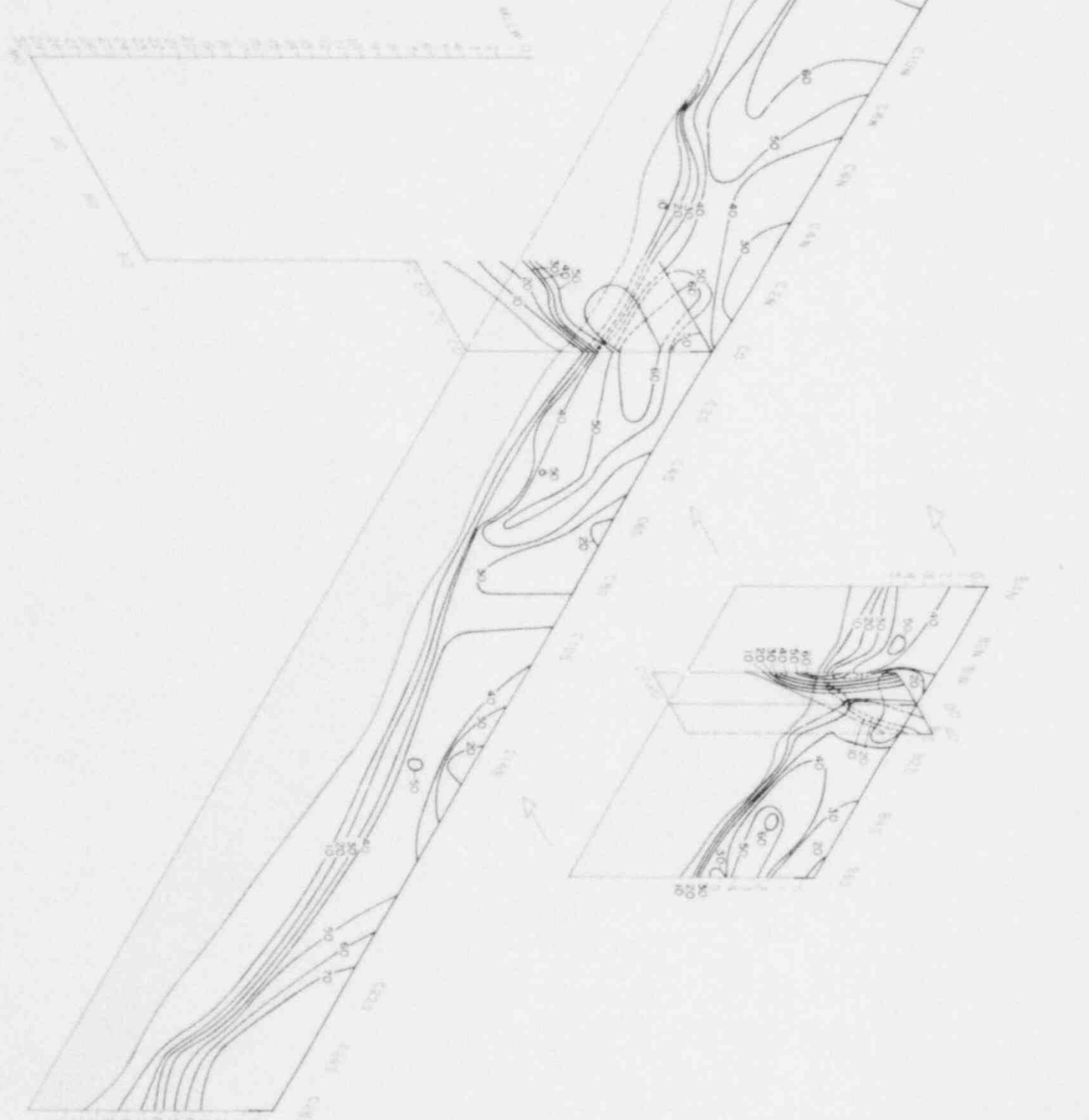

Figure II-56. Isometric vertical cross-sections of percent light transmittance for 27 November 1979.

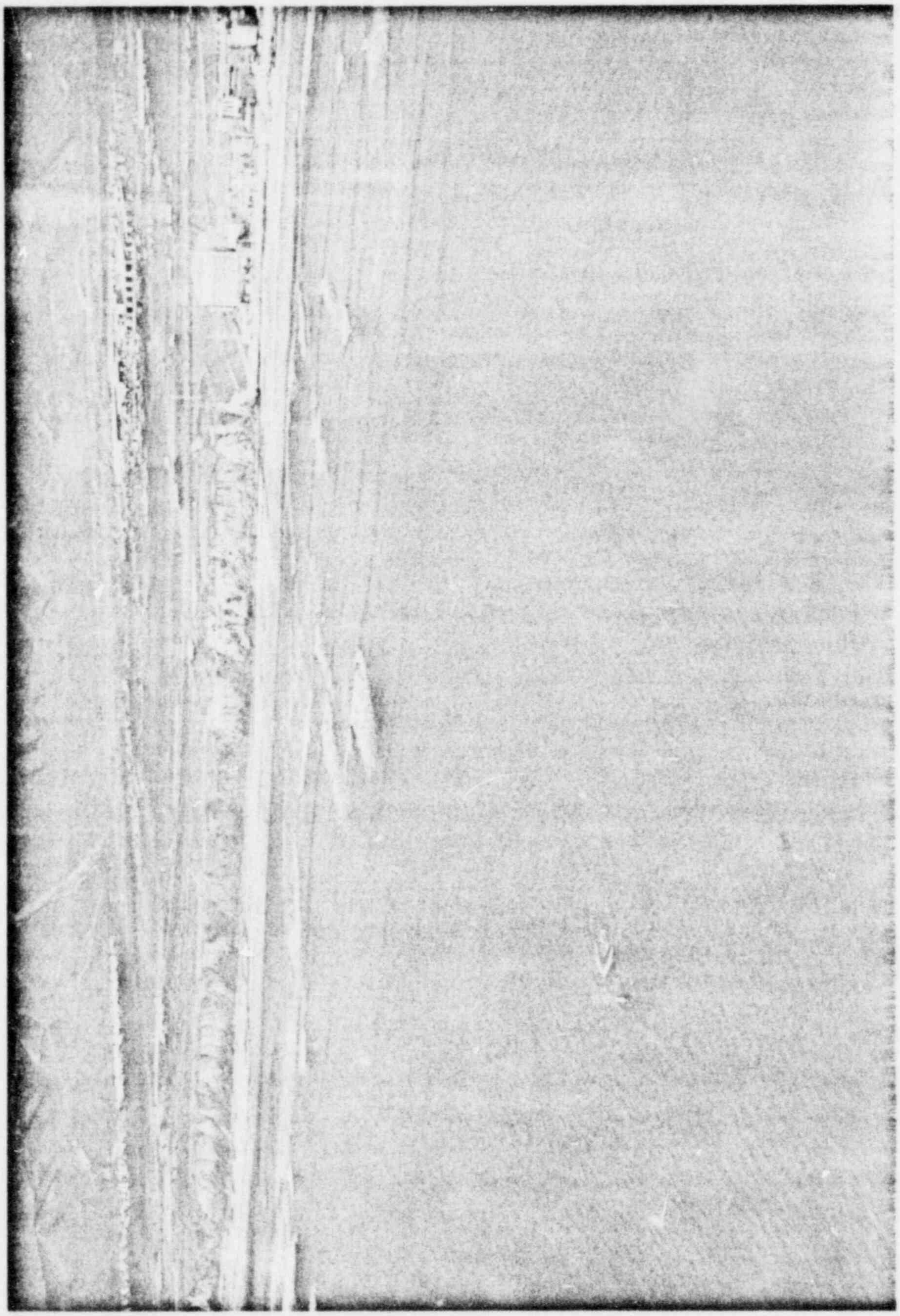

Figure II-57. Aerial photograph showing from 2000 feet downcoast to 600 feet upcoast of the discharge, 11 January 1979.

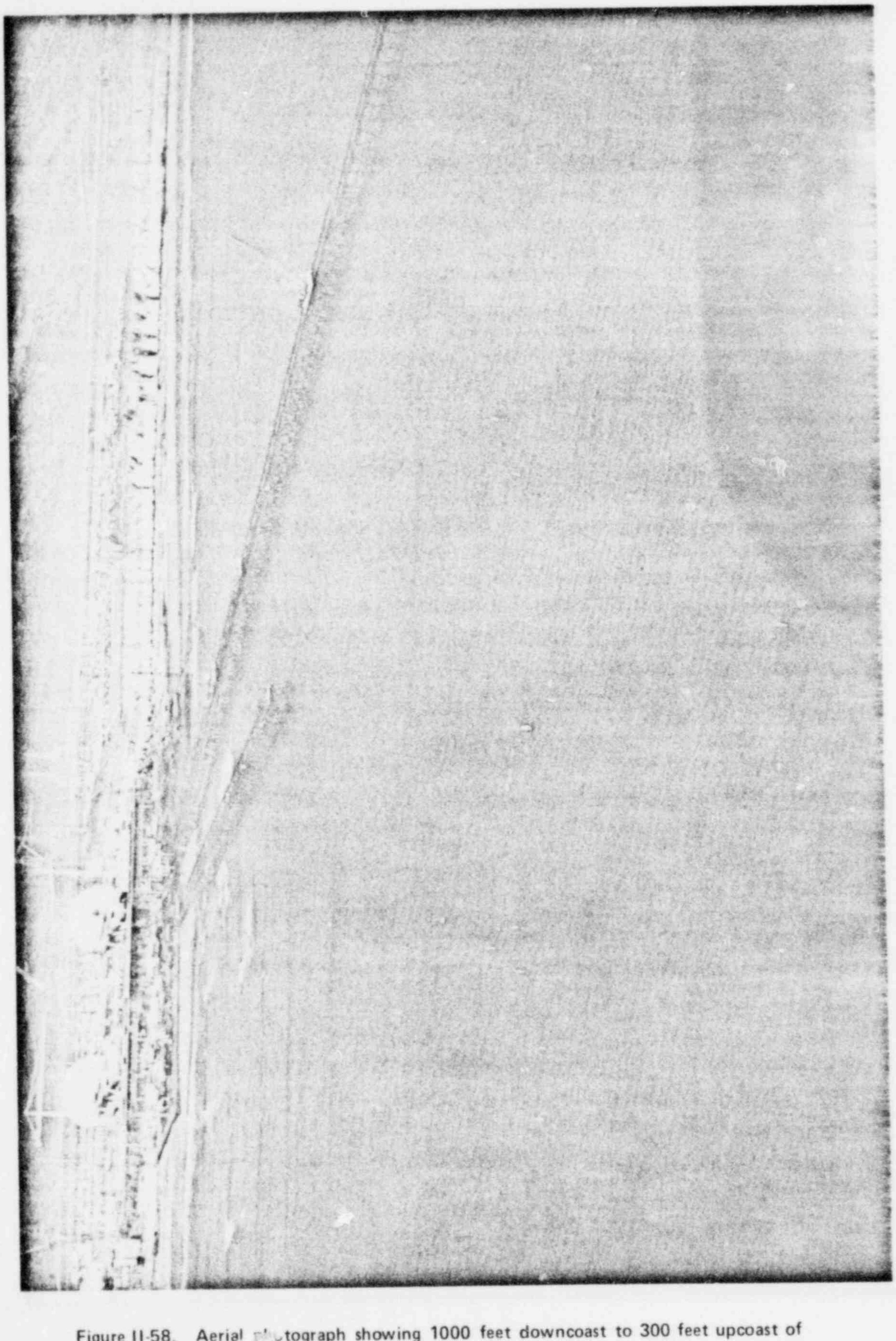

Figure II-58. Aerial photograph showing 1000 feet downcoast to 300 feet upcoast of the discharge, 11 January 1979.

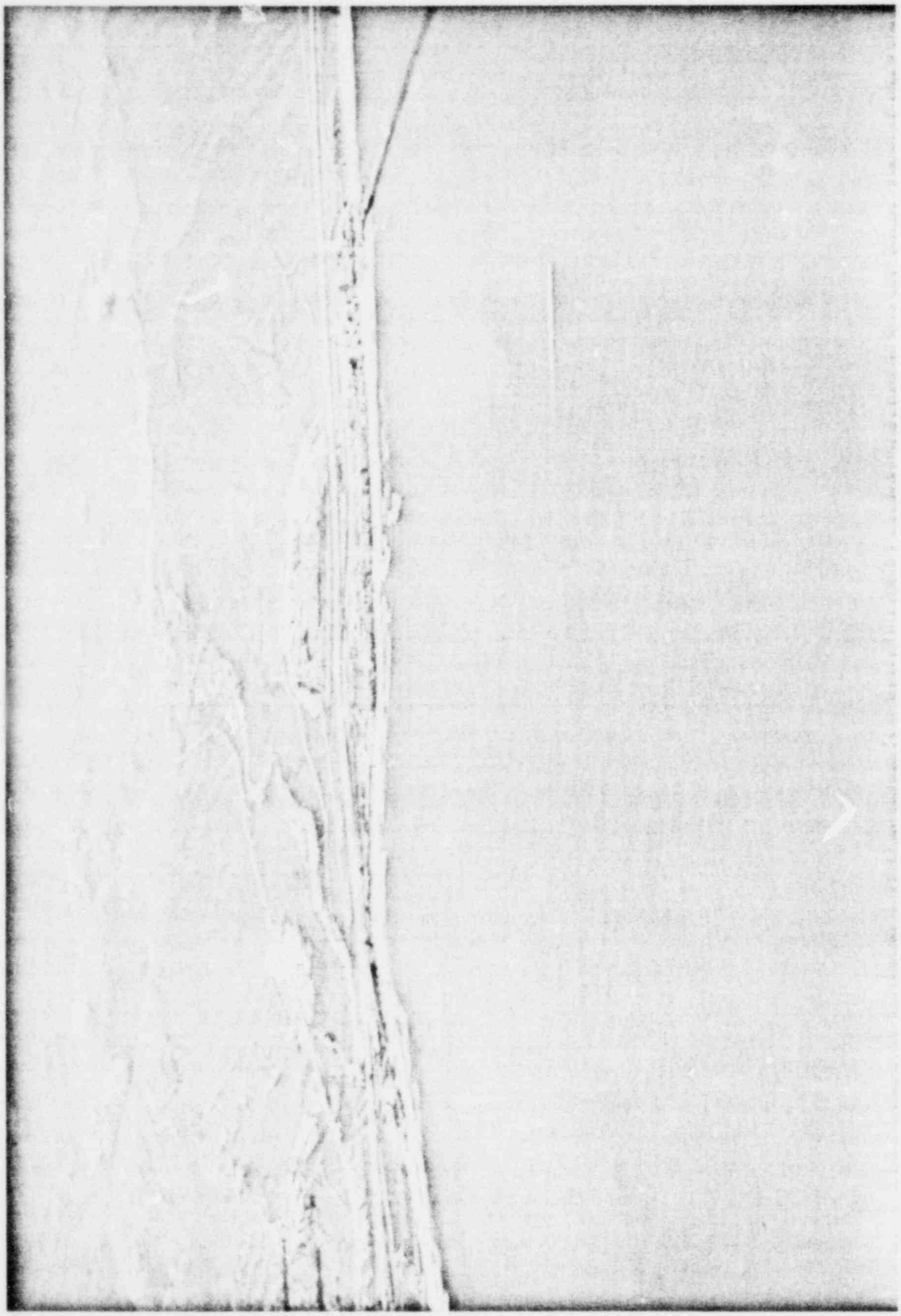

Figure II-59. Aerial photograph showing from the discharge to 8000 feet upcoast, 14 March 1979.

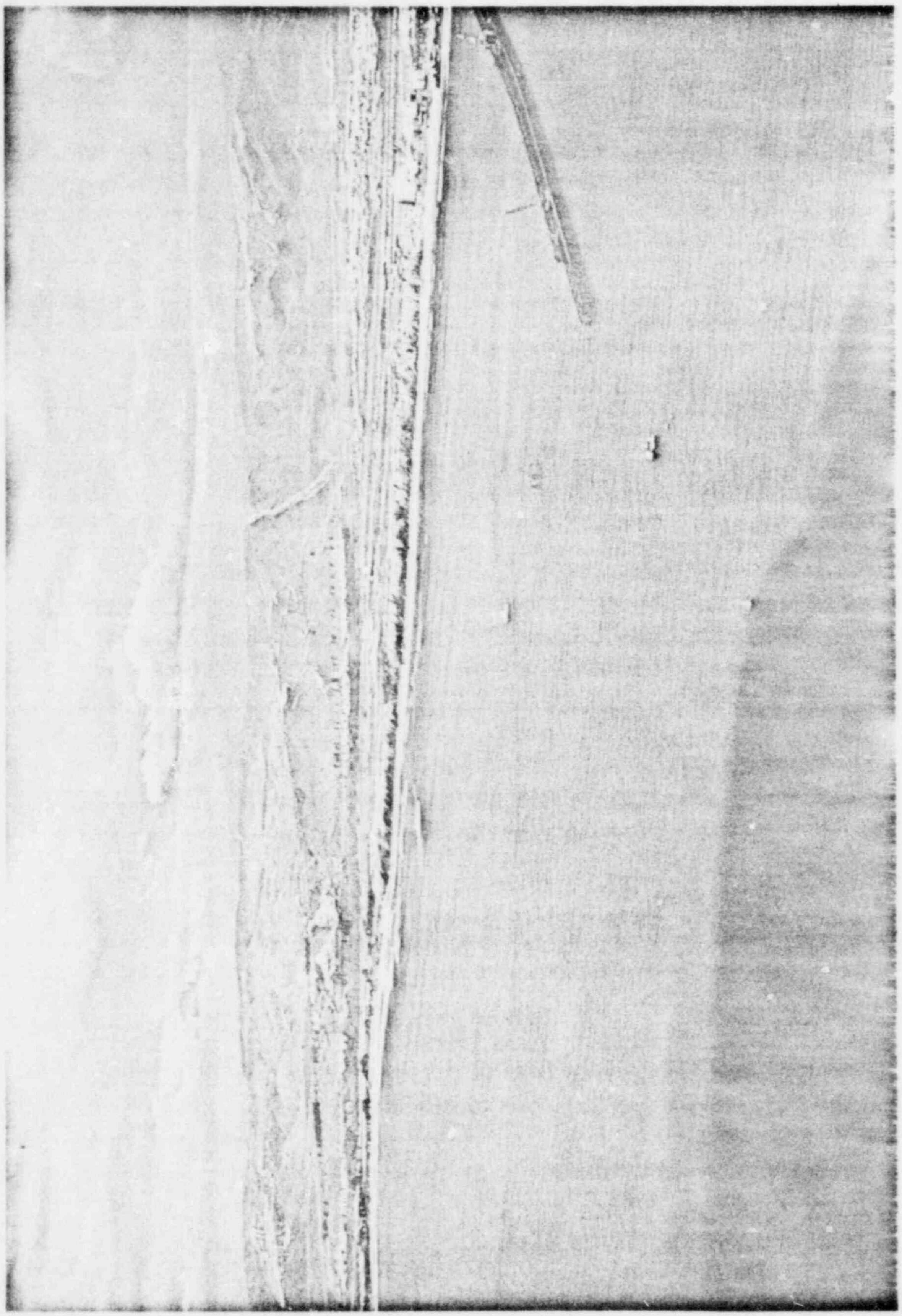

Figure II-60. Aerial photograph showing from 1500 feet downcoast to 7000 feet upcoast of the discharge, 14 March 1979.

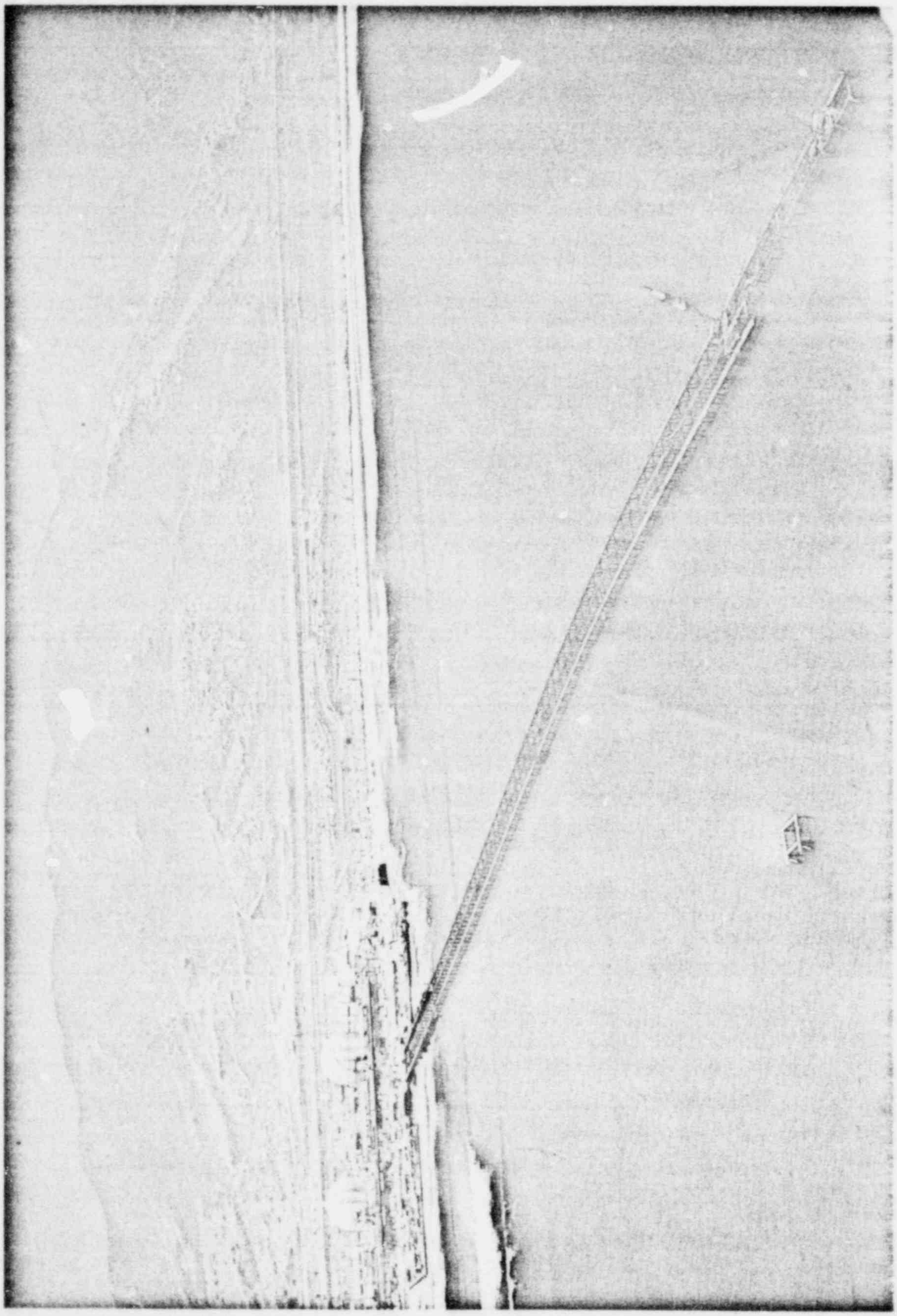

Figure II-61. Aerial photograph showing from 500 feet downcoast to 5000 feet upcoast of the discharge, 1 June 1979.

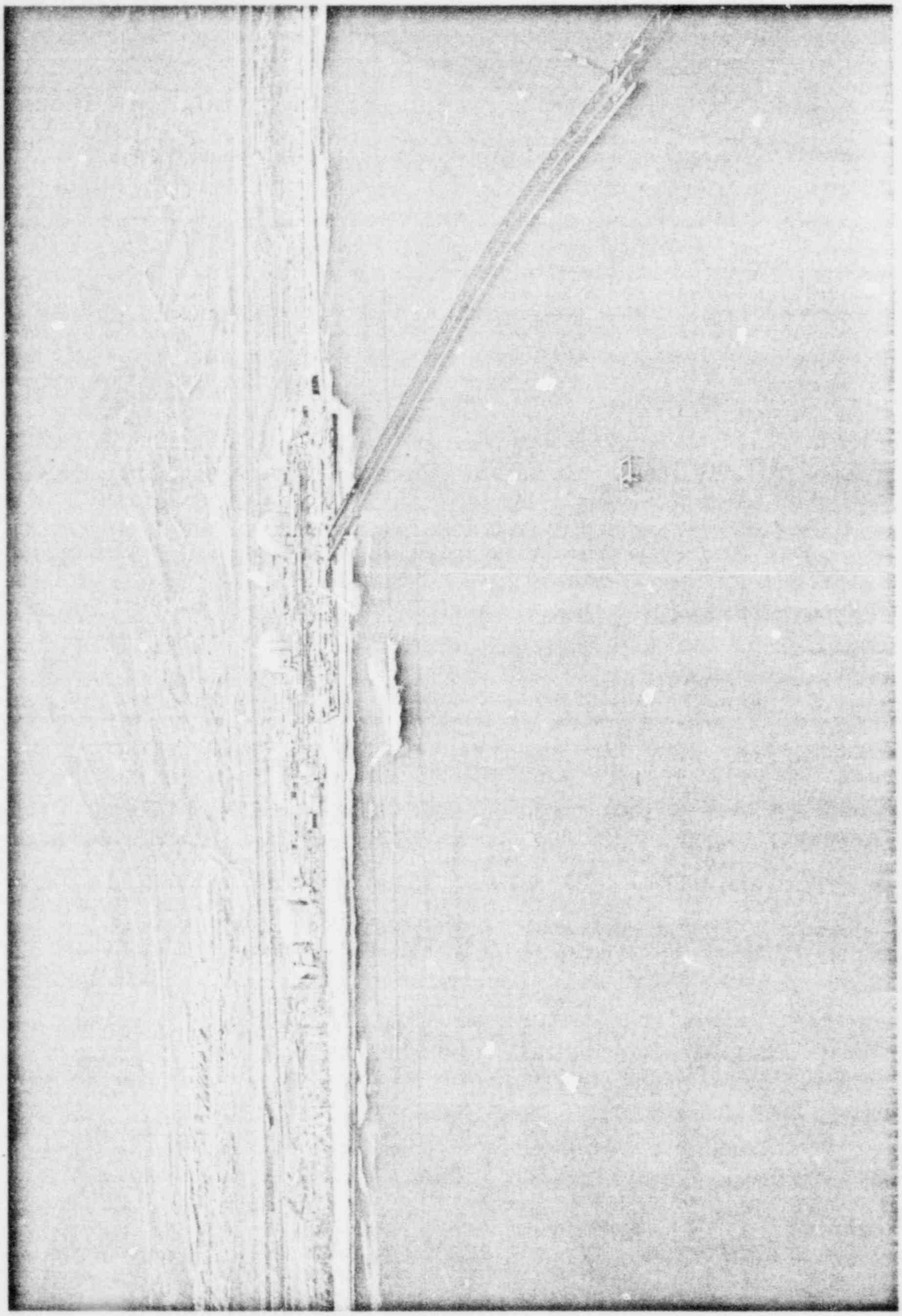

Figure II-62. Aerial photograph showing from 1500 feet downcoast to 1000 feet upcoast of the discharge, 1 June 1979.

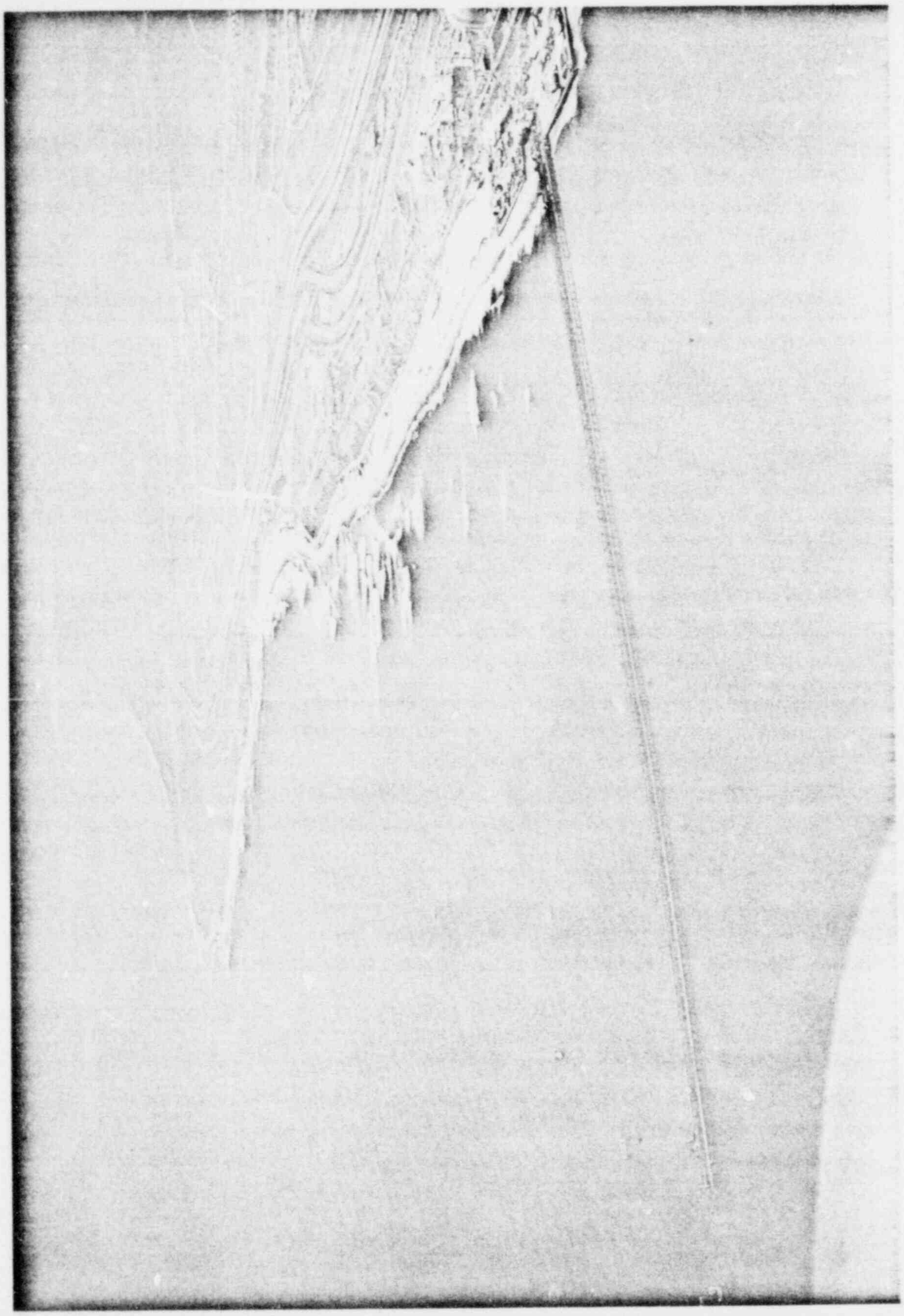

Figure II-63. Aerial photograph showing from 1000 feet downcoast to 8000 feet upcoast of the discharge, 11 July 1979.

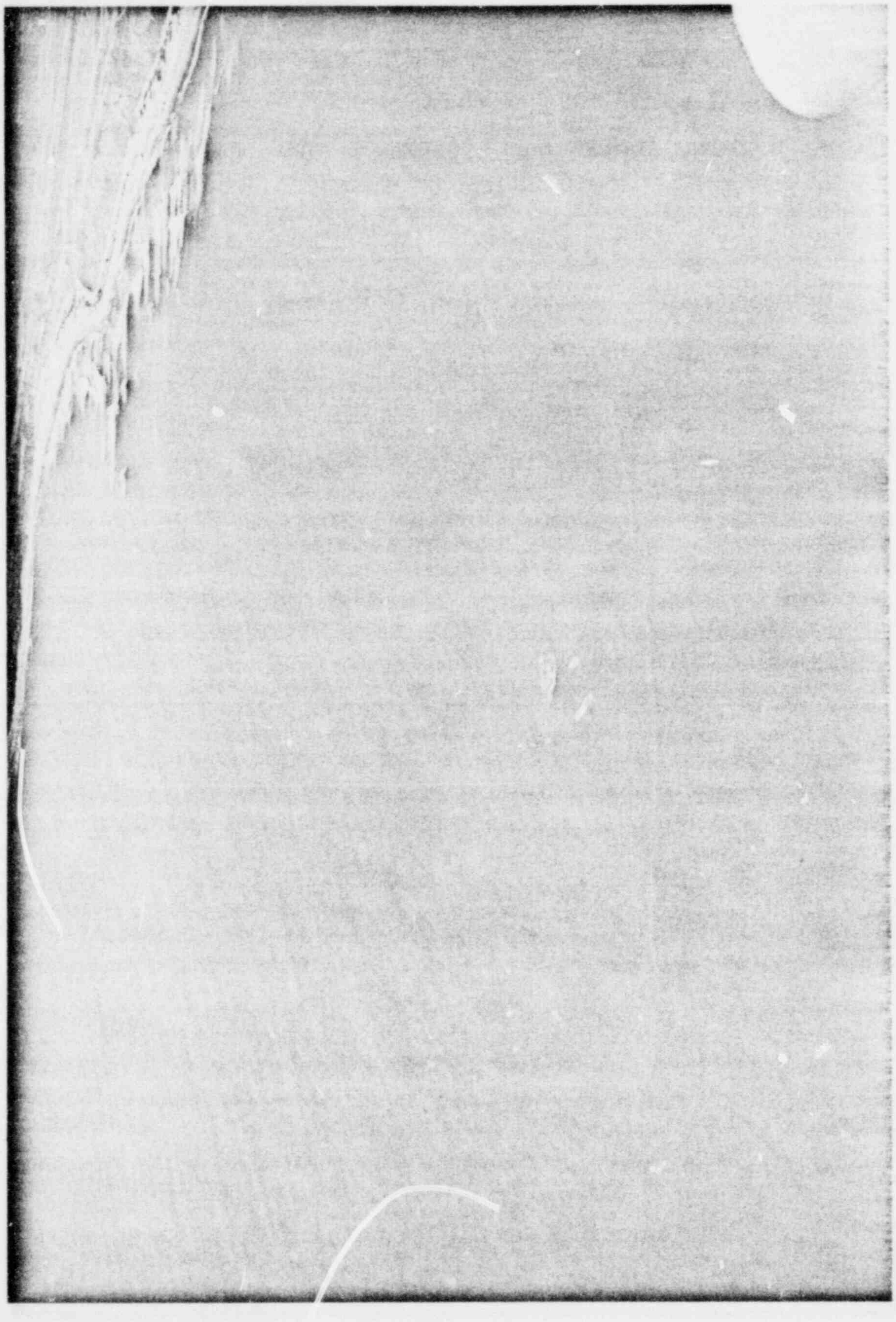

Figure II-64. Aerial photograph showing from 2000 feet downcoast to 12000 feet upcoast of the discharge, 11 July 1979.

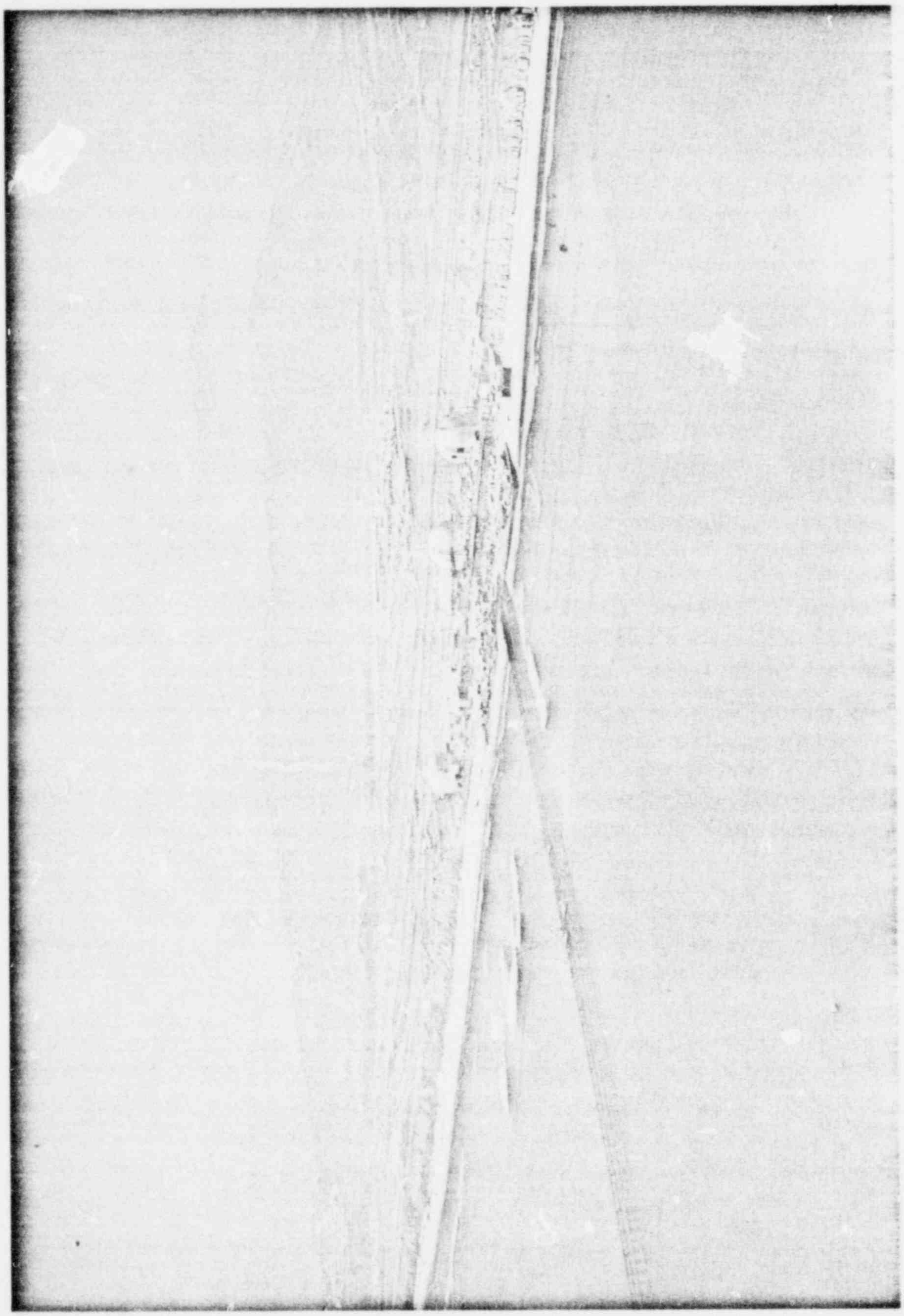

Figure II-65. Aerial Photograph showing from the discharge to 3000 feet downcoast, 5 September 1979.

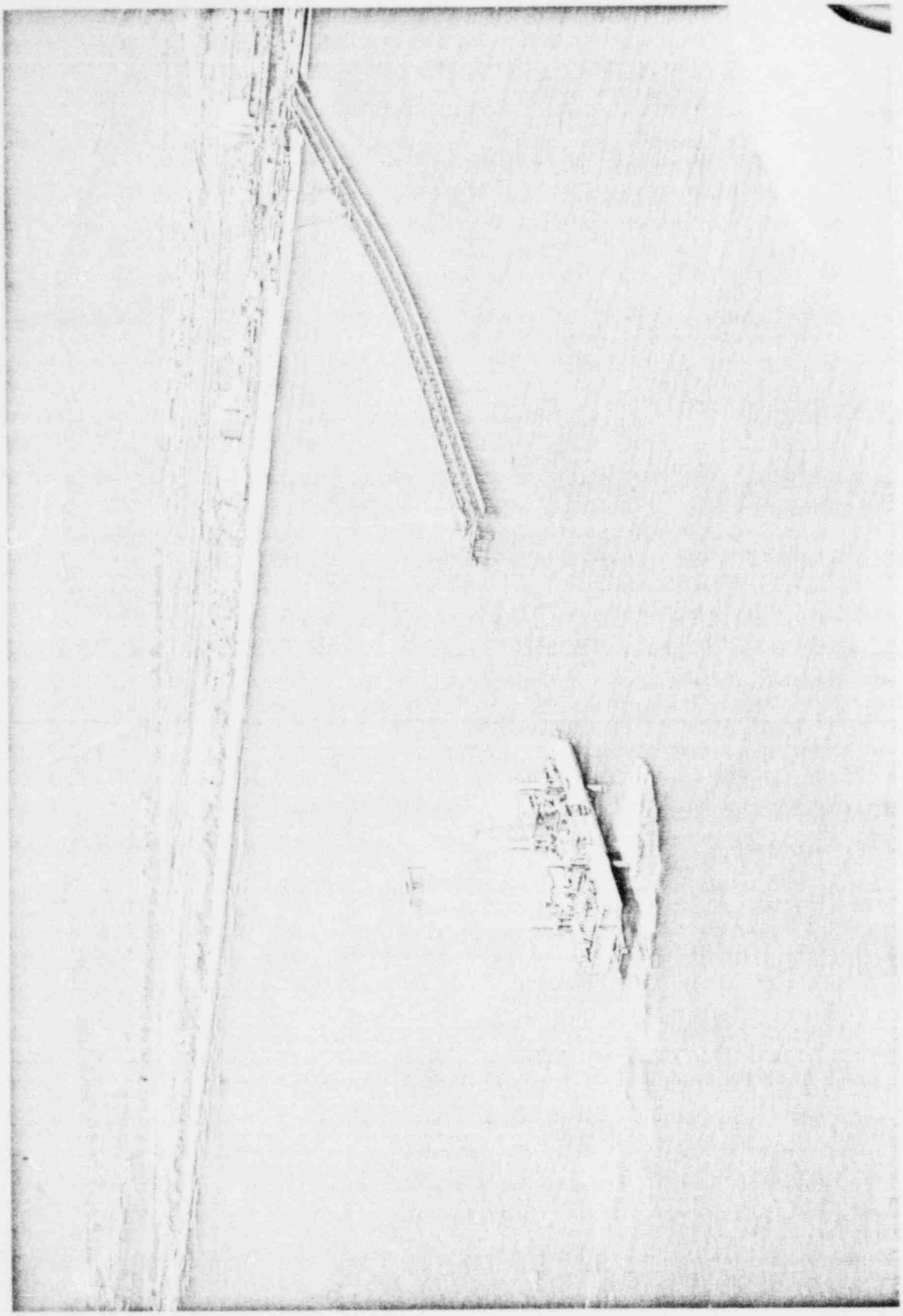

Figure II-66. Aerial photograph showing from 2000 feet downcoast to 2500 feet upcoast of the discharge, 5 September 1979.

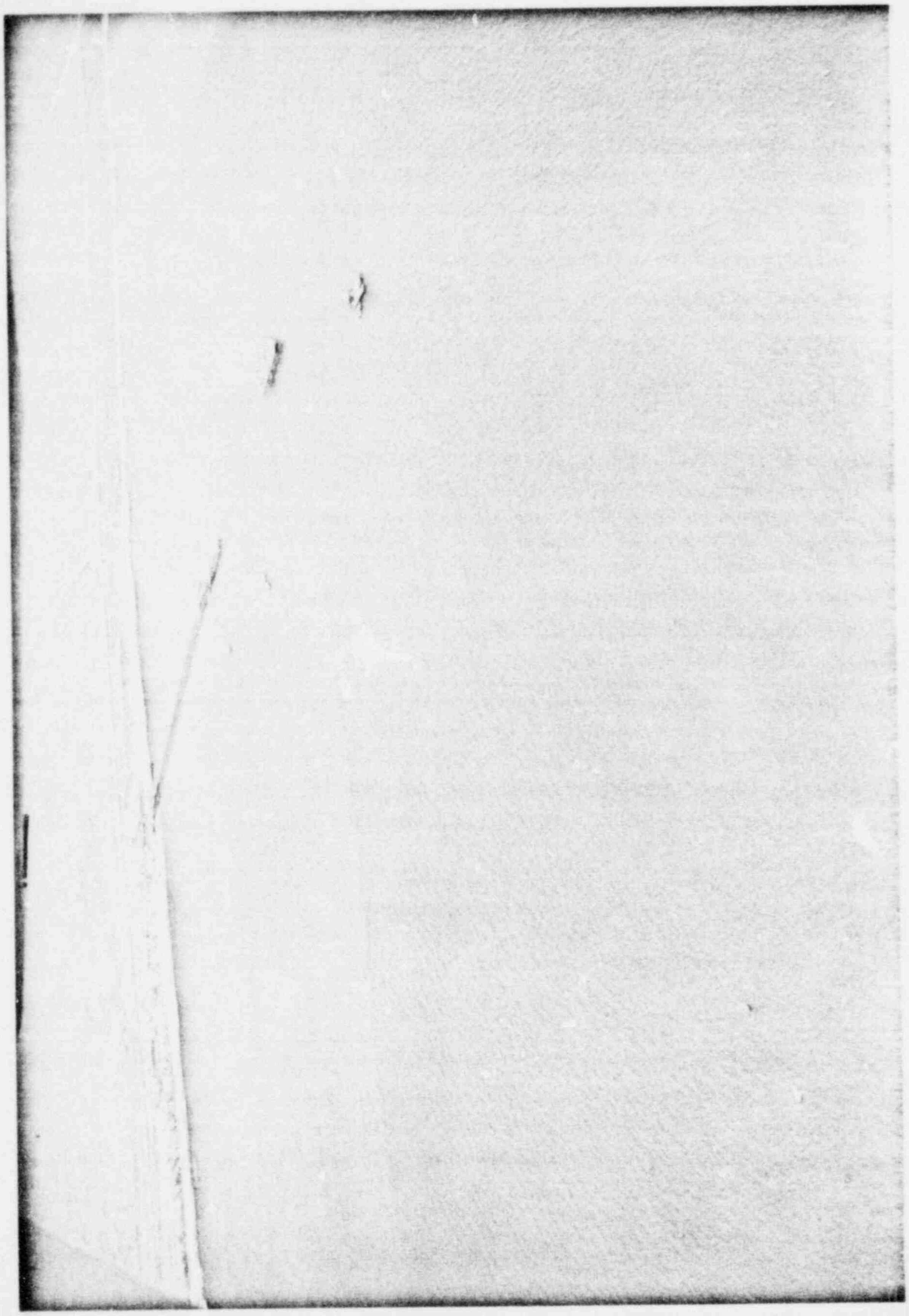

Figure I:-67. Aerial photograph showing from 8000 feet downcoast to 3000 feet upcoast of the discharge, 7 November 1979.

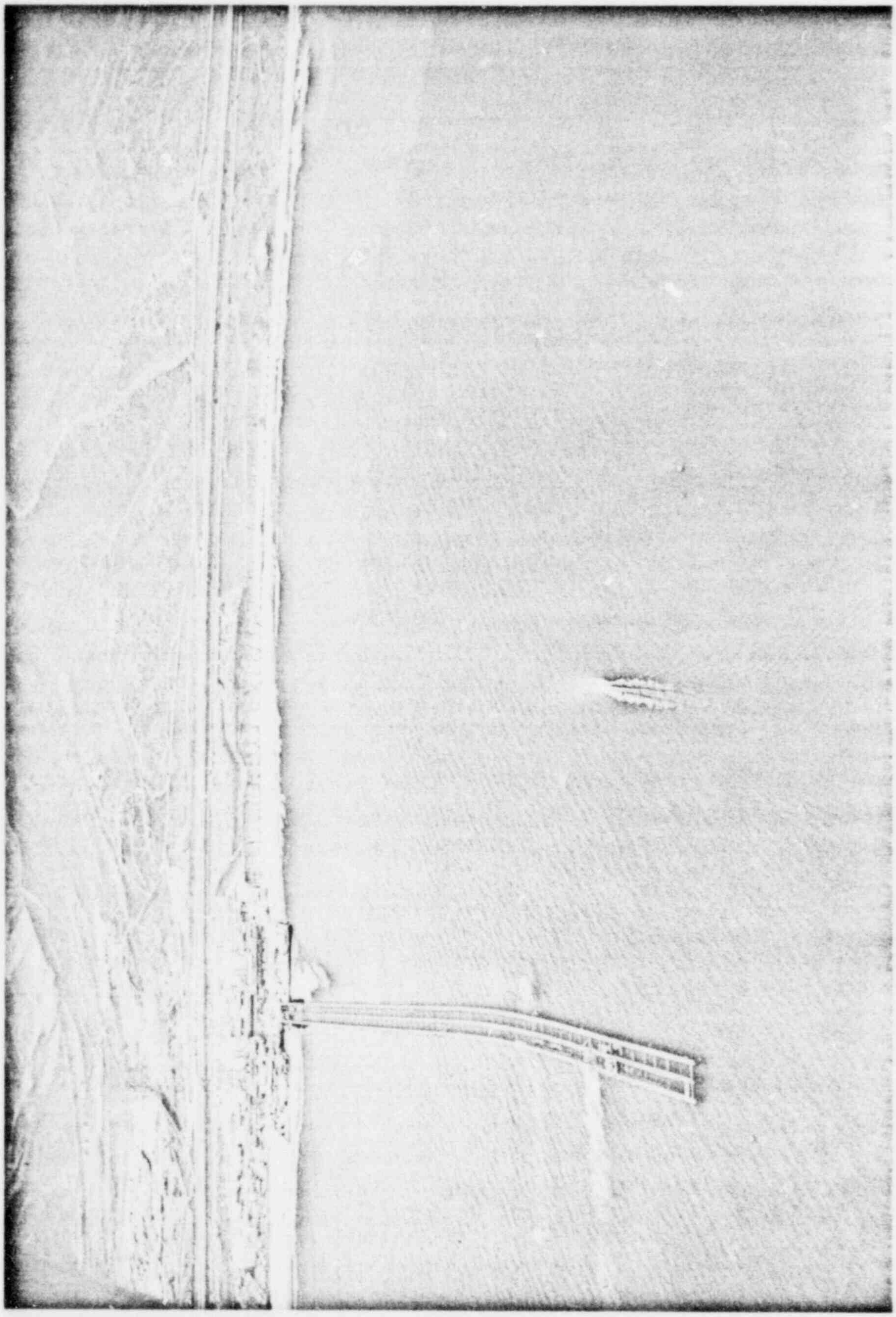

Figure II-68. Aerial photograph showing from 6000 feet downcoast to 500 feet downcoast of the discharge, 7 November 1979.

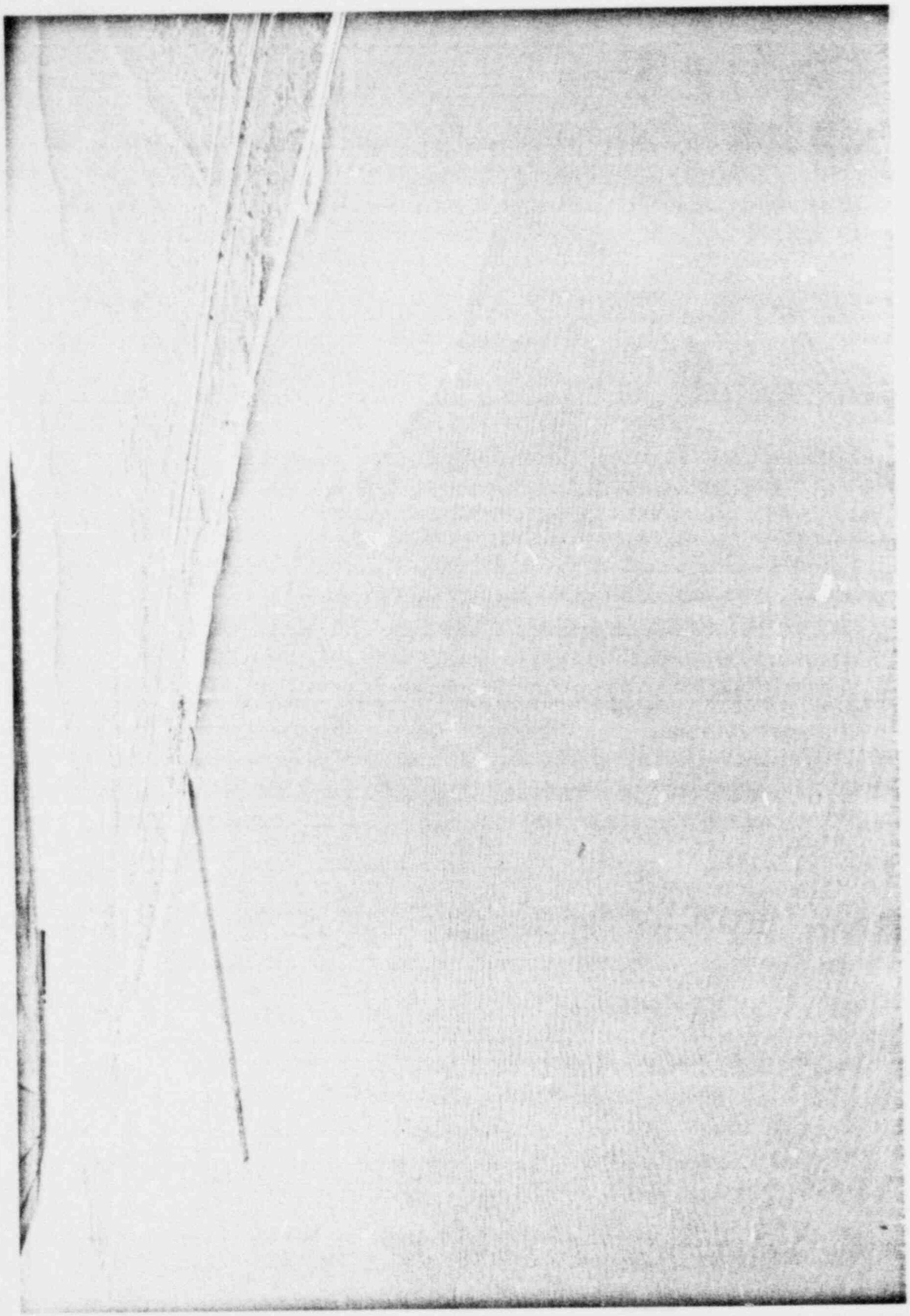

Figure II-69. Aerial photograph showing from the discharge to 8000 feet downcoast, 7 November 1979.

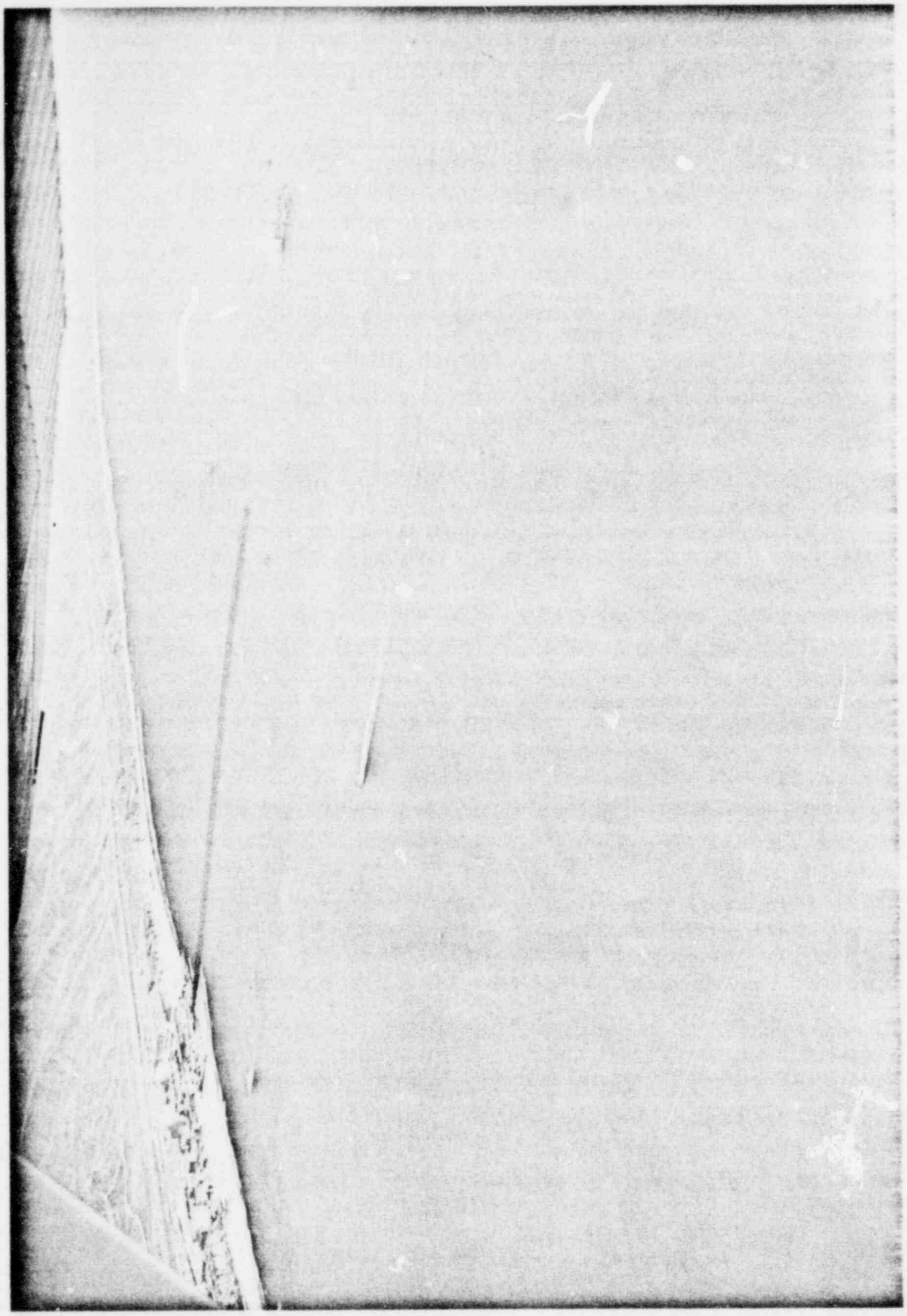

Figure II-70. Aerial photograph showing from 4000 feet downcoast to 8000 feet upcoast of the discharge, 27 November 1979.

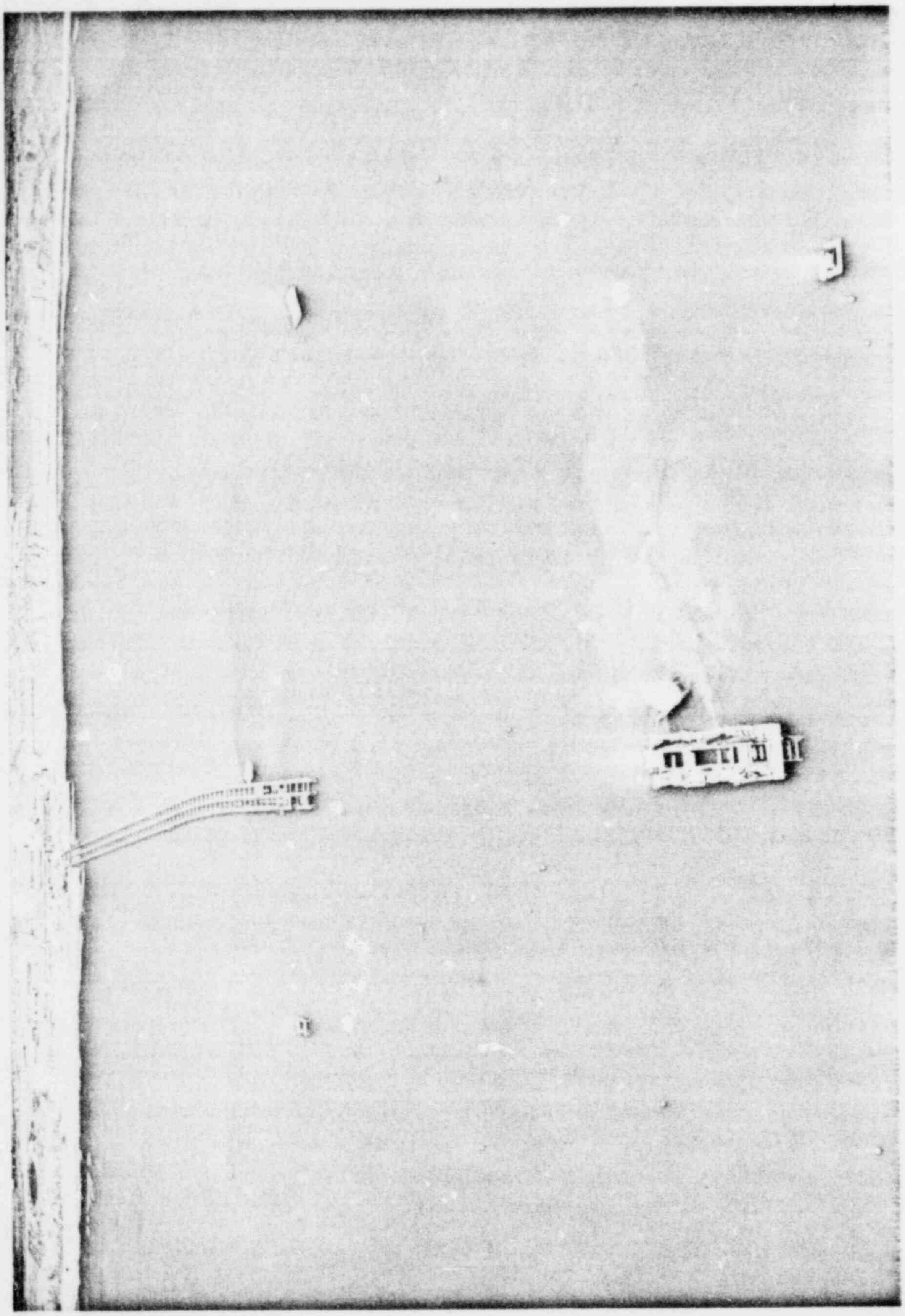

Figure II-71. Aerial photograph showing from 5000 feet downcoast to 500 feet upcoast of the discharge, 27 November 1979.

Figure VI-3. Barn kelp *Macrocystis* canopy from December 1978 through November 1979, based on infrared aerial photographs.

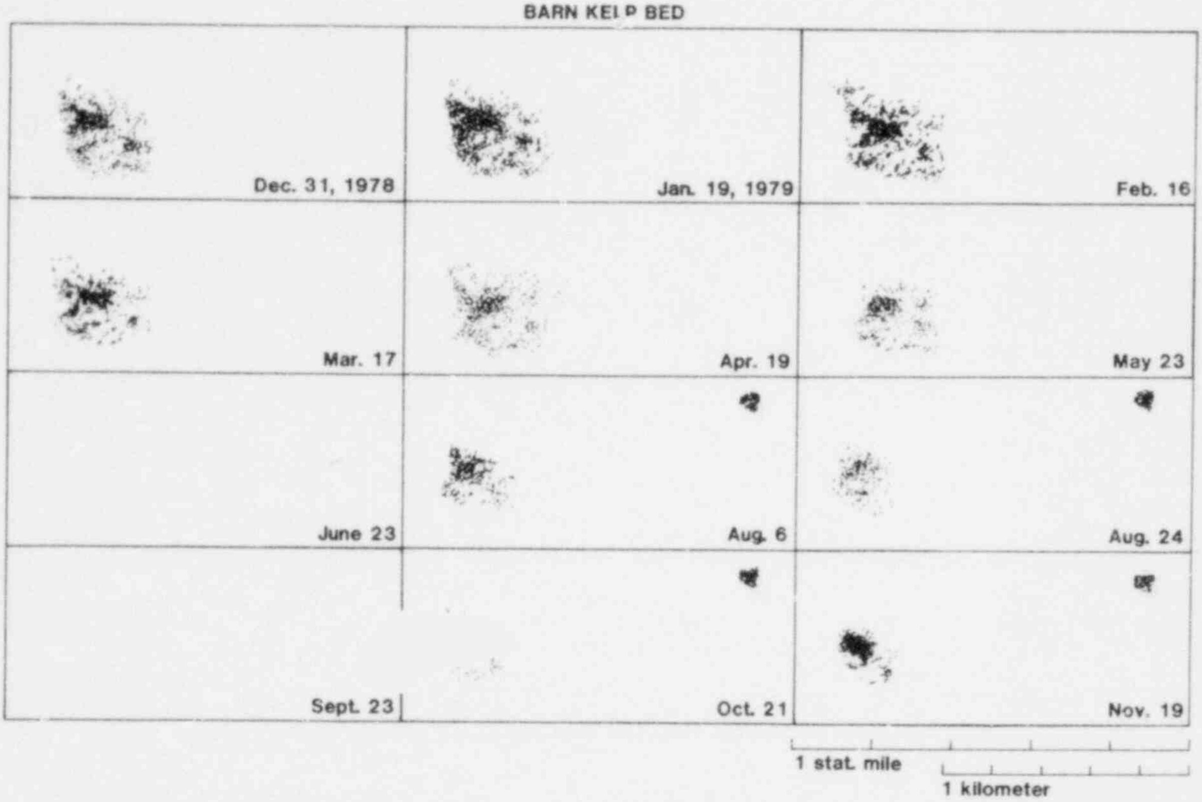

Figure VI-2. San Onofre <u>Macrocystis</u> canopy from December 1978 through November 1979, based on infrared aerial photographs.

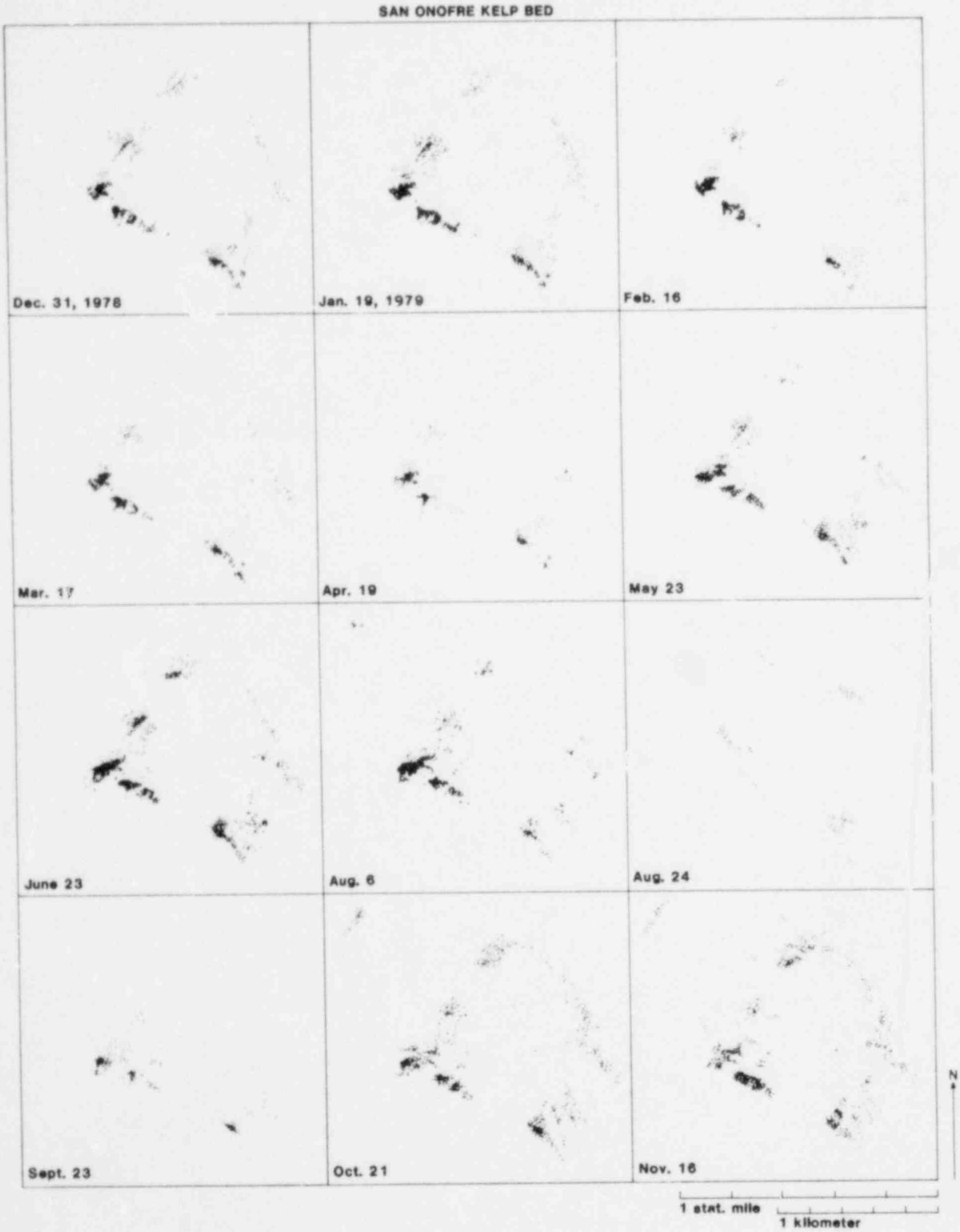

Figure VI-1. San Mateo Macrocystis canopy from December 1978 through November 1979, based on infrared aerial photographs.

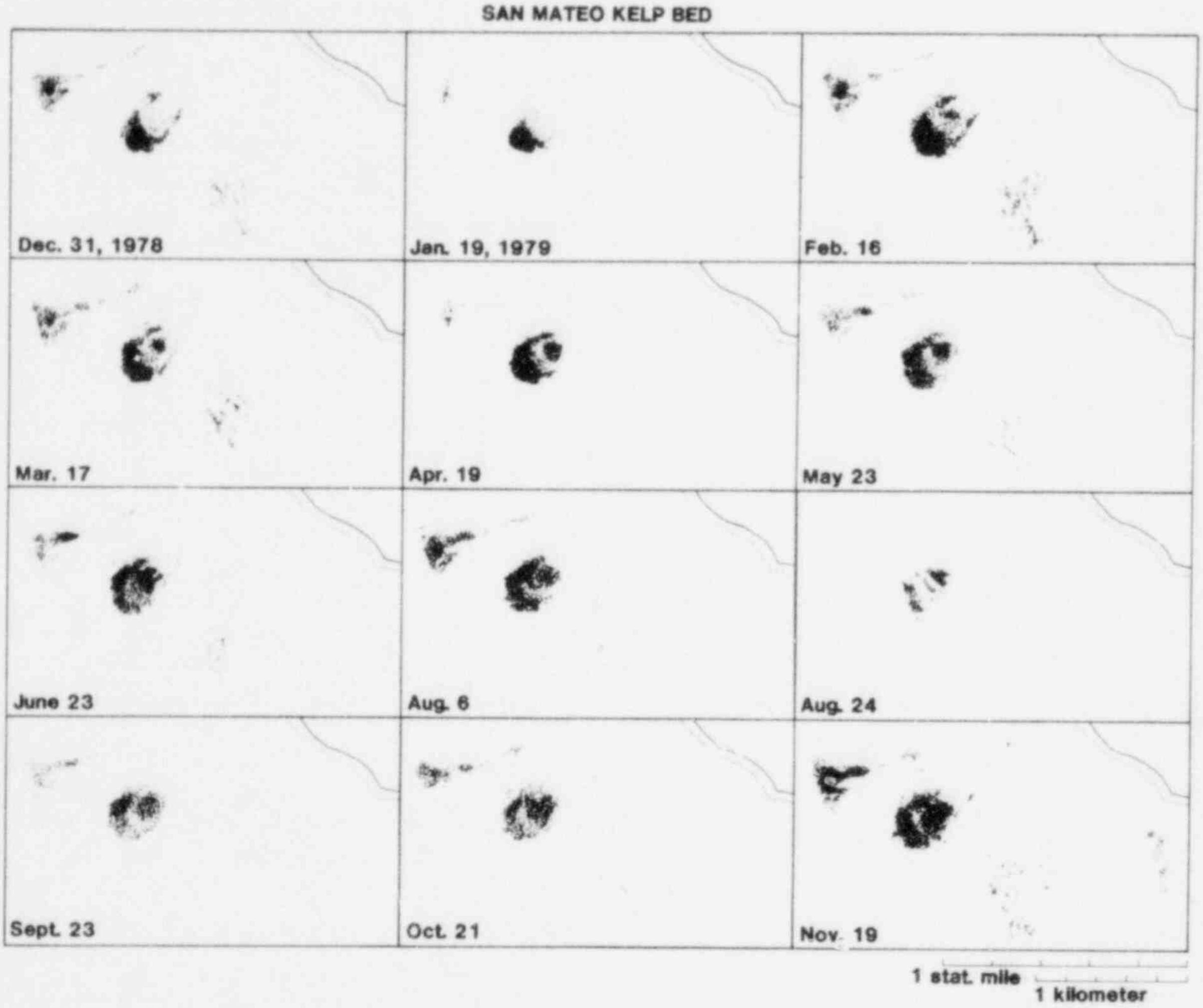

Table VI-1. Monthly sedimentation rates recorded at the upcoast and downcoast kelp bed stations during 1979 ($g/m^2/day$).

Month	Stations	
	Upcoast	Downcoast
January	-	-
February	2282.6	697.5
March	694.8	252.6
April	700.8	345.5
May	1209.5	257.3
June	1119.1	237.7
July	3276.6	272.6
August	1095.8	287.0
September	514.0	185.9
October	215.7	164.2
November	284.4	124.8
December	657.7	173.7

APPENDIX VI - KELP

Figure V-1. Annual mean values of sediment physical-chemical characteristics at subtidal stations: a) organic carbon, b) carbonate carbon, c) water clarity, and d) change in sediment height.

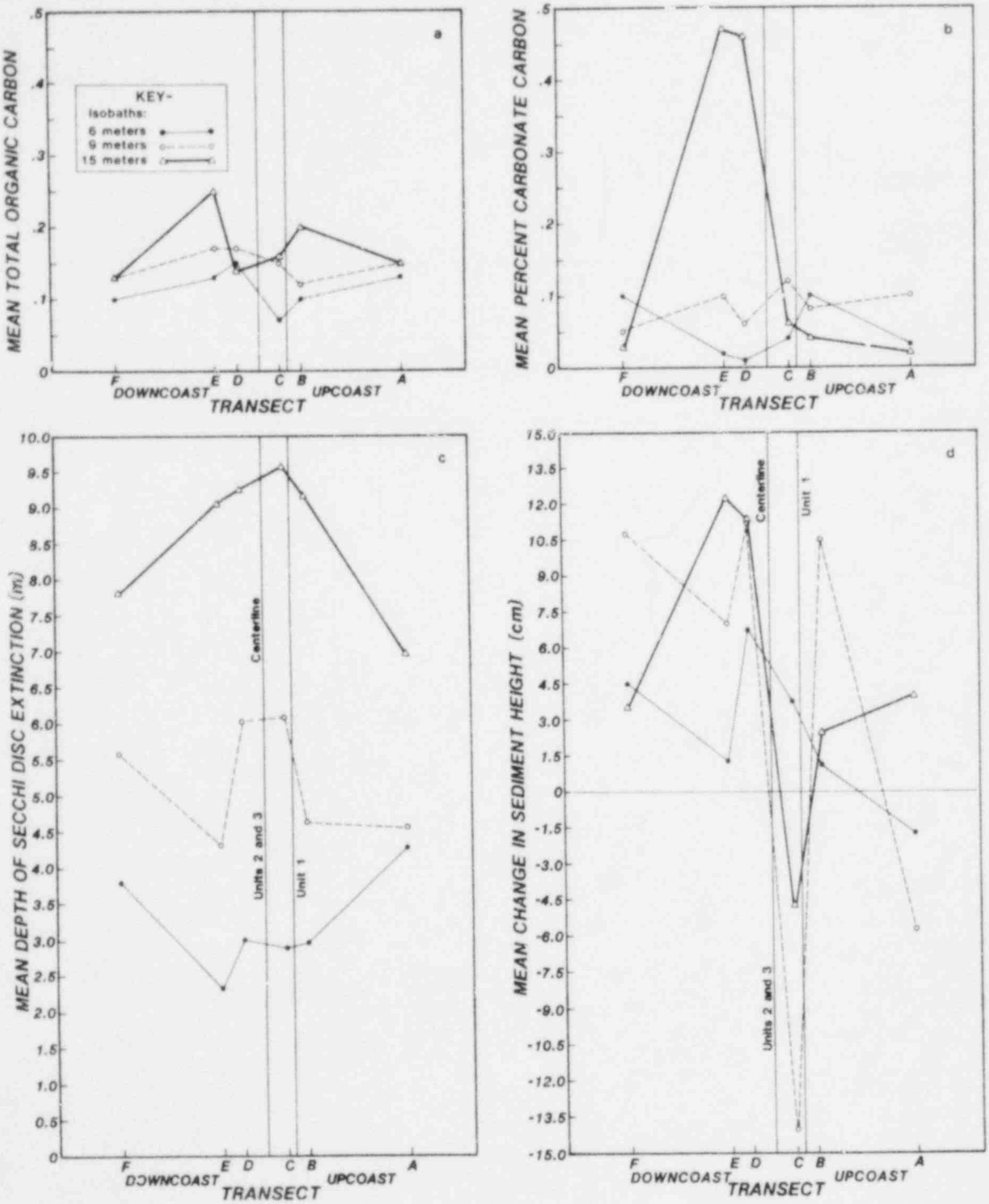

Table V-1. Number of benthic infaunal species displaying a particular feeding type, February, May, August, and November 1979 (Cont).

Station	Filter Feeders	Carnivores	Omnivores	Surface Deposit Feeders	Sub-surface Deposit Feeders	Total Deposit Feeders
			August			
A1	8	5	4	16	7	23
A2	17	21	7	30	15	45
A3	19	22	7	41	13	54
B1	10	7	4	11	4	15
B2	16	21	8	29	14	43
B3	23	21	5	39	17	56
C1	9	9	2	11	4	15
C2	22	21	19	30	15	45
C3	21	22	10	47	20	67
D1	9	8	3	12	5	17
D2	14	16	6	26	16	42
D3	16	17	9	42	18	60
E1	7	6	4	13	7	20
E2	13	19	7	27	14	41
E3	15	15	4	33	11	44
F1	10	3	3	13	7	20
F2	12	15	7	22	9	31
F3	20	23	8	45	17	62
Mean	14.50	15.06	6.50	27.06	11.83	38.89
			November			
A1	3	6	2	10	6	16
A2	12	9	7	24	11	35
A3	18	22	9	39	11	50
+B1	6	5	2	12	4	16
B2	11	13	9	31	12	43
B3	19	20	5	28	13	41
C1	6	4	1	9	7	16
C2	13	13	7	31	16	47
C3	16	18	8	39	16	55
D1	8	5	2	15	7	22
D2	13	15	6	25	13	38
D3	18	11	6	34	12	46
E1	6	8	3	10	4	14
E2	16	18	7	24	12	36
E3	16	12	6	40	16	56
F1	8	11	4	13	6	19
F2	16	20	6	20	14	34
F3	21	25	6	35	18	53
Mean	12.56	13.06	5.33	24.39	11.00	35.39

Table V-1. Number of benthic infaunal species displaying a particular feeding type, February, May, August, and November 1979.

Station	Filter Feeders	Carnivores	Omnivores	Surface Deposit Feeders	Sub-surface Deposit Feeders	Total Deposit Feeders
			February			
A1	2	1	1	7	2	9
A2	9	12	4	20	11	31
A3	14	15	2	22	18	40
B1	5	3	2	11	2	13
B2	14	15	4	17	12	29
B3	14	15	4	27	12	39
C1	8	4	1	14	5	19
C2	10	10	4	15	10	25
C3	12	18	6	31	12	43
D1	5	5	3	10	5	15
D2	18	10	5	15	12	27
D3	12	14	6	28	13	41
E1	6	5	4	14	3	17
E2	11	11	6	22	10	32
E3	10	6	6	21	15	36
F1	6	6	3	11	5	16
F2	10	11	4	18	10	28
F3	16	16	5	29	18	47
Mean	10.11	9.83	3.89	18.44	9.73	28.17
			May			
A1*	0	0	0	0	0	0
A2	16	16	5	29	15	44
A3	23	25	4	36	14	50
B1	4	7	5	13	9	22
B2	14	15	5	34	8	42
B3	17	21	4	34	13	47
C1	6	10	4	14	9	23
C2	12	16	8	22	18	40
C3	18	22	6	33	18	51
D1	10	8	5	16	5	21
D2	12	18	3	21	13	34
D3	16	19	6	36	12	48
E1	10	10	3	20	7	27
E2	16	21	8	26	14	40
E3	16	7	3	26	17	43
F1	9	9	3	16	5	21
F2	[illegible]	20	6	21	10	31
F3	18	16	6	34	11	45
Mean	13.71	15.29	4.94	25.35	11.65	37.00

*No samples taken at A-1 in May

APPENDIX V - SEDIMENT INFAUNAL HABITAT

Table IV-1. Tidal datum elevations at SONGS site.

Elevation (ft)	Datum*
7.7	Extreme Highest Tide**
7.1	Average Yearly High Tide
5.3	Mean Higher High Water
4.55	Mean High Water
2.7	Mean Tide Level
0.85	Mean Low Water
0.0	Mean Lower Low Water
-1.9	Average Yearly Low Tide
-2.6	Extreme Lowest Tide**

* Based upon tides at Oceanside, California.
** Includes effects of storm surge.

Table IV-2. Grain size measures.

Phi (ϕ) Size	Descriptive Size	Measured Size (m)	Measured Size (mm)	Measured Size (μ)
- 9	boulder	1/2	512	
- 8	boulder	1/4	256	
- 7	cobble	1/8	128	
- 6	cobble	1/16	64	
- 5	cobble		32	
- 4	pebble		16	
- 3	pebble		8	
- 2	pebble		4	
- 1	granule		2	
0	very coarse sand		1	
1	coarse sand		1/2	
2	medium sand		1/4	
3	fine sand		1/8	
4	very fine sand		1/16	63
5	coarse silt		1/32	31
6	medium silt		1/64	16
7	fine silt		1/128	8
8	very fine silt		1/250	4
9	clay			2
10	clay			1
11	clay colloids and organic colloids			0.5
12				0.25
13				0.12
14				0.06
15				0.03
20				<0.01

APPENDIX IV - SEDIMENTOLOGY

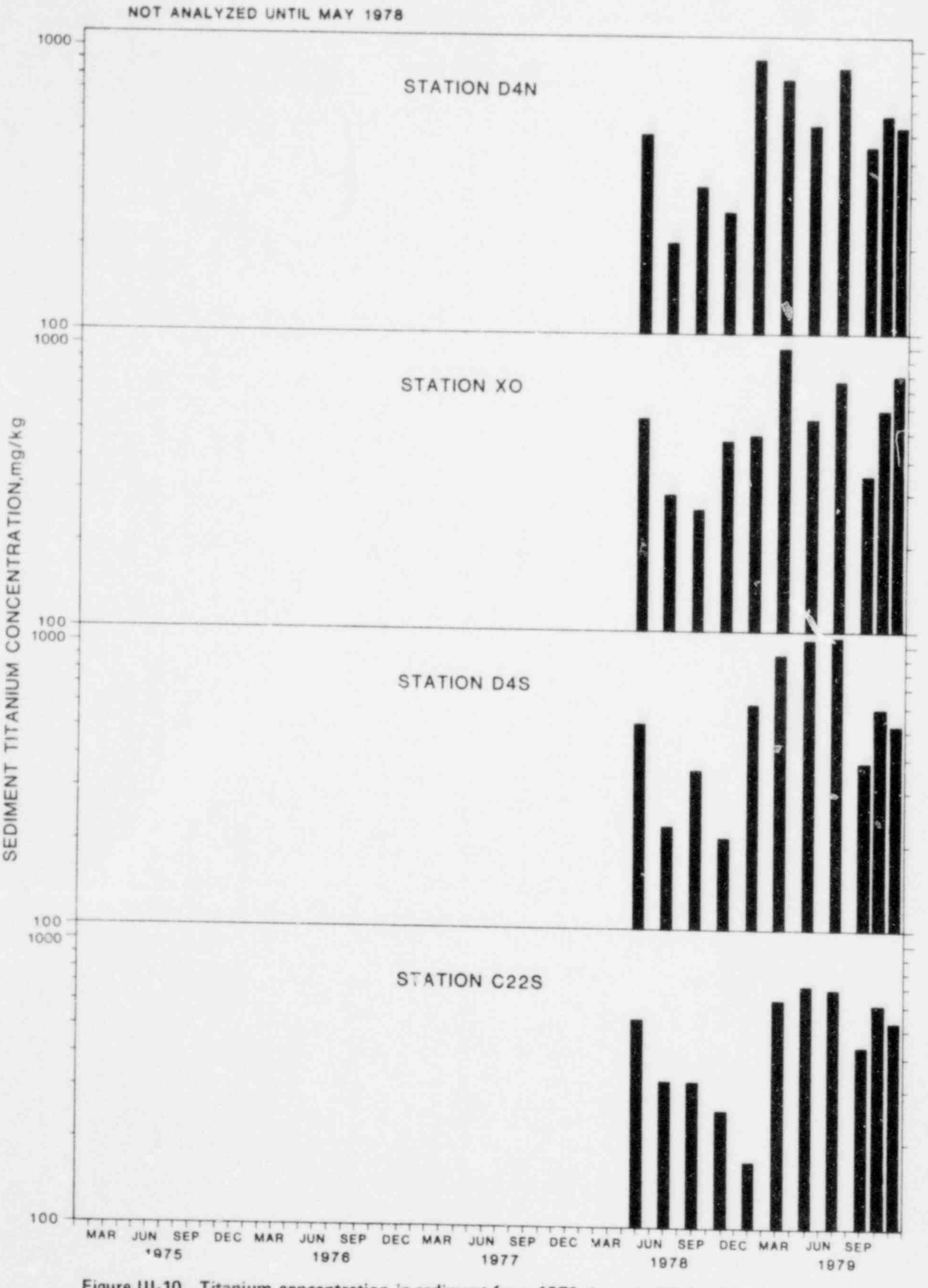

Figure III-10. Titanium concentration in sediment from 1978 through 1979 at SONGS 1 stations.

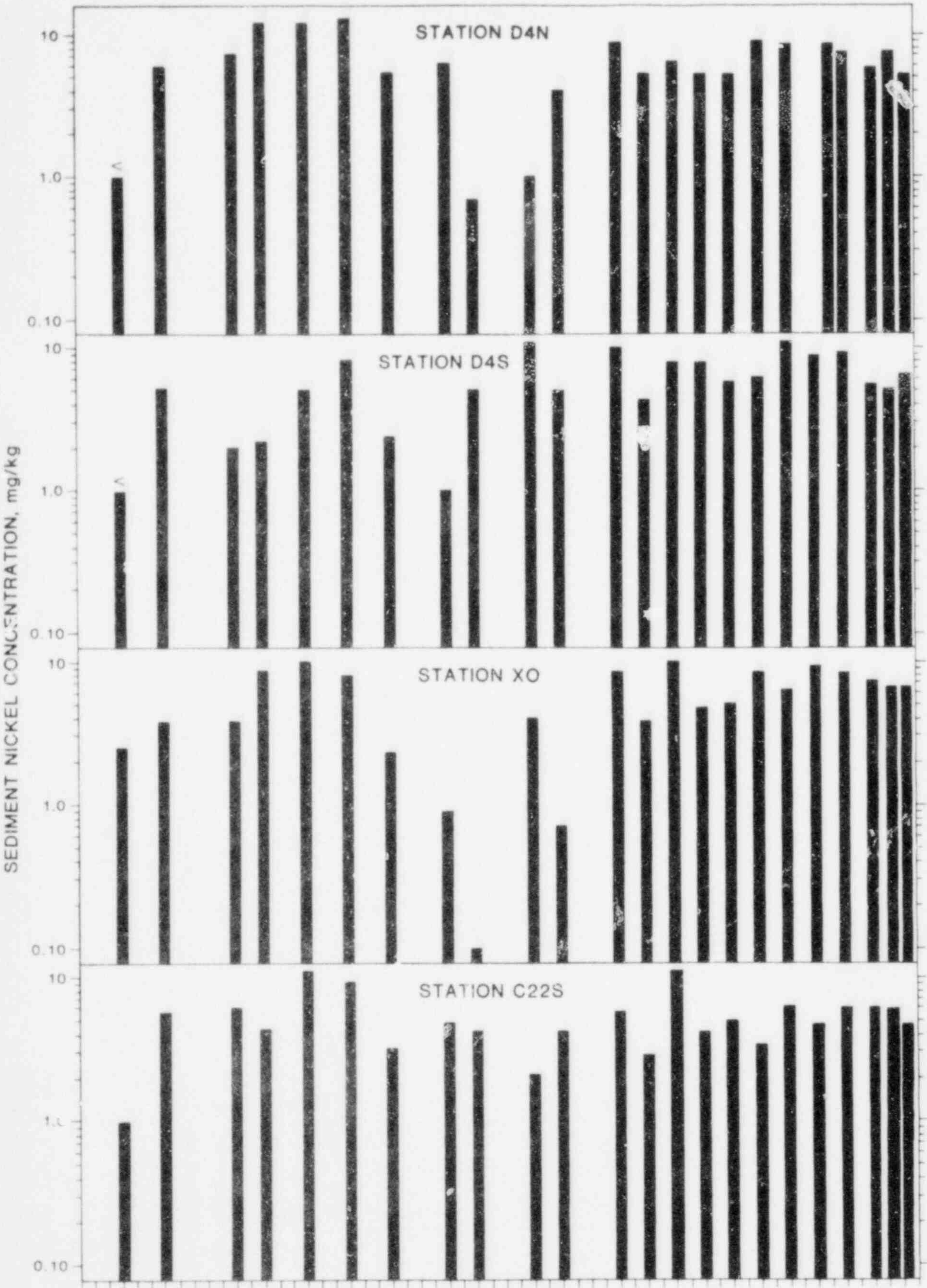

Figure III-9. Nickel concentration in sediment from 1975 through 1979 at SONGS 1 stations.

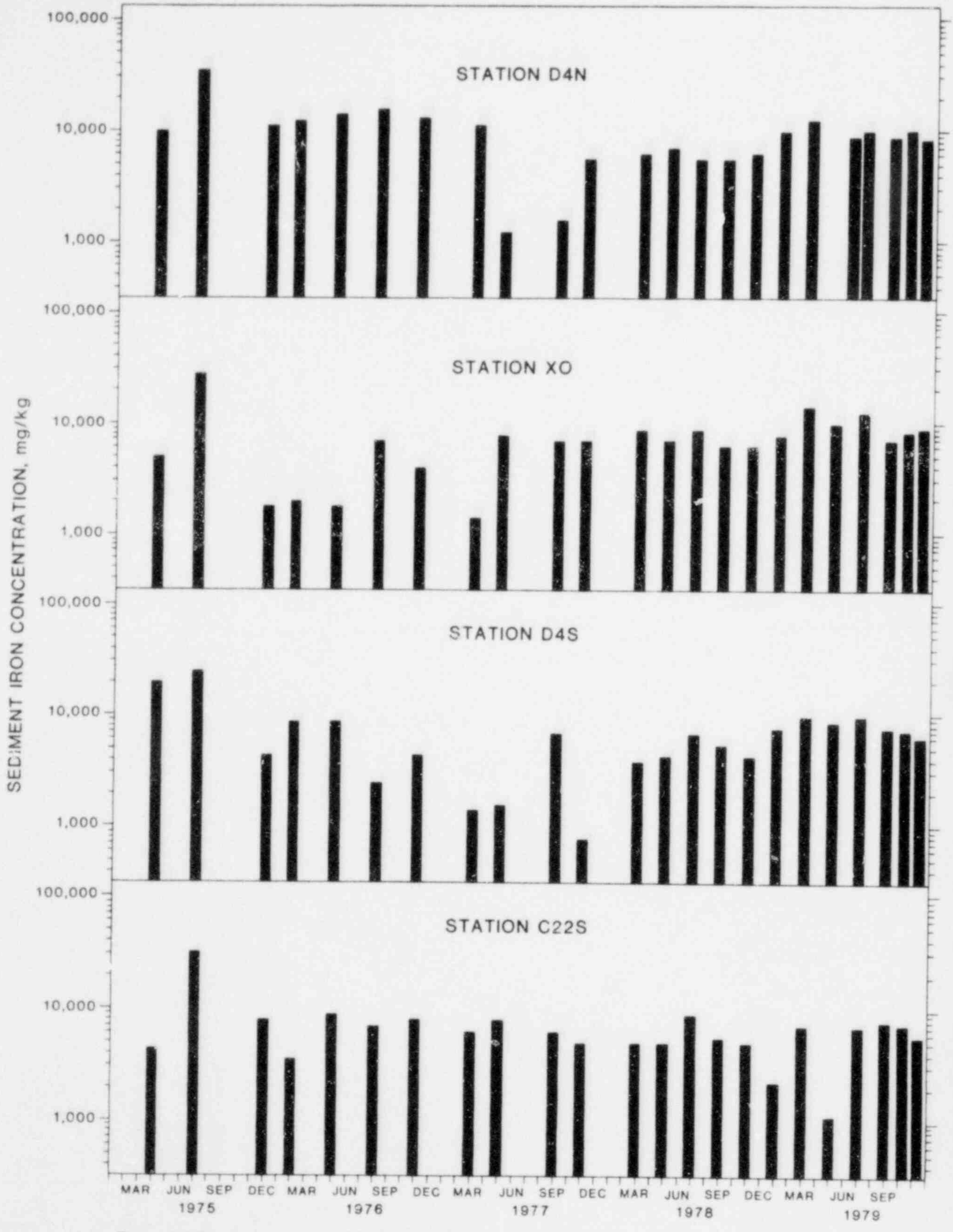

Figure III-8. Iron concentration in sediment from 1975 through 1979 at SONGS 1 stations.

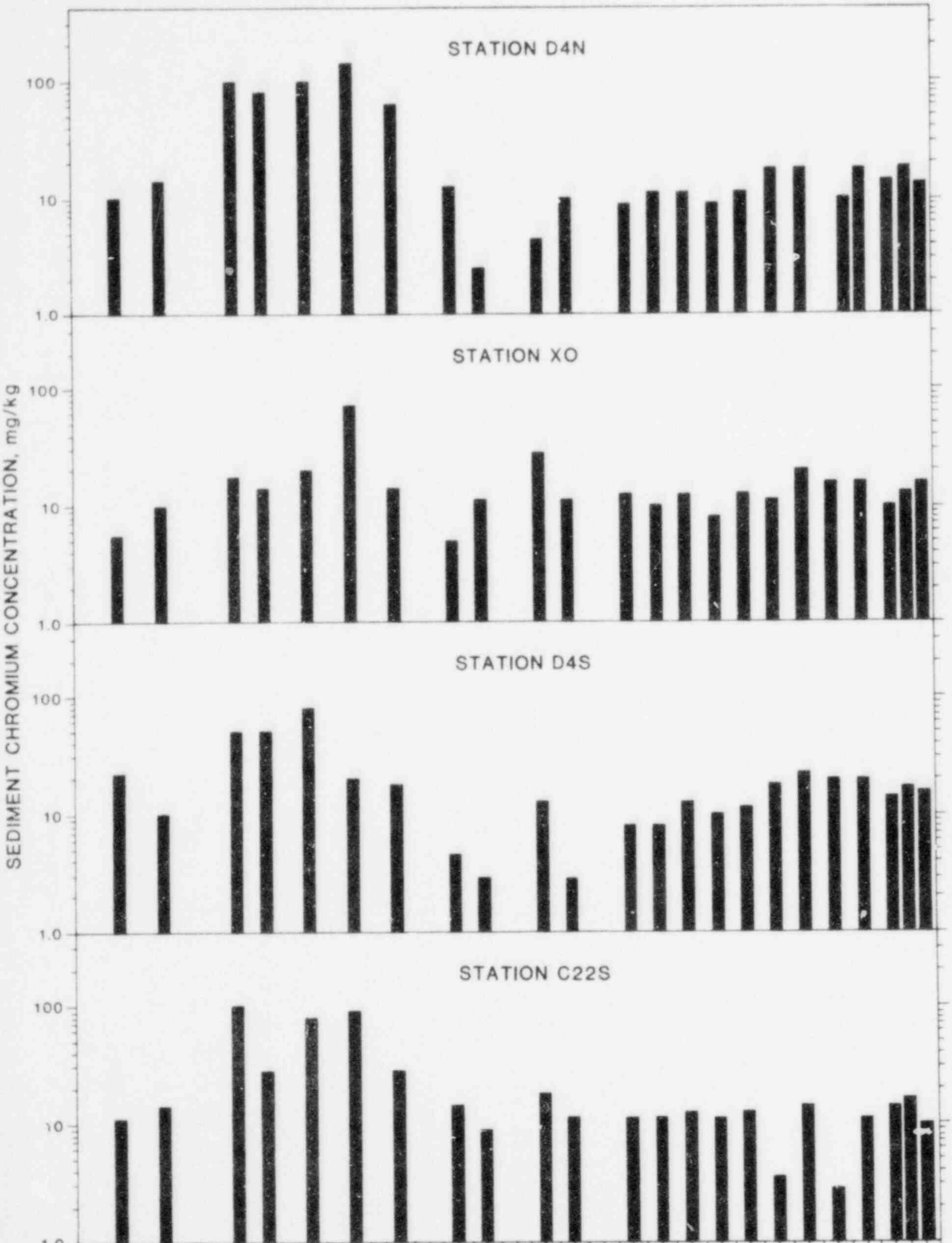

Figure III-7. Chromium concentration in sediment from 1975 through 1979 at SONGS 1 stations.

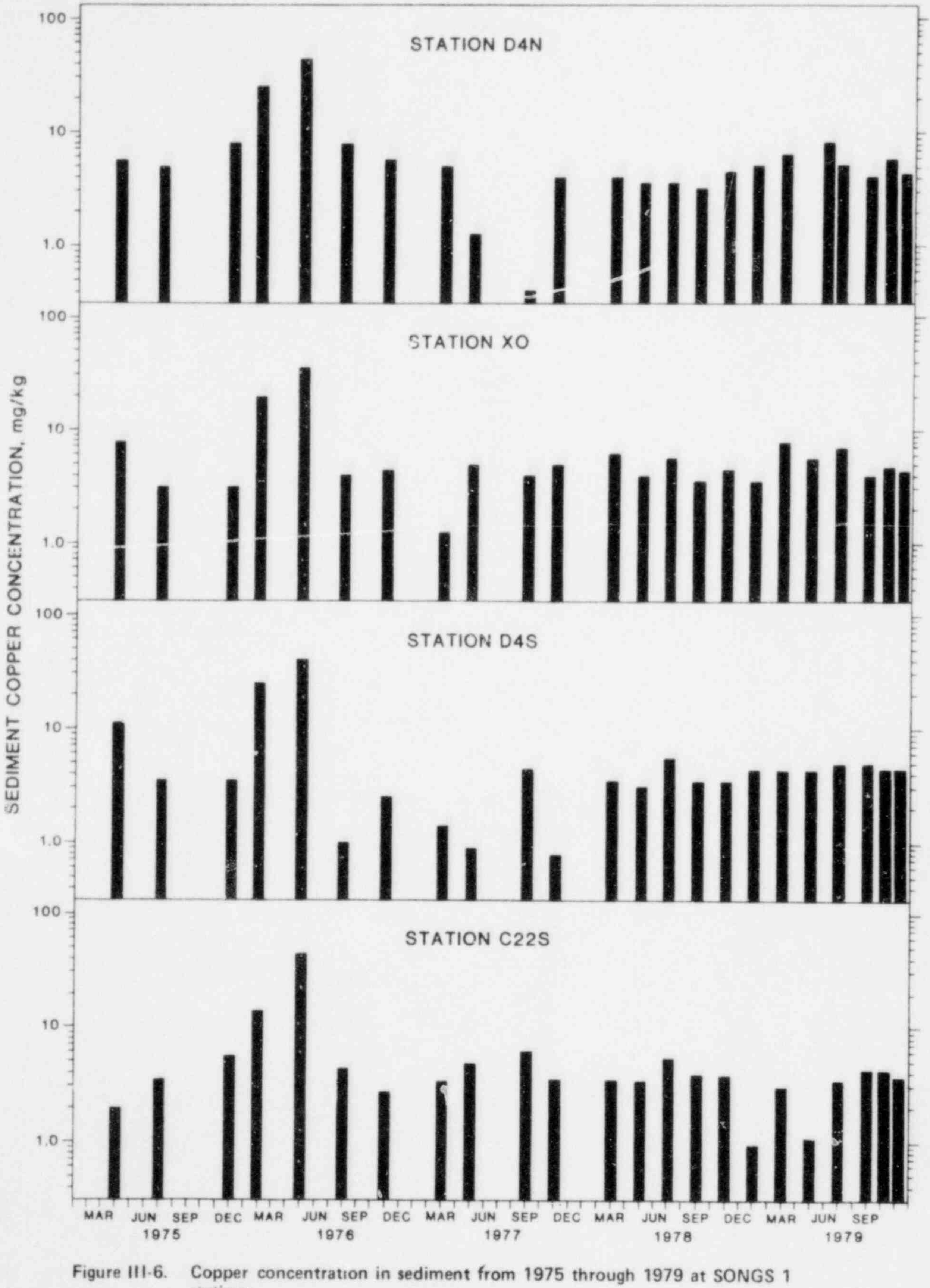

Figure III-6. Copper concentration in sediment from 1975 through 1979 at SONGS 1 stations.

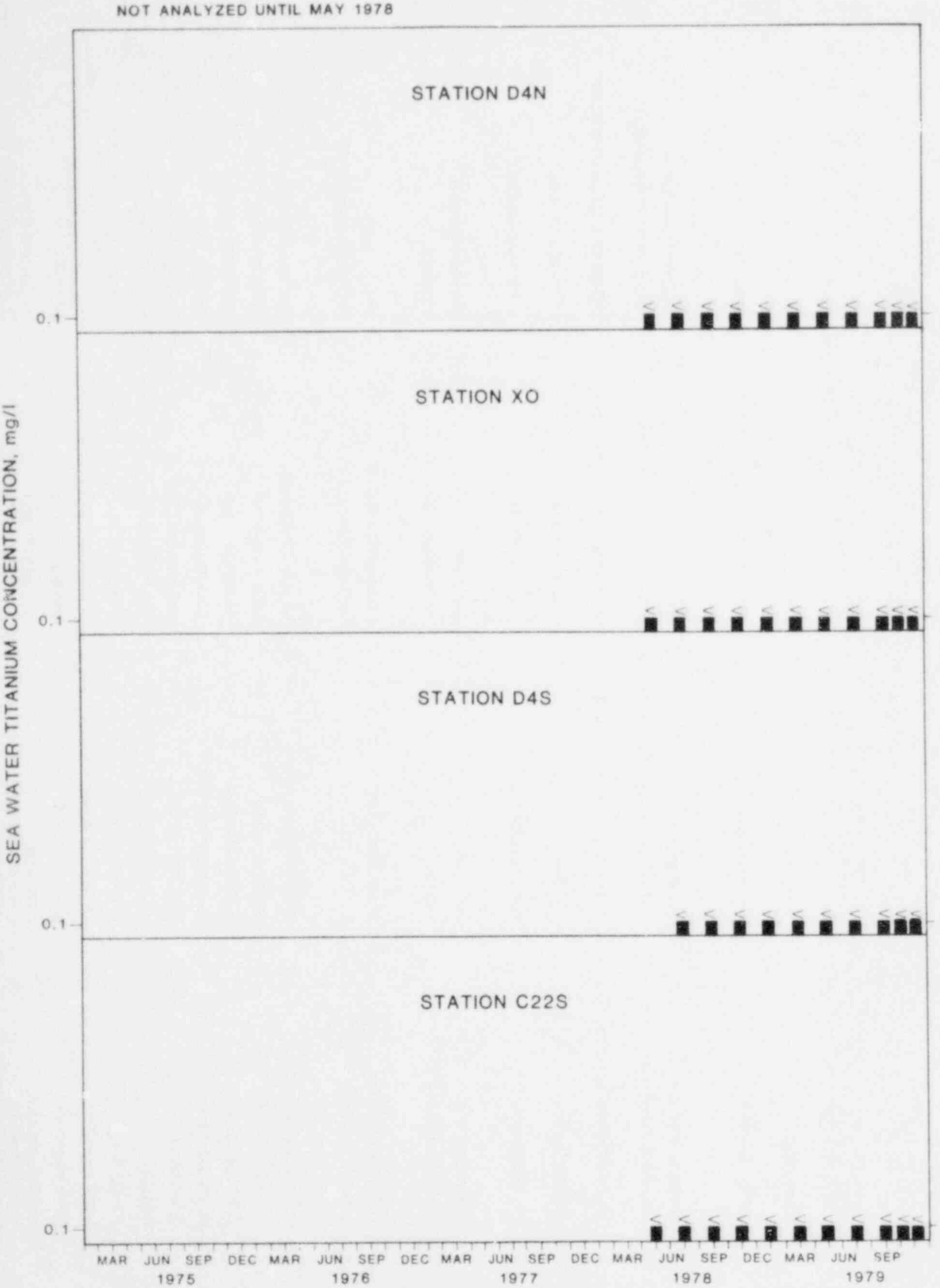

Figure III-5. Titanium concentration in seawater from 1978 through 1979 at SONGS 1 stations.

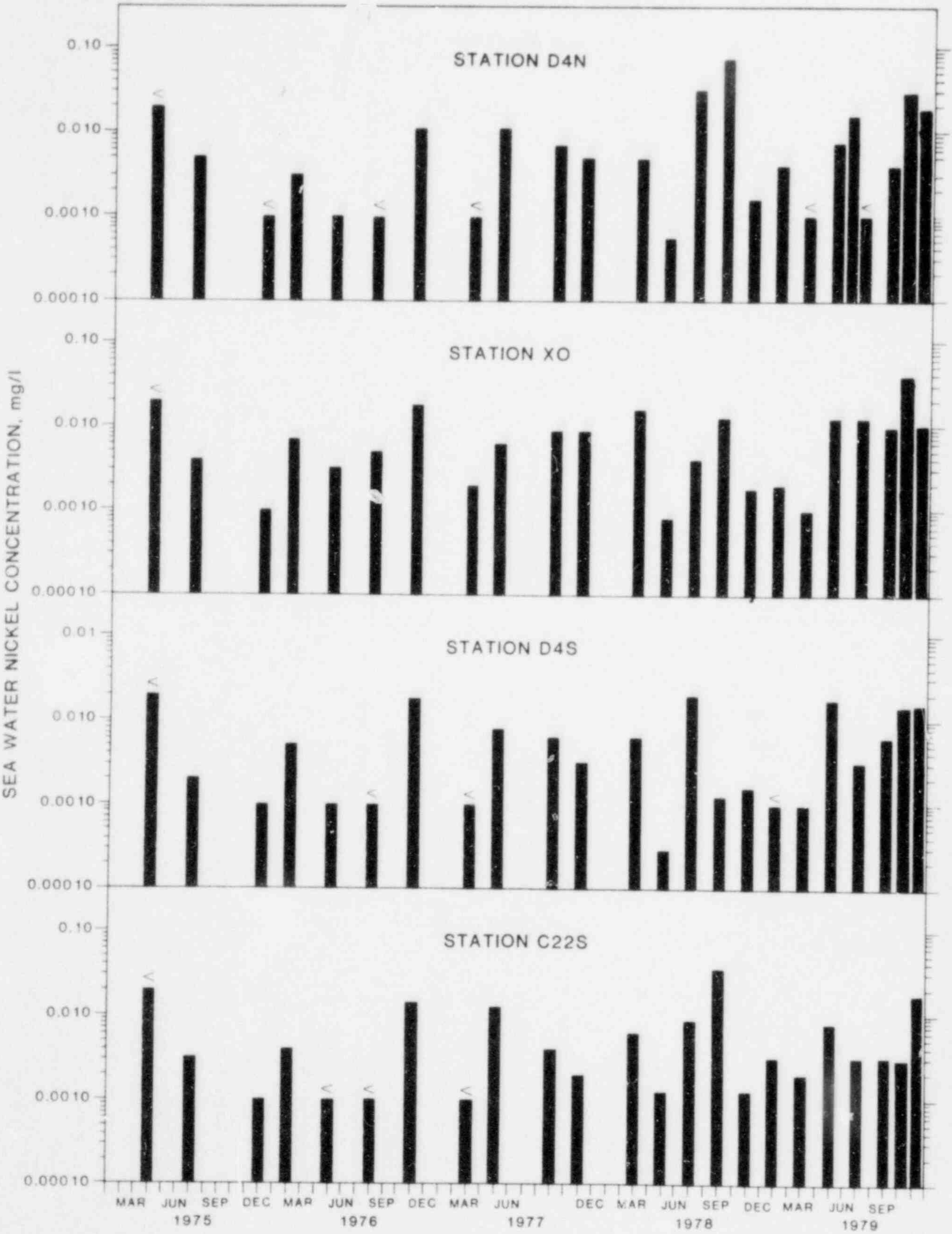

Figure III-4. Nickel concentration in seawater from 1975 through 1979 at SONGS 1 stations.

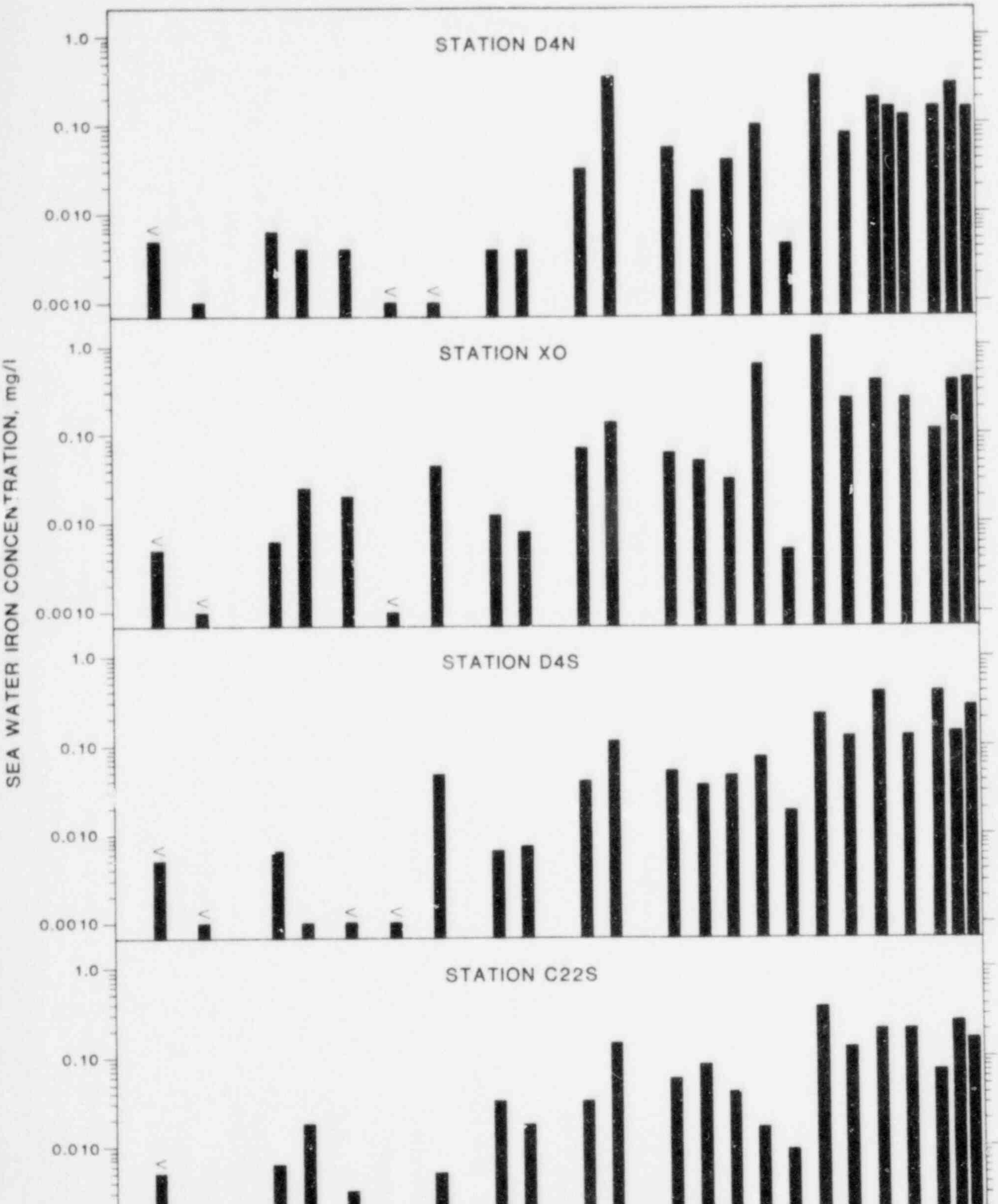

Figure III-3. Iron concentration in seawater from 1975 through 1979 at SONGS 1 stations.

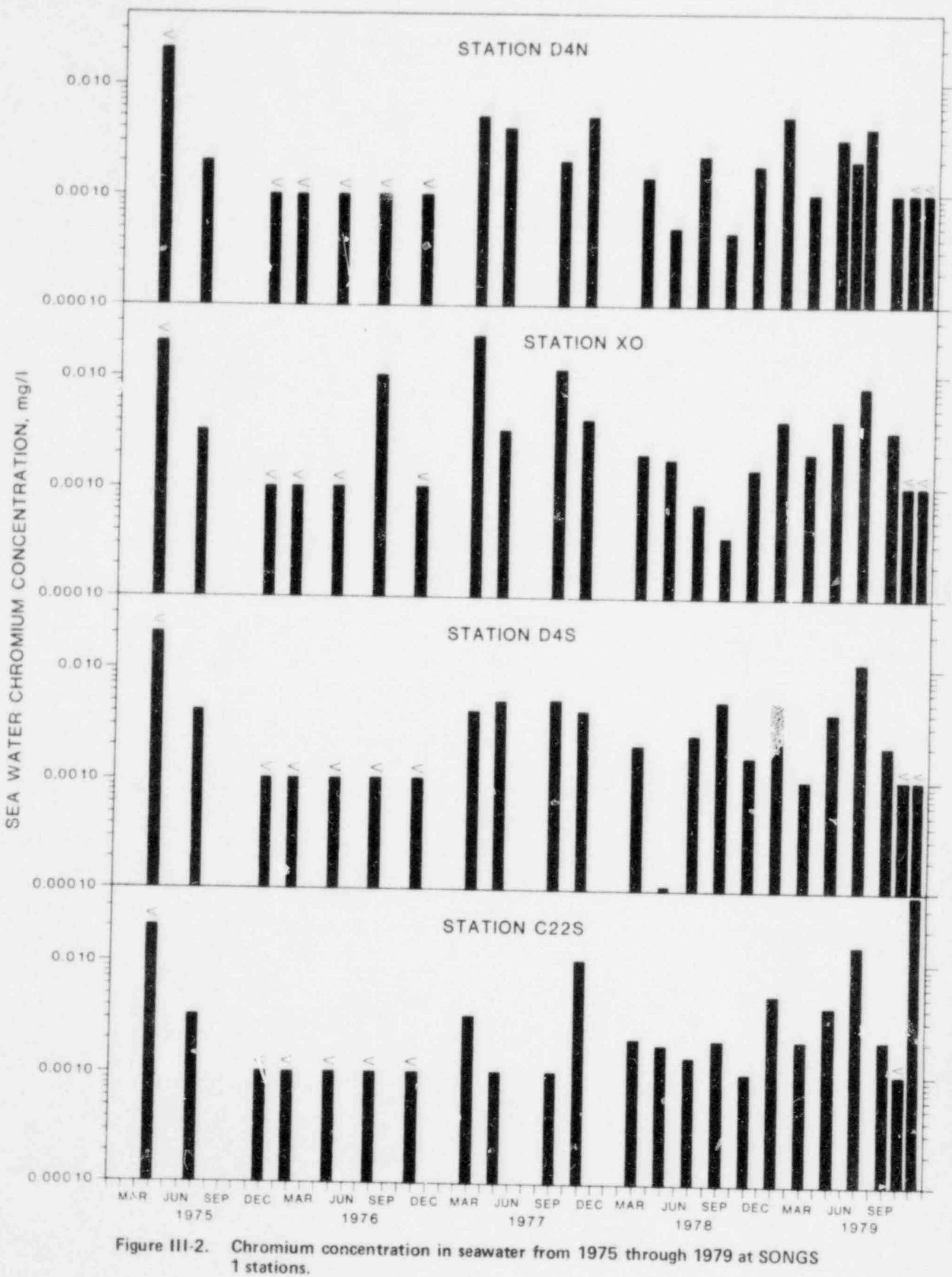

Figure III-2. Chromium concentration in seawater from 1975 through 1979 at SONGS 1 stations.

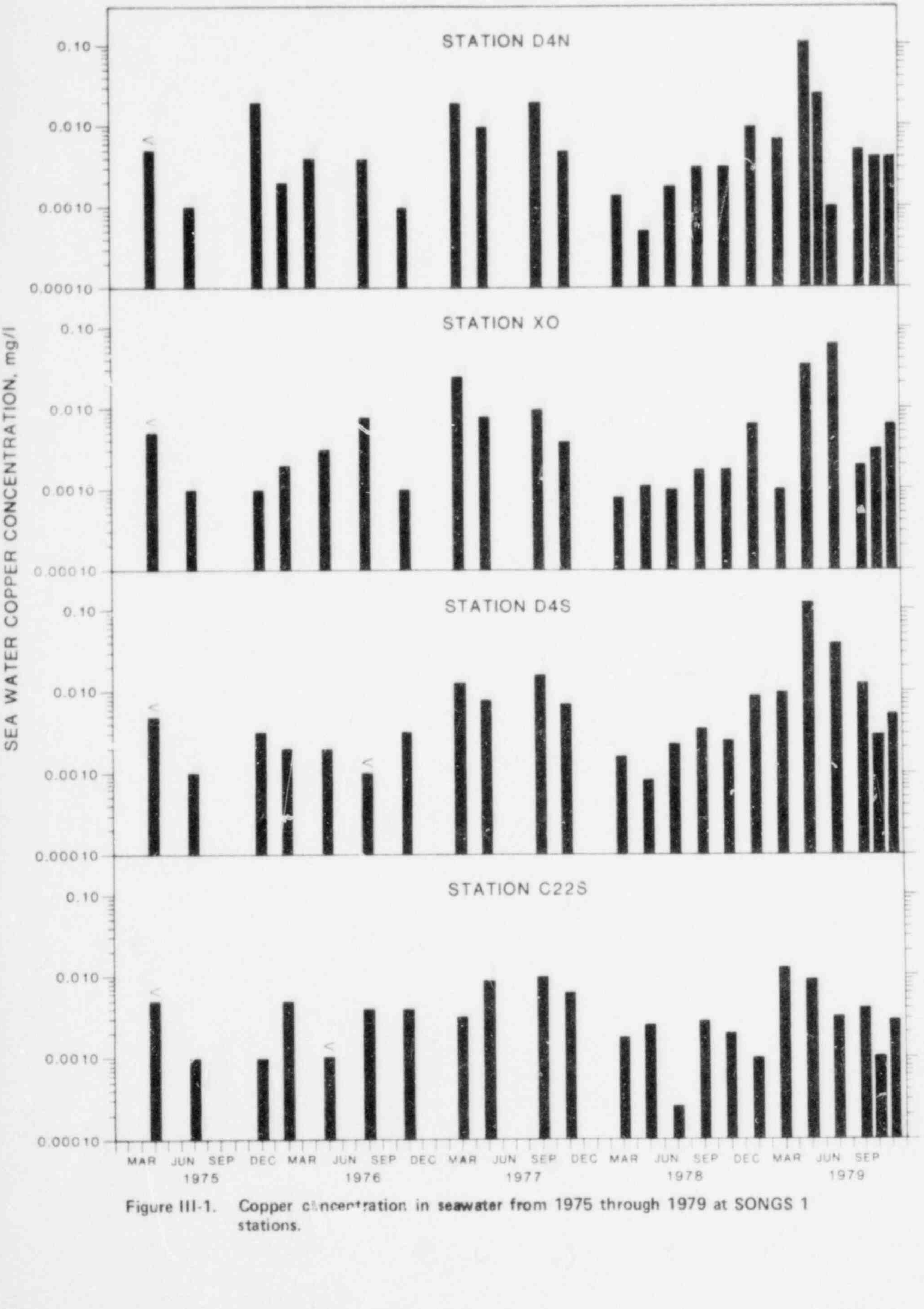

Figure III-1. Copper concentration in seawater from 1975 through 1979 at SONGS 1 stations.

APPENDIX III - WATER QUALITY

FIGURES

Table III-5. **Range, mean, and standard deviation of heavy metals concentrations for SONGS 2 and 3 stations during 1979.**

Metal	Item	Receiving Water (mg/l)				
		Sampling Station				
		J0	J2S	J4N	J4S	J22S
Copper	Min/Survey[a]	0.001/Mar,Nov 9	0.002/Nov 9	0.003/Mar	0.002/Sep	0.002/Sep
	Max/Survey[a]	0.19/May	0.018/Sep	0.024/Nov 9	0.011/Jul,Nov 9	0.10/Jul
	Mean	0.060	0.009	0.011	0.009	0.026
	Std Dev	0.0739	0.0048	0.0072	0.0031	0.0338
Chromium	Min/Survey	0.001/Nov 9	0.001/Nov 9	0.001/Nov 9	<0.001/Nov 9	0.001/Nov 9
	Max/Survey	0.011/Jul	0.007/Jul	0.005/Jul	0.006/Jul	0.006/Jul
	Mean	0.004	0.003	0.002	0.003	0.003
	Std Dev	0.0036	0.0021	0.0014	0.0017	0.0018
Iron	Min/Survey	0.07/Jul	0.04/Mar	0.07/Jul	0.07/Jul	0.07/Jul
	Max/Survey	0.22/Nov 9	0.30/Jan	0.23/May	[illegible]/May	0.26/Jan
	Mean	0.15	0.18	0.15	0.18	0.17
	Std Dev	0.061	0.097	0.081	0.094	0.069
Nickel	Min/Survey	0.001/Mar	0.001/Jan,Jul,Sep	0.001/Mar	0.001/Jan,Sep	0.001/Jan
	Max/Survey	0.022/May	0.026/May	0.014/May	0.020/Nov 9	0.013/May
	Mean	0.009	0.007	0.006	0.006	0.005
	Std Dev	0.0070	0.0090	0.0048	0.0064	0.0043
Titanium		All Measurements 0.1				

Metal	Item	Sediments (mg/kg)				
		Sampling Station				
		J0	J2S	J4N	J4S	J22S
Copper	Min/Survey	4.9/Nov 9	5.1/Jan	3.9/Jan	1.6/Jan	3.3/Jan
	Max/Survey	7.3/Jul	6.6/Jul	5.4/Jul	7.0/Mar	5.3/May
	Mean	6.1	5.8	4.6	5.1	4.2
	Std Dev	0.83	0.57	0.50	1.12	0.64
Chromium	Min/Survey	17/Nov 9	15/Sep	12/Sep,Nov 9	14/May,Sep	13/Mar
	Max/Survey	22/Jul	23/Mar	19/Mar	20/Jul	17/May,Nov 9
	Mean	20	19	15	16	15
	Std Dev	1.7	2.3	2.6	2.1	1.5
Iron	Min/Survey	9490/Nov 9	9240/Nov 9	7110/Sep,Nov 9	6990/May	6450/Mar
	Max/Survey	12200/Jul	11800/Mar	10000/Jul	10280/Jul	8180/May
	Mean	10934	10168	8623	8255	7267
	Std Dev	951.9	978.1	1292.2	1295.3	575.3
Nickel	Min/Survey	8.0/Nov 9	7.4/Sep	6.2/Sep,Nov 9	6.5/Sep	6.0/Mar
	Max/Survey	11/May	9.7/May,Jul	8.2/May	10/Mar	7.9/May
	Mean	9.4	8.9	7.0	8.1	6.8
	Std Dev	1.09	0.82	0.72	1.23	0.56
Titanium	Min/Survey	709/Nov 9	507/Sep	395/Sep,Nov 9	458/Sep	404/Mar
	Max/Survey	982/May	1150/Mar	933/May	1160/Mar	908/Nov 9
	Mean	874	839	668	694	605
	Std Dev	99.0	195.8	216.3	280.0	165.2

[a] Minimum or maximum concentration measured and date of survey when measured.

Table III-1. Surface dissolved oxygen at required SONGS 1 operational and SONGS 2 and 3 preoperational monitoring stations during 1979.

Survey Date	Unit 1 - Operational				Units 2 and 3 - Preoperational				
	C0 (Intake)	X0 (Discharge)	C22S (Control)	Unit 1 Mean	J2N	J2S	J4S	F22S	Units 2 & 3 Mean
Jan 11	7.7	7.6	7.9	7.7	7.9	7.9	7.9	7.8	7.9
Mar 14	8.6	8.7	9.0	8.8	8.7	8.7	8.6	9.1	8.8
May 16	9.1	8.7	9.2	9.0	9.3	9.3	9.3	9.8	9.4
Jul 11	8.1	8.3	8.3	8.2	8.0	8.0	8.0	8.1	8.0
Sep 5	7.9	8.0	7.1	7.7	7.7	8.2	8.1	7.9	8.0
Nov 7	8.4	7.6	8.2	8.1	7.9	7.8	7.9	8.1	7.9
Nov 27	8.0	7.7	8.0	7.9	a	a	a	8.1	-

[a] Not measured during November 27 survey.

Table III-2. Surface dissolved oxygen percent saturation at required SONGS 1 operational and SONGS 2 and 3 preoperational monitoring stations during 1979.

Survey Date	Unit 1 - Operational				Units 2 and 3 - Preoperational				
	C0 (Intake)	X0 (Discharge)	C22S (Control)	Unit 1 Mean	J2N	J2S	J4S	F22S	Units 2 & 3 Mean
Jan 11	94.2	98.3	94.8	95.8	93.8	94.7	94.4	93.3	94.1
Mar 14	106	119	108	111	103	103	102	109	104
May 16	110	117	113	113	110	116	111	120	113
Jul 11	108	115	111	111	102	102	102	107	103
Sep 5	108	111	95.3	105	103	109	108	107	107
Nov 7	102	104	100	102	96.8	95.6	96.7	101	97.5
Nov 27	99.6	104	96.8	100	a	a	a	98.5	-

[a] Not measured during November 27 survey.

Table III-3. Surface hydrogen ion concentration (pH) at required SONGS 1 operational and SONGS 2 and 3 preoperational monitoring stations during 1979.

Survey Date	Unit 1 - Operational				Units 2 and 3 - Preoperational				
	C0 (Intake)	X0 (Discharge)	C22S (Control)	Unit 1 Mean	J2N	J2S	J4S	F22S	Units 2 & 3 Mean
Jan 11	8.02	7.99	8.07	8.03	8.03	8.02	8.02	8.07	8.04
Mar 14	8.24	8.20	8.05	8.16	8.21	8.19	8.23	8.09	8.18
May 16	8.01	7.99	7.97	7.99	7.98	7.98	7.98	8.06	8.00
Jul 11	7.95	8.20	8.03	8.06	8.17	8.17	8.34	8.00	8.17
Sep 5	8.15	[illegible]	8.08	8.12	8.19	8.18	8.18	8.15	8.18
Nov 7	8.20	8.19	8.10	8.16	8.16	8.14	8.14	8.09	8.13
Nov 27	8.28	8.26	8.26	8.27	a	a	a	8.25	-

[a] Not measured during November 27 survey.

APPENDIX III · WATER QUALITY

TABLES