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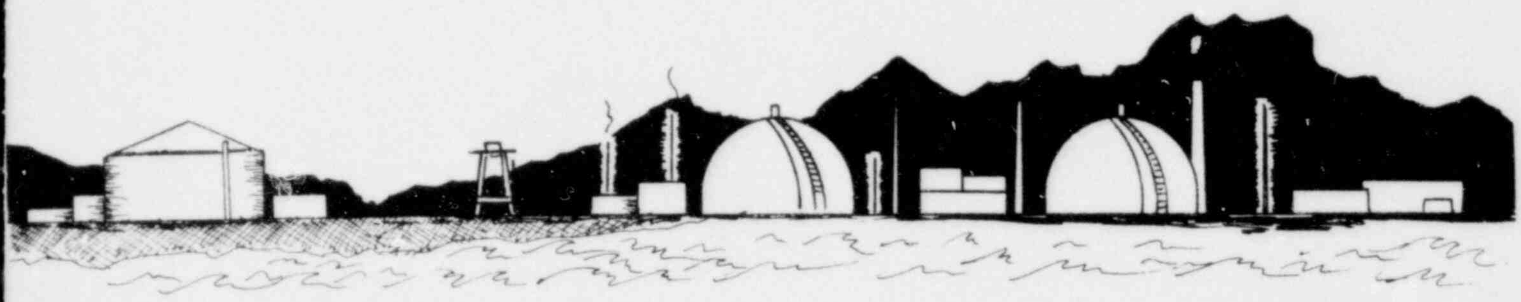

1980 ANNUAL REPORT
VOLUME III

MARINE ENVIRONMENTAL ANALYSIS AND INTERPRETATION

San Onofre Nuclear Generating Station

SOUTHERN CALIFORNIA EDISON COMPANY

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SCE

SOUTHERN CALIFORNIA EDISON COMPANY

JUNE 1981

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Plate 1 San Onofre Nuclear Generating Station Units 1, 2, and 3.

Plate 4B Rocky intertidal areas offshore San Onofre Nuclear Generating Station.

Plate 2B-1 January 31, 1980, San Onofre inactive.

Due to SONGS inactivity, no discharge plume exists. The high level of natural turbidity is due to high river discharge at San Onofre and San Mateo Creeks. The large river discharge volume has inundated the sand spits that normally form at the river mouths during periods of low river flow (see subsequent photographs). Sediment from San Onofre Creek hugs the downcoast shore (S) under the influence of wave action before dispersing offshore near the SONGS Plant. Turbidity caused by rip currents (RC) is evident. A density front (DF) associated with the turbid plume can be detected at various locations offshore. Movement of the plume upcoast is discerned by the turbid wake (W) associated with the San Mateo kelp bed (K). Turbidity upcoast from San Mateo Point and also at the San Onofre kelp bed is relatively minor.

Plate 2B-2 February 23, 1980, San Onofre in full operation.

Substantial turbidity is seen as a result of sediment input (S) at San Onofre and San Mateo Creeks. Again, river discharge hugs the coast as it proceeds in the downcoast direction until reaching the San Onofre vicinity. Turbid plumes associated with rip currents (RC) are evident. A turbid mass of water proceeds offshore as defined by the density fronts (DF). A nonturbid plume exists at the San Onofre outfall indicating the non-turbid nature of the water at the intake depth and location. The creation of this non-turbid plume at the outfall (O) implies that only the surface water layer is highly turbid.

Plate 2B-3 March 9, 1980, San Onofre fully operational.

As seen in previous photographs, the turbid water discharged by the rivers (S) moves downcoast within the surf zone until it is dispersed offshore near San Onofre. The San Onofre outfall (O) is discharging a turbid plume of characteristic color in the upcoast direction. Thus, the wave-induced current within the surf zone and the current at the outfall location are moving in opposite directions. The large turbid plume generated by the river discharge and rip current (RC) processes merges with the smaller plume of the outfall. The turbid zone, in general, seems to be contained between the San Onofre outfall and San Mateo Point.

Plate 2B-4 April 2, 1980, San Onofre fully operational.

A turbid water mass associated with surf zone and rip current (RC) processes is evident with intense turbidity at San Mateo Point and just upcoast of the San Onofre pier. The outfall (O) is visible as a small turbid streak directed downcoast. The width of the surf zone increases just upstream of the San Onofre pier due to the existence of the bathymetric bulge at this location. The level of turbidity is very low upcoast of San Mateo Point. Much of the turbidity that exists downcoast of San Mateo Point is generated by wave-induced resuspension within and near the surf zone at both San Mateo Point and the San Onofre bulge. The kelp beds (K) are visible but are not within the turbid plume as defined by the density front (DF).

Plate 2B-5 July 10, 1980, San Onofre pumps only, no heat.

The general level of surface turbidity is low relative to the previous photographs. A turbid plume associated with the bulge is seen just off the shore. Rip currents (RC) nearshore are observed. A turbid plume from the San Onofre outfall (O) is evident, however, due to the lack of heated discharge, this surface expression is devoid of thermal effects. The San Onofre kelp bed is seen offshore.

Plate 2B-6 July 17, 1980, San Onofre pumps only, no heat.

Very little surface turbidity is seen in this photograph. Surf zone turbidity (RC) is at a low level. The turbidity associated with the unheated discharge of the outfall (O) is barely visible. The kelp bed (K) is seen offshore.

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SUMMARY

This report presents analyses and discussions of oceanographic and marine biological studies conducted in 1980 and previous years near the San Onofre Nuclear Generating Station (SONGS) located on the southern California coastline between the cities of San Clemente and Oceanside. Physical, chemical, and biological data were analyzed to: 1) assess the operational effects of SONGS Unit 1; 2) determine the effects of Units 2 and 3 construction; and 3) provide a baseline for future assessment of the effects of Units 2 and 3 once they become operational.

These studies meet all requirements of the Nuclear Regulatory Commission - Environmental Technical Specifications (ETS) for Unit 1 and Preoperational Monitoring Program (PMP), as well as the California Regional Water Quality Control Board, San Diego Region - National Pollutant Discharge Elimination System (NPDES) permit for receiving water and sediment monitoring of Units 1, 2, and 3, and Construction Monitoring Program (CMP) for Units 2 and 3.

Unit 1 was only operational for four months of 1980 and was offline from April through December. Offshore construction for Units 2 and 3 was finished in April and the CMP was completed after the end of the first quarter. In addition, the second year of the formal PMP was completed in mid-1980.

The individual summaries below detail study findings of 1980 and previous years under specific oceanographical and biological disciplines.

TEMPERATURE

Temperature studies have been conducted at San Onofre for the past 17 years. Bimonthly studies conducted from 1964 through 1968 documented temperature conditions prior to Unit 1 operation. Similar temperature studies were conducted from 1968 until 1975, as a portion of the Marine Environmental Monitoring Program (MEM). These studies documented the thermal effect of Unit 1 operation on receiving water by temperature profile measurements at 32 stations, and infrared-radiometer mapping.

Beginning in 1975, temperature measurements were obtained at 34 sampling stations (similar to those sampled in the previous MEM studies) in accordance with the Environmental Technical Specification Program (ETS) and data collection at the surface, mid-depth, and bottom of two continuous temperature monitoring stations was initiated. Temperature profile sampling locations were increased to 51 stations in 1976. These temperature measurements fulfilled monitoring requirements of NPDES permits.

In May 1978, 23 additional offshore profiling stations were initiated as a portion of the Preoperational Monitoring Program (PMP) for Units 2 and 3. An additional continuous temperature sampling station was established in the preoperational study area near San Onofre kelp bed. In August 1979, continuous bottom temperature measurements at five PMP benthic cobble stations were initiated. Unit 1 was offline from 9 April 1980 through the end of the year. PMP studies were continued until September 1980.

These temperature studies at San Onofre represent one of the largest data bases pertaining to coastal generating stations. Results of these studies show:

1. Historically, sea surface temperature generally followed the annual cycle of insolation, while the bottom temperature appeared to follow the annual upwelling cycle, becoming cooler toward summer months when the upwelling activity throughout the southern California area reached its annual peak, and when vertical mixing was at a minimum due to temperature stratification.

2. The annual temperature cycle during 1980 was somewhat different from previous years, with winter and summer temperatures warmer than average conditions and spring temperatures somewhat cooler than average conditions.

3. The complex time history of natural temperature observed at San Onofre was the result of the interaction of several atmospheric and oceanographic phenomena. The frequency of variations in natural temperature covered the entire range of the frequency spectrum, from seasonal fluctuations to fluctuations within a few hours. 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 fluctuations in temperature.

4. Localized upwelling conditions significantly affected natural temperatures in the San Onofre area. When relatively strong winds associated with storms and/or atmospheric pressure systems blew from the northwest at San Onofre, localized upwelling occurred and resulted in elimination of the thermocline and decreased surface temperatures. These localized upwelling periods caused surface temperatures to decrease by 2 to 4°C in one to two days. It required three to four days for surface temperatures to return to previous levels after these upwelling events.

5. Regional upwelling affected temperature throughout the southern California area. Offshore circulation patterns transported portions of this upwelled water mass inshore to the San Onofre area. This resulted in long-period temperature fluctuations of approximately 30 days which corresponded to regional upwelling indices. These long-period temperature responses were usually characterized by a lag of from several days to 15 days.

6. Spatial variations caused natural surface temperature in the offshore study area to vary between stations with the magnitude of this variation ranging from 0.8 to 2.2°C (4°F). This was significant since the circulating seawater system for Units 2 and 3 are designed with multiport diffusers to avoid increasing surface temperature more than 2.2°C (4°F).

7. 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 the year, and then increased with distance offshore during the second half of the year. No consistent pattern of temperature spatial distribution was apparent in the alongshore direction.

8. Results of continuous temperature measurements revealed that simultaneous temperature measurements 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 may not accurately represent ambient conditions for the area of the generating station.

9. Although absolute temperature between locations are not always similar, the fluctuations in temperature between continuous sampling locations were often similar. 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.

10. The circulating cooling water system from Unit 1 produces a surface thermal plume approximately 3 to 4 m thick in the vicinity of the discharge. Temperatures within this plume range from 0.6 to 2.2°C above natural temperature. The extent of the 1°F (0.6°) elevated temperature field has averaged 600 acres for the five-year period, 1976-1980. For the same period, the surface area enclosed by the 4°F (2.2°C) elevated temperature field averaged 16 acres. Since 1976, the 4°F (2.2°C) elevated temperature field has been observed to be less than 1 acre for 40% of the time.

11. During the past five years, the 1°F elevated temperature field ranged from less than 1 acre to 1800 acres. The large range of size in the plume's elevated temperature field is due to the variability in the natural temperature stratification, currents, and the rate of heat dissipation to the ocean and the atmosphere.

12. Considering the large temporal (4 to 5°C) and spatial (0.5 to 2.0°C) variations of natural surface temperature observed throughout the study area, the variability of temperature resulting from the Unit 1 thermal discharge (0.6 to 2.2°C) is relatively small, especially when the limited extent of the 2.2°C (4°F) elevated temperature field is considered. Thus, the thermal impact of Unit 1 is considered negligible.

TURBIDITY

Turbidity studies have been conducted at San Onofre for the past 17 years. Bimonthly studies conducted from 1964 through 1968 documented turbidity conditions prior to Unit 1 operation. Similar studies were conducted from 1968 until 1975, as a portion of the Marine Environmental Monitoring Program (MEM). These studies documented the effect of Unit 1 operation on receiving water by light transmittance profiles and Secchi disc measurements at 32 stations.

Beginning in 1975, turbidity measurements were obtained at 34 sampling stations (similar to those sampled in the previous MEM studies) in accordance with the Environmental Technical Specification Program (ETS). Turbidity sampling locations were increased to 51 stations in 1976. These turbidity measurements also fulfilled monitoring requirements for NPDES permits.

In May 1978, 23 additional offshore profiling stations were added as a portion of the Preoperational Monitoring Program (PMP) for Units 2 and 3. Surface and mid-depth water samples from 42 stations were collected and analyzed for suspended and settleable solids. In August 1979, measurements of continuous near

bottom light intensity and estimation of sedimentation rates at five PMP benthic cobble stations were initiated. PMP studies were continued until September 1980. A special turbidity study in the offshore area of Units 2 and 3 diffusers was conducted weekly from March to September 1980. The study consisted of field sampling of light transmittance, ambient light intensity, and suspended solids concentrations at 20 stations throughout the study area.

These turbidity studies at San Onofre represent one of the largest data bases pertaining to coastal generating stations. Results of these studies show:

1. Major sources of turbidity in the vicinity of San Onofre include the surf zone, the offshore seabed, and terrestrial drainage.

2. The dominant natural processes affecting turbidity in the vicinity of the generating station include rainfall and associated terrestrial drainage, waves, currents, eddies, plankton density, and upwelling. Rainfall and associated terrestrial drainage most directly affected ocean bottom light intensity.

3. Natural geological and topographic conditions inherent to the San Onofre site favor the occurrence of high turbidity in waters as far as about 2 km offshore in the area from San Mateo Point to approximately 1 km downcoast of the generating station. Specific conditions responsible for this are: San Mateo and San Onofre Creeks close to the site, the naturally protruding shoreline in the vicinity of the generating station site and its reliefed underwater topography, fine grain sediment deposits on the offshore seabed, and the headland at San Mateo Point upcoast of the generating station.

4. Natural turbidity near the station is particularly high during the winter-spring rainy season, when the turbid discharge from San Mateo and San Onofre Creeks converges on the protruding shoreline, and is transported about 500 m offshore by rip currents.

5. The protruding shoreline in the area from 1.3 km upcoast to 1.1 km downcoast of Unit 1 collects turbid waters from adjacent surf zones by intercepting the longshore currents. The intensified wave breaking action, due to a convergent refraction of waves over the topographically reliefed offshore seabed, also contributes to the occurrence of strong local turbidity in this area of the surf zone. Thus, even without the contribution of flood runoffs from the creeks, natural turbidity is usually higher in the surf zone near San Onofre. Since the protruding shoreline configuration favors rip current activity, the surf zone turbidity is readily transported to the area offshore of the surf zone.

6. According to a conservative estimation of sediment resuspension, fine grain bottom sediment on the offshore slope is stirred up into the water column by wave action about 40% of the time at a depth of 6 m (20 ft), about 30% of the time at 9 m (30 ft), about 20% of the time at 12 m (40 ft), and about 10% of the time at 15 m (50 ft). Suspended sediment concentration in the near bottom layer of the water column is on the order of about 100 mg/liter. As a consequence, the offshore seabed (water depths of 3 to 15 m) is relatively unstable, exhibiting an average of 0.3 m (1 ft) in sand level changes in a year.

7. The headland at San Mateo Point interacts with impinging coastal currents to produce a downdrift eddy, at times. Under prevailing southerly currents in the study area, this eddy stretches to the offshore zone near the generating station and brings turbidity from the upcoast surf zone to this area. This eddy, though containing less turbidity than creek runoff or rip currents, is considered a significant additional source of natural turbidity due to its persistent occurrence.

8. Natural turbidity conditions at San Onofre and most coastal waters vary extensively with time. Ambient light intensity generally followed a seasonal cycle during 1980, with lowest light intensities during winter months and highest intensities during summer months. Within this seasonal cycle, several short-term fluctuations in the amount of turbidity were observed. These fluctuations were due to rainfall, waves, and upwelling.

9. The most dominant feature of turbidity data collected at San Onofre was the natural decrease in turbidity with distance offshore.

10. Unit 1 does not add to the turbidity of waters circulated through its cooling water system, but redistributes the frequently more turbid bottom and mid-depth waters to the surface. The circulating seawater system of Unit 1 created a distinguishable surface turbid plume only during periods of intense natural vertical stratification of turbidity.

11. Turbidity caused by waves which resuspend bottom sediments in the nearshore area had the greatest effect on water clarity in the vicinity of the Unit 1 discharge.

12. During 1980, the influence of the plume from Unit 1 was strictly local in scope. As in previous years, influence of Unit 1 on the distribution of turbidity was less than natural variablity of turbidity with space and time in the nearshore coastal environment and therefore, the impact of Unit 1 on turbidity was considered negligible.

WATER QUALITY

Dissolved oxygen (DO) and hydrogen ion concentration (pH) studies began at San Onofre in 1967. These studies compared bimonthly measurements of surface values in the vicinity of the discharge to a downcoast control station to determine the operational affects of Unit 1. These studies were initiated as a portion of the Marine Environmental Monitoring (MEM) program, and were included as a portion of the Environmental Technical Specification (ETS) program which began in 1975. Beginning in January 1977, vertical profiles of DO and pH were collected simultaneously with temperature and turbidity profiles at 51 stations. From May 1978 through July 1980, 23 additional vertical profiling stations were sampled bimonthly in conjunction with the Preoperational Monitoring Program (PMP) for Units 2 and 3.

Quarterly monitoring of heavy metals in receiving waters and sediments at four stations began in 1975 as a portion of ETS. From May 1978 to September 1980, five additional offshore Unit 2 and 3 sampling stations were added as a portion of the PMP.

Results of these studies show:

1. Surface waters at San Onofre are normally at or slightly above the oxygen saturation level (7 to 9 mg/liter, depending on temperature and salinity) due to the immense source of oxygen in the atmosphere and photosynthetic activity.

2. During spring and summer, vertical density stratification results in decreased dissolved oxygen with depth by inhibiting the mixing of surface and bottom waters. During the winter there is little or no density stratification with depth and dissolved oxygen is relatively uniform throughout the water column.

3. Upwelling conditions can over-ride density gradient boundaries when strong offshore winds from the west-northwest force warm surface water offshore. The displaced surface water mass is replaced by the underlying cooler, nutrient-rich bottom water, which wells up through the water column. The biological and water quality characteristics (such as nutrients, turbidity, DO, pH, COD, etc.) in this upwelled cool bottom water can be significantly different from the displaced surface water mass.

4. Plankton blooms often affect the vertical distribution of dissolved oxygen. Phytoplankton often increase mid-depth dissolved oxygen concentrations during daylight hours, by release of oxygen to the water as a by-product of photosynthesis. During the past four years, evidence of phytoplankton blooms were often observed in water quality profile data during the March and May bimonthly surveys in the offshore study area for Units 2 and 3. Respiration by high concentrations of zooplankton occasionally caused a sharp decrease in dissolved oxygen with depth.

5. Dissolved oxygen concentrations at the Unit 1 intake and discharge were not depressed more than 10% from samples collected at the downcoast control, and therefore the discharge was in compliance with State of California and ETS specifications. Dissolved oxygen values at San Onofre were comparable to naturally occurring values found throughout the southern California bight. Surface dissolved oxygen concentrations were not significantly different during bimonthly surveys when comparing inshore (10 m depth) to offshore (20 m depth) sampling stations.

6. The hydrogen ion concentration in southern California coastal waters varies in a narrow band around a mean of approximately 8.1. Natural ranges for pH in the San Onofre area have been defined as 7.3 to 8.5, based on information gathered from 1967 to 1973 (Allan Hancock Foundation 1975).

7. Vertical profile measurements taken at San Onofre show slight vertical stratification of pH, with higher surface values and a general decrease in pH with depth.

8. Historically, surface pH at San Onofre has been within the normal range observed in southern California. Unit 1 operation did not cause surface pH to vary by more than 0.2 units, and therefore was in compliance with State of California and ETS specifications. There were no consistent spatial trends observed in on-offshore or longshore directions.

9. A cumulative six-year study of copper, chromium, and nickel, has revealed no apparent patterns of spatial or temporal distribution in the water column or sediment samples. Sediment concentrations of copper, chromium, nickel, and iron exhibited no significant increase in the vicinity of the Unit 1 discharge (Station X0) throughout the six-year study.

10. Titanium concentrations in receiving waters and ocean bottom sediments showed no substantial increases in the Unit 1 or Units 2 and 3 sampling areas since its initiation in 1978. Most all receiving water samples had concentrations at or near the detection limit.

11. A measurable increase in water column iron concentrations throughout the study area was observed in yearly mean values for the past four years. Since the increase was observed throughout the area including control stations, it is not due to the operational influence of the generating station. The general increase in yearly mean iron concentrations in the water column correlated to the general decrease in yearly mean percent light transmittance from bimonthly surveys.

12. The concentrations of iron in the water column have generally followed the seasonal pattern of turbidity in the San Onofre area since 1976. Increased iron concentrations were usually observed during winter months when rainfall and increased wave action increased the amount of suspended material in the water column.

SEDIMENTOLOGY

Sedimentology studies associated with environmental investigations of San Onofre intertidal and subtidal habitats have been conducted since 1963. Original program visual substrate observations were supplemented by grab and core samples in 1972. Replication of core samples in both the intertidal and subtidal areas was increased to current levels in 1978. The purpose of the 1980 studies was to determine effects of San Onofre Units 2 and 3 construction, dredging and trestle emplacement upon intertidal and subtidal sedimentary environments. Quarterly at five intertidal stations, five replicates at seven tidal elevations were collected for sediment grain size analysis. In addition, beach profiles at each station were determined. On a quarterly basis core substrate samples were collected for grain size and carbon analysis at 18 benthic stations. Benthic stations were located at depths of 6, 9, and 15 m and sampling replication was depth dependent.

1. Intertidal beach profile measurements showed only minor erosion or accretion upcoast of the construction pad. Erosion and accretion tended to be greater downcoast of the pad.

2. Grain size analysis of intertidal sediments revealed that the mean grain sizes, coarse fraction content, sorting, skewness, and kurtosis of the samples were comparable to those reported in 1979. These properties indicate that changes in the intertidal sediments since 1979 were caused by natural winter storms.

3. Subtidal sedimentation rates were lowest and least variable at offshore stations. The sedimentation rate was higher in 1980 than in 1979 and

suggested that most changes in sea floor elevation were caused by lateral-motion of the bottom sediments. The motion of the sediments was primarily by traction along the bottom and only minor sediment transport was by suspension. No correlation of sedimentation rate with high waves was evident.

4. Four subtidal sediment facies (sediment types defined on the basis of distinctive physical or textural properties) corresponding to those recognized in 1978 were observed: 1) a moderately sorted, very fine sand typical of an inshore facies, 2) a poorly to very poorly sorted coarse silt group representing an offshore mud facies, 3) a moderately well to poorly sorted medium to fine sand recognized as a relict sand facies, and 4) a bimodal fine to very fine sand that was poorly sorted. The distribution of these facies was attributed to natural processes in the nearshore zone; no effect of construction or dredging was evident.

5. Organic and carbonate carbon content of subtidal sediments exhibited no consistent areal pattern. Modal carbon content values were similar to those reported in 1979, but extreme values were substantially higher. Relict sediments tended to have high carbonate carbon and low organic carbon content.

6. Intertidal and benthic sedimentology studies since 1978 revealed that sediment regimes have attained equilibrium conditions, accommodating construction and dredging influences. Major seasonal changes in these conditions have resulted primarily from storms and natural fluctuations and secondarily from the presence of the laydown pad which disrupted longshore sediment movement. Since the trestle has been removed and dredging completed, subtidal conditions are expected to return to preconstruction status. However, intertidal sediment regimes will probably remain at the present equilibrium state until the laydown pad is removed.

PLANKTON

SCE plankton studies have been conducted at San Onofre since 1964. The early semiannual surveys included surface samples taken by a towed net at 3-5 stations and continued into 1975. From 1975 to mid-1978 Unit 1 operational samples were taken bimonthly at 7 stations throughout the 10-m (30-ft) depth water column with a pump system. A two-year combined Units 2 and 3 preoperational and Unit 1 operational program was completed in mid-1980. Samples in this integrated program were replicated on 3 days every 2 months at 17 stations. Stations were located at depths of 10, 15, and 30 m (30, 50 and 100 ft).

1. The two-year Preoperational Monitoring Program (PMP) successfully concluded the gathering of baseline data for evaluating the possible effects of future operation of San Onofre Units 2 and 3 on plankton resources in the receiving waters.

2. Examination of combined Unit 1 operational ETS and Units 2 and 3 preoperational data revealed several recurring spatial patterns of plankton resources in the San Onofre region. There was a generally decreasing trend of zooplankton abundance, and chlorophyll a and phaeopigment concentrations proceeding from inshore to offshore stations. Vertical stratification of zooplankton abundance and chlorophyll a concentration was greatest at the stations

farthest offshore on the 30-m isobath, with greater concentration or abundance most frequently in the lower depth stratum. Significant variability in chlorophyll a and phaeopigment concentrations, and zooplankton abundance and biomass was usually present among the three days of a single survey.

3. Over a period of six years, from 1975 to 1980, zooplankton abundance has tended to be low in winter and summer, and high in spring or early summer. Mean total zooplankton abundance in 1980, was lowest in July and highest in May. Zooplankton total abundance was greater at the 10- and 15-m stations than at the 30-m stations for the two-year comprehensive program. The upcoast onshore-offshore reference transect near San Mateo Point generally exhibited lower total abundance than other transects for the combined operational/preoperational surveys.

4. Zooplankton species composition and rank order of abundance was similar from 1975 through 1980. Individual taxa generally exhibited spatial distributions similar to the total abundance. Several taxa showed seasonal patterns of abundance.

5. Zooplankton dry weight biomass, measured for the two-year combined study was generally lowest in winter and highest in spring. The overall pattern of biomass distribution reflected that of total zooplankton abundance.

6. Over a six-year period, plankton variables (zooplankton total abundance, chlorophyll a, and phaeopigment concentrations) have generally exhibited greater concentrations (abundance) in the lower depth stratum. The vertical stratification of variables in 1980 was less distinct than previous years. Little stratification at 10- and 15-m depth stations was present; at 30-m stations, higher values of each variable measured were generally found in the upper stratum.

7. Chlorophyll a concentration, a reflection of phytoplankton abundance, is generally lowest in winter and highest in spring. A pattern of increasing chlorophyll a concentration through the spring maximum followed by a decline through summer and fall was evident in 1980. This is consistent with general seasonal patterns observed at San Onofre over the last six years.

8. Phaeopigment concentrations are the degradation products of chlorophyll and may occur in high concentrations if the phytoplankton in an area has been killed. During the last six years, phaeopigment concentrations have generally paralleled the distribution of chlorophyll a. Phaeopigment concentrations during 1980 were low throughout the year and generally reflected the spatial and temporal pattern described for chlorophyll a.

9. Phytopigment fluorescence ratios, the ratio of chlorophyll a and phaeopigment concentrations, are one way of assessing the health of phytoplankton populations. These ratios, calculated for two years of combined Unit 1 ETS operational/Units 2 and 3 preoperational studies, indicate that phytoplankton stocks in the study area were in a healthy state during all surveys. Seasonal fluctuation of this ratio reflected the seasonal cycle present for chlorophyll a.

10. Periodic climatic patterns which affect local oceanographic phenomena, such as upwelling and intrusion of offshore surface water, influenced distributional patterns of plankton observed offshore of San Onofre from 1975 to 1980.

11. No patterns of plankton distribution or abundance (concentration) were observed that could be related soley to the operation of San Onofre Unit 1.

12. More than five years of study indicates the inherent variability within the planktonic community offshore of San Onofre exceeds any differences attributable to Unit 1 operations.

SANDY INTERTIDAL

Sandy intertidal studies in the vicinity of San Onofre Nuclear Generating Station have been ongoing since 1964. Early studies were performed as part of the preoperational and later operational monitoring portion of the Marine Environmental Monitoring (MEM) program for San Onofre Unit 1. These early studies included scoop and shovel excavation sampling for biota. In 1974 the Sand Disposal Monitoring (SDM) program introduced core sampling which was continued under the 1976 through 1980 Construction Monitoring Program (CMP). The CMP objectives were to determine if construction or dredging activities would have a detrimental effect on the sandy intertidal community. The program was only conducted in February 1980, since construction activities were terminated in March. The program consisted of: 1) core sampling of infaunal organisms along intertidal transects; 2) the determination of beach profiles along each transect line; and 3) grain size analysis of sediments adjacent to each sampling site.

The findings to date include:

1. Emerita analoga, the sand crab, has remained the most consistently abundant organism in the sandy intertidal community since sampling began in 1964.

2. Emerita exhibit seasonal abundance fluctuations with high numbers appearing in spring when settlement of pelagic larvae occurs.

3. Sandy intertidal areas adjacent and distant to construction-related structures appear to be very similar in community composition and abundance.

4. Composition and density of the community was typical of previous winter collections.

5. The community continued to be dominated by the sand crab Emerita with the polychaete worm Hemipodus subdominant.

6. Sparseness of the community precluded detailed analysis.

7. No adverse effect on the sandy beach intertidal community by San Onofre has been demonstrated and the community remains similar to that observed on similar beaches throughout the southern California bight.

INTERTIDAL COBBLE

Intertidal cobble studies have been conducted at San Onofre since 1963. These studies have developed from the early qualitative sampling conducted annually into quarterly quadrat sampling at uniform intervals conducted through 1974. The Unit 1 ETS operational/Units 2 and 3 construction effects study conducted from 1975 through 1977 employed permanently positioned quadrats surveyed quarterly. This program was substantially reduced in scope as findings from the ETS study indicated that human activity such as clamming and natural processes such as sand movement were the major factors influencing the intertidal cobble communities. The resulting and currently existing observational study is conducted to maintain continuity with the previous program.

1. Comparison of data collected at all cobble stations in 1980 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. Natural occurrences of sand accretion; longer term shifts in substrata composition; human intervention resulting from recreational activities such as tidepooling, clamming, and surfing activities; and unnatural occurrences of erosive mats of debris caught at fixed quadrats, were the only directly observable community altering factors in the intertidal cobble quadrats.

4. Clamming activity was more frequent at the stations near San Onofre Unit 1 during the 1980 surveys than during 1979 surveys. This was comparable to the amount of activity observed in years prior to 1979.

5. New areas of cobble surface were exposed to settlement of organisms, during both winter and summer periods at all stations. Wave induced cobble movement, changes in beach slope, fresh water runoff and sedimentation, accretion and erosion of sand, size heterogeneity of cobble habitat components, and other factors probably contributed to this change in substratum exposure.

6. The upcoast reference area was not within the +1°F (0.6°C) influence of San Onofre Unit 1 discharge during temperature surveys during 1980. Variation in biological factors due to generating station operation was not discernible.

7. As previously noted (SCE 1980e), construction of San Onofre Units 2 and 3 may have 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.

8. Based on data collected, there was no evidence that the operation of San Onofre Unit 1 caused changes in the intertidal cobble biota. This is in agreement with previous findings.

SEDIMENT INFAUNA HABITAT

Marine Environmental Monitoring (MEM) of benthic communities near the San Onofre Nuclear Generating Station began in 1963 and continued under this program until 1973. Semiannual MEM diver observations were supplemented in 1969 with infaunal core sampling. In 1974 the Sand Disposal Monitoring program (SDM) was initiated and infaunal sampling continued at three stations with increased replication. The Construction Monitoring Program (CMP) followed in 1976 when dredging and offshore construction for Units 2 and 3 began. Infaunal sampling by coring continued and sediment sampling for grain size and carbon content was initiated at 18 stations. Replication of both biological and geological samples were increased and dependent on water depth. The 1980 program was conducted only in March and June, since construction was terminated in March and trestle structures were removed in April. The subtidal infaunal program included: 1) replicate box core sampling at stations near SONGS and in appropriate reference areas; and 2) the determination of sediment movement, deposition rate, grain size analysis, and carbon analysis at all sampling stations.

1. Stations upcoast and immediately adjacent to the construction activities for Units 2 and 3 and operational Unit 1 supported elevated numbers of species and individuals compared to reference areas. These patterns appear related to a combination of elevated sediment organics from San Onofre Unit 1 operation and sediment accumulation near the trestle associated with construction inhibited longshore transport.

2. Stations downcoast and immediately adjacent to the construction areas of Units 2 and 3 discharge and intake structures generally supported fewer numbers of species and individuals than reference areas. These patterns appear related to net errosion of sediment near the trestles associated with construction structural impediments to longshore transport.

3. Species numbers increased proceeding offshore from the 6 to 15 m isobath stations. This pattern was consistent with natural distributions observed throughout the southern California bight and reported by other authors.

4. Benthic infaunal results indicated that the community was dominated by deposit feeding species.

5. Community distribution patterns were characterized by dominant taxonomic groups representing Annelida, Mollusca, and Arthropoda and included the following:

   a. Groups of species which 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.

6. Important factors associated with community distribution and abundance patterns appeared to be water depth, sediment composition, water clarity, sedimentation, and organic carbon content of the sediment.

7. Effects of construction activities are not expected to persist since dredging has ceased and structural impediments to longshore transport have been removed.

HARD BENTHOS

Benthic dive surveys evolved from qualitative surveys in 1963 into semiquantitative assessments through 1974. The Unit 1 ETS operational/Units 2 and 3 construction effects study included nondestructive sampling in permanently marked 10-m^2 (108-ft^2) transects at 13 stations (5 in kelp forests) along the 10-m (33-ft) depth contour from 1975-1980. Preoperational data for Units 2 and 3 were collected at 10 additional offshore stations (8 in kelp forests) along the 12- to 14-m (39- to 46-ft) depth contours from mid-1978 through mid-1980. A quantitative point contact technique was employed to sample macroorganisms and substrata composition.

General

1. The two-year Preoperational Monitoring Program (PMP) successfully concluded the gathering of baseline data for evaluating the possible effects of future operation of San Onofre Units 2 and 3 on benthic resources in the receiving waters.

2. 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 (which influences water motion and light), substrata stability, light intensity, and biological interactions.

3. Analyses of data collected from 1975 through 1980 indicate no long-term ecological effects have been associated with the operation of Unit 1 or the construction of Units 2 and 3 at the inshore cobble stations, the kelp stations, or the offshore cobble stations.

Inshore 10-m (33-ft) Cobble Habitat

1. Comparison of substrata composition at the inshore cobble stations during six years of monitoring indicates that sand accretion and erosion 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 may occur within one year or take at least three years.

Kelp Forest Cobble Habitat and Offshore 14-m (46-ft) Cobble Habitat

1. The structure of the offshore San Mateo, San Onofre, and Barn Kelp forest cobble communities appears to be primarily a function of substrata composition and stability, and secondarily, a function of competitive interactions among organisms.

2. Physical data including light, sediment deposition, and total organic carbon collected between 1979 and 1980 indicates the San Onofre Kelp forest is spatially heterogeneous, particularly with regard to light patterns. Similar data collected in the San Mateo Kelp forest and near the Barn Kelp forest document the wide range of variability associated with these parameters in the study area.

3. Substrata data collected at six sites within the San Onofre Kelp forest suggest this area is situated on an extensive plain of cobbles and boulders covered with a comparatively thin (hence, dynamic) layer of sand. The influence of the possible geological setting on the development of kelp forest communities is not understood, however, the variable temporal pattern of the San Onofre Kelp forest as indicated by substantial changes in substrata composition and kelp canopy expansion and contraction during the past six years must be closely associated with these predominant processes.

4. Storms of approximately the 30-50 year magnitude during winter 1980, similar to those observed during the 1978 sampling period, resulted in a substantial reduction of foliose algal cover at all PMP offshore cobble stations. The red algae Rhodymenia spp. at the offshore cobble station located approximately 1,300 m (4,265 ft) downcoast of the Unit 2 diffuser in the San Onofre Kelp forest exhibited considerable growth, in terms of percent cover, during the 1980 sampling period. A comparison of the distributional patterns of Rhodymenia suggests reduced light intensity, as a function of biological overstory shading and/or natural turbidity, results in a favorable light environment for growth of Rhodymenia.

FISH

Fish sampling offshore San Onofre began in 1963 and continued through 1972 as semiquantitative visual observations by divers. Quantitative sampling techniques started as short term studies using gill nets and otter trawls in 1972 and 1973. In 1975, the ETS program began using multiple mesh gill nets at six stations located along the 9.1-m (30-ft) isobath near the Unit 1 discharge and at a downcoast reference site. This sampling technique continued through 1980, and was augmented in 1978 by gill netting at an upcoast reference site and at complimentary offshore (13.7-m, 45-ft) stations. Otter trawl sampling was also added in 1978 and conducted in the three gill net areas at 6.1-, 12.2-, and 18.3-m (20-, 40-, and 60-ft) depth contours through 1980. Fish collected in gill net and otter trawl samples were identified to species, counted, measured, and sexed. More detailed analyses, such as gonosomatic indices, were performed on queenfish and white croaker which were the most abundant San Onofre species.

1. The fish community offshore San Onofre in 1980 as in the past was composed of a diverse assemblage of demersal and water column fishes displaying a wide variety of feeding habits.

2. The queenfish, Seriphus politus; white croaker, Genyonemus lineatus; walleye surfperch, Hyperprosopon argenteum; and white surfperch, Phanerodon furcatus are ubiquitous throughout the area in both sand and cobble/sand habitats. Northern anchovy, Engraulis mordax; queenfish; and white croaker are the numerically dominant taxa. The California halibut, Paralichthys californicus, and speckled sanddab, Citharichthys stigmaeus, are common in sand habitats.

3. Spatial distributional variability appears related to type and stability of substrata. Unstable substrata (i.e., sand) tends to support ephemeral assemblages of fish relying on prey items in the water column, while hard substrata (cobble) areas support a temporally predictable assemblage of fish displaying bottom feeding habits.

4. The treatment site near San Onofre Unit 1 did not contain unique fish groups relative to the reference areas nor did a given species group numerically dominate the treatment site. Thus, no significant differences in community structure were observed between the treatment and reference sites.

5. Analysis of population abundances of queenfish and white croaker on the three years of trawl data revealed onshore movement of adults from deep (> 30-m) offshore areas in late winter followed by movement up in the water column in spring to avoid cold, upwelled bottom waters. During summer, both species were concentrated at the shallow (6- to 12-m) inshore depths, indicating continued inshore movement by adults and recruitment of young-of-the-year. In fall and early winter (1978-1980), offshore movement by adults was observed in association with unstable conditions in the water column influenced by oceanic events such as storm activity while young-of-the-year over-wintered inshore.

6. Distinct seasonal variations in reproductive condition were observed for queenfish and white croaker in all habitats. White croaker spawned prior to or during movement to and from the deep (> 30-m) over-wintering habitat, while queenfish after leaving the over-wintering grounds, spawned during the spring through summer period. Reproductive condition of females caught near the Unit 1 discharge was not different from other areas during 1980 as observed in 1979.

7. Length frequency distributions of queenfish and white croaker caught with gill nets and otter trawls were bimodal during most of each year. Young-of-the-year (age 0+) and small adults (ages 1+ to 3+) composed the two modes encountered in the sand habitats. Younger specimens composed a larger portion of the catch in the shallow (6- to 12-m) depths than at the deeper (14- to 18-m) sampling sites. In cobble habitats the bimodal size frequency lacked age 2+ white croaker and age 3+ queenfish which was related to the catch efficiency of gill nets for adults.

8. Female queenfish and white croaker were more abundant than males along the inshore (6-, 9-, and 12-m) isobaths of the sand and cobble habitats. Sex composition at the offshore (14- and 18-m) habitats was approximately equal to a 1:1 ratio.

9. The other species studied in detail (walleye surfperch, white surfperch, northern anchovy, speckled sanddab, and California halibut) did not show as distinct seasonal abundance patterns, although white surfperch and northern anchovy appeared to move on- and offshore with queenfish and white croaker. White surfperch and walleye surfperch both fed or rested over sand and moved to feed near kelp beds. California halibut were in the shallow area apparently feeding on fodder fish concentrated there. Speckled sanddab remained offshore apparently preferring the cooler waters and perhaps avoiding predation by California halibut. Northern anchovy adults were

distributed in large patchy schools mainly in the shallow sand habitat during summer. Larval anchovies ranged between shallow and deep sand habitats, and were captured inshore in late winter when most other fish populations were still offshore.

10. The fish community and populations in the San Onofre area did not appear to be adversely affected by the discharge of Unit 1 cooling water since intensive studies began in 1975.

FISH IMPINGEMENT

Impingement studies began at San Onofre in 1968 and continued through 1971 with qualitative evaluations of fish and invertebrates expressed in terms of biomass. In 1972, heat treatment losses were monitored by biologists who identified fish to species, estimated losses as numbers of individuals, and determined total losses in terms of biomass. Beginning in 1974 and continuing to date, impingement losses were quantified by fish species, number of individuals, and size and sex of individuals of selected species.

1. An estimated total of 459,573 $\pm$ 54,893 (1 standard deviation of the total) individuals weighting 21,799.85 $\pm$ 3,372.56 kg (48,069 $\pm$ 7,437 lbs) were impinged under normal operational conditions by San Onofre Unit 1 in 1980 during 152 days of operation. A total of 5,936 individuals weighing 400.89 kg (884 lbs) were impinged in two heat treatments in 1980.

2. The numerically dominant species impinged during normal flow were queenfish (70.1%), white croaker (8.[illegible]%), walleye surfperch (7.2%), and white surfperch ([illegible].1%). Walleye surfperch, queenfish, white croaker, and white surfperch, accounted for 65.7%, 19.2%, 0.4%, and 0.2% of the total heat treatment catch by number, respectively.

3. Analysis of length structure of queenfish, <u>Seriphus politus</u>, impinged by Unit 1 was similar to that observed in 1979 and reflected the length structure of queenfish caught offshore by trawls and gill nets.

4. Analysis of sex ratios for queenfish indicates that San Onofre Unit 1 did not impinge a disproportionately large number of female queenfish relative to their numbers in the receiving water. For queenfish, a pronounced shift from female to male dominated impingement catch was observed for the first time since 1978. The reason for this shift to male dominated impingement catch is presently unknown, since females were more numerous offshore during most trawl and gill net surveys. Perhaps severe storm activity early in 1980 resulted in a change in the spatial distribution of males relative to females thereby increasing their susceptibility to impingement.

5. The 1980 estimate of total fish impinged by San Onofre Unit 1, including queenfish, white croaker, walleye surfperch, and white surfperch, standardized to the number of operational days between January and July, indicates that more fish were impinged in 1980 than during any of the five previous years. The higher impingement rate in 1980 may [illegible]lted from extremely stormy conditions during the early part of the year.

6. Evaluation of monthly impingement catch for the past four years indicate that highest impingement catches of total fish including queenfish, white croaker,

walleye surfperch, and white surfperch occur from January through July. This seasonality results from the co-occurrence of seasonal reproductive and movement patterns, and oceanic disturbances such as storms and upwelling.

7. Total impingement from 1975 to 1980 has ranged from a low of 198,266 individuals (24,631 lbs) in 1976 to a high of 601,193 individuals (43,820 lbs) in 1978. Queenfish have numerically dominated the impingement catch for this period and in combination with white croaker, walleye surfperch, and white surfperch historically comprise the greatest percentage of the annual impingement catch.

8. The major factors responsible for impingement at San Onofre Unit 1 appear related to (1) the number of days of Unit 1 operation, (2) season in which Unit 1 operation occurs, (3) oceanic disturbances in the form of storms and sporadic upwelling, and (4) seasonal movement and reproductive patterns of seasonally abundant species such as queenfish, white croaker, walleye surfperch, and white surfperch.

KELP

The kelp beds in the San Onofre region have been periodically monitored by several groups over the past 70 years. Early methods included manual positioning and soundings by boat in 1911 and oblique aerial photography in the 1950's. From 1963-1973 the beds were qualitatively examined in conjunction with San Onofre Generating Station Unit 1 operational diving studies. Transplant experiments of warm-water tolerant strains of Macrocystis were conducted by Dr. W. J. North in the early 1970's. Since then, electronic positioning and aerial photography have documented fluctuations in canopy extents and surrounding hard substrate on a quarterly basis. Additionally, hard benthic sampling transects as part of Environmental Technical Specifications (ETS) for Unit 1 operational, Units 2 and 3 Construction Monitoring Program (CMP) and Preoperational Monitoring Programs (PMP) have been located in or near the kelp beds within the period 1975-1980. More recently (1979-1980), monthly nutrient and continuous light, temperature, and sedimentation data were collected. Independent monitoring and extensive experimental kelp studies examining cause-effect mechanisms have been performed by the Marine Review Committee Kelp Project (1976-1980) oriented to predicting the effects of Units 2 and 3 upon the San Onofre kelp bed.

1. Several periods of canopy deterioration have been documented in the San Onofre region since 1911 including the period between July and December 1980.

2. Heavy deterioration was apparent in 1980 at Barn kelp 5.5 m downcoast of San Onofre where the kelp canopy disappeared and the remaining kelp plants were in various states of distress.

3. Observations made at San Mateo and San Onofre kelp beds suggested that both canopies will recover at a faster rate than the Barn kelp bed assuming favorable environmental conditions exist.

4. Canopy deterioration and associated kelp plant distress resulted from naturally occurring events.

5. The exact cause of kelp bed deterioration is unknown; however, data suggests that abnormally high surface and bottom water temperatures in August and abnormally low levels of surface water nitrogen from May through December, was partly responsible for kelp bed deterioration.

6. Kelp forests represent complex ecosystems within which light levels, temperature, nutrients, storms, and biological interrelationships play key roles in determining development and regression.

7. Kelp forest in general are very unstable and can appear and disappear within short periods of time. Well-documented examples have occurred throughout southern California at Point Loma, Palos Verdes, and San Onofre.

8. Although much speculation has been advanced as to the cause of major kelp declines, attempts to establish clear relationships between physical measurements and responses of kelp plants are extremely difficult and have not been successful.

9. Throughout southern California, stable kelp beds occur in regions of less water motion on high relief rock substrate with a southern exposure. The more unstable beds occur along exposed west-facing shorelines.

10. The San Onofre kelp bed is characterized by a low-relief substrate composed primarily of cobble.

11. On a short-term basis, the three kelp bed canopies of the San Onofre area vary independently.

12. The kelp beds of the San Onofre region as a whole can be described as relatively short-lived and unstable.

CONCLUSIONS

The following general conclusions can be drawn from the findings of 1980 and previous year's studies examining impacts of Unit 1 operation and construction of Units 2 and 3. These statements and auxiliary findings were detailed above. In all cases, effects of operation and construction on the marine communities and resources of the San Onofre region were minimal and localized. No adverse effects on the beneficial uses of the receiving waters were detected by these sampling programs. Community and resource fluctuations following natural events such as storms were greater in magnitude than any effects attributed to the generating station. The communities in the study area are adapted to an ever-changing habitat, and their tolerance limits apparently fall well within the magnitude of any plant-induced effects.

Plate 1-1. San Onofre Nuclear Generating :·ition, Units 1, 2, and 3.

CHAPTER 1

INTRODUCTION

This report volume (Volume III) presents integrated analyses and interpretations of data collected during oceanographic and marine biological studies conducted in 1980 and previous yearsfor the Southern California Edison Company (SCE) in the vicinity of the San Onofre Nuclear Generating Station. Volumes I and II contain presentations of summary data and comprehensive raw data, respectively. The studies met regulatory requirements of the Federal Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) through the California Regional Water Quality Control Board-San Diego Region (CRWQCB-SDR) administration.

PURPOSE OF STUDIES

The primary study purpose was to continue the collection of preoperational baseline data prior to the operation of Units ? and 3. Secondary objectives included a continuing assessment of Unit 1 operational effects and completion of the Units 2 and 3 construction effects study.

REPORT ORGANIZATION AND APPROACH

Volume I was prepared to meet regulatory reporting requirements for submission of a data summary by 1 April 1980. The synopsis therein includes only that data required by the regulatory agencies.

Volume II includes a comprehensive presentation of all raw data collected for SCE at San Onofre in 1980 and not reported elsewhere.

The chapters in this volume are organized by general study element (i.e. temperature, water quality, fish, benthos, etc.). All objectives associated with a particular element are addressed in that chapter.

Each chapter contains a separate introduction followed by a background of the subject studies at San Onofre from inception through 1980. In order to facilitate complete and timely review of major ideas, the overall discussion follows the background which is then followed by the 1990 methods and results detail.

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) 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.

HISTORICAL BACKGROUND

A chronological summary of major SCE marine ecological programs at San Onofre is found in Figure 1-2.

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

Studies of the effects of San Onofre 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, designated as the Sand Disposal Monitoring Program (SDM), 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 then 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 PMP was complementary to the Unit 1 NPDES/ETS program and essentially expanded the study area further offshore into the area of Units 2 and 3 diffusers and added control stations.

1980 PROGRAM DEVELOPMENTS

A schedule of activities accomplished in 1980 is presented in Table 1-1.

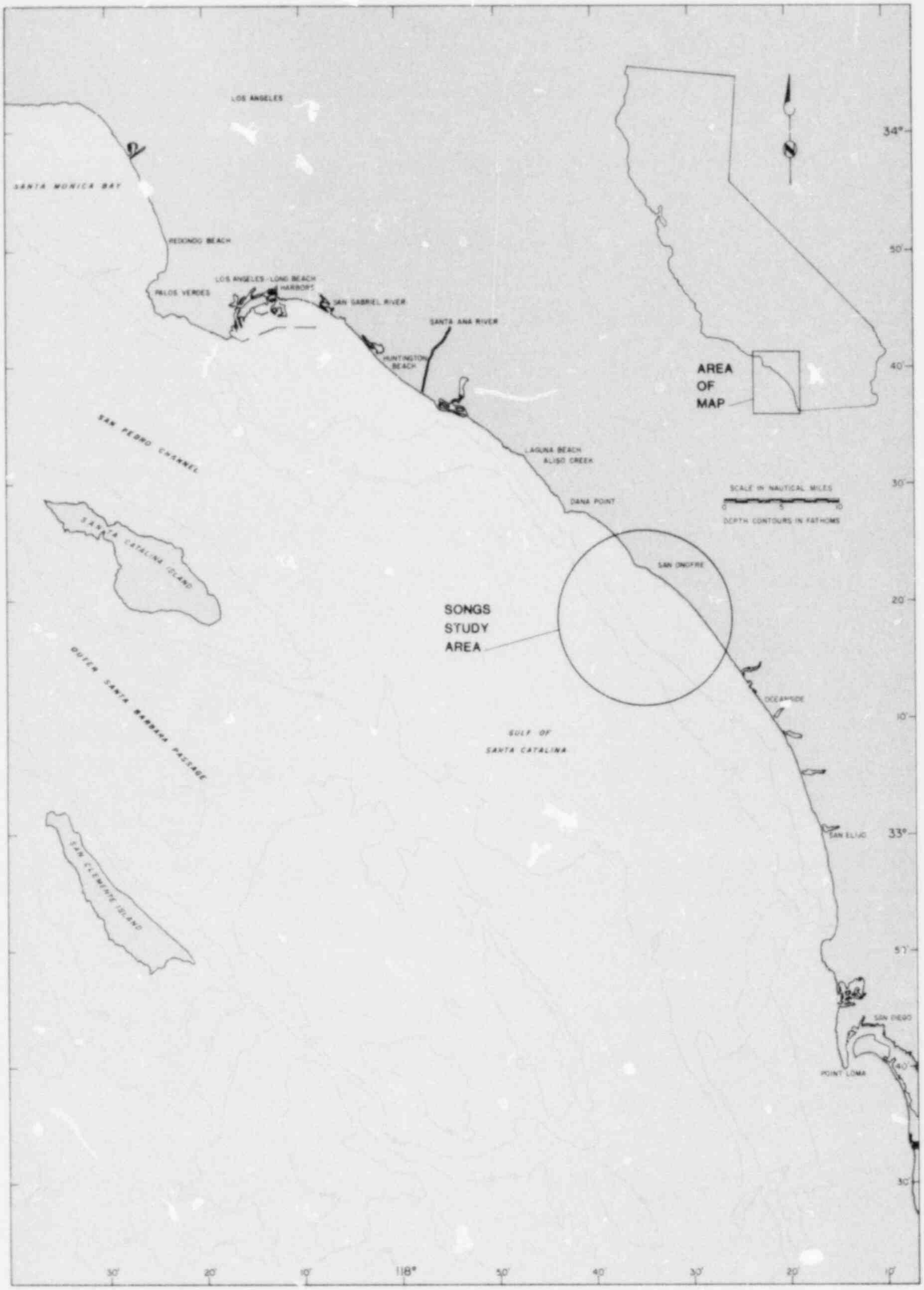


Figure 1-1. Study area location.

Program and Study Elements	M J S D 1974	M J S D 1975	M J S D 1976	M J S D 1977	M J S D 1978	M J S D 1979	M J S D 1980
Marine Environmental Monitoring (MEM)							
Oceanography - bimonthly temperature, currents, turbidity, water quality	1964-XXXXXXXX	XXXX					
Biological - plankton, benthos, intertidal							
Environmental Technical Specifications (ETS)/NPDES							
Oceanography - bimonthly temperature, turbidity, water quality, continuous temperature		XXXXXXXXX	XXXXXXXXX	XXXXXXXXX	XXXXXXXXX	XXXXXXXXX	XXXXXXXX
Biological - plankton, hard benthos, kelp, gill netting, impingement							
Sand Disposal Study (SDS)							
Kelp, intertidal and subtidal infaunal and benthos	XXXXXX	XXXXXXXXX	XXXX				
Construction Monitoring Program (CMP)							
Sedimentology, kelp, infaunal (intertidal and subtidal), intertidal special study			XX	XXXXXXXXX	XXXXXXXXX	XXXXXXXXX	
Preoperational Monitoring Program (PMP)							
Oceanography - bimonthly temperature, turbidity, water quality, continuous temperature					XXXXXX	XXXXXXXXX	XXXX
Biological - plankton, hard benthos, gill netting, trawling, kelp, special study - ichthyoplankton (78-mid 79)							
Interim Studies/NPDES							
Oceanography - continuous temperature, aerial turbidity photographs							XXXX
Biological - trawling, kelp							
316(b) Program							
Biological - monthly larval entrainment, transit loss determination						XXXXXX	XXXX

M = March J = June S = September D = December

Figure 1-2. Major Southern California Edison San Onofre marine ecological programs.

Environmental Technical Specifications/National Pollutant Discharge Elimination System

The Unit 1 operational study program continued throughout 1980.

The Federal Water Pollution Control Act 316(b) ichthyoplankton entrainment inventory and loss study was completed in 1980 which meets the objective of the ETS plankton entrainment study requirement. The ichthyoplankton inventory study report will be finalized in 1981 and submitted to the CRWQCB-SDR.

Preoperational Monitoring Program

The formal PMP investigation which began in mid 1978 terminated in mid 1980 in accordance with NRC authorization following two complete years of baseline data collection.

NPDES/Interim Program

In order to maintain continuity with pertinent preoperational study elements (i.e. continuous temperature monitoring, turbidity studies, trawling, and kelp programs), an interim monitoring program was initiated by SCE in mid 1980 coincident with termination of the PMP.

Construction Monitoring Program

The CMP investigation was suspended in March 1980 in accordance with CRWQCB-SDR authorization a construction activity was completed. A study to assess the effects of the temporary seawall removal will be initiated prior to its removal, anticipated to be in 1984

Table 1-1. 1980 data collection record.

	INTERIM	ETS	NPDES	CMP	PMP	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oceanographic Surveys																	
Temperature Vertical Profiles		X	X		X	8		13		14		9		10		5	
Aerial Infrared Radiometry		X	X			8		13		14		9				5	
Surface Temperature Mapping						8		13		14		9		10		5	
Shoreline Temperature		X	X			8		13		14		9		10		5	
Continuous Temperature Maintenance	X	X			X	3	4	4,26	4,25	1	4	3	[illegible]	4	1	3	9
Turbidity Vertical Profiles		X	X		X	8		13		14		9		10		5	
Secchi Disc Visibility		X	X		X	8		13		14		9		10		5	
Suspended and Settleable Solids								13		14		9					
Aerial Photographs of Turbidity		X				8		13		14		9				5	
Heavy Metals		X	X		X	10		10		13		8				3	
Dissolved Oxygen		X	X		X	8		13		14		9		10		5	
Hydrogen Ion Concentration		X	X		X	8		13		14		9		10		5	
Currents						7,8		12,13		13,14		8-9					
Density Profiles						8		13		14		9		10		5	
Salinity Profiles						8		13		14		9		10		5	
Biological Surveys																	
Plankton		X	X		X	8,10,13		10-12		15-18*		19		16		5	
Intertidal																	
Sand				X			13-15										
Cobble								13,14			14,15						19,20
Subtidal																	
Sand				X				5-7		28-30							
Cobble (including kelp beds)		X	X	X	X	24----10[a]			28----------6			24-----18			23-----3		
Fish																	
Gill Nets		X	X		X		26-27		23-24		25-26*		21-22		20-23		10-11
Otter Trawls	X						26-27		23-24		25-26		21-22		20-23		10-11
Impingement**																	
Normal Operation		X	X			b	b	b	b		b	b					
Heat Treatments		X	X			13		23									
Kelp Bed																	
Nutrients						18	3	13	11	7	13	11	8	12	10	3	9
Mapping				X				10-16				25					31
Qualitative Assessment[c]									16		30						11
Photography		X				9			13					18			8
SOK Density Assessment	X																17-19

[a] Survey required several days to complete.
[b] Frequency greater than once/week.
[c] Diving survey by Dr. Wheeler J. North.
*Preoperational Monitoring Program terminated.
**SONGS offline for refueling and repairs from 10 April through end of 1980. Circulators were on briefly from 12 June to 18 July. Sampling continued during this period.

Note: Numbers indicate sampling dates.

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 436 MW.

A once-through cooling system is used to cool the steam condensers. As illustrated in Figure 1-3 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).

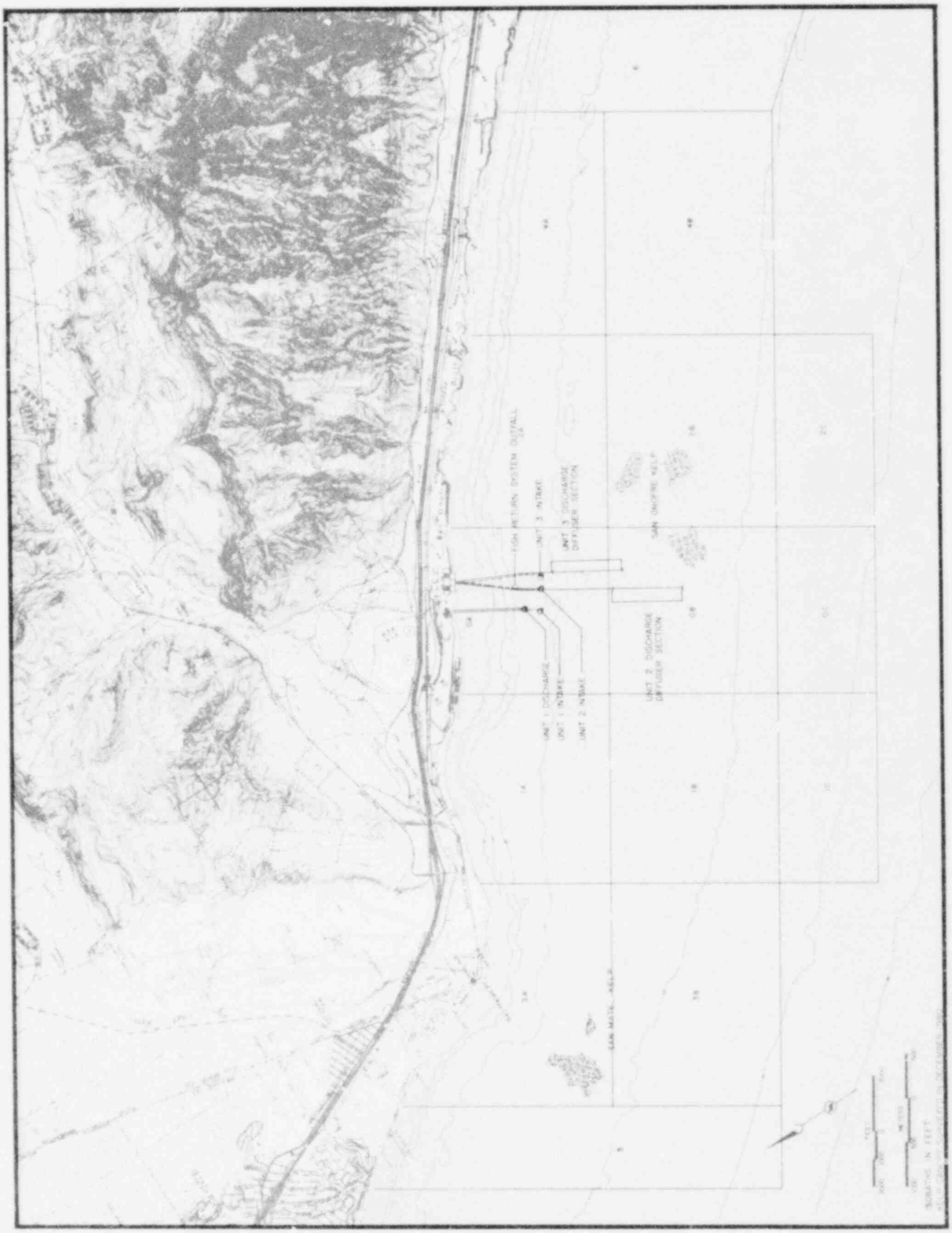


Figure 1-3. Location of intake and discharge conduits for San Onofre Nuclear Generating Station Unites, 1, 2, and 3.

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 (23.4 ft)
Cap Height Above Bottom	4.7 m (15.5 ft)	5.4 m (17.9 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 (6.8 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	21°F	19.1°F
Baseload or Peaking	Base	Base
Station Capacity (MW net)	436	1127 ea
Capacity Factor - 1980	19.8	Under Construction
Availability - % of Time in 1980	23.2	Under Construction
Theoretical Yearly Flow (gals)	18.43×10^{10}	43.6×10^{10} (ea)
Actual - 1980 Yearly Flow (gals) (approx.)	6.75×10^{10}	(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)

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 1127 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 1-3, 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).

GENERATING STATION OPERATION

Unit 1

The station was offline from 10 April through the end of 1980 due to problems associated with the steam generator which required extensive system repair. The circulating pumps resumed operation briefly in June and July, and fish impingement studies resumed during this period (detailed log in Vol. II).

An illustration depicting plant operation including mean daily megawatt output (station load), implant ΔT ([°C] discharge temperature minus intake temperature], and circulating water flow at SONGS Unit 1 during 1980 is presented in Figure 1-4.

Units 2 and 3

Intermittent testing of Unit 2 circulating water pumps occurred after March in 1980 (Figure 1-5). This testing procedure was associated with startup activities.

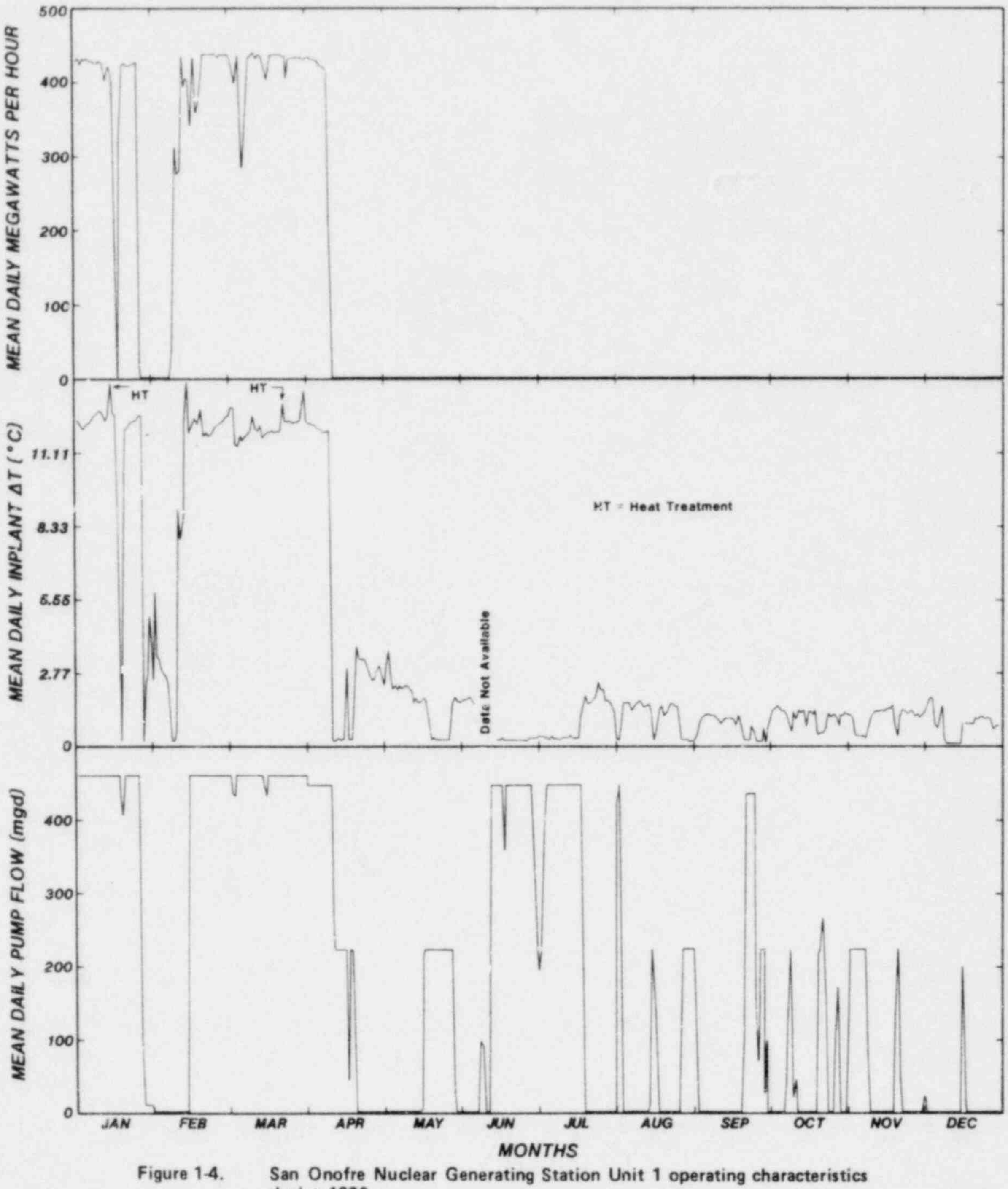


Figure 1-4. San Onofre Nuclear Generating Station Unit 1 operating characteristics during 1980.

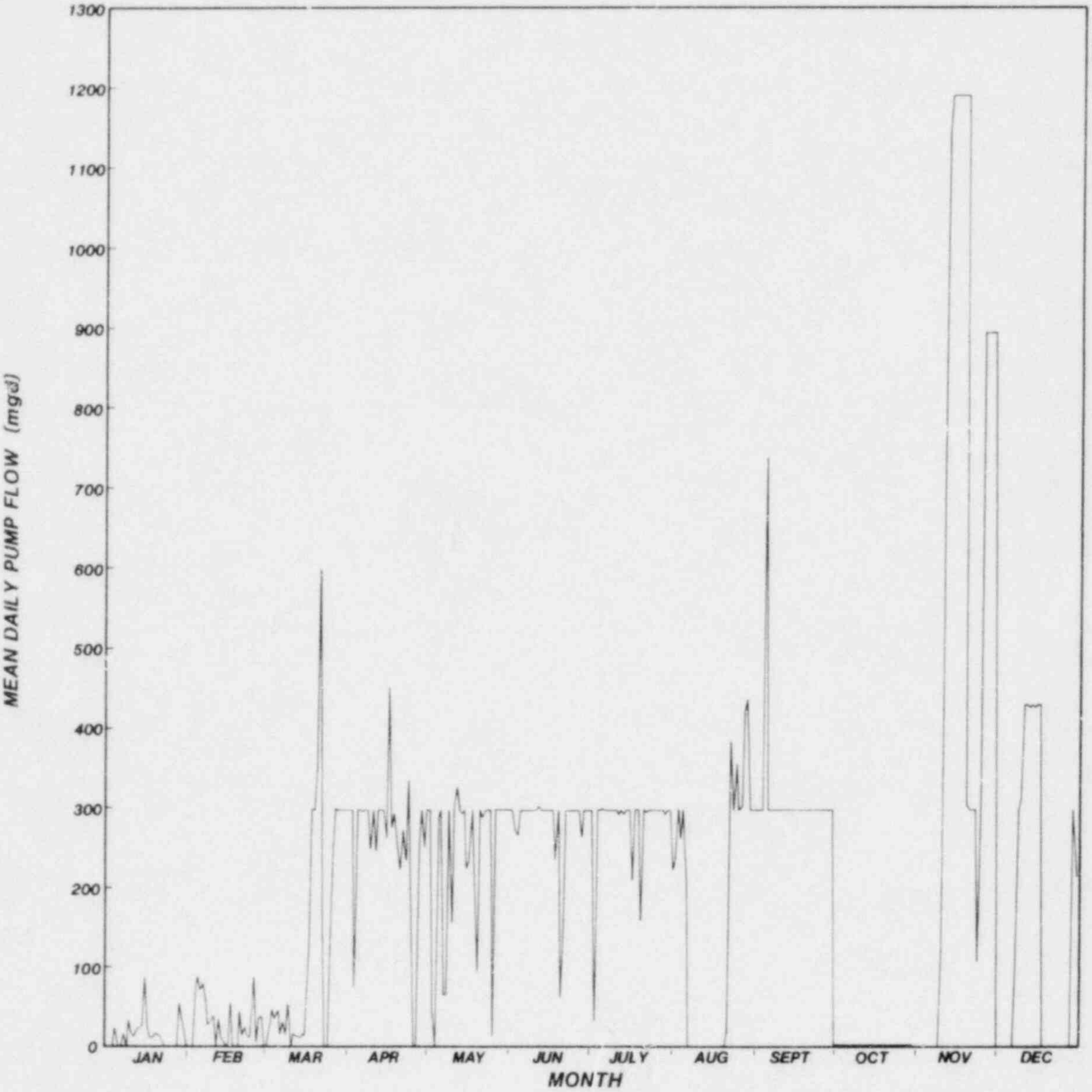


Figure 1-5. San Onofre Nuclear Generating Station Unit 2 pump flow characteristics during 1980.

CHAPTER 2

OCEANOGRAPHY

INTRODUCTION

The oceanographic environment in the vicinity of San Onofre Nuclear Generating Station is dynamic with physical and chemical features changing constantly. This chapter presents the results, analysis, and interpretation of physical, chemical, and geological oceanographic measurements for the San Onofre environment. Parameters examined included temperature, turbidity, dissolved oxygen, pH, selected heavy metals, beach and bottom sediment characteristics, beach slope, and deposition rates of suspended materials. In addition, wave, nearshore current, nutrient, light intensity, air temperature, wind speed and direction, and precipitation were obtained to aid in the definition of oceanographic conditions and determination of any San Onofre effects on the marine environment.

CHAPTER 2A

TEMPERATURE

INTRODUCTION

Temperature was extensively measured throughout the San Onofre area during 1980 primarily to complete the two year baseline study for Units 2 and 3. This preoperational data base can subsequently be compared to results of studies conducted during Units 2 and 3 operation in order to determine the thermal effect of Units 2 and 3 and to evaluate the impact of that effect with respect to natural background conditions.

Temperature measurements were also obtained and utilized in the continuing study of operational effects of Unit 1. Unit 1 was not in operation from 9 April 1980 through the end of the year, and therefore, temperature measurements after 9 April 1980 represent natural conditions at San Onofre.

The temperature studies met all objectives and requirements of the Environmental Technical Specifications (ETS) program for Unit 1 and the Preoperational Monitoring Program (PMP) for Units 2 and 3 established by Nuclear Regulatory Commission (NRC) as well as the monitoring required by National Polluant Discharge Elimination System (NPDES) permit issued by California Regional Water Quality Control Board, San Diego Region (CRWQCB, SDR).

This chapter presents: 1) a pertinent summary of data collected by SCE studies in 1980; 2) an analysis of data to meet objectives; and 3) a description of temperature, its interaction with generating station activities, and a perspective of temperature in the study area and the southern California area.

Previous volumes of this years annual report have presented all basic data obtained in SCE studies. Volume I presented a summary of data required by regulatory agencies and was submitted to the appropriate agencies on 31 March 1981 (SCE 1981a). Volume II contains all basic raw data collected for SCE programs during 1980, including the basic regulatory required data and additional supplemental data obtained in order to fulfill objectives of the study (SCE 1981b).

BACKGROUND

In order to put 1980 studies in perspective, the following section presents background information on temperature data collected at San Onofre during the past 17 years. A brief history of temperature studies conducted at San Onofre is presented in Table 2A-1.

HISTORICAL STUDIES

Temperature studies relating to the generating station have been conducted in the San Onofre area since mid-1963, approximately five and a half years prior to operation of Unit 1. Preoperational water temperature studies for Unit 1 began in July 1963. Regular bimonthly oceanographic surveys were initiated in 1964, and 28 field surveys were conducted between May 1964 and December 1968.

Table 2A-1. Time history of temperature measurements at San Onofre.

Temperature Studies	Types of Data Collected	Dates	Instrumentation	Frequency	Locality/ Stations	Depths Sampled
Major Programs						
Marine Environmental Monitoring						
Unit 1 Preoperational	Temperature/depth profiles	1963-1968	Bathythermograph, mercury thermometer	Bimonthly	32	Surface to bottom
Unit 1 Operational	Temperature/depth profiles	1968-1975	Bathythermograph, mercury thermometer	Bimonthly	32	Surface to bottom
	Aerial infrared mapping	19[illegible]-1975	Infrared radiometer	Bimonthly, 3 flights/survey	Area of Unit 1 discharge	Surfa e layer
Environmental Technical Specifications						
Unit 1	Temperature/depth profiles	1975-1976	Termistor probe	Bimonthly	34	Surface to bottom
		1976-1980	Thermistor probe	Bimonthly	51	Surface to bottom
	Aerial infrared mapping	1975-1977	Infrared radiometer	Quarterly, 1-3 replicates	Area of Unit 1 discharge	Surface layer
		1977-1980	Infrared radiometer	Bimonthly, 1-3 replicates	Area of Unit 1 discharge	Surface layer
	Intertidal temperatures	1975-1977	Mercury thermometer	Bimonthly	5/3 replicates	Surf zone
		1977-1980	Mercury thermometer	Bimonthly	11/3 replicates	Surf zone
	Continuous temperature measurements	1975-1980	Continuously recording thermographs	Continuous, hourly	Stations C2S, C22S	Surface, 4 meters near-bottom
	Inplant intake and discharge temperatures	1975-1980	Thermistors	Continuous, hourly	Unit 1 intake and discharge conduits	
Preoperational Monitoring Program						
Units 2 and 3	Temperature/depth profiles	1978-1980	Thermistor probe	Bimonthly	23	Surface to bottom
	Continuous temperature measurements	1978-1980	Continuously recording thermographs	Continuous, hourly	Station F2S	Surface, 4.6 meters, 9.1 meters, near-bottom
	Continuous bottom temperature measurements	1979-1980	Continuously recording benthic sensing packages	Continuous, hourly	5 PMP hard bottom benthic stations	Near-bottom
	Aerial infrared mapping	1978-1980	Infrared radiometer	Bimonthly, 1-3 replicates	Units 2 and 3 diffuser area	Surface layer

Temperature profile measurements at 32 sampling stations were used to document preoperational temperature conditions for Unit 1. This program of bimonthly surveys, known as the Marine Environmental Monitoring Program (MEM), was continued after Unit 1 began full operation in 1968 until 1975. In addition to the temperature profile measurements, infrared radiometer measurements were obtained in order to map the surface extent of thermal field produced by the circulating water system for Unit 1. Detailed results of the monitoring program were reported in periodic progress reports. The results of these studies were summarized in the Thermal Effect Study, Final Summary Report (SCE 1973).

Beginning in 1975, temperature measurements were continued as a portion of the ETS monitoring program. Bimonthly temperature profiles at 34 stations located in the twelve environmental surveillance zones were used to document spatial variability in temperature throughout the San Onofre study area. Many of the temperature profiling locations sampled in the ETS program were the same as those used in the previous MEM program. Aerial infrared radiometer measurements were obtained quarterly and used to map the surface extent of the thermal plume from Unit 1. Continuous temperature measurements at near surface, mid-depth (4.5 m), and near bottom at two locations were initiated in late 1975. One

location was 610 m (2000 ft) away from the discharge. Data from this location was used to determine effect of Unit 1 operation on receiving water temperature. The other continuous temperature measurement station was located 6.7 km downcoast from Unit 1 and was used to document natural conditions and variability of temperature. Shoreline temperature measurements were also obtained to determine the shoreward extent of the thermal plume and to obtain temperature data at rocky intertidal stations.

In 1976, the CRWQCB, SDR issued NPDES permits for Units 1, 2, and 3 which included a temperature monitoring program similar to the ETS program. Temperature profiling station locations were increased to 51 stations to better define temperature structure in the vicinity of the generating station. After March 1977, the frequency of infrared radiometer surveys were increased from quarterly to bimonthly.

Temperature measurements at 23 additional offshore profiling stations were initiated in 1978 as a portion of the Preoperational Monitoring Program (PMP) required by the NRC to determine natural background conditions prior to operation of Units 2 and 3. Bimonthly infrared radiometer (IR) flight coverage was extended to document surface temperature conditions in the offshore area of Units 2 and 3 diffusers. Another continuous temperature station was established in the vicinity of the diffusers for Units 2 and 3 in August 1978 to document natural temporal variations prior to operation of Units 2 and 3.

Beginning in August 1979, a program to collect continuous bottom temperature, light intensity, and sedimentation data was initiated at five offshore hard bottom PMP benthic locations throughout the San Onofre area. These temperature measurements assist in ascertaining effects of bottom temperature on growth in hard bottom benthic and kelp communities.

Temperature was also measured during biological sampling programs. Vertical profiles of temperature were obtained during plankton, ichthyoplankton, and fish surveys in order to obtain temperature data for correlation with biological characteristics. Surf temperatures were also obtained during intertidal sampling. Bottom water and sediment temperatures were measured during quarterly benthic infauna sampling surveys.

Inplant intake and discharge temperatures for Unit 1 have been measured at the tsunami wall hourly since June 1975 to monitor station operating conditions.

1980 STUDIES

During 1980, water temperature was measured by vertical temperature profiles, aerial infrared radiometer flights, shoreline bucket thermometers, and continuous recording devices. Bimonthly temperature surveys conducted in January, March, May, and July were for both the ETS and PMP studies. During each of these bimonthly field surveys, profile measurements were taken at 74 sampling stations (Figures 2A-1 and 2A-2), and one to three aerial infrared radiometer flights and shoreline temperature measurement sets were obtained.

In August 1980, bimonthly temperature measurements for Units 2 and 3 PMP were terminated after completion of the two-year data base. Operational effect studies for Unit 1 were continued in accordance with ETS requirements during the September and November surveys. Continuous temperature measurements at Station F2S near San Onofre kelp bed were continued. The program of continuous temperature, light intensity, and sedimentation measurements at five hard bottom PMP benthic locations was discontinued in early October 1980.

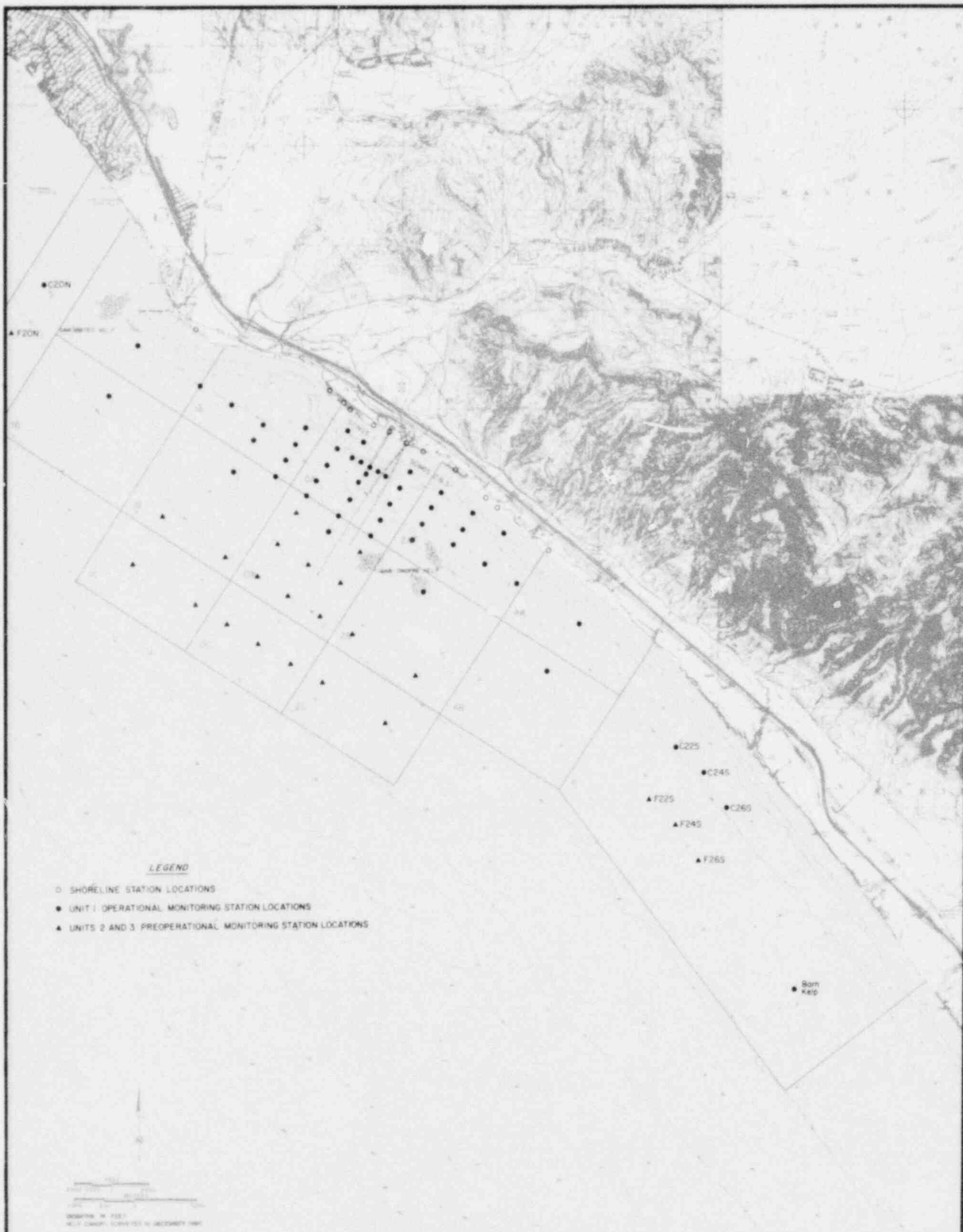


Figure 2A-1. Environmental surveillance zones and location of oceanographic sampling stations.

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

Results of previous Unit 1 operational studies have been extensively documented in annual reports. Formal requests to delete ETS requirements were submitted to the NRC in October 1980 based upon the accomplishment of the objectives within the mandated scope.

DISCUSSION

Temperature is the physical oceanographic parameter most directly affected by coastal generating stations which use ocean water for once-through cooling of steam condensers. Since the most ostensible effect of San Onofre Nuclear Generating Station 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 San Onofre. Temperature is also a good indicator of natural phenomena in the marine environment and can be used to identify oceanographic processes such as upwelling, storms, major currents, internal waves, and general characteristics of water masses.

Temperature was extensively measured throughout the 70 km^2 San Onofre study area as part of the physical and biological monitoring programs. The objectives of these studies were to: 1) establish preoperational baseline conditions before operation of Units 2 and 3; 2) document large spatial and temporal changes in temperature throughout the study area; 3) determine the horizontal and vertical extent of the thermal plume from Unit 1; 4) determine the area of influence of Unit 1; 5) estimate the extent to which heated water from Unit 1 was recirculated back into the intake of the circulation water system; and 6) provide temperature data for the analysis and interpretation of biological findings.

NATURAL PROCESSES AFFECTING TEMPERATURE

The temperature observed at any moment in time is the result of a combination of several atmospheric and oceanographic phenomena. These phenomena include seasonal warming and cooling, upwelling, winds, storms, cloud cover, rain, major currents, localized currents, tidal curent transient eddies, waves, internal waves, etc. The resulting temperature variations with time present a complex pattern. The following presents a discussion of the major physical processes affecting temperature.

Seasonal Trends

Natural surface temperature follows a cyclic heat balance consistent with the seasonal variation in the amount of insolation. Natural temperatures are coolest in the winter months, when insolation is at a minimum, and increased in the spring and summer months as insolation increases. Natural temperature generally decreases after its peak in summer.

The amount of vertical stratification of temperature generally follows the seasonal insolation patterns. During winter months, temperatures are relatively uniform throughout the water column on the shallow continental shelf area. Increased insolation during spring and summer result in warmed surface temperatures and the formation of a thermocline, defined as a rapid decrease in temperature with depth. The intensity of this thermocline generally increases in the spring and summer months and decreases in late summer and fall as surface waters are cooled and the depth range of the thermocline increases.

The presence of a thermocline limits vertical mixing between the warmer surface waters and cooler bottom waters. Bottom waters do not follow the same seasonal pattern of surface waters since the thermocline limits exchange between

surface and bottom waters. Bottom waters generally become cooler in spring and early summer as a thermocline is established and intensifies. Bottom temperatures increase in late summer and fall as the thermocline becomes deeper and less intense.

Local Winds and Upwelling

With the exception of the annual warming and cooling cycle, wind and storm associated upwelling results in the largest fluctuations of daily mean natural temperature.

Upwelling occurs when relatively strong winds due to storms and/or atmospheric pressure systems blow from the west or northwest. These winds create surface currents which flow offshore. In coastal nearshore areas, cooler bottom water rises up through the water column to replace the surface waters which have been displaced offshore, resulting in a breakdown of thermal stratification of receiving waters and reducing surface and bottom water temperatures.

During a one to two day episode of relatively strong upwelling winds, surface temperatures are reduced by 2 to 4°C. It generally takes surface temperature from three to four days to return to values prior to the occurrence of upwelling.

Discrete short periods of upwelling are observed at San Onofre when winds from the west-northwest (300°T) blow for approximate 4 hrs or more with speeds of 10 mph or greater. Other than the periods when local winds at San Onofre were as described above, the surface water temperature at San Onofre is not directly affected to a significant extent by upwelling.

Offshore Circulation Patterns

The oceanic water mass adjacent to the southern California coast is primarily affected by the waters transported south by the California Current, which is modified by a countercurrent (Davidson Current) and upwelling. These major current regimes in the southern California area are illustrated in Figure 2A-3. The California Current flows southward along the coast of California and is relatively close to the coast north of Point Conception. At Point Conception, the coastline makes an abrupt change to an east-west orientation and the flow of water departs the coastline. South of Tanner and Cortes bank the main portion of the California Current curls toward land, and separates into two branches; one branch, known as the Southern California Countercurrent, turns back to the north between Santa Catalina Island and the Tanner-Cortes bank area. North of Santa Catalina Island, the Southern California Countercurrent turns towards shore and then flows south along the Continental Shelf. Along the coast, surface circulation from San Pedro to San Diego is complicated by the predominantly southern flow, a northerly current from the San Diego offshore region, coastal geometry, and bottom topography. These California Current conditions are shown as the Oceanic Period on Figure 2A-3a.

Although the California Current is present throughout the year, it is modified by upwelling and the Davidson Current during certain times of the year. Upwelling is prevalent along the offshore areas of the California coast generally from March through July. Its effect on surface water circulation is shown on Figure 2A-3b. Regional upwelling in the offshore areas indirectly affect temperatures at San Onofre through transport by currents. Also, submarine canyons, such as Newport, La Jolla, Scripps and others, can act as conduits to bring cold bottom water to the surface very nearshore during upwelling periods. These cold water spots over the canyons can be transported away from the canyons, causing this cold dense bottom water to be trapped on the narrow Continental Shelf.

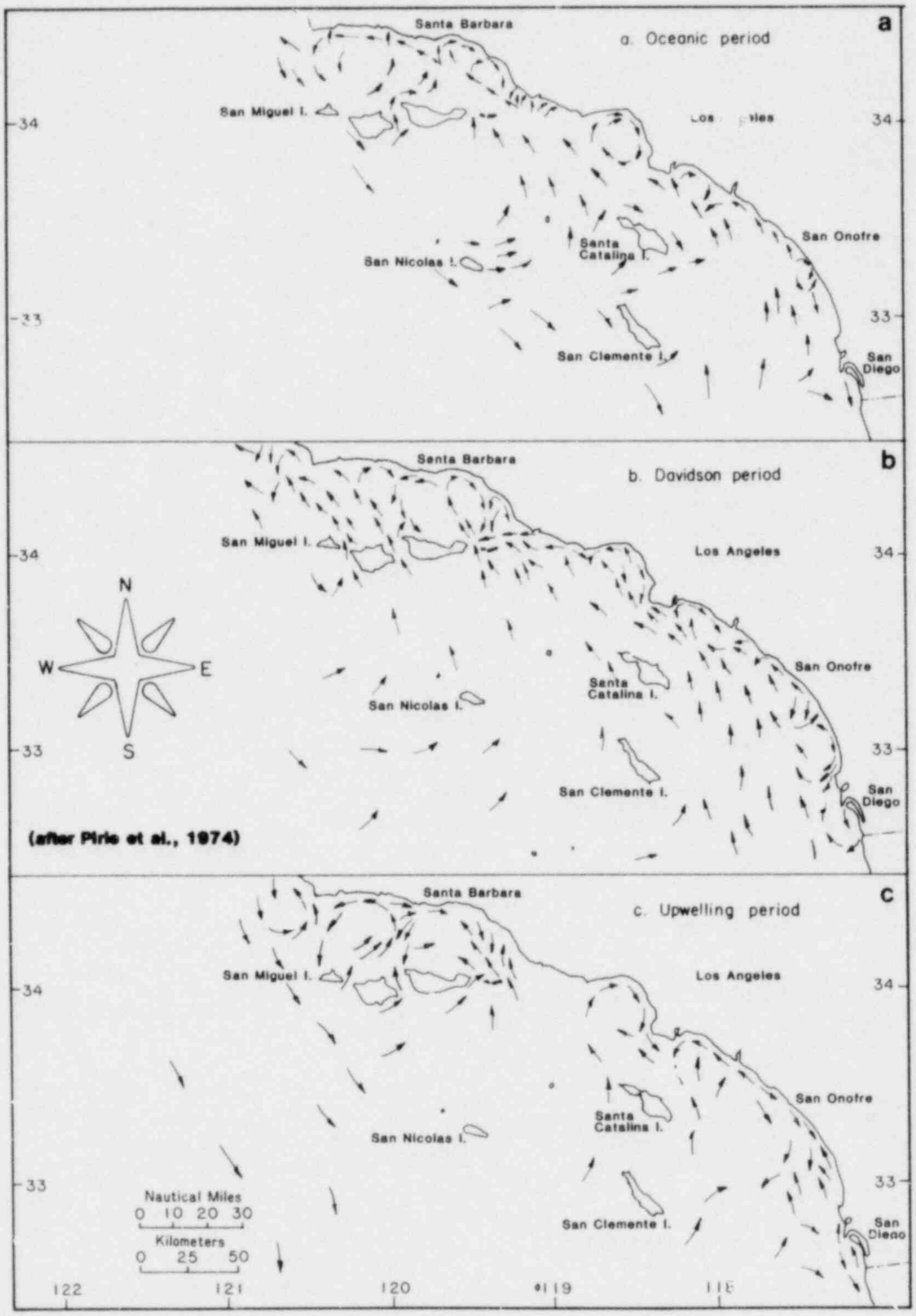


Figure 2A-3. Major offshore circulation patterns in the Southern California Bight.

During the winter months of November to February, thermal stratification, and therefore density stratification, is greatly reduced due to decreased insolation and mixing by storms. During this period, the Davidson Current surfaces. The Davidson Current is a northward flowing current from the Coast of Baja California, which is normally below a depth of 200 m during the rest of the year. The circulation of surface waters in southern California during the Davidson period is shown on Figure 2A-3c.

NATURAL TEMPERATURE CONDITIONS

The natural temperature cycle at San Onofre, based on the past 15 years, is shown as monthly mean temperatures on Figure 2A-4. The annual temperature cycle at San Onofre during 1980 was not typical of the average temperature conditions as illustrated by the comparison of monthly mean surface temperature at Station F2S to the monthly mean of surface temperatures at San Clemente Pier from 1965 through 1979. Natural surface temperature in January, February, and March 1980 was warmer (0.7 to 1.8°C) than the mean of the previous 15 years, while in April and May 1980, natural temperature was similar to previous years. In June and July 1980, monthly mean natural surface temperature was 1.3 and 1.1°C cooler than the 15-year mean. During August 1980, monthly mean surface temperature was 1.1°C warmer than the historical average. During the remainder of 1980, monthly mean temperatures were similar to the 15-year mean. Seasonal trends of natural temperature at San Onofre for 1980 can be characterized as having a warm winter period, a relatively late spring for increasing temperature, and a relatively warm summer in August. The decrease in surface temperature during the late summer and fall was typical of average conditions.

Temporal Trends

Temporal trends for surface and bottom temperatures are shown in the daily averaged temperature records presented on Figures 2A-5 and 2A-6, respectively. The 1980 annual cycle of surface temperature generally followed the regular

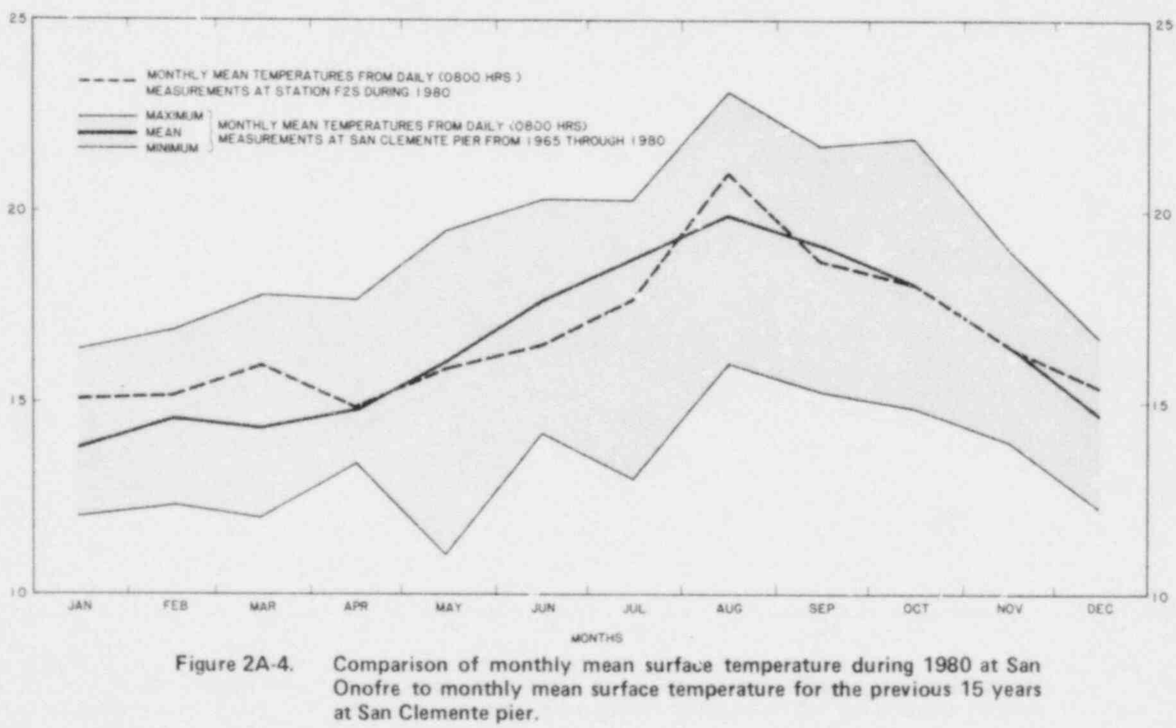


Figure 2A-4. Comparison of monthly mean surface temperature during 1980 at San Onofre to monthly mean surface temperature for the previous 15 years at San Clemente pier.

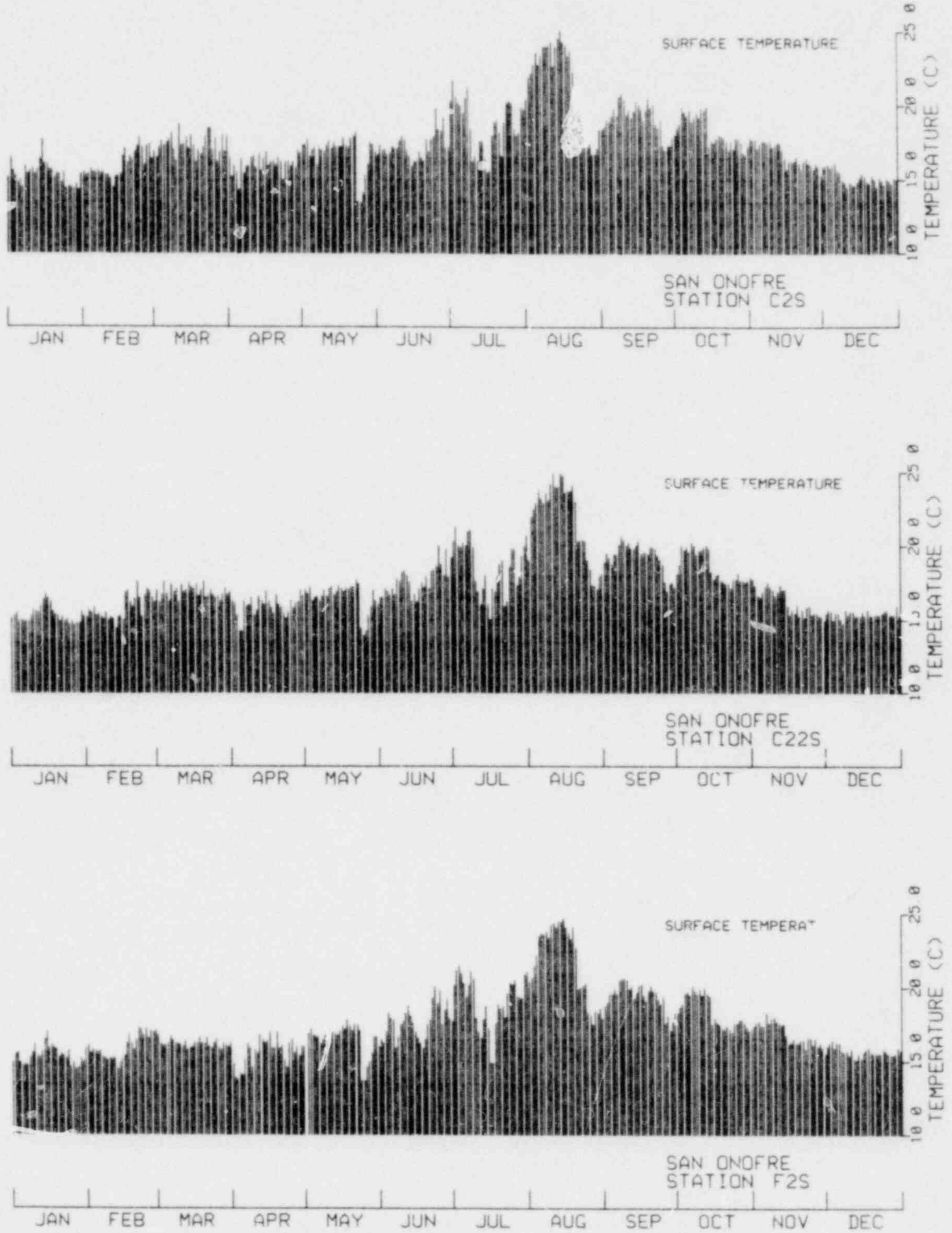


Figure 2A-5. Annual cycle of sea surface temperature. 1980.

trend, consistent with the seasonal variation in the amount of insolation. Natural sea surface temperature was coolest during the winter months, when insolation was at its minimum, and increased during the spring and summer months as insolation increased. Sea surface temperature decreased steadily after a

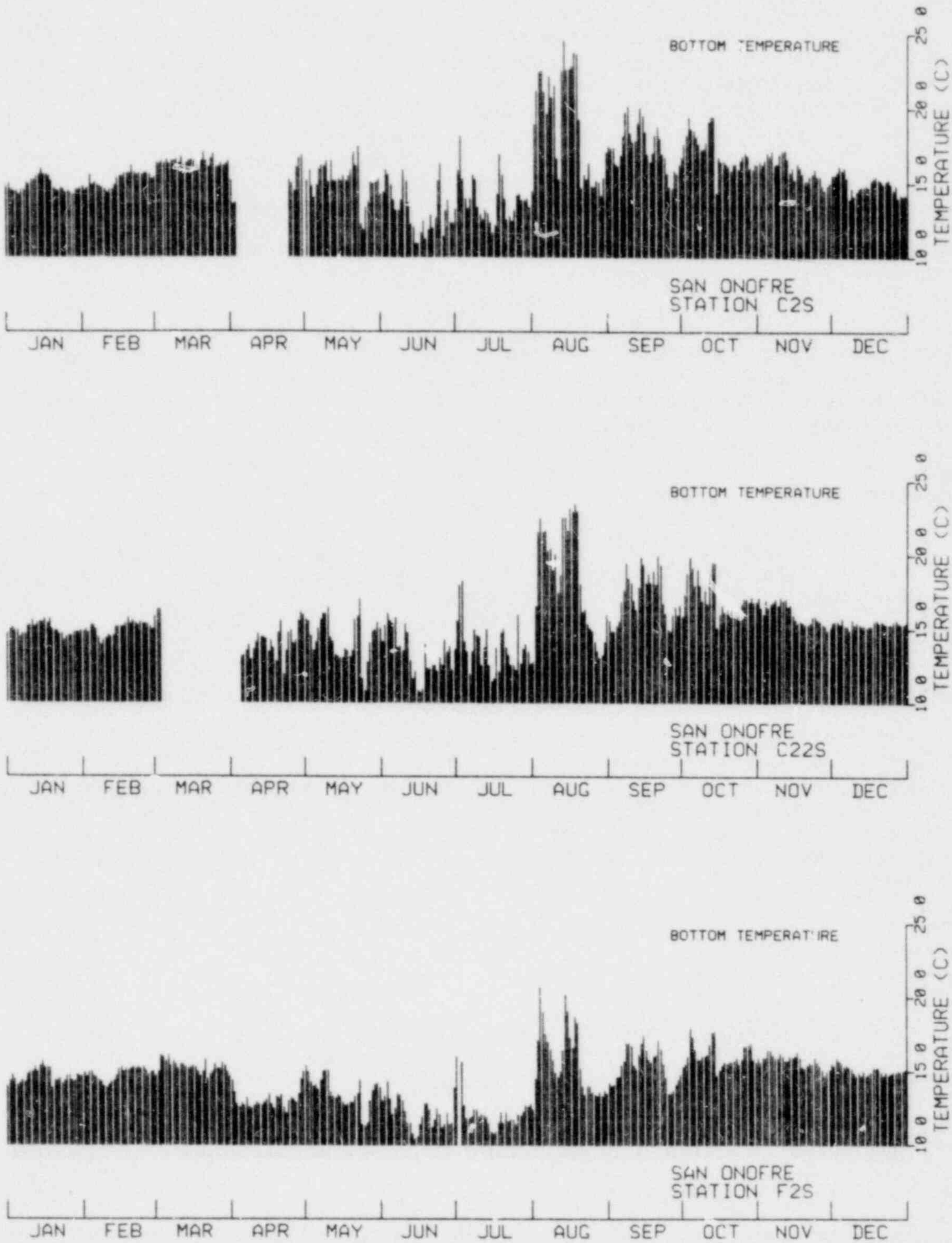


Figure 2A-6. Annual cycle of bottom temperature, 1980.

peak in August. Within these seasonal trends, short-period warming and cooling trends were observed due to oceanographic and meteorological processes and resulted in temperature changes of as much as 4 to 5°C.

The bottom temperature followed a somewhat different trend from that of sea surface temperature. Bottom temperature generally cooled from late spring to early summer and subsequently warmed until October. In December and January, bottom temperature remained essentially the same as at the surface, indicating that during these two winter months the water column was well mixed from surface to bottom.

The bottom temperature trends at the two shallow (10 m) stations, C2S and C22S (Figure 2A-2), were quite similar to each other. However, the trend at the deeper (15 m) station, F2S, varied somewhat from that of the two shallow stations. In particular, at Station F2S, temperature variations were smoother and the range of fluctuations smaller than at the shallow stations.

Typical temperature structures in a shore-perpendicular section during the summer months are presented on Figure 2A-7. The data were taken along Line 2S (a shore-perpendicular transect located just south of San Onofre) during 1979 and 1980. Summer temperature along this transect was strongly characterized by the presence of a thermocline, the result of surface heating from insolation and bottom cooling from upwelling. A strong thermocline with a temperature gradient of up to 3°C/m occurred during the month of July. The thermocline appeared to stay in depths of 4 to 8 m below the surface.

Vertical temperature structure in a shore-perpendicular section in fall, winter, and late spring is shown on Figure 2A-8. Inshore waters in November and January appeared well mixed, as expected. In May, signs of gradual warming at the surface and gradual cooling at the bottom are evident, indicating that May was a month of transition.

Temporal Variations

Spectral analysis of the four-year continuous data base revealed that frequency of natural temperature variation spanned the entire range of the frequency spectrum -- from seasonal fluctuations to fluctuations within a few hours. Short-term fluctuations in winter were typically small (on the order of 1°C) and quite large (4-5°C) in summer. Diurnal and semi-diurnal temperature changes caused by tidal currents were detected in the data. Dominant variations in surface and bottom temperature at Station C2S exhibited periodicities of about 60 days, 37 days, 30 days, 20 days, 10 days and 25 hours (SCE 1980). Other than the 25-hour cycle which represents diurnal tidal cycles, relationships of these various periodicities to known geophysical cycles are not readily clear, but are due to a combination of oceanographic and meteorological processes.

Surface and bottom temperature records at Station F2S are compared on Figure 2A-9 with the upwelling index computed by Bakun (1980). The input data for the computation of upwelling index was the six-hourly synoptic surface atmospheric pressure field prepared by Fleet Numerical Weather Central, and the upwelling indices shown are daily averages in a 3 degree square centered at latitude 33°N and longitude 119°W (near San Clemente Island, located approximately 80 miles offshore of San Onofre). The upwelling index, as defined by Bakun (1975), is the offshore directed component of Ekman transport expressed in cubic meters per 100 m (328 ft) of coastline, and is considered an indication of the rate of upwelling of deeper waters to replace surface waters driven offshore by the stress of the wind.

The regional upwelling processes were aperiodic, but exhibited durations of 10 to 30 days as well as numerous short pulses lasting a few to several days (Figure 2A-9). Temperature fluctuations which appear to correspond to each of

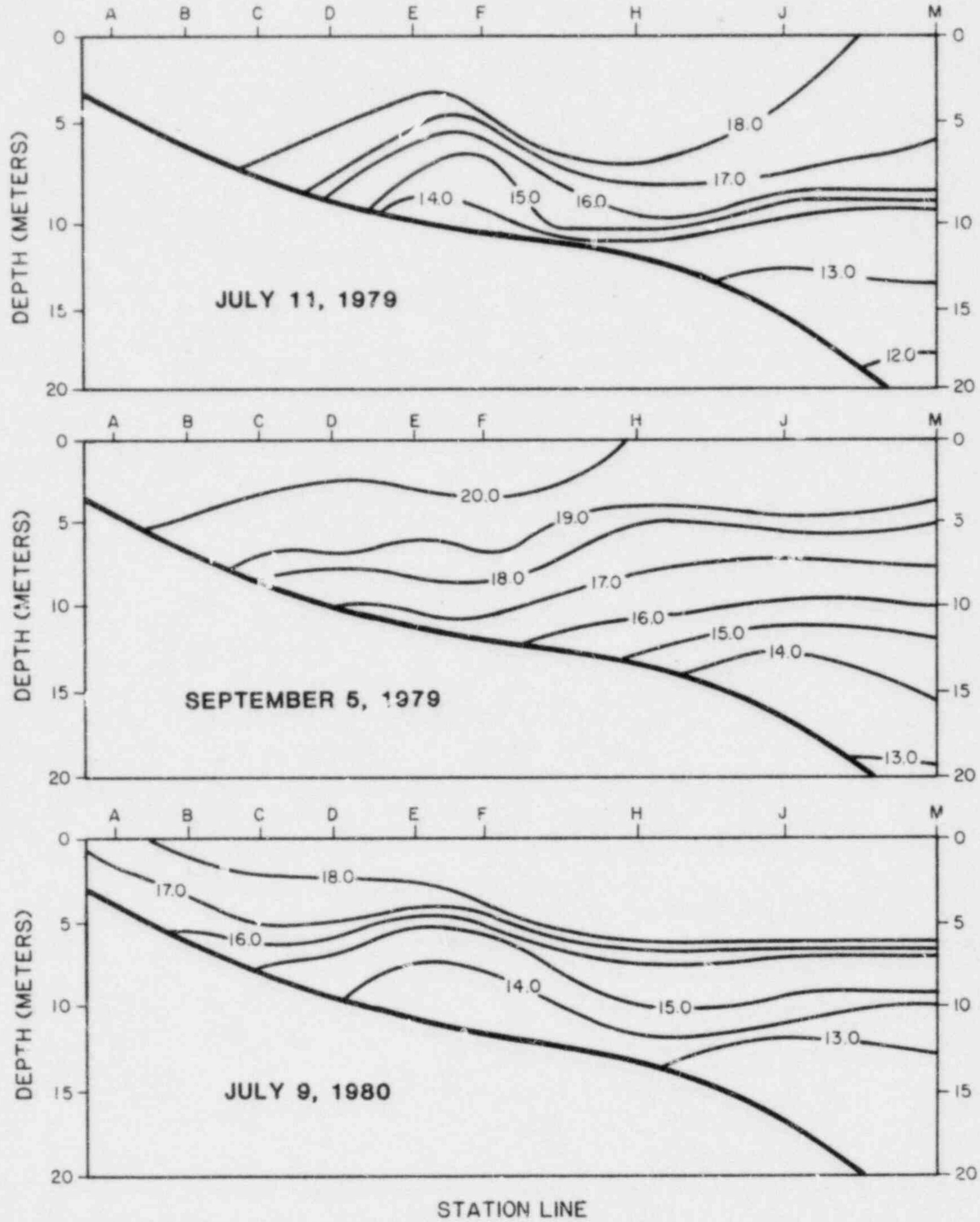


Figure 2A-7. Typical temperature distribution in a shore-perpendicular section during summer months along Line 2S, 1980.

the upwelling pulses are marked with an arrow on Figure 2A-9. Local winds measured at San Onofre during these periods were of the upwelling type from the northwest. It is evident that the temperature response to the upwelling pulse cycles frequently occurred as abrupt cooling.

Following the peak cooling activity of the upwelling cycle, temperature began a gradual rise to previous levels. This implies that the rebounding

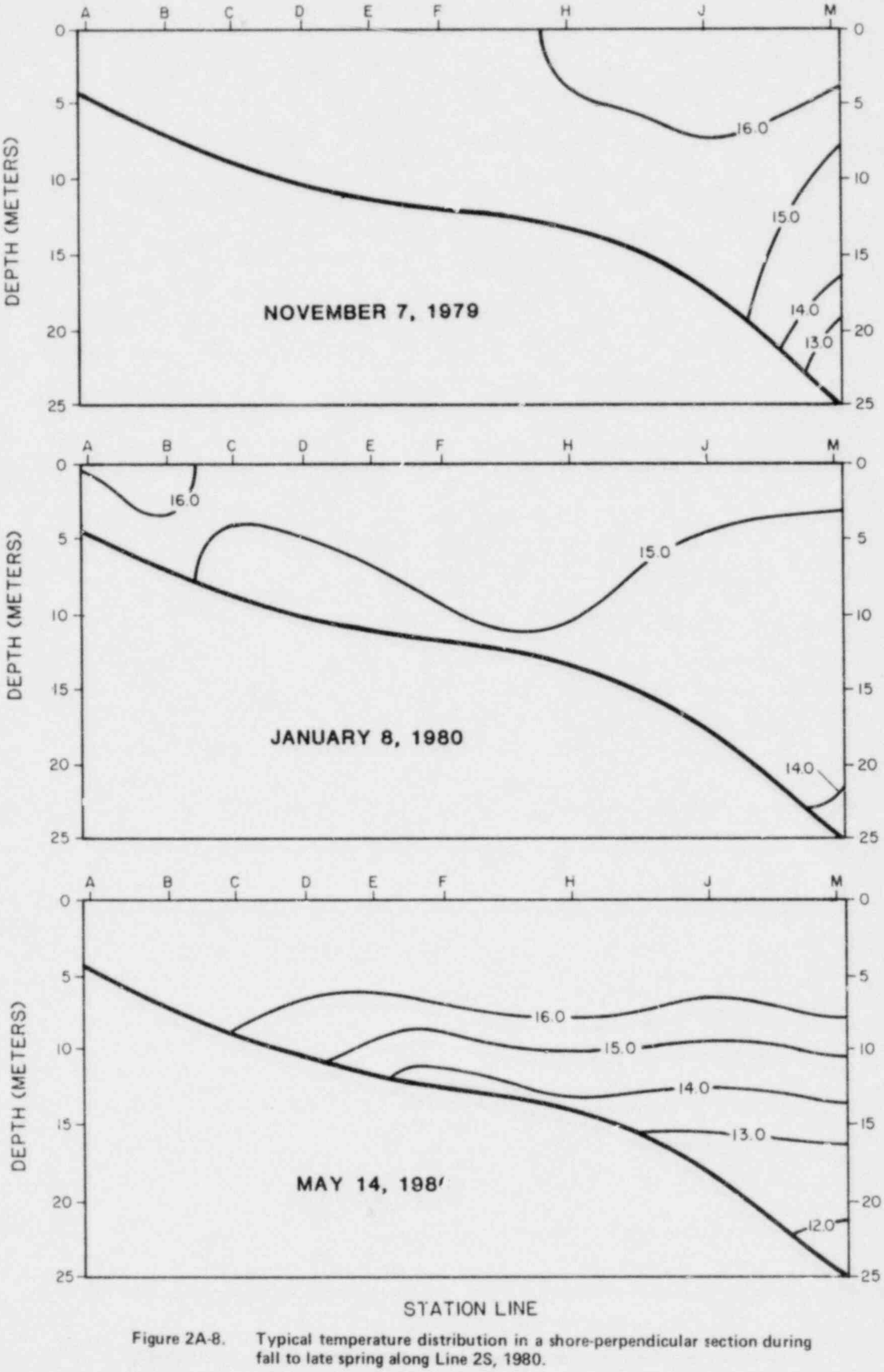
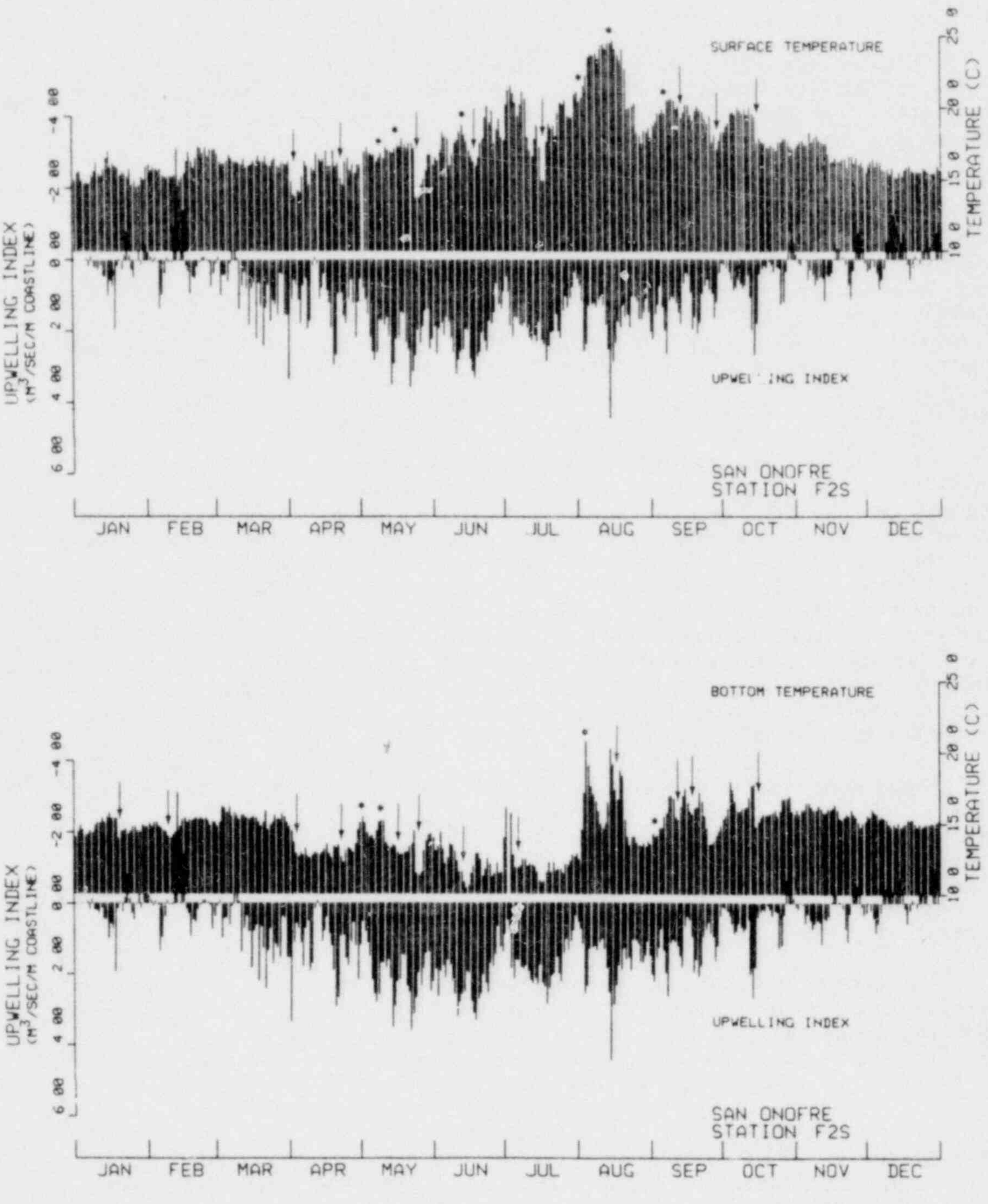


Figure 2A-8. Typical temperature distribution in a shore-perpendicular section during fall to late spring along Line 2S, 1980.



KEY: • UPWELLING PULSE NOT ACCOMPANIED BY MAJOR TEMPERATURE FLUCTUATION

↓ TEMPERATURE FLUCTUATION CORRESPONDING TO UPWELLING PULSE

Figure 2A-9. Comparison between temperature at Station F2S and upwelling index calculated by Bakun for 1980.

process may be due partly to heating from insolation of the water previously upwelled and partly to the mixing with warmer ambient water, each a relatively slow process. As compared with the generally slow process of rebounding at the surface, rebound at the bottom occurred frequently as abrupt warming, exhibiting solitary pulses.

Offshore upwelling events marked with asterisks on Figure 2A-9 were not observed in local wind records at San Onofre, nor in the temperature data, indicating that the offshore upwelling indices are not always directly applicable to the San Onofre area.

Temperature fluctuations with periods around 30 days were well correlated with upwelling cycles of similar periodicity, especially in the month of July. The temperature response also appeared to exhibit a lag of several to about 15 days behind the upwelling cycle in June and August 1980 (Figure 2A-9). The temperature response to upwelling excitation exhibited dependence on the upwelling cycle frequency. The temperature drop was usually around 4°C when responding to short duration, local upwelling pulses, but as much as 7°C when responding to a long (30-day) regional upwelling cycle.

Spatial Trends

Continuous temperature records at the surface of Stations C2S and F2S revealed a small on-offshore spatial trend which varied with time of year. During January and February, there was no difference in the monthly means of surface temperature at these two stations. Monthly mean surface temperatures at the inshore station (C2S) in March, April, and May were slightly warmer (0.2 to 0.3°C) than at the offshore continuous temperature station (F2S). During the remainder of the year, monthly mean surface temperature at the offshore station was from 0.2 to 0.7°C warmer than the inshore stations. This spatial on-offshore trend in surface temperature is apparently a normal seasonal pattern at San Onofre, as a similar pattern was observed in 1979 monthly mean surface temperature records (SCE 1980). This seasonal pattern was also observed in results of bimonthly measurements.

Alongshore spatial trends were observed during individual bimonthly surveys. During some surveys, surface temperatures in the downcoast area were from 0.5 to 1.0°C warmer than those in the San Mateo Point area, while in other surveys this pattern was reversed. No consistent alongshore temperature gradient was apparent with time.

Spatial Variations

The complicated circulation patterns create large spatial fluctuations in surface temperature throughout southern California. To a continuous temperature sampling location such as used at San Onofre, these large spatial variations cause changes in temperature with time as nearshore circulation transports different water masses past the sampling locations.

The complicated pattern of surface temperature distribution is illustrated in a series of infrared satellite imagery shown on Figures 2A-10 through 2A-12. These computer-enhanced images of surface temperature distributions during 14-16 April 1980 were obtained from the TIROS-N/NOAA Satellite. These figures also illustrate how much the complex pattern changes in a day. The lighter areas represent cold water and darker areas represent warmer waters.

Several of the longer period fluctuations observed in temperature at San Onofre are also apparent in other temperature records in the southern California

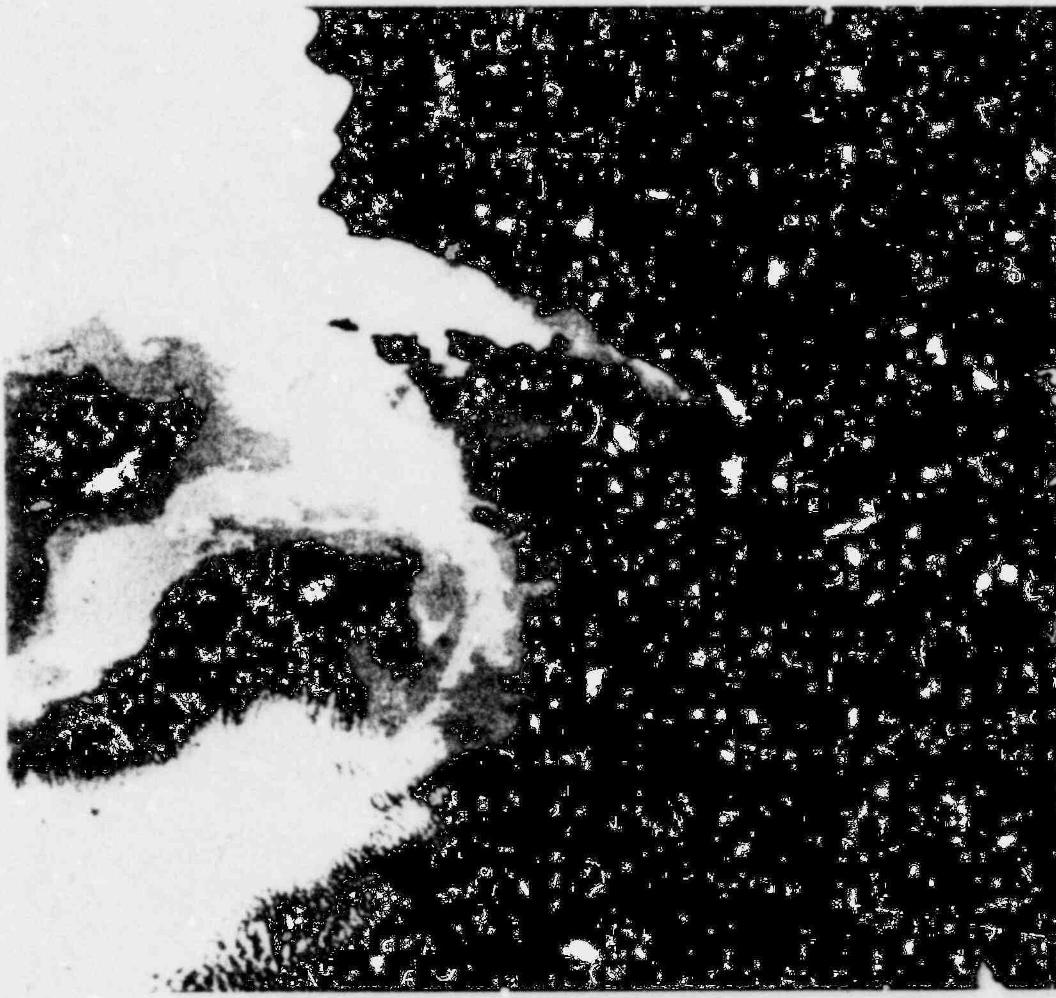


Figure 2A-10. Computer enhanced satellite infrared imagery of surface temperature offshore of southern California, April 14, 1980.

area as shown on Figure 2A-13. Daily temperature observations were obtained at 0800 hrs at several piers throughout southern California. A comparison of these temperature records from La Jolla, San Clemente, Balboa, and Zuma Beach Piers shows that several of the longer period temperature variations (variations over two weeks in duration) are similar, and that some of the shorter duration temperature variations recorded at San Clemente Pier (the closest location to San Onofre, 8 km upcoast), appear quite similar to the temperatures recorded at San Onofre. The similarity of temperature records decreased with increasing separation. La Jolla Pier is located approximately 62 km downcoast from San Onofre, and Balboa and Zuma Beach Piers are located approximately 40 and 135 km upcoast of San Onofre, respectively.

According to the bimonthly temperature data in a shore-perpendicular section along Line 2S in 1979 and 1980 (Figure 2A-7), maximum temperature difference between the warmest surface temperature and the coldest bottom temperature varied with season from 1°C in January 1979 to 8°C in July 1980. Maximum temperature difference between surface and bottom waters was associated with the development of a thermocline which effectively separated surface waters warmed by insolation from bottom waters cooled by upwelling.

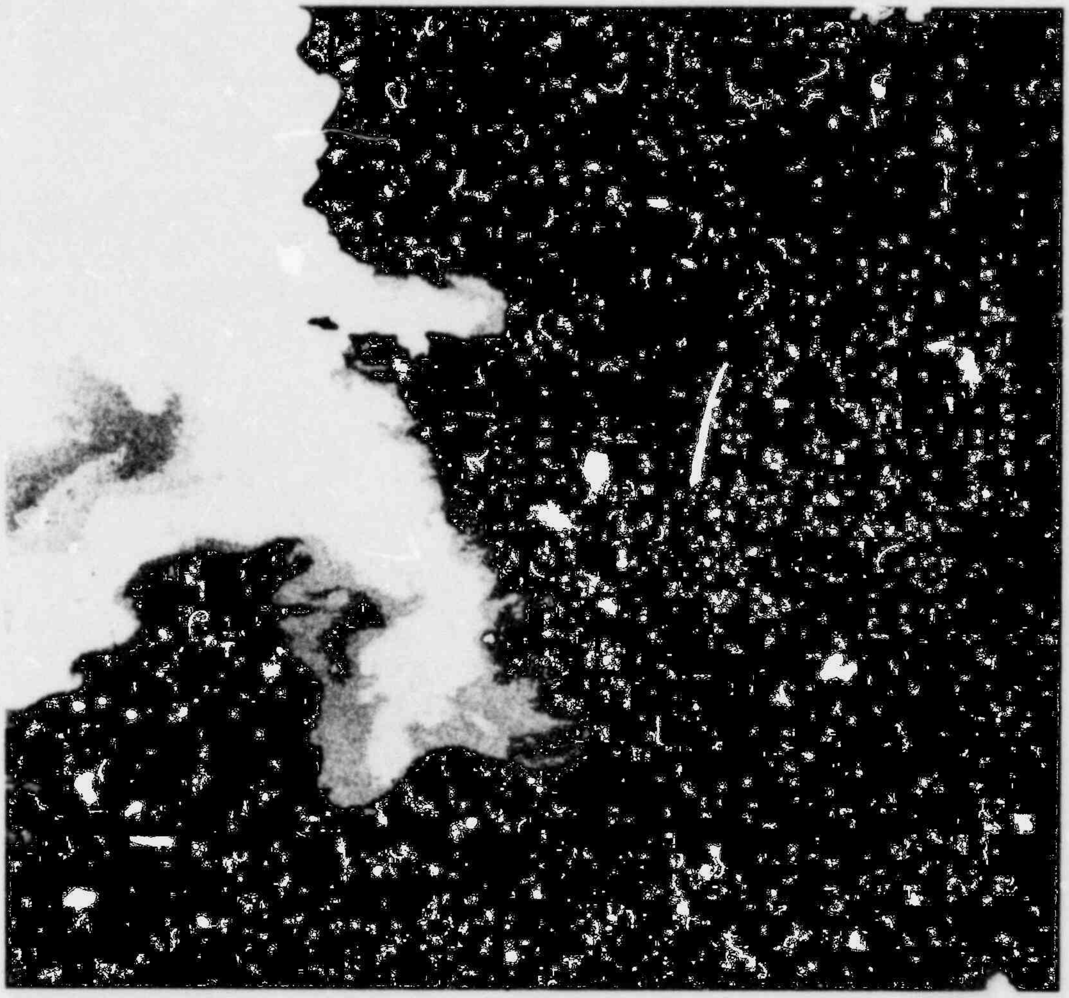


Figure 2A-11. Computer enhanced satellite infrared imagery of surface temperature offshore of southern California, April 15, 1980.

Compared with the pronounced spatial variation in the vertical, variations in the horizontal direction were much less. Between the shore-most station (A2S) and the offshore-most station (M2S), the temperature difference at the sea surface generally remained less than 1°C in 1979 and 1980. Difference at the bottom was somewhat larger, averaging 3.4°C in 1980 and 4.2°C in 1979.

At preoperational sampling stations for Units 2 and 3, the difference between survey maximum and minimum natural surface temperatures varied from 0.8 to 2.2°C during the four 1980 surveys. This was a significant spatial variation in natural temperature since the circulating seawater systems for Units 2 and 3 are designed with multiport diffusers to avoid increasing surface temperatures more than 2.2°C (4°F) at any location more than 300 m (1000 ft) away from the discharge. Therefore, the operation of Units 2 and 3 will not affect the surface temperature more than the natural spatial variation observed during summer months.

INFLUENCE OF UNIT 1 ON TEMPERATURE

Natural conditions which affect the size of the thermal field include natural temperature stratification, currents, rate of mixing in receiving waters,

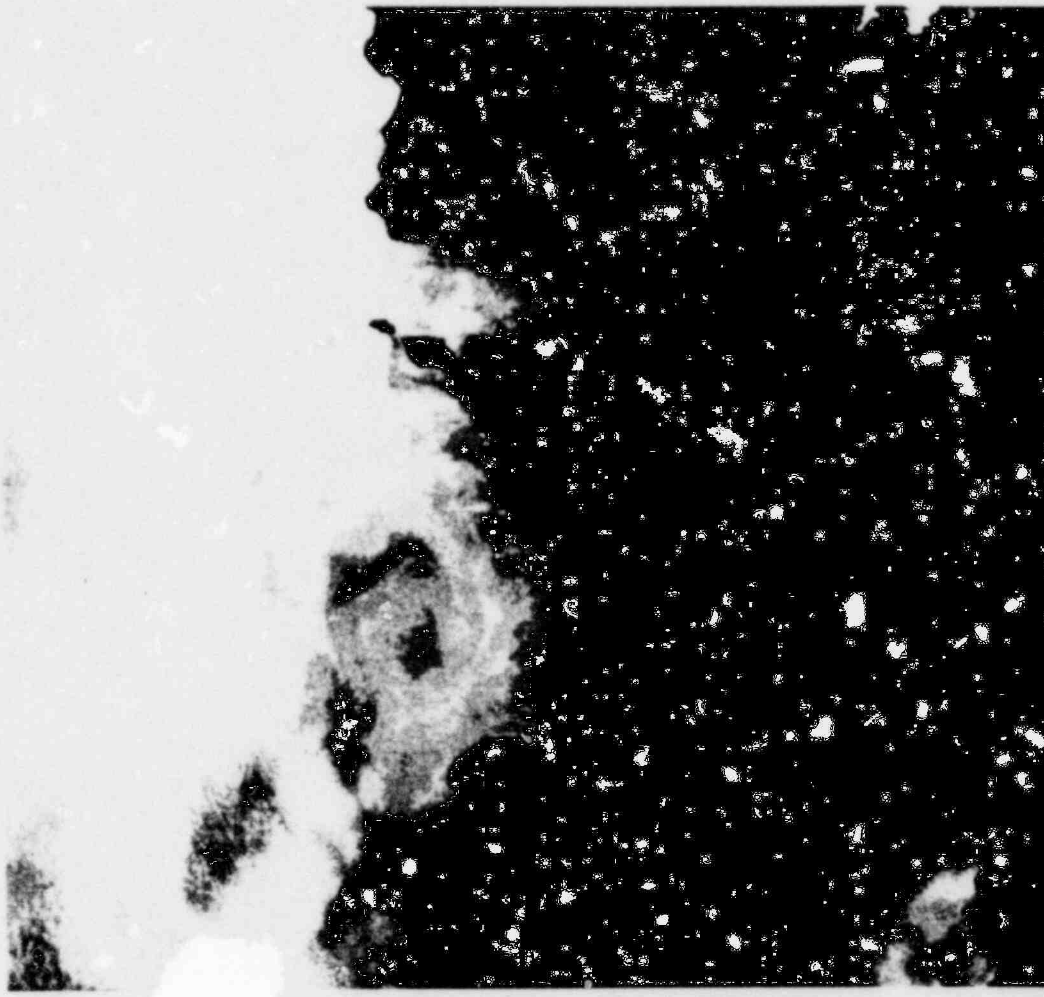


Figure 2A-12. Computer enhanced satellite infrared imagery of surface temperature offshore of southern California, April 16, 1980.

tide height, and winds (IAEA 1974). Variation in natural temperature stratification had the most significant effect on the surface area of the 1° and 4°F elevated temperature fields (SCE 1980). Aerial extent of the thermal field was typically less during periods of natural temperature stratification with depth.

Winds, currents, and rate of heat dissipation also significantly affected the surface area of the 1°F elevated temperature field. The extent and area of the field was generally small during periods of higher velocity currents and high atmospheric heat dissipation.

Areas of Influence

The area of thermal influence of Unit 1 for 1976 through 1980 is illustrated by the composite of areal extents of the 1°F and 4°F elevated temperature fields shown on Figures 2A-14 and 2A-15. The surface area enclosed by the 1°F elevated temperature field ranged from less than 1 acre to 1800 acres, and averaged 604 acres for the five-year period. The surface area enclosed by the 4°F elevated temperature field ranged from less than 1 acre to 230 acres, averaging 16 acres. The 4°F elevated temperature field was observed to be less than 1 acre 40% of the time. The elevated temperature field extended horizontally farther alongshore

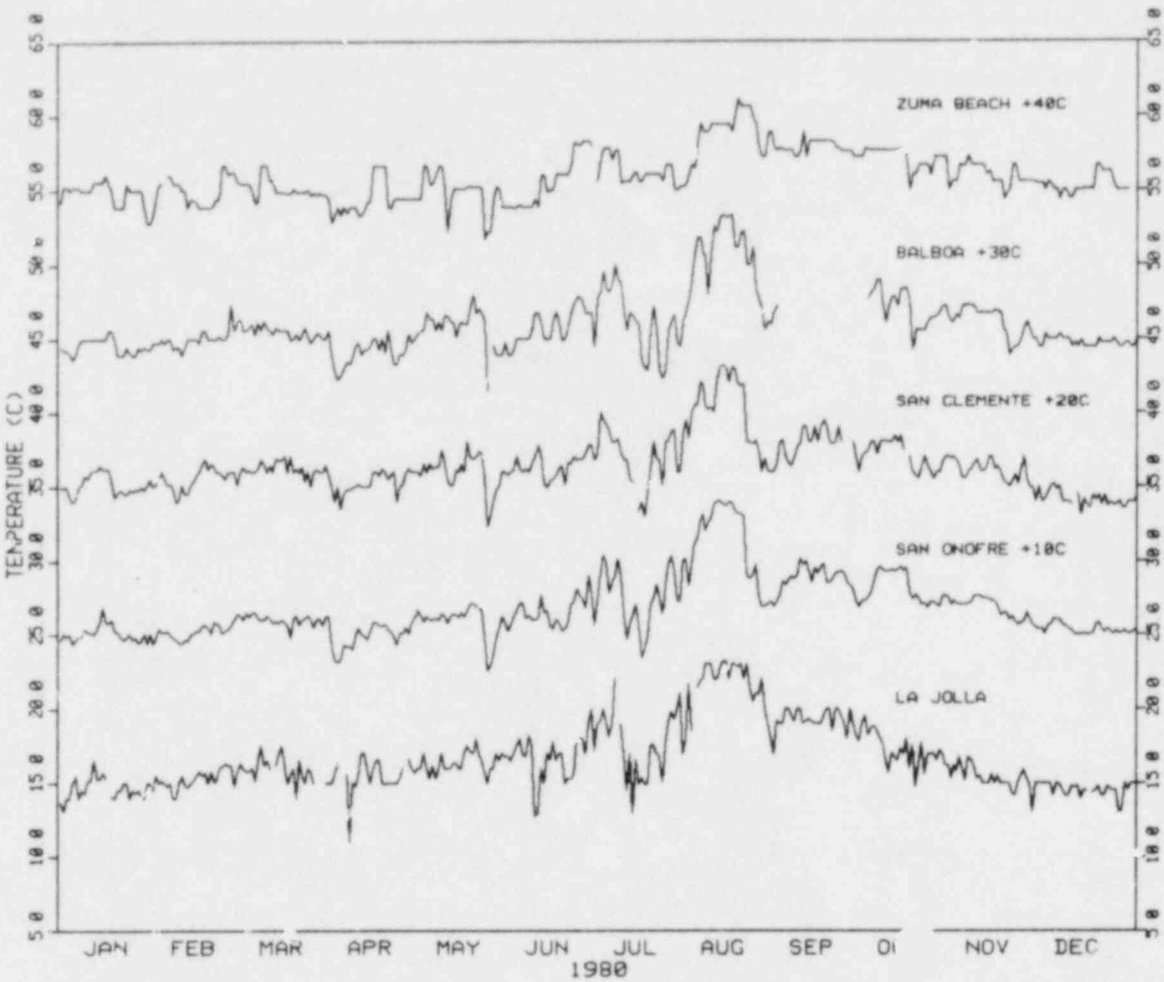


Figure 2A-13. A comparison of temperature at San Onofre to daily observations at nearshore temperature stations throughout the Southern California Bight.

than offshore. The average extent of the 1°F field was 1344 m upcoast, 1088 m downcoast, 618 m offshore, and 649 m inshore of the discharge for the past five years. The average extent of the 4°F field was 123 m upcoast, 90 m downcoast, 102 m offshore, and 90 m onshore.

The area of thermal influence from Unit 1 is shown by the maximum observed limits of the horizontal extent of the 1°F and 4°F elevated temperature fields for 1976 through 1980 (Figures 2A-14 and 2A-15). The maximum observed limit encloses all of the observed contours for that particular elevated temperature. The 75% limit represents the maximum observed limit by 75% of the thermal fields. This does not mean, however, that 75% of the fields were as large as the 75% limit; which would be quite small in extent. Similarly, the 50% and 25% limits represent the maximum extent enclosed by 50% and 25% of the thermal fields.

The average surface area of the 1° and 4°F elevated temperature fields for January and March 1980 (455 and 13 acres, respectively) were smaller than the average area for January and March of the four previous years (838 and 48 acres). Since Unit 1 was only operational during the first two surveys of 1980, further comparative analyses of 1980 data to historical data could not be conducted.

The vertical extent of the surface thermal field from Unit 1 for 1980 was similar to historical results of surveys offshore of the generating station. The average depth of the 1°F thermal field for 1976 through 1980 was limited to approximately 4 m (13.1 ft) at stations within 150 m (500 ft) of the discharge and to approxmately 3 m (10 ft) at stations within 300 m (1000 ft) of the discharge. The warm water lens does not come in contact with the bottom except at shallow nearshore stations.

Recirculation

One of the most common parameters used in evaluating a thermal discharge is the increase in temperature of the seawater as it circulates through the heat exchanger of the cooling water system. This in-plant delta-t represents the amount of waste heat discharged to the ocean. Unit 1 cooling water system is designed to produce an in-plant delta-t of approximately 12°C. Therefore, the discharge temperature is theoretically 12°C warmer than the receiving water temperature. However, due to the proximity of the intake and discharge structures for Unit 1 (150 m separation), a portion of previously discharged water can, at times, be recirculated through the cooling water system when the intake withdraws previously discharged warm water. This can result in a discharge temperature which is warmer than the ambient temperature of receiving waters by more than the in-plant delta-t would indicate. Therefore, intake and discharge temperatures were compared to an ambient temperature to estimate the periods and amounts of recirculation of previously discharged warm waters and to determine the actual increase in temperature experience by the environment.

During periods of normal plant operation (1976 to 1980), intake temperatures exceeded surface ambient temperatures by 1°C or more, 24% of the time. For intake temperature to be 1.0°C warmer than ambient, 8% of the previously discharged waters must be recirculated through the cooling water system. Yet, an absolute determination of this type cannot be made since natural temperature varies 0.5 to 1.0°C spatially, as previously discussed.

In-plant intake temperatures were generally cooler than surface ambient temperatures during the warmer months, when natural water column stratification was present, and generally warmer during cooler months when stratification was reduced or absent. From May through September, the surface waters were naturally warmer than mid-depth waters at the depth of the intake. This natural temperature stratification tended to mask any differences between ambient and intake temperature which would have reflected recirculation conditions. Also, this natural stratification of temperature with depth from May to September would limit exchange between waters above and below the thermocline. Therefore, little recirculation of previously discharged, warmed surface waters to mid-depth waters withdrawn by the intake is expected during this period.

The differences between discharge and surface ambient temperatures were greater than the in-plant delta-t by as much as 1.4°C for short periods during late fall and winter months. These data suggest partial recirculation of heated water back into the intake during these periods. From measurements during winter months, it was estimated that approximately 5 to 10% of previously discharged waters were recirculated through the generating station.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

Figure 2A-14. Maximum area of influence of the 1°F elevated temperature field, 1976-1980.

Figure 2A-15. Maximum area of influence of the 4°F elevated temperature field, 1976-1980.

APPROACH

The fundamental purpose of temperature studies at San Onofre was to determine the thermal impact of the generating station cooling water systems on the marine environment. In order to determine this thermal impact, the changes in water temperature were evaluated in light of natural temperature conditions.

An integrated study approach to sampling was used to fulfill the objectives and the overall purpose of the study. This integrated study approach consisted of intensive field measurements every two months to determine both natural and plant induced 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 picture of temperature conditions throughout the study area was obtained from bimonthly survey measurements including vertical temperature profile, aerial infrared radiometer, and shoreline temperature measurements.

Surface, mid-depth, and bottom temperature was continuously measured at three stations to determine temporal variations in temperature due to natural conditions and to the operation of Unit 1. Surface, mid-depth, and bottom temperature was continuously measured at one location (Station C2S) 610 m (2000 ft) downcoast of Unit 1 discharge (Station X0) to document natural and plant induced changes in temperature with time. A Unit 1 control station (Station C22S), located beyond the influence of Unit 1, documented natural temporal fluctuations of temperature. In the vicinity of Units 2 and 3 diffusers (Station F2S), continuous temperature measurements documented natural variations in temperature conditions prior to operation of Units 2 and 3. Continuous temperature measurements at hard bottom benthic stations for PMP began in August 1979 and documented temperature conditions experienced by the benthic community.

Inplant intake and discharge temperature data were continuously recorded by SCE within the upper 3 ft of the intake and discharge conduits. Intake and discharge temperature data were compared to ambient downcoast temperature (C22S, surface) to estimate the extent to which previously discharged water is recirculated back into the intake of the circulating water system and determine the increase in discharge temperature as a result of recirculation.

DATA SOURCES

In addition to information collected during SCE studies, other data sources were utilized in the study of temperature at San Onofre. Other data sources used included: 1) published historical data summaries pertaining to oceanographic conditions in southern California; 2) meteorological summaries for California; 3) meteorological records at San Onofre; 4) daily surface temperatures from locations throughout the southern California area; 5) calculated upwelling indices; and 6) infrared satellite imagery.

There is a vast amount of oceanographic data from the southern California area available in the literature. Summaries of historical oceanographic data by the Southern California Coastal Water Research Project (SCCWRP 1973) and the State Water Pollution Control Board (SWPCB 1959) were used to characterize oceanographic and temperature conditions throughout the southern California area. Meteorological summaries from the National Weather Service provided information on wind speed and direction, air temperature, cloud cover, rainfall, barometric pressure, relative humidity, and other meteorological conditions (NOAA 1980). These meteorological summaries supplement continuous air temperature and wind measurements collected at the generating station. Daily sea surface

temperatures from four locations throughout the southern California area were obtained from Scripps Institute of Oceanography (IMR 1980). Upwelling indices were obtained from the National Oceanic and Atmospheric Administration/National Marine Fisheries Service (Bakun 1980), and are based on differences in atmospheric pressure measured throughout the northeast Pacific Ocean. Infrared satellite imagery of sea surface temperature throughout the southern California area were obtained from the Jet Propulsion Laboratory.

METHODS

This section presents a synopsis of the methods used in the investigation of temperature conditions. There were six basic types of temperature measurements for this portion of the study including: 1) vertical temperature profiles; 2) continuous temperature monitoring; 3) aerial infrared radiometer measurements; 4) shoreline temperature measurements; 5) continuous bottom temperature measurements; and 6) continuous inplant intake and discharge temperatures. A detailed description of methods is presented in the Brown and Caldwell Procedures Manual for Environmental Surveillance at San Onofre (BC 1978). The methods and equipment utilized for temperature measurements in conjunction with biological sampling are presented in the appropriate biological sections.

TEMPERATURE PROFILES

Vertical profile measurements were used to document the natural spatial trends and variability of temperature for Units 2 and 3 and to document vertical extent of the thermal field for Unit 1. Vertical profiles of temperature were measured at 51 Unit 1 operational sampling stations and at 23 additional preoperational monitoring stations for Units 2 and 3 (Figures 2A-1 and 2A-2) during field surveys of 8 January, 13 March, 14 May, and 9 July 1980. The PMP program was terminated in September 1980, after two years duration. Since Unit 1 was offline and the PMP was terminated, temperature profiles during the 10 September and 5 November 1980 surveys were obtained only at the 34 required stations of the ETS program.

CONTINUOUS TEMPERATURE MONITORING

Continuous temperature measurements were used to determine temporal trends and variations in temperature prior to operation of Units 2 and 3 and to determine the thermal effect of Unit 1 in light of the natural variability of temperature. Continuous temperature measurements were also utilized as an indicator parameter of oceanographic and meteorological phenomena such as upwelling, storms, major current regimes, local eddies, etc.

Continuous temperature data were recorded hourly at three depths at Stations C2S and C22S, as outlined in ETS Section 3.1.1.a.(5). Station C2S was located in Surveillance Zone 0A, 610 m (2000 feet) downcoast of the Unit 1 discharge in 9 m (30 feet) of water and Station C22S was located in Zone 6, 6710 m (22,000 feet) downcoast of the Unit 1 discharge in 9 m (30 feet) of water. Continuous temperature data was also recorded hourly at four depths at Station F2S as part of the PMP for Units 2 and 3. Station F2S is located in Surveillance Zone 0B, 610 m (2000 feet) downcoast and 915 m (3000 feet) offshore of Unit 1 discharge in 14 m (45 feet) of water. These stations provided continuous temperature readings for documentation of daily variation for near surface, mid-depth, and near bottom waters in the vicinity of the existing Unit 1 discharge (C2S) and at a location outside the influence of the existing thermal discharge (C22S), and provide baseline data in the vicinity of Units 2 and 3 discharges (F2S) prior to operation of those units.

AERIAL INFRARED MEASUREMENTS

Infrared radiometer measurements, taken from an aircraft, were used to map surface extent of the thermal field from Unit 1 and natural spatial variability of temperature in the area of Units 2 and 3 diffusers. Aerial infrared mapping surveys were conducted during the first four and the sixth bimonthly surveys in conjunction with the temperature profiling surveys. During each of the infrared radiometer surveys, up to three surface temperature mapping flights were conducted during different tidal phases.

SHORELINE TEMPERATURE MEASUREMENTS

Shoreline temperatures were measured during bimonthly surveys in order to determine the shoreward extent of the thermal plume from Unit 1. Measurements were taken at five shoreline stations as outlined in ETS Section 3.1.1.a.(5), plus an additional six stations (Figure 2A-2) in order to aid in determining whether or not the elevated temperature field of Unit 1 came in contact with the shoreline.

CONTINUOUS BOTTOM TEMPERATURE MEASUREMENTS

In August 1979, benthic sensing packages were deployed at five PMP benthic cobble stations shown in Chapter 5B. These benthic sensing packages were used to continuously sample physical parameters important to the benthic community including temperature, ambient light intensity in the photosynthetic range, and rate of sedimentation. The benthic packages were deployed until early October 1980.

RECIRCULATION ANALYSIS

Due to the proximity of the intake and discharge structures of the seawater cooling system for Unit 1 (150 m: 500 ft separation), a portion of previously discharged warmed water could be, at times, circulated through the station's cooling water system. This would result in an increased discharge temperature. Therefore, intake and discharge temperature were compared to an ocean ambient temperature to determine the frequency and intensity of increased discharge temperature due to recirculation.

RESULTS AND ANALYSES

This section presents an analysis of 1980 results in order to fulfill the objectives of temperature studies at San Onofre.

The natural daily mean surface temperature recorded at Station F2S in the vicinity of Units 2 and 3 diffusers is shown in Figure 2A-16. This record exhibits a large range of temperature during 1980. For the first five months, temperatures were generally between 15 and 17°C. From June through the middle of August, temperature increased to approximately 24°C and then decreased to approximately 19 to 20°C during September and the first half of October. Temperature decreased to between 15 and 16°C in December.

With these seasonal trends, short period warming and cooling trends were observed. Several of these short period trends resulted in large changes in temperature, as much as 4 to 5°C.

Relatively strong west-northwest winds of the upwelling type (10-20 mph), which were associated with storms on 1-2 April, 23-24 May, and 14-17 October

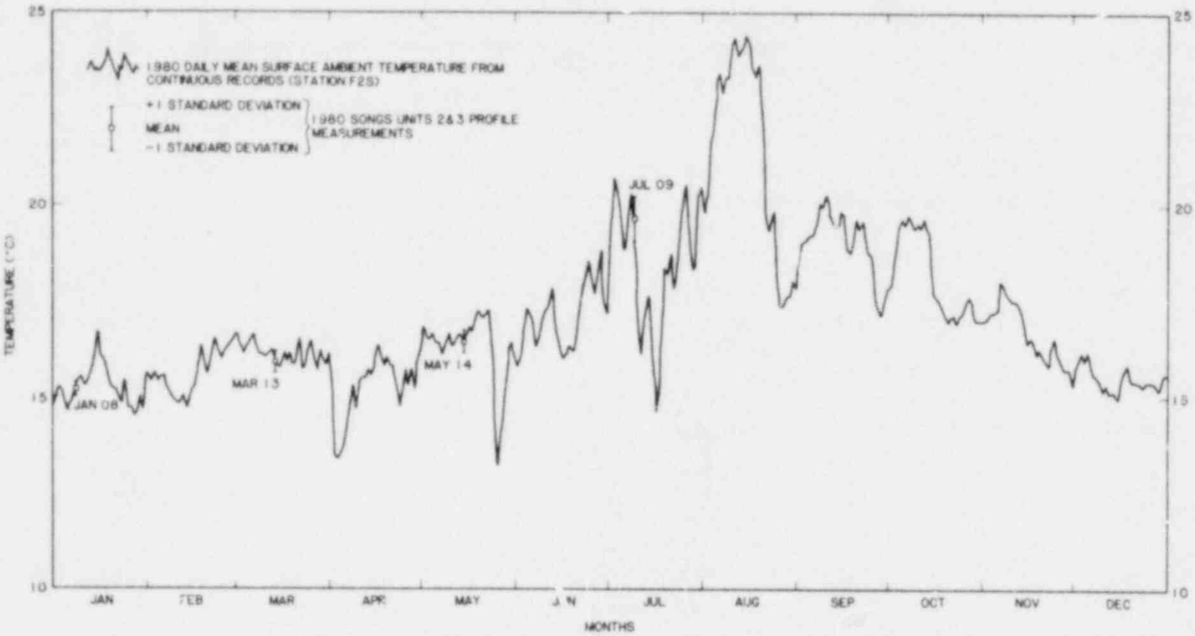


Figure 2A-16. Daily mean natural surface temperature at San Onofre.

1980, resulted in rapid decreases in surface temperatures. Average daily surface temperature decreased from 16.1°C on 31 March to 13.4°C on 2 April. Surface temperature remained below 14°C from 3-5 April and then returned to 15°C by 7 April. After a storm on 20-22 April, clearing winds of 10 to 20 mph from the west on 23-24 April also resulted in upwelling, which decreased average daily temperatures from 16.9°C on 23 April to 13.3°C on 25 April. By 29 April, thermal stratification was established and surface temperature had increased to 16.2°C. On 14-15 October 1980, winds with speeds of 10 to 20 mph from the west resulted in upwelling which reduced average surface temperature from 19.2°C on 14 October to 17.7°C on 15 October.

During summer months, when thermal stratif..ation is gr=atest, west and northwest winds greatly affected the surface temperature. These winds were usually less intense than those associated with winter storms (10-15 mph) and occurred during strong afternoon sea breeze or were associated with larger atmospheric pressure systems. On 9-10 July, afternoon winds from the west-northwest (300°T) persisted for approximately five hours at speeds of 10 to 15 mph, and resulted in upwelling which reduced average daily surface temperatures from 20.3°C on 8 July to 16.1°C on 11 July 1980. Similar afternoon winds on 15 July resulted in surface temperature decreasing 17.6°C to 15.6°C. Strong winds (15-20 mph) on 20 August reduced daily average surface temperature from 23.6°C on 19 August to 19.7°C on 21 August. On 24 August, 8 to 11 mph winds for a period of 10 hours further reduced surface temperature to 17.4°C. On 26 September, 10-15 mph winds from the west-northwest for six hours reduced surface temperatures 18.7 to 17.1°C.

With the exception of the annual warming and cooling cycle, which resulted in 8°C change in natural temperature over the year, wind and storm associated upwelling resulted in the largest fluctuations of daily mean natural temperature. Surface temperatures were rapidly reduced by 2 to 4°C by upwelling during a 1 to 2 day episode of relatively strong winds and it generally took surface temperature from 3 to 4 days to warm back up to values prior to the occurrence of upwelling.

The magnitude and duration of temperature fluctuations exhibited a large range of variability. These temperature fluctuations are illustrated on Figure 2A-17 which presents results of digital filtering of actual hourly surface temperature measurements at Station F2S into three frequency bands. The top graph in the figure presents filter cyclic fluctuations of periods of greater than 60 days and therefore represents the annual temperature cycle at San Onofre during 1980. The second graph on Figure 2A-17 presents the filtered band of cyclic fluctuations of periods of less than eight days. Some relatively large daily temperature fluctuations are illustrated in these records. These short duration temperature fluctuations were generally smallest (0.5 to 1.5°C) during winter months, (January, February, November, and December) and increased in magnitude to between 2 and 5°C during summer months. Previous analysis of current and temperature data have shown that daily temperature fluctuations are well correlated with tidal currents (BC 1979 and SCE 1980). During the summer, other temperature fluctuations with periods of 5 to 14 days, resulted in 2 to 4°C temperature variations.

Results of digital filter of continuous temperature records from the bottom sensor at Station F2S are shown in Figure 2A-18. Bottom temperature at Station F2S followed a significantly different seasonal pattern from surface temperature. Bottom water temperature cooled approximately 1.7°C during the spring when a shallow thermocline was established and intensified. The seasonal pattern shows that bottom water temperature was coolest in July and then warmed to its seasonal peak during the middle of October. The shorter period fluctuations in bottom water temperature (periodicities of less than 8 days) were generally much less than those observed in surface waters. Daily variations in bottom water temperature were significantly less than surface waters. During

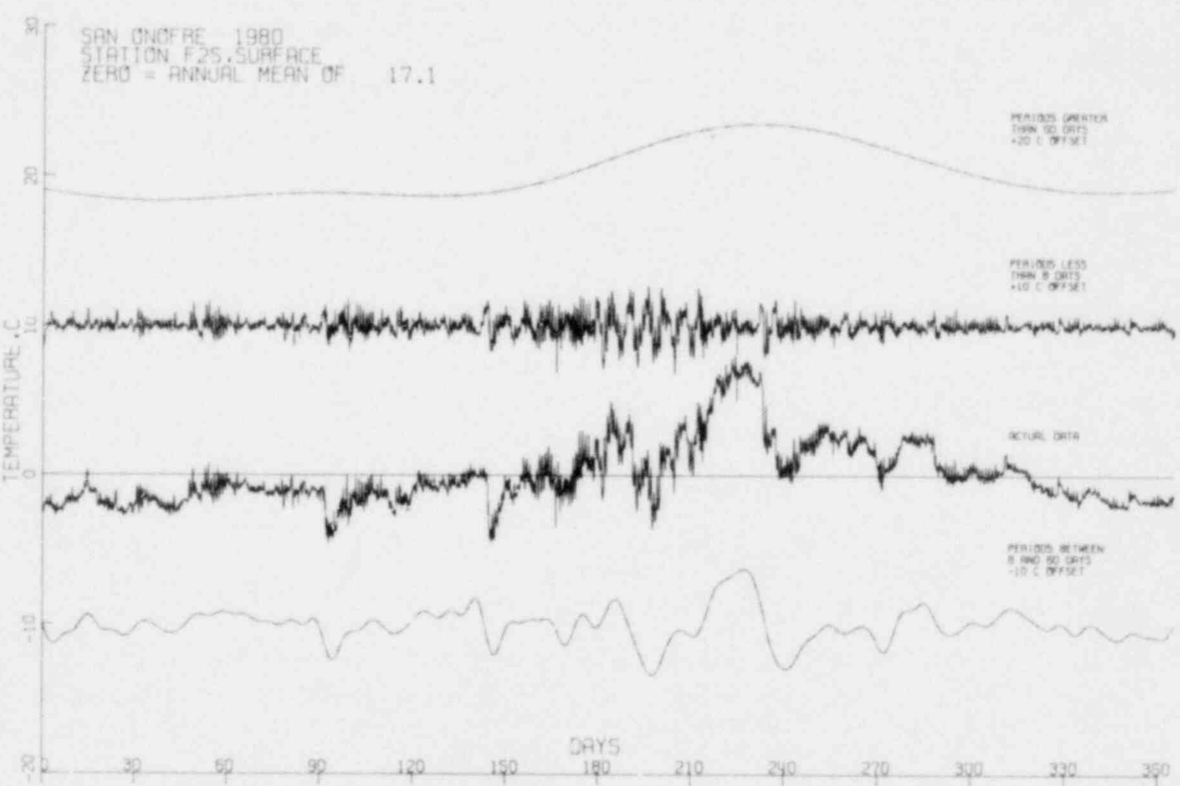


Figure 2A-17. Continuous temperature data filtered into frequency bands for Station F2S, surface, 1980.

winter and spring months, bottom water temperature had only small daily temperature fluctuations of generally less than 1°C. In August, several discrete periods of relatively large daily fluctuations in bottom temperatures were observed, which resulted in temperature deviations of from 2 to 8°C.

SPATIAL TRENDS AND VARIATIONS

Continuous temperature records at the surface of Station C2S and F2S reveal a small on-offshore spatial trend which varies with time of the year. During January and February, there was no difference in the monthly means of surface temperature at these two stations. During March, April, and May, monthly mean surface temperatures at the inshore station (C2S) were slightly warmer (0.2-0.3°C) than at the offshore continuous temperature station (F2S). During the remainder of the year, monthly mean surface temperature at the offshore station was from 0.2 to 0.7°C warmer than the inshore stations.

There were also trends in the vertical stratification of temperature with time. The stratification of temperature with depth followed the normal seasonal pattern. The difference between monthly mean surface and bottom temperature from the two continuous temperature stations in 9 m of water increased from approximately 0.5°C in January to 4.0°C in July and then decreased to no difference in December. A similar pattern was observed at the continuous temperature station in 14 m of water except the largest monthly average stratification occurred one month later in August and was 6.9°C.

Vertical temperature profiles during bimonthly surveys were used to document spatial trends and variability in the San Onofre area. Some spatial

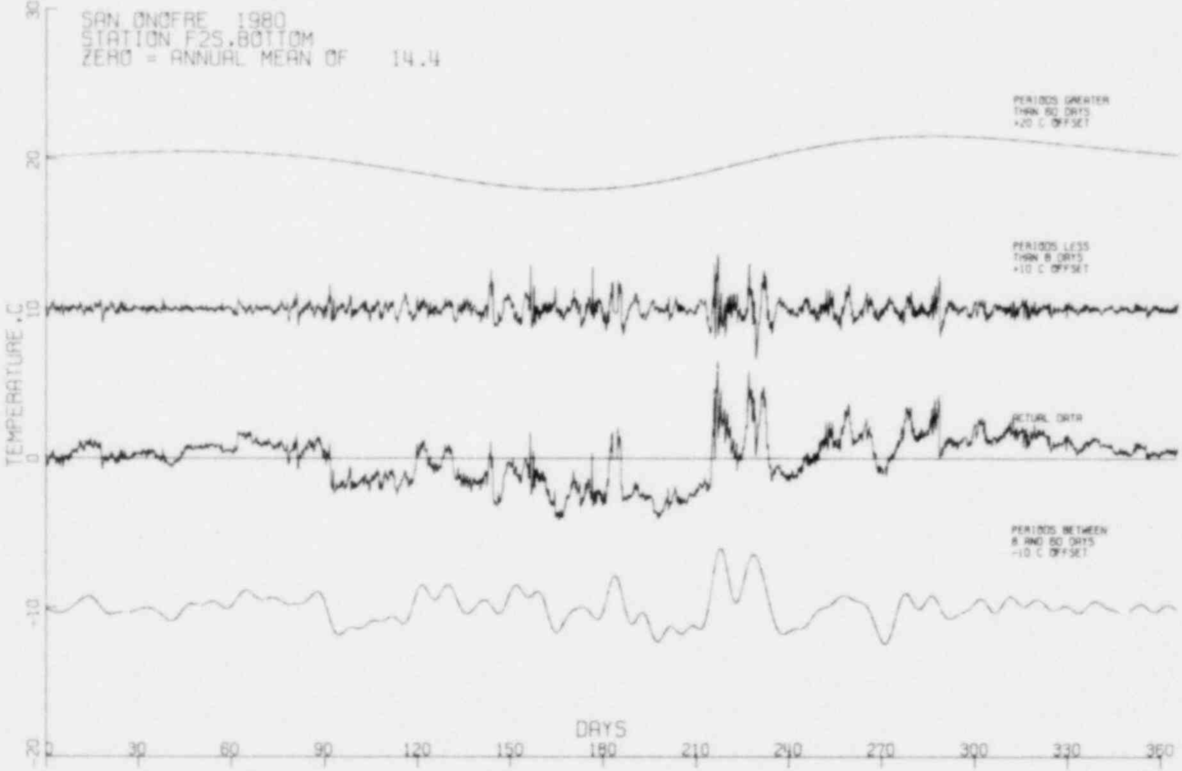


Figure 2A-18. Continuous temperature data filtered into frequency bands for Station F2S, Bottom, 1980.

trends were observed in the on-offshore direction and alongshore. No on-offshore trends were observed during the January and November surveys. Offshore waters were approximately 1.0°C and 0.2°C cooler than inshore waters during the March and May surveys, respectively. During the July and September surveys, offshore surface waters were approximately 1.0°C and 0.5°C warmer than nearshore waters, respectively. During the March, May, and July surveys surface temperature in the downcoast area were from 0.5 to 1.0°C warmer than those in the San Mateo Point area. During the September and November surveys, this pattern reversed with surface temperatures near San Mateo Point approximately 0.5°C warmer than downcoast stations. These spatial trends and variations were affected to some extent by the time required to obtain profile measurements at all sampling stations, generally 4 to 5 hours. Nevertheless, similar patterns to those observed in results of profile measurements were observed in the results of infrared radiometer flights which required less than an hour for mapping surface temperature characteristics in the area.

HORIZONTAL EXTENT OF THERMAL FIELD FROM UNIT 1

Aerial infrared mapping was used to determine the extent of the thermal plume from Unit 1. A composite of the location of the 1°F (0.6°C) and 4°F (2.2°C) elevated temperatures during infrared radiometer flights of 1980 are shown on Figures 2A-19 and 2A-20, respectively. The areas of the 1 and 4°F elevated temperature fields were determined for comparison to previous years. Unit 1 was operational during only two surveys of 1980. Characteristics of 1 and 4°F elevated temperature fields, plant operating characteristics, and meteorological conditions during each of the infrared flights are presented in Table 2A-2.

The average area of the 1°F elevated temperature field was 455 acres with a range of 160 to 780 acres. Upcoast and downcoast extent of the thermal field averaged approximately 900 m (3,000 ft) away from the point of discharge, and offshore extent averaged approximately 800 m (2,600 ft). During periods of plant operation, the 1°F elevated temperature field came in contact with the shoreline during each of the infrared flights of 1980.

The average area of the 4°F elevated temperature field was approximately 13 acres and ranged from not being observed during two IR flights to 31 acres in extent. The horizontal extent of the 4°F elevated temperature field away from the point of discharge averaged approximately 100 m (330 ft) in all directions. The 4°F elevated field did not come in contact with the shoreline.

The 1°F elevated temperature fields were generally centered around the discharge during 1980 and did not extend upcoast to the San Mateo kelp beds nor offshore to the San Onofre kelp beds as shown on Figure 2A-19.

The 4°F elevated temperature field was non-existent or was confined to the immediate area of the discharge as shown on Figure 2A-20.

VERTICAL EXTENT OF THERMAL FIELD FROM UNIT 1

The vertical extent of the 1°F elevated field was limited to a depth of 3 to 4 m (10 to 13 ft) in the vicinity of the discharge and became shallower with distance from the discharge. Since the warmed water in the discharged water is buoyant compared to the surrounding waters, the thermal field appears as a warm-water lens immersed in the receiving waters. This warm water lens has its greatest thickness at the point of discharge and becomes thinner with distance from the discharge due to buoyant spreading in the horizontal direction.

Table 2A-2. Characteristics of the 1°F and 4°F elevated temperature fields for Unit 1 during 1980.

Date	Time	Height (ft)	Wind Speed (kn)	Wind Direction (°T)	Air Temperature (°F)	Plant Load MW	Plant Load ΔT(°F)	Natural Surface Temperature (°F)
Jan 8	0822-0901	3.0	4.3	145	58.7	447	22.5	59.0+0.5
	1100-1132	4.0	6.3	175	60.1	446	22.5	60.1+0.2
	1420-1451	3.4	7.2	150	59.5	447	22.5	59.7+0.5
Mar 13	0900-0945	3.2	5.4	270	60.4	455	21.5	63.0+0.4
	1256-1342	-0.8	7.0	015	64.2	453	21.4	63.5+0.4

	Thermal Field Area[a] (acres)		Thermal Field Horizontal Extent (m)[b] 4°F				1°F			
Date	4°F	1°F	UC	DC	IS	OS	UC	DC	IS[c]	OS
Jan 8	16	780	230	150	30	150	1220	1310	750	1430
	d	570	-	-	-	-	820	1390	750	1250
	31	515	20	245	200	400	1100	980	750	700
Mar 13	18	160	200	150	240	20	670	240	750	220
	d	250	-	-	-	-	790	490	750	370

KEY: UC=Upcoast DC=Downcoast IS=Inshore OS=Offshore

[a] Surface area enclosed by the 4°F and 1°F elevated temperature field.

[b] Extent along the sea surface of the 4°F and 1°F temperature contours as measured from the point of discharge (XO).

[c] Thermal field came in contact with shoreline.

[d] No field observed.

RECIRCULATION

The comparison plots of the recirculation analysis presented in Volume I, 1980 (SCE 1981a) show that intake temperature was warmer than ocean ambient temperature during the entire month of January and most of February and March. Intake temperatures during January were generally 1°C warmer than ambient temperatures and in February and March were between 1 and 2°C warmer than the ambient temperature. By April, enough thermal stratification was present to cause the difference between intake and ambient temperatures to fluctuate about zero, and have a slightly negative monthly mean (ambient surface temperature warmer than intake temperature). The plant went off line on 9 April 1981 and discharge temperature was similar to intake temperature during the rest of the year, with the exception of periods when Unit 1 testing was conducted.

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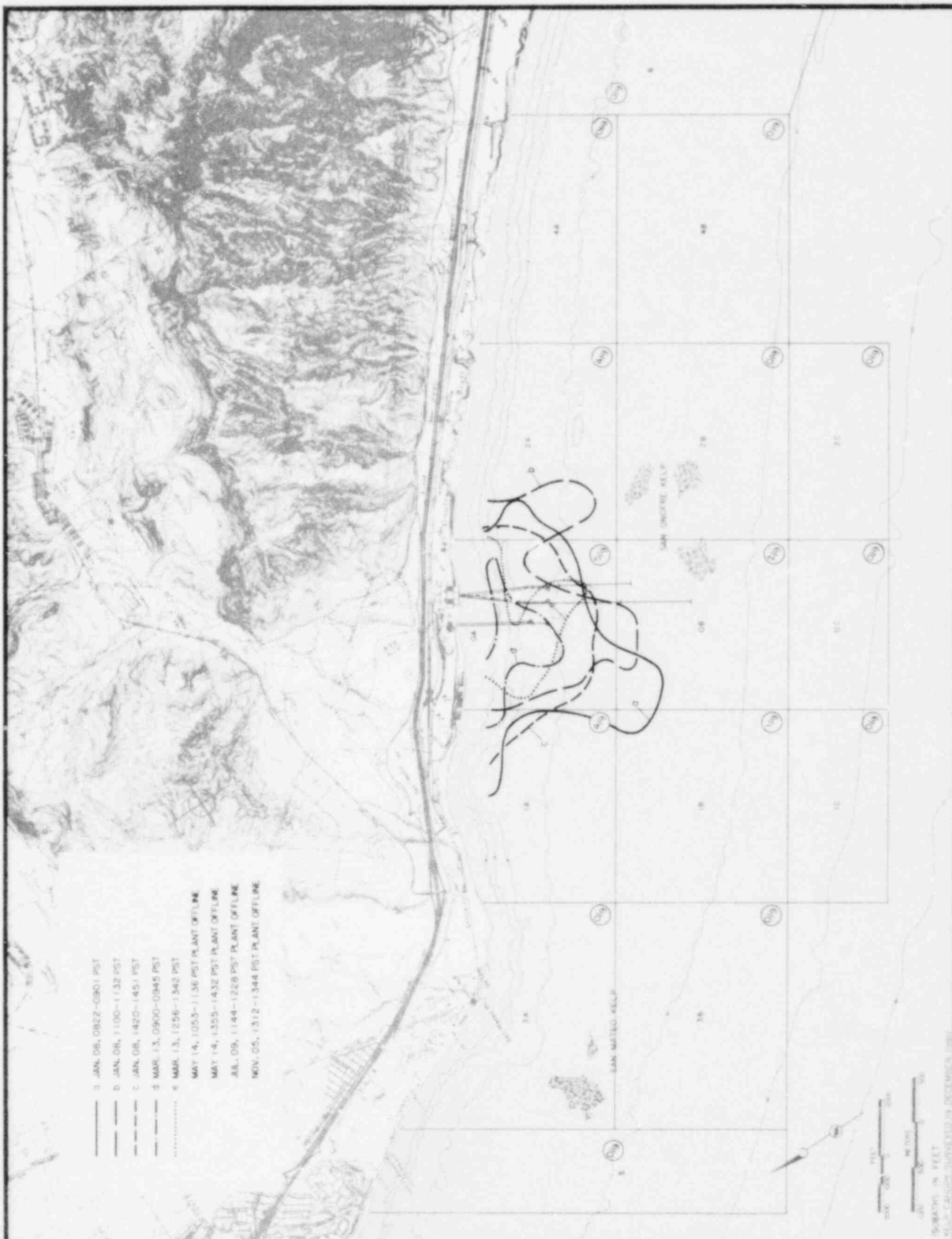

Figure 2A-19. Composite 1°F elevated temperature fields from aerial infrared measurements during 1980.

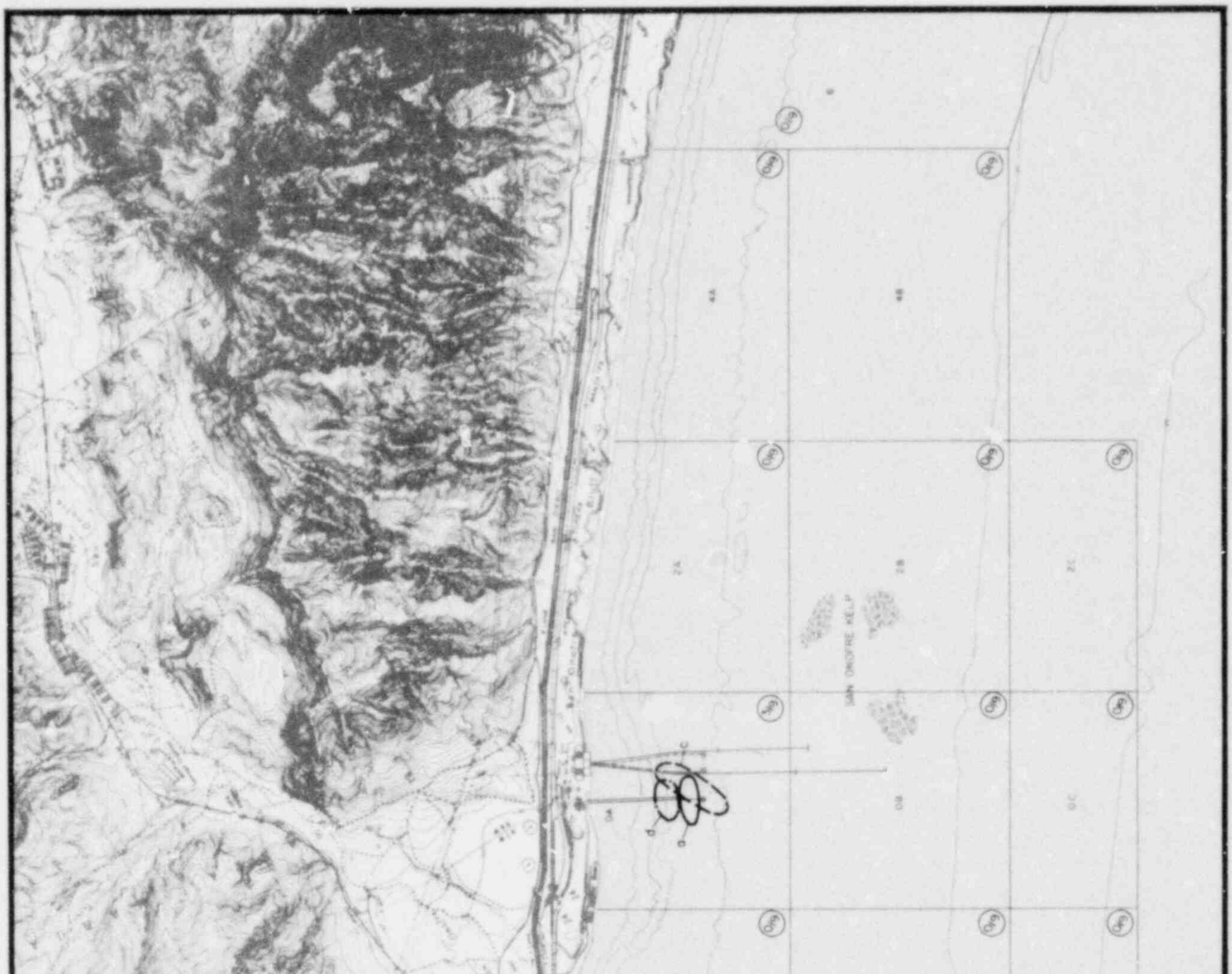

Figure 2A-20. Composite 4°F elevated temperature fields from aerial infrared measurements during 1980.

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CHAPTER 2B

TURBIDITY

INTRODUCTION

Turbidity was extensively measured throughout the San Onofre area during 1980 primarily to complete the two-year baseline study for Units 2 and 3. This preoperational data base can subsequently be compared to results of studies conducted during Units 2 and 3 operation in order to determine the effect of the circulating seawater systems for Units 2 and 3 on water clarity, and to evaluate the impact of that effect with respect to natural background conditions.

Turbidity measurements were also obtained and utilized in the continuing study of operational effects of Unit 1. Unit 1 was not in operation from 9 April 1980 through the end of the year. Circulating seawater pumps for Unit 1 were operated periodically when Unit 1 was offline. Unit 2's circulating water system was tested at low flow rates periodically during 1980 (See Chapter 1 for circulating flow data).

The turbidity studies met all objectives and requirements of the Environmental Technical Specifications (ETS) program for Unit 1 and the Preoperational Monitoring Program (PMP) for Units 2 and 3 established by the Nuclear Regulatory Commission (NRC), as well as the monitoring required by the National Pollutant Discharge Elimination System (NPDES) permit issued by the California Regional Water Quality Control Board, San Diego Region (CRWQCB, SDR).

This chapter presents: 1) a pertinent summary of data collected by SCE studies in 1980; 2) an analysis of data to meet objectives; and 3) a description of turbidity, its interaction with generating station activities, and a perspective of turbidity in the study area and the southern California area.

Previous volumes of this year's annual report have presented all basic data obtained in SCE studies. Volume I presents a summary of data required by regulatory agencies, and was submitted to the appropriate agencies on 31 March 1981 (SCE 1981a). Volume II contains all data collected for SCE programs during 1980, including the basic regulatory required data and additional supplemental data obtained in order to fulfill objectives of the study (SCE 1981b).

BACKGROUND

In order to put 1980 studies in perspective, the following section presents background information on turbidity data collected at San Onofre during the previous 17 years. A brief history of turbidity studies conducted at San Onofre is presented in Table 2B-1.

HISTORICAL STUDIES

Turbidity studies relating to the generating station have been conducted in the San Onofre area since mid-1963, approximately five and a half years prior to operation of Unit 1. Preoperational turbidity studies for Unit 1 began in 1963. Regular bimonthly oceanographic field surveys were initiated in 1964, and

Table 2B-1. Time history of turbidity measurements at San Onofre.

Turbidity Studies	Type of Data Collected	Dates	Instrumentation	Frequency	Locality/ St[illegible]	Depths Sampled
Major Programs						
Marine Environmental Monitoring						
Unit 1 Preoperational	Light transmittance/ depth profiles	1963-1968	Transmissometer, depth probe	Bimonthly	32	Surface to bottom
	Secchi disc measurements	1963-1968	Secchi disc	Bimonthly	32	N/A
Unit 1 Operational	Light transmittance/ depth profiles	1968-1975	Transmissometer, depth probe	Bimonthly	32	Surface to bottom
	Secchi disc measurements	1968-1975	Secchi disc	Bimonthly	32	N/A
Environmental Technical Specifications						
Unit 1	Light transmittance/ depth profiles	1975-1976	Transmissometer	Bimonthly	34	Surface to bottom
		1976-1980	Transmissometer	Bimonthly	51	Surface to bottom
	Secchi disc measurements	1975-1976	Secchi disc	Bimonthly	34	N/A
		1976-1980	Secchi disc	Bimonthly	51	N/A
	Aerial photography	1975-1977	35 mm [illegible] color camera	Quarterly	Unit 1 area	Surface waters
		1977-1980	35 mm SLR color camera	Bimonthly	Unit 1 area	Surface waters
Preoperational Monitoring Program						
Units 2 and 3	Light transmittance/ depth profiles	1978-1980	Transmissometer	Bimonthly	23	Surface to bottom
	Continuous light intensity measurements	1979-1980	LICOR PAR light sensor, benthic sensing package	Continuous, hourly	5 PMP hard bottom benthic stations	1 meter from ocean bottom
Special Studies						
Unit 1 Operational	Suspended solids	1978-1980	Submersible pump, analyzed for suspended and settleable fractions	Bimonthly	28 stations	Surface, 4 meters
Units 2 and 3 Preoperational	Suspended solids	1978-1980	Submersible pump, analyzed for suspended and settleable fractions	Bimonthly	14 stations	Surface, 4 meters
Units 2 and 3 Preoperational Special Turbidity Study	Light transmittance/ depth profiles	1980	Transmissometer	22 weekly surveys	20 stations	Surface to bottom
	Light attenuation/ depth profiles	1980	LICOR PAR light sensor, submarine photometer	22 weekly surveys	20 stations	Surface to bottom
	Aerial photography	1980	High resolution airborne camera	22 weekly surveys	San Onofre	Surface waters
	Suspended solids	1980	Submersible pump, analyzed for total and organic fractions	22 weekly surveys	20 stations	Surface to bottom

28 field surveys were conducted between May 1964 and December 1968. Light transmittance profile measurements and Secchi disc observations at 32 sampling stations were used to document preoperational turbidity conditions for Unit 1. This program of bimonthly surveys, known as the Marine Environmental Monitoring Program (MEM), required by CRWQCB, SDR, was continued after Unit 1 began full operation in 1968 until 1975.

Beginning in 1975, turbidity measurements were continued as a portion of the ETS monitoring program. During bimonthly surveys, light transmittance profiles and Secchi disc observations at 34 stations located in the twelve environmental surveillance zones were used to document spatial variability in turbidity throughout the San Onofre study area. Many of the sampling stations used in the ETS program were the same as those used in the previous MEM program. Aerial color photographs were obtained quarterly and used to document visual surface turbidity due to natural conditions, as well as to turbid plumes from Unit 1.

In 1976, the CRWQCB, SDR issued NPDES permits for Units 1, 2, and 3 which included a turbidity monitoring program similar to the ETS program. Sampling station locations were increased to 51 stations to better define turbidity conditions in the vicinity of the generating station. After March 1977, the frequency of aerial color photographs was increased from quarterly to bimonthly.

Turbidity measurements at 23 additional offshore profiling stations were initiated in May 1978 as a portion of the PMP required by the NRC to determine natural background conditions prior to operation of Units 2 and 3 and the effects of construction of Units 2 and 3. The coverage of aerial photographs was extended offshore to document surface turbidity conditions in the area of Units 2 and 3 diffusers. Beginning with the July 1978 bimonthly survey, water samples from the surface and mid-depth (4 m) were collected at selected stations and analyzed for the amount of suspended and settleable solids. The measurement also gave an indication of the effects of construction of Units 2 and 3 on turbidity.

Beginning in August 1979, a program to collect continuous light intensity, bottom temperature, and sedimentation data at the five offshore hard bottom PMP benthic locations throughout the San Onofre area was initiated. These light intensity measurements were used to ascertain effects of turbidity on light intensity and growth in hard bottom benthic and kelp communities.

Turbidity was also measured during biological sampling programs. For example, vertical profiles of light transmittance were obtained during plankton and fish surveys in order to obtain turbidity data for correlation with biological characteristics. Secchi disc depths and diver estimated underwater visibility were recorded during quarterly sampling at benthic infauna stations. Sediment settling tube data were also collected in conjunction with benthic infaunal sampling at 18 stations during the past four years.

1980 STUDIES

During 1980, turbidity was measured by vertical profiles of light transmittance, aerial color photography, Secchi disc observations, and continuous near bottom light intensity measurements. Bimonthly turbidity surveys conducted in January, March, May, and July were for the ETS and PMP studies. During each of these bimonthly field surveys, vertical profile measurements of light transmittance and Secchi disc observations were taken at 74 sampling stations (Figures 2A-1 and 2A-2), and aerial photographs of turbidity were obtained.

In August 1980, bimonthly turbidity measurements for Units 2 and 3 PMP were terminated after completion of the two-year data base. Construction activities for the offshore portions of the circulating water systems of Units 2 and 3 were completed in early 1980. The program of continuous temperature, light intensity, and sedimentation measurements at the five hard bottom benthic stations was discontinued in October 1980.

Studies of the operational effects of Unit 1 were continued in accordance with ETS requirements during the September and November surveys. This resulted

in bimonthly measurements of light transmittance and Secchi disc depths of visibility at 34 stations, and quarterly aerial photographic flights. Suspended solids sample collection was deleted after the July 1980 survey.

A special turbidity study was conducted from March to September 1980. The study consisted of weekly field sampling at 20 stations in the vicinity of Units 2 and 3's discharge diffusers. Light transmittance, ambient light intensity, and suspended solids concentrations were determined for the entire water column at each station. Field surveys coincided with aerial photographic flights, as weather permitted. This special study was conducted to document the predischarge turbidity and light conditions in the Units 2 and 3 study area, and to assess the amount and duration of decreased light intensity in the water column near the San Onofre kelp bed.

Results of previous studies have been extensively documented in annual reports. Formal requests to delete ETS requirements were submitted to the NRC in October 1980 based upon the accomplishment of the objectives within the mandated scope.

DISCUSSION

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

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

Turbidity is important to biological communities as well as for aesthetic reasons. Turbidity 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.

Turbidity was extensively measured throughout the 70 km^2 San Onofre study area as part of the physical and biological monitoring programs. The objectives of turbidity studies were to: 1) establish preoperational baseline conditions before operation of Units 2 and 3; 2) document large spatial and temporal changes in turbidity throughout the study area; 3) determine the horizontal and vertical extent of the turbid plume from Unit 1, when present, and 4) provide turbidity data for the analysis and interpretation of biological findings.

SOURCES AND NATURAL PROCESSES AFFECTING TURBIDITY

There exist diverse sources of turbidity associated with natural physical processes which combine to impact background turbidity in the waters off San Onofre. Major sources of turbidity in the vicinity of the generating station include the surf zone, offshore seabed, and terrestrial drainage. Major natural processes affecting turbidity in the San Onofre area include waves, local currents, shoreline topography, offshore circulation patterns, and biological activity.

Surf Zone

Waves and the associated nearshore circulation combine to affect the distribution and intensity of turbidity in the surf zone. As energy in a breaking wave is expended on the bottom, large amounts of sediment are suspended in the waters of the surf zone. Breaking waves generate longshore currents which transport this intense turbidity parallel to shore inside of the surf zone. Turbidity from the surf zone is eventually entrained into rip currents which transport this turbidity offshore. The turbidity in these rip currents coalesces into a single large turbidity mass outside the surf zone, which then diffuses and expands with diminished speed to about 1 km offshore. This turbid mass is also partly fed by resuspension of sediment from the local seabed by wave orbital motion.

The protruding shoreline topography from 1.3 km upcoast to 1.1 km downcoast of the generating station favors convergence of waves which results in increased turbidity and stronger and more numerous rip currents. These rip currents frequently result in a large turbid zone offshore of the bulge which extends to about 2 km offshore.

Offshore Sea Bed

Sediment on the offshore seabed in the study area is composed of very fine grain size sand. The median diameters of this sediment recorded at benthic infauna stations in 1979 are presented in Table 2B-2. The median was 3.60 phi (0.0825 mm) for sediments from water depth ranging from 4.5 to 15 m (15 to 50 ft). The sieve analysis of these materials revealed extremely good sorting; averaging about 0.60 in phi measure. Undoubtedly, sediment exhibiting a median diameter this small would also contain some non-negligible fractions of silt.

Table 2B-2. Median diameters of bottom sediment at benthic infauna stations, 1979.

Station	Water Depth (ft)	Feb 12-22	May 21-22	Aug 28-30	Nov 28-29	Annual Mean
A1	12	3.89	-	3.28	3.53	3.57
A2	28	3.80	3.68	3.75	3.86	3.77
A3	50	3.99	3.86	3.87	3.98	3.93
B1	18	3.34	3.06	3.00	3.20	3.15
B2	30	3.57	3.54	3.63	3.90	3.66
B3	50	4.24	4.09	4.13	4.05	4.13
C1	20	3.43	3.41	3.19	2.85	3.22
C2	30	2.83	3.53	3.49	3.89	3.44
C3	50	4.08	4.00	4.10	3.84	4.01
D1	16	3.33	3.68	3.32	3.44	3.44
D2	30	3.48	3.63	3.67	3.64	3.61
D3	50	3.95	3.26	3.92	2.99	3.53
E1	15	3.48	3.44	3.35	3.60	3.47
E2	80	3.24	3.48	3.59	3.88	3.55
E3	50	2.80	3.21	3.43	3.44	3.22
F1	16	3.33	3.26	3.28	3.37	3.31
F2	27	3.49	3.75	3.65	3.57	3.62
F3	50	4.21	3.97	4.11	4.13	3.10

Phi	MM
2	0.250
3	0.125
4	0.0625

Note: All values are in mean phi values over 3 to 4 samples at each station

Because of its fine size, sediment in the offshore seabed is readily resuspended by wave orbital motion as well as by superimposed tidal and wind-driven currents. The critical water velocity required to resuspend this sediment from the seabed is estimated at about 20 cm/sec under a horizontal current (Vanoni, ed. 1975), and about 18 cm/sec under wave orbital motion (Horikawa and Watanabe 1967). These velocities occur routinely in the study area (SCE 1980). The resuspended sediment is transported by existing currents, generally in an alongshore direction.

A quantitative measure of sediment suspension by wave action in the study area was estimated. According to these estimations, bottom sediment in the offshore region of San Onofre is expected to remain in a state of resuspension about 40% of the time at a water depth of 6 m (20 ft), about 30% of the time at 9 m (30 ft), 20% of the time at 12 m (40 ft), and 10% of the time at 15 m (50 ft).

The sedimentation chamber data obtained during the 1979 benthic infauna surveys (SCE 1980) provides additional information on the resuspension of

sediments. This data is summarized in Table 2B-3, presenting the amount of settled solids in a 1 inch diameter tube maintained at an average height of 1 m (3 ft) above the bottom and collected monthly at each of the 18 stations. This data represents a time-integrated indicator of suspended sediment, which can be approximated to equivalent average concentration of suspended sediment using the empirical relationship advanced by Horikawa (1978). The computed equivalent concentration values are presented in Table 2B-4, along with a summary of station-averaged sedimentation chamber data. The results show the occurrence of significant levels of sediment suspension along the offshore slope bottom waters out to a water depth of about 15 m (50 ft). The suspended sediment concentration is higher (152.5 mg/liter) along the shallowest Transect 1 (water depth 4.6 m: 15 ft), as compared with Transect 2 (56.5 mg/liter, depth 9 m: 30 ft) and Transect 3 (72.1 mg/liter, depth 15 m: 50 ft). Suspended sediment concentrations at 15 m of depth were higher than those at 9 m of depth. A maximum calculated suspended sediment concentration was 700 mg/liter, which corresponded to the data for February 1978, along Transect 1.

Table 2B-3. Weight of material (grams dry weight) collected in sedimentation chambers (1" dia.) at benthic infauna stations during 1979.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
A1	241.9	171.5	296.8	175.6	176.0	377.4	787.3	262.5	149.1	102.5	126.1	112.6
A2	122.0	69.6	69.2	75.5	78.4	88.5	94.6	99.9	40.7	58.1	66.6	77.7
A3	96.3	74.3	348.2	81.5	73.6	64.3	79.1	52.2	45.3	18.6	0.0	12.5
B1	***	819.4	178.5	797.8	420.0	316.3	167.1	172.5	259.6	272.4	489.9	604.3
B2	259.7	213.9	80.8	228.9	174.7	314.9	321.4	208.3	159.6	136.4	214.0	235.2
B3	128.6	102.1	65.1	85.3	111.4	63.0	56.3	60.3	79.9	20.5	25.3	24.7
C1	***	696.0	103.4	302.9	341.3	488.9	519.7	387.7	219.5	150.[illegible]	361.5	491.7
C2	202.3	282.4	76.9	130.5	144.4	129.3	24.9	143.6	103.9	73.4	38.1	28.9
C3	170.4	159.8	104.3	115.1	***	182.0	129.0	234.2	94.1	***	***	29.2
D1	234.0	304.5	230.3	427 6	216.7	255.8	109.5	429.3	287.5	559.5	302.7	578.1
D2	164.2	98.8	157.6	92.0	85.4	207.8	***	347.8	108.6	78.9	168.3	265.1
D3	162.8	136.7	52.3	195.0	***	93.5	97.1	103.7	101.2	56.4	91.9	59.3
E1	117.8	139.0	249.5	318.0	312.7	320.4	59.7	270.5	236.7	166.4	122.8	191.9
E2	163.1	65.7	266.3	94.1	206.3	73.0	86.8	91.7	84.4	59.6	98.4	68.7
E3	410.7	208.2	119.4	388.7	174.8	191.6	183.6	97.3	65.1	84.7	61.5	87.5
F1	146.8	147.5	93.4	219.0	68.7	306.5	235.0	501.2	417.7	204.3	272.9	89.6
F2	135.3	112.6	118.0	143.6	111.7	168.0	102.4	236.0	136.4	78.6	133.0	91.9
F3	76.8	55.8	115 9	57.9	76.5	44.0	61.6	424.8	77.1	41.8	43.4	58.9

*** Missing data

Another important indication of the effect of the fine grain offshore sediment on suspension is the observed range of sand level fluctuation. These data, taken at the fixed stake stations during the 1979 benthic infauna surveys, are summarized in Table 2B-5. An average range of sand level fluctuation during the entire record period was 31 cm (1 ft). A maximum range was 80 cm (2.6 ft), recorded at Station C3 where the water depth was about 15 m (50 ft). The average range was highest (42 cm: 1.4 ft) at stations in 9 m (30 ft) of water.

Table 2B-4. Sedimentation chamber data for 1979 and their corresponding suspended sediment concentration values.

Station	A	B	C	D	E	F	Average
Annual Station Averages of Sedimentation Chamber Data (gram/month)							
1	248.2	408.9	376.6	328.7	208.7	225.2	296.7
2	78.4	212.3	117.2	161.3	113.2	130.6	135.1
3	79.8	68.7	135.3	104.5	172.8	93.4	107.8
Average	135.1	224.9	211.5	202.0	164.9	149.7	179.9
Equivalent Sediment Concentration in Ambient Water (mg/l)							
1	180.4	229.9	156.3	135.8	84.9	127.5	152.5
2	20.1	66.3	70.8	80.8	61.8	39.3	56.5
3	86.2	33.3	55.9	42.7	112.7	101.9	72.1
Average	95.6	109.8	94.3	86.4	86.5	89.6	93.7

Table 2B-5. Sand level fluctuations measured from fixed states at benthic infauna stations, 1979.

Station	Water Depth (ft)	Maximum (cm)	Minimum (cm)	Difference (cm)
A1	12	125	115	10
A2	28	117	61	56
A3	50	100	89.5	10.5
B1	18	120	96	24
B2	30	90	73	17
B3	50	105	85	20
C1	20	97	80	17
C2	30	155	80	75
C3	50	164	84	80
D1	16	96	80	16
D2	30	124	82	42
D3	50	111.4	90	21.4
E1	15	114	80	34
E2	80	115	85	30
E3	50	115	100	.5
F1	16	122.5	85	37.5
F2	27	111.6	81	30.6
F3	50	110	89.2	20.8

SUMMARY

Station	A	B	C	D	E	F	Average
1	10	24	17	16	34	38	23
2	56	17	75	42	30	31	42
3	11	20	80	21	15	21	28
Average	26	20	57	26	26	30	31

Terrestrial Drainage

Rainfall produces turbidity in nearshore waters by introducing large amounts of terrestrial material in surface runoff. This runoff brings large quantities of fine grain sediment into the San Onofre area. Major sources of localized terrestrial drainage are San Onofre and San Mateo Creeks, which are intermittent streams located just upcoast of San Onofre near San Mateo Point. In addition to these very local sources which produce high levels of turbidity in the vicinity of the station, regional sources (Santa Ana River and San Juan Creek to the north, Santa Margarita and San Luis Rey Creeks to the south) can also increase the overall levels of turbidity throughout the area. The amount of rainfall in southern California fluctuates considerably from year to year, and it is not unusual for the yearly rainfall to vary by a factor of three between any two given years. Precipitation during the rest of the year is essentially negligible.

As the flood season begins, the turbid discharge from the creeks initially moves directly offshore from their outlets. As the coarse sediment from the stream discharge accumulates off the outlet to form a bar, the discharge is increasingly deflected in the alongshore direction, emptying into the surf zone instead of directly into the offshore zone. The turbid discharge issuing from the river mouth is then mostly transported laterally within the confines of the surf zone, extending into the offshore zone only where rip currents occur. During the flood season, between winter and spring, the dominant longshore current moves southward. At this time, the turbid river discharge from San Mateo and San Onofre Creeks reaches the protruding shoreline at San Onofre, and is transported seaward by well-developed rip currents at this location. Because the river discharge is buoyant, the turbidity originating at the river mouths forms a surface layer and spreads widely in the offshore zone.

Shoreline Topography

In the San Onofre area, unique geological and topographic conditions exist which modify prevailing physical processes in such a manner as to intensify the natural turbidity level. These topographic features include a protruding shoreline and the related offshore seabed in the vicinity of the generating station, and the headland at San Mateo Point.

The shoreline fronting the generating station extends about 200 m (650 ft) beyond the adjacent shoreline over a distance of about 2 km of its frontage (from 1.3 km upcoast to 1.1 km downcoast). This protrusion is a natural formation, very likely a remnant of the alluvial delta of the San Onofre and San Mateo Creek systems. The protrusion is contiguous to a broad underwater relief extending seaward to a water depth of about 9 m (30 ft) at a distance of about 1.5 km (0.9 mile) from the shoreline.

Immediately off the protruding shoreline, the surf zone is very wide, and breaking waves are more frequent and intense there due to convergent wave refraction over the topographically reliefed underwater slope in front of it. This wave convergence favors the occurrence of more numerous rip currents and higher turbidity in the surf zone at this location. An inspection of aerial photographs indicates that the turbidity being transported by the rip currents off San Onofre extends as far as about 500 m (1640 ft) or more from the shoreline, whereas it is only about half this length in areas away from the protrusion.

The convergent waves at the protruding shoreline also enhance the possibility of sediment agitation on the seabed due to intensified orbital wave motion. The turbidity in the water column from wave agitation generally remains in the lower layer, usually within several feet above the seabed.

As the longshore current from the adjacent shoreline arrives at the protruding shoreline, the current gains seaward momentum as it is deflected offshore. Thus, not only locally generated turbidity, but also turbidity originating from the adjacent shoreline tends to be transported seaward off the protrusion.

The headland of San Mateo Point, located about 3 km north of the generating station, extends about 1000 m (3300 ft) beyond the general trend of the coastline. Its underwater projection, believed to extend near the 30 ft isobath, represents an additional seaward extension of approximately 1000 m. This topography is substantial enough in size to present a major obstruction to coastal currents operating in the broad nearshore zone.

An important and recurrent phenomenon associated with the San Mateo Point headland is the formation of a stationary eddy stretching south from this location during the time of southerly flowing coastal currents. This eddy often creates a relatively stable turbid plume extending southward from the headland for several kilometers alongshore. Turbidity supplied to this eddy from the upcoast surf zone will be relatively slow to dissipate to the downdrift coast, and may contribute to increased turbidity offshore of the generating station.

Offshore Circulation Patterns

Offshore circulation patterns affect turbidity off San Onofre by introducing different water masses to the area. These water masses contain various levels of turbidity. Observed temporal variations of turbidity are partially due to these water masses being transported to the study area. Typical offshore circulation patterns for southern California are discussed in the temperature chapter and presented on Figure 2A-3.

Circulation patterns during upwelling can significantly influence turbidity in the San Onofre area. Regional upwelling can decrease local turbidity by introducing clearer bottom waters from offshore into the area. On the other hand, localized upwelling at San Onofre can increase turbidity throughout the water column by introducing turbid nearshore bottom waters to surface waters.

Biological Activity

The amount of turbidity in the water column directly affects the penetration of natural light utilized by marine phytoplankton and algae. Conversely, the concentration of plankton can be a major factor contributing to decreased water clarity and depth of ambient light penetration. Plankton blooms offshore of San Onofre can cause significant spatial variations in water clarity throughout the area due to their patchy distribution.

NATURAL TURBIDITY CONDITIONS

Turbidity throughout southern California was characterized by the California State Water Pollution Control Board (SWPCB) in 1959. Yearly mean light extinction coefficients are presented in Figure 2B-1 for nearshore waters between Point Conception and San Diego. Turbidity throughout the southern California bight generally decreased uniformly with distance offshore (increasing depth). Local decreases in turbidity occur near peninsulas, points, and other coastal protrusions. Local increases in turbidity occur near coastal embayments and near areas of terrestrial drainage.

Temporal Trends

Turbidity conditions off San Onofre ranged from extremely turbid to clear, and were heavily influenced by seasonal fluctuations in rainfall, waves, and winds. This seasonal cycle was characterized by high turbidity in winter when waves and rainfall are greatest; variable turbidity during spring and summer; and a decrease in turbidity during the Davidson Current period in fall, before the onset of winter storms.

Turbidity measurements during 1980 were consistent with those of previous years, indicating the large variability in natural turbidity found in the nearshore coastal environments. The dominant natural phenomena which affected continuously measured bottom light intensity, in order of relative importance, were: 1) rainfall; 2) wave intensity; 3) upwelling and local winds; and 4) ambient surface light intensity.

Rainfall was the phenomena which most directly affected ocean bottom light intensity. Decreases in light intensity at all stations were recorded during occurrences of rainfall and subsequent storm water runoff. Periods of greatest total rainfall and longest duration of rainfall corresponded to longer periods of reduced bottom light intensity.

The wave energy impinging on the coastline is the second most important factor affecting light intensity. Wave energy is closely associated with rainfall as both precipitation and increased wave action are associated with local storms. In general, wave energies were greatest from January through April. During periods when maximum significant wave height was greater than approximately 4 ft, major decreases in bottom light intensity were observed.

Upwelling is a third phenomena which affects light intensity. Upwelling follows a seasonal cycle, with maximum intensities occurring in May and June. Upwelling winds occur from roughly March through October in southern California. Periods when upwelling indices of greater than 200 m^3/sec/100 m of coastline persisted for 2 to 3 days correlated with long period decreases in light intensity. This decreased light intensity is probably due to increased wave intensity associated with these winds and the upwelling of more turbid bottom waters to surface waters in the nearshore area. Localized periods of downwelling, due to winds from the southeast, resulted in increased light intensity at the bottom for durations of from 2 to 10 days.

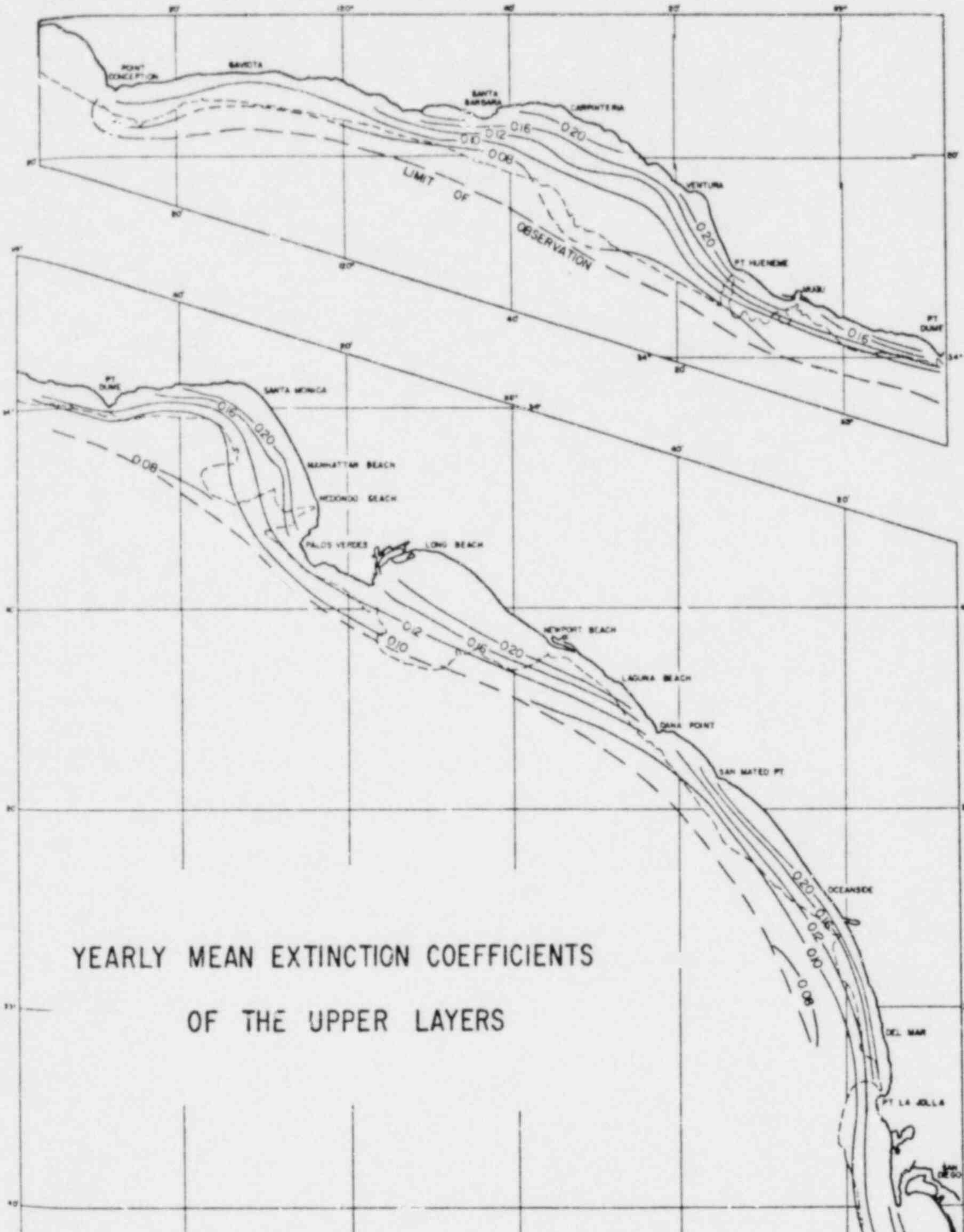

Figure 2B-1. Yearly mean light extinction coefficients (1/m) in the Southern California Bight (SWPCB 1959).

Light intensity and temperature records at the benthic cobble stations were highly coherent among stations, which indicates that the upwelling phenomena is occurring over an area much larger than the San Onofre study area. Upwelling events are persistent on approximately the same time scale as the winds creating the upwelling. When upwelling decreases, light intensity and temperature records return to their natural values within several days.

Temporal Variations

Natural turbidity conditions at San Onofre and most coastal waters vary extensively with time. Significant variations in light transmittance from survey to survey are evident in both the 1979 and 1980 data, summarized on Figures 2B-2 and 2B-3, which show percent light transmittance values in shore-parallel (Line C) and shore-perpendicular (Line 2S) transects, respectively. Light transmittance during bimonthly surveys of 1980 was significantly less than observed in 1979 along the shore-parallel transect. A zone of high turbidity (light transmittance less than 10%/m) was confined to the near-bottom for most of 1979. During 1980, the high turbidity zone was found to occupy the entire water column for five of the six surveys. A similar pattern was observed in the shore-perpendicular transects as shown on Figure 2B-3. These differences between 1979 and 1980 may be an artifact of the wave energy on sampling days for bimonthly surveys.

A three-year comparison of surface light transmittance between 1978 and 1980 is summarized in Figure 2B-4. In this figure, each plotted point represents an average of all the recorded data along each of the designated lines for the six bimonthly surveys of the respective years, with the exception of 1980 in which there was only four surveys in the offshore area (January, March, May, and July). Comparing 1978 and 1979, there appears to have been a transmittance decline of about 15% m at the three offshore lines (H, J, and M); however, nearshore lines were similar. Between 1979 and 1980, a similar decline affected the nearshore lines (C, D, E, and F) as well.

Spatial Trends

The most dominant feature of turbidity data in 1980 was the natural decrease in turbidity with distance offshore. This decrease was also evident in 1978 and 1979 (Figure 2B-4).

An interesting aspect in this trend for offshore decline in turbidity is the presence of a transition zone in the vicinity of Lines E and F where the water depth ranges between about 10 and 11 m (35 and 38 ft) (note the junction of the two trend lines, Figure 2B-4). The decrease of turbidity with distance offshore is distinctly more rapid inshore of this transition zone relative to offshore.

The normalized light attenuation coefficient plotted against water depth, as shown in Figure 2B-5, indicates this transition zone more clearly. The normalized light attenuation coefficient is the vertical light attenuation per unit meter of water depth averaged for the given water column. It is apparent that the data in Figure 2B-5 follow two distinct trends, with the transition occurring in the vicinity of Line F. The following explanations are offered to account for possible implications of this transition zone.

The underwater topography related to the protruding shoreline at San Onofre extends to a point about 1400 m (4600 ft) from the shore where the water depth is about 9 m (30 ft). The suspended material over this topographic feature is composed mainly of settleable solids, due to the close proximity to the seabed and the surf zone. Offshore of the protrusion, the bottom depth increases and the

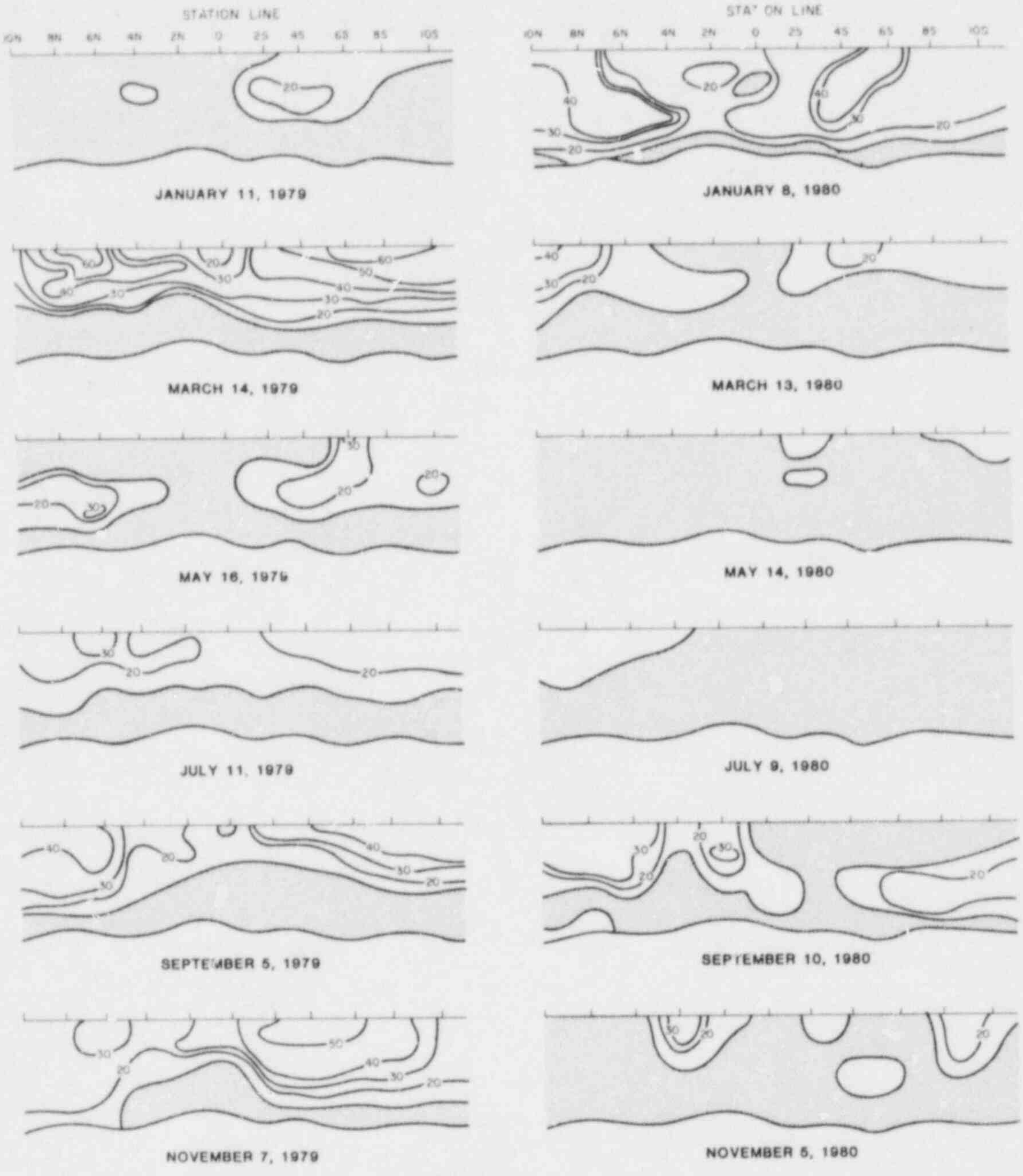

Figure 2B-2. Percent light transmittance in a shore-parallel section along Line C, 1979 and 1980.

suspended solids in the water column outweigh the settleable solids by a factor of nearly two.

An inspection of a number of aerial photographs taken over the San Onofre area indicate distinct boundaries of coastal turbidity occurring within about 1.5 km from the shoreline. This situation was even consistent during the heavily wet years of 1973 and 1978.

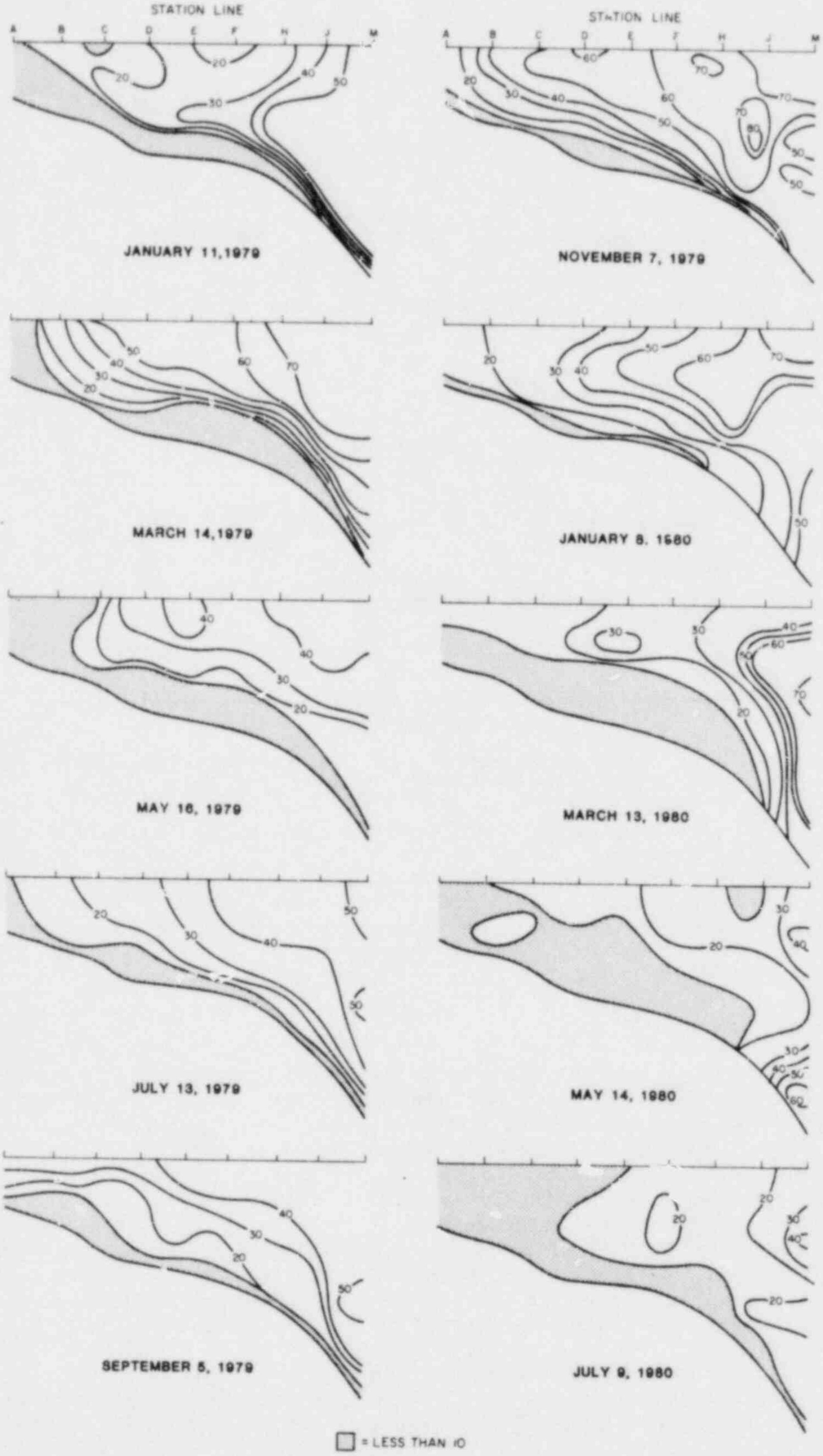

Figure 2B-3. **Percent light transmittance in a shore-parallel section along Line 2S, 1979 and 1980.**

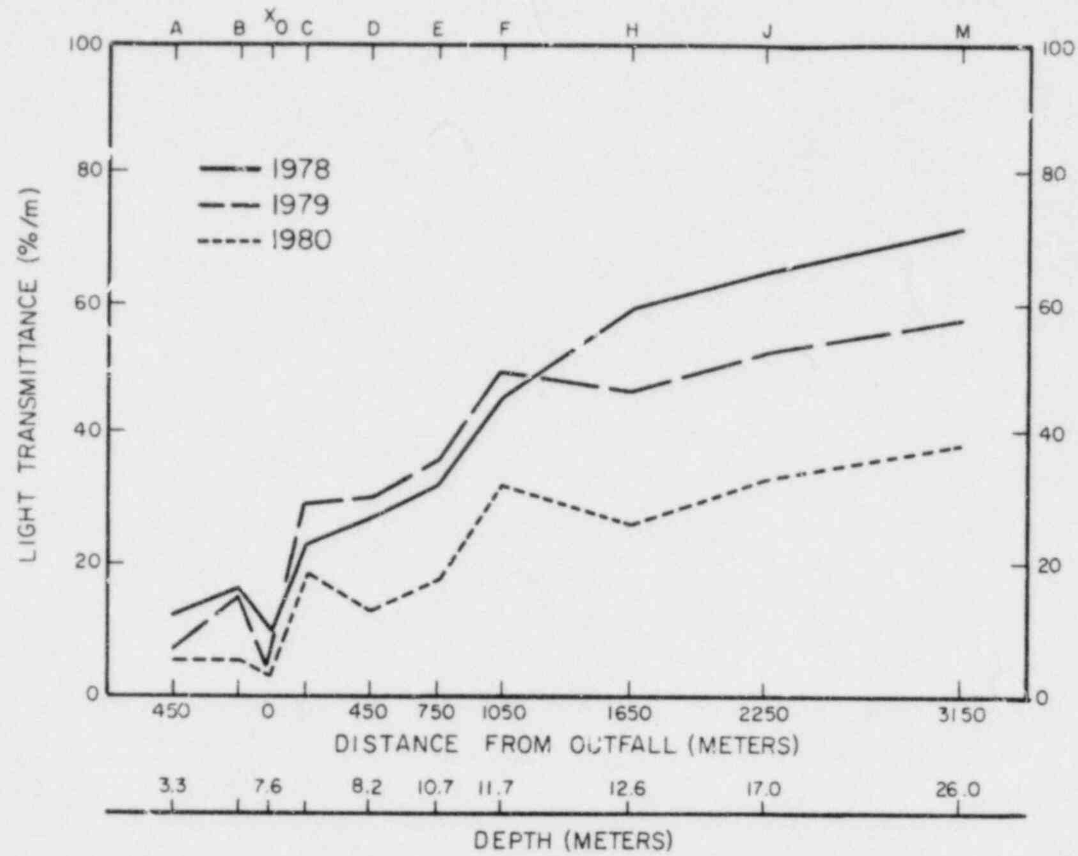

Figure 2B-4. Annual average values of percent light transmittance in a shore-perpendicular section along Line 2S for 1978, 1979, and 1980.

The eddy, which elongates southward from the San Mateo Point headland during periods of downcoast currents, entrains turbidity from the surf zone as well as from the turbid discharge from the local creeks. An inspection of aerial photographs indicates that the offshore limit of this eddy usually terminates at the 30 ft isobath. The point of transition (approximately 11 m) is where the bottom slope changes. Offshore of this location, the bottom is relatively flat compared to inshore, where depth decreases rapidly toward shore. The transition zone is also where waves more frequently stir up bottom sediments as they approach the shallower nearshore area.

The normalized light attenuation coefficients presented in Figure 2B-5 were calculated using values measured throughout the water column, including more turbid water near the seabed and relatively less turbid surface waters. Therefore, this parameter is dependent on the depth of water over which it is integrated. At the deeper offshore stations, the amount of less turbid surface waters is much greater than in the shallower inshore areas; therefore, the normalized light attenuation coefficient is significantly larger. The main source of turbidity in the offshore area is the seabed, as compared to the nearshore area which includes input from the seabed as well as the surf zone. Therefore, the transition zone is due to the water depth of stations considered and the greater amount of turbidity sources in the nearshore area.

The longshore distribution of surface turbidity in the Unit 1 and Units 2 and 3 study areas is shown in Figures 2B-6 and 2B-7, respectively. These figures show yearly averages of surface light transmittance for 1978, 1979, and 1980.

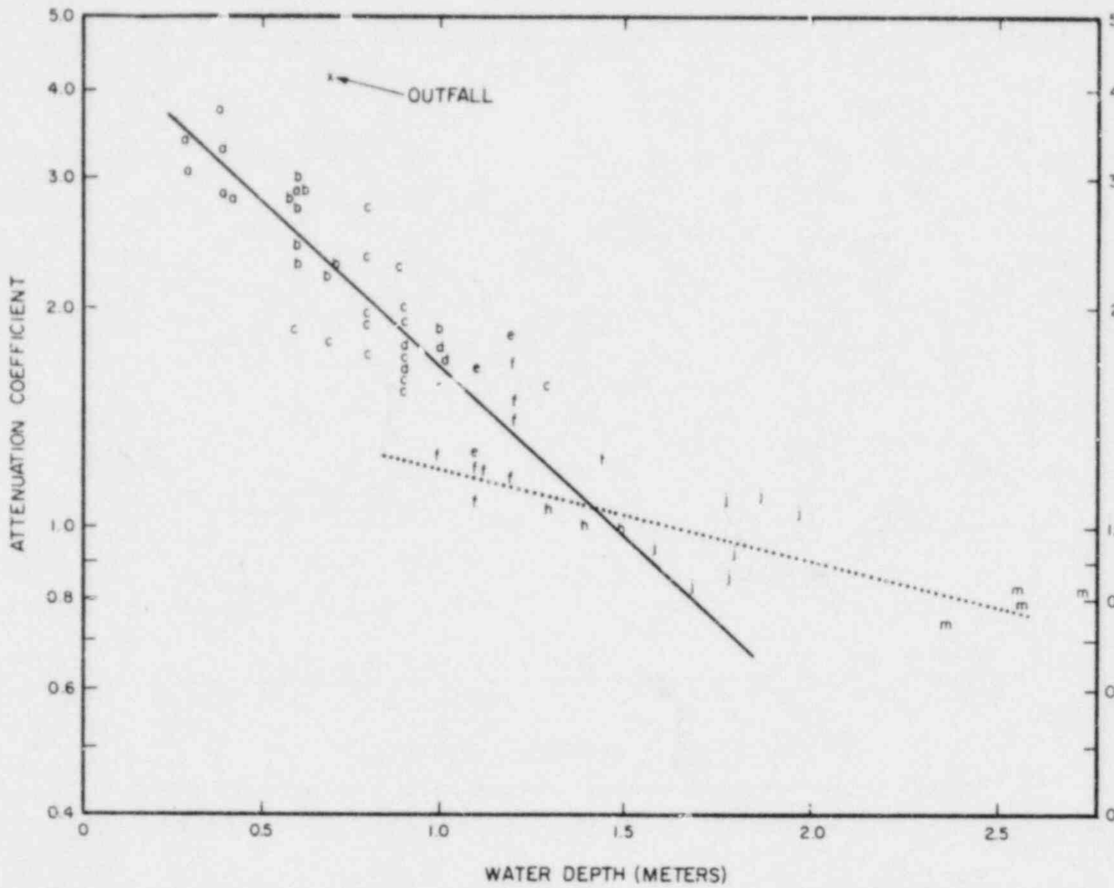

Figure 2B-5. **Light attenuation coefficients normalized for unit meter of water column as a function of water depth.**

At C-line stations, the light transmittance in 1980 generally decreased from the two previous years. This decrease was particularly pronounced south of the outfall location (XO) between Stations CO, and C8S, where during the previous two years the water had been somewhat less turbid than north of Station CO. This situation appears to have resulted from currents during 1978 and 1979 which transported thermal and turbid plumes from Unit 1 upcoast of the discharge. During the 1980 surveys, there was little or no current and turbid and thermal plumes (during plant operation) were centered around the discharge.

At J-line stations in the offshore study area, the alongshore distribution of turbidity was relatively stable as in the previous two years. However, the average light transmittance in 1980 (based on four surveys), was about 15% lower than 1979 (based on six surveys). Similarly, average light transmittance during the six surveys of 1979 was less than similar averages for the six surveys during 1978.

Spatial Variation

Spatial variations in turbidity throughout the study area are well documented by bimonthly profile and Secchi disc data presented in Volume II of this report (SCE 1981b). The natural variability of turbidity in the San Onofre study area was large. Significant differences in turbidity were observed with distance offshore, with turbidity generally greatest in the nearshore area where changing bottom topography caused varying amounts of breaker activity. This was

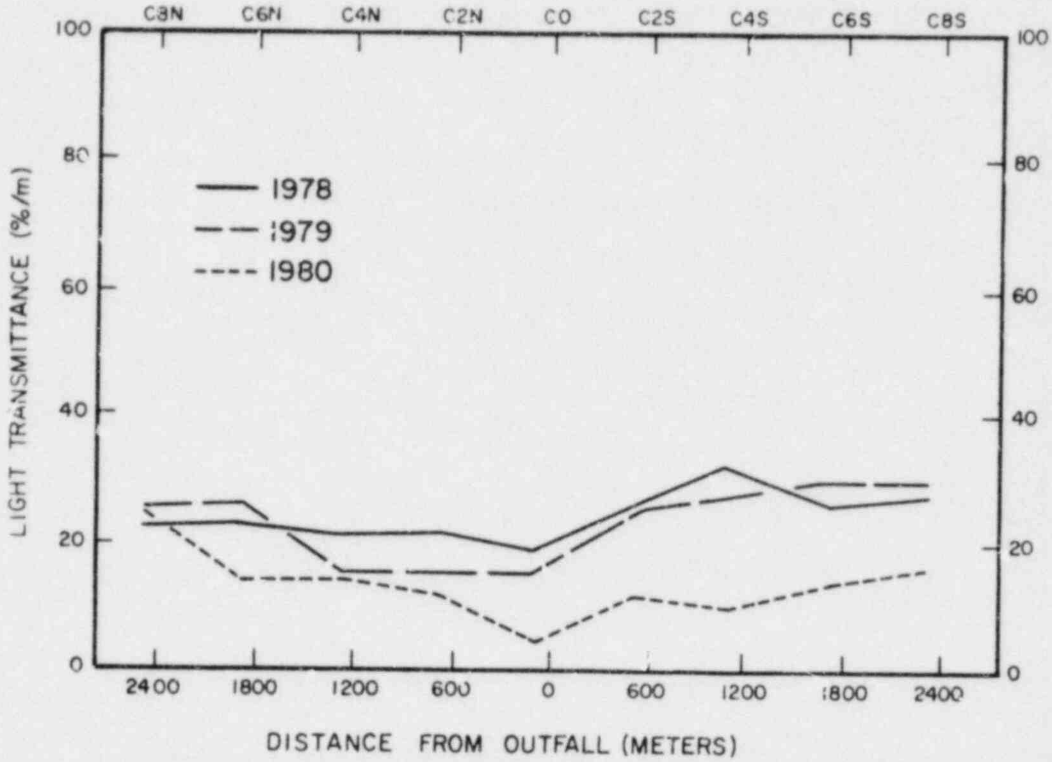

Figure 2B-6. Annual average values of light transmittance at surface along Line C for 1978, 1979, and 1980.

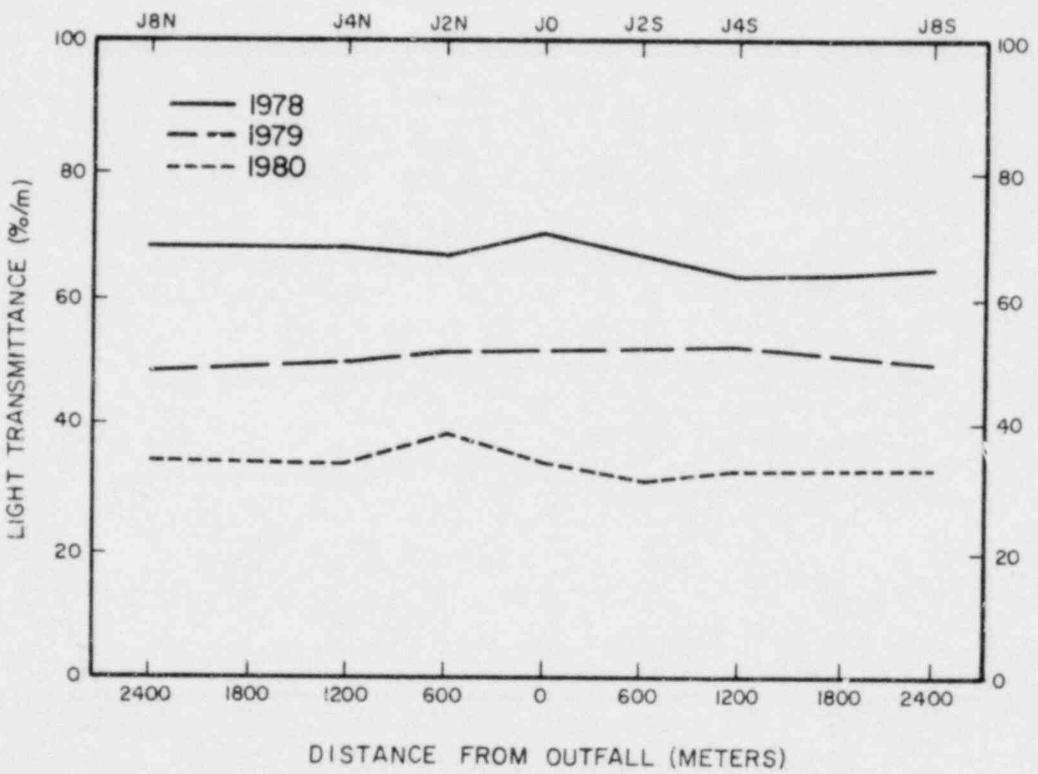

Figure 2B-7. Annual average values of light transmittance at surface along Line J for 1978, 1979, and 1980.

particularly evident in the protuding shoreline area adjacent to the generating station.

Spatial variations in the Units 2 and 3 study area were greatest when waters were relatively clear off San Onofre, as typified by the January survey in 1980, which reflects conditions prior to winter storms. Spatial variability was at a minimum when waters were turbid throughout the study area (July 1980).

INFLUENCE OF UNIT 1 ON TURBIDITY

Unit 1 does not add to the turbidity of waters circulated through its cooling system, but redistributes the frequently more turbid bottom and mid-depth waters to the surface. The spatial extent of discharged turbid waters is dependent on the natural gradient of turbidity with depth, specific gravity of the entrained particles, current speed and direction, buoyancy of the discharged plume, and capacity of wave energy to cause mixing of the plume with surrounding waters.

Effects of the circulating water system for Unit 1 on turbidity is best viewed in light of four generalized regimes of turbidity conditions noted of the study area. The first regime represents a condition of nearly isoturbid waters which is typical during winter conditions of heavy rainfall and increased wave energies. During these conditions, waters throughout the water column are turbid and entrained near bottom water is not appreciably more turbid than natural surface waters; therefore, no distinguishable turbid surface plume from the Unit 1 discharge is apparent. Typical winter rainfall conditions were not represented by the January 1980 bimonthly survey, but have been observed in previous years.

The second regime exists during periods when there is definite vertical stratification of turbidity with depth in the area of the Unit 1 intake and discharge. During this condition, the effect of Unit 1 on turbidity can be distinguished from that of natural processes. Unit 1 withdraws turbid waters from mid-depth and near bottom and discharges them to less turbid surface waters as a warm buoyant turbid plume. Entrainment of turbid near-bottom waters by the vertical discharge jet from Unit 1 is also apparent during this condition. The natural stratification of turbidity with depth during the 8 January bimonthly survey was typical of this regime. At stations in 9 m (30 ft) of depth, natural turbidity varied between 21 and 22% light transmittance at the surface to less than 10% near the bottom. The turbid surface plume generated by Unit 1 extended from 1800 m upcoast to 1200 m downcoast (5900 and 3900 ft, respectively) of the discharge. Light transmittance was depressed by as much as 30% in the offshore area (12 m) of the turbid plume where unaffected waters would have had light transmittance of approximately 40% per meter.

The third regime exists when the receiving waters are relatively clear throughout the water column. During this condition, no turbid surface plume is created by the Unit 1 discharge. This condition was observed during the November 1978 bimonthly survey.

A fourth regime exists when there is significant turbid fresh water discharged from San Onofre and San Mateo Creeks, and relatively small waves. During these conditions, an intense turbid surface plume is created by the river discharge. A patch of relatively clear surface water is caused by the Unit 1 discharge which brings clearer bottom waters to the surface in the immediate vicinity of the discharge.

Turbidity caused by waves which resuspend bottom sediments in the near-shore area had the greatest effect on water clarity in the area of the Unit 1

discharge. Significant wave heights of approximately 4 ft during the 13 March, 9 July, and 5 November 1980 surveys, created enough turbidity throughout the water column within the Unit 1 study area to mask turbid plumes due to circulation of cooling waters.

Unit 1 water circulation pumps were operating at approximately 0.04% of their normal rate during the bimonthly surveys of 14 May and 10 September 1980. At this flow rate, no turbidity within the study area could be attributed to the discharge of Unit 1 cooling waters. The lowest survey mean light transmittance occurred during the 14 May survey.

During 1980, Unit 1 was operated in either: 1) full mode (buoyant and momentum discharge); 2) pumping mode only (momentum discharge); or 3) no pumping mode. The description of the mode of plant operation is presented in Chapter 1. Aerial photographs were taken during each of these modes, as shown in Plates 1 through 6 at the end of this chapter. The operational modes are designated in the photographs with symbols T (=buoyant discharge), M (=momentum discharge), and O (=no pumping).

The situation representing the non-pumping mode is shown in Plate 1, which coincided with the time of heavy natural turbidity in the ambient water due to the silt discharge from the local creeks, masking the outfall structure from view.

Plates 2, 3, and 4 show the situations during the full-mode operation. When the coastal water was heavily silted with the runoff from the nearby creeks (Plate 2), it is evident that the turbidity in the ambient water is distinctly greater than in the plume. The aerial extent as well as the intensity of natural turbidity is far greater as compared with the plume turbidity. A small patch of less turbid water above the outfall, formed by a water rising with the buoyant plume, indicates that only the surface water is highly turbid.

In Plates 3 and 4, taken after the silt discharge from the creeks has diminished, the plume turbidity is higher than in the surrounding water but generally comparable to the turbidity being generated in the surf zone. In Plates 2, 3, and 4, the plume is relatively narrow (about 100 m), and only about 1 km long.

The plume during the pumping mode is shown in Plates 5 and 6. The main difference between the two photos was that in Plate 5 relatively strong swell activity arriving from the southerly direction was stirring up the material on the offshore seabed, making it readily entrainable by the discharge from the outfall. This effect is shown by a turbid patch surrounding the outfall structure in Plate 5. At this time, the plume was non-buoyant and appeared to be causing only a local disturbance close to the outfall. In Plate 6, the sea state was milder with little apparent agitation of seabed material by waves. As a result, the turbidity associated with the non-buoyant plume was appreciably lower than in Plate 5, indicating that the non-buoyant plume alone had a limited capability to entrain seabed material.

The influence of Unit 1 cooling water upon turbidity within the nearshore environment is usually less than that of the natural processes. It is evident that the natural variablity of turbidity within the nearshore waters is greater than variations caused by the Unit 1 discharge.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

APPROACH

The fundamental purpose of turbidity studies at San Onofre was to determine the effects of the cooling water systems on water clarity in the marine environment. In order to determine the impact of the generating station, changes in distribution of turbidity must be evaluated in light of natural variations. At San Onofre and most coastal areas, natural turbidity conditions vary extensively with time.

An integrated study approach to sampling was used to fulfill the objectives and the overall purpose of the study. This integrated study approach consisted of intense bimonthly field measurements to determine both natural and generating station induced spatial variations in turbidity, continuous light intensity measurements at the bottom to document natural temporal variations and to determine how temporal changes in turbidity affect the amount of light available to kelp and benthic communities, and discrete turbidity measurements in conjunction with biological sampling.

A detailed picture of turbidity conditions throughout the study area was obtained from bimonthly survey measurements including vertical profiles of light transmittance, Secchi disc observations, aerial color photography, and analysis of the amount of suspended solids in receiving waters.

Continuous measurement of the amount of photosynthetically active radiation (PAR) reaching the bottom was used to document natural temporal fluctuations in the amount of turbidity and its effect on the penetration of natural light in the offshore area of Units 2 and 3.

DATA SOURCES

In addition to information collected during SCE studies, other data sources were utilized in the study of turbidity at San Onofre. Other data sources used included: 1) published historical data summaries pertaining to oceanographic conditions in southern California; 2) meteorological summaries for California; 3) stream flow data from San Onofre and San Mateo Creeks; 4) wave measurements at Oceanside; 5) calculated upwelling indices; and 6) special turbidity studies conducted by SCE.

There is a vast amount of oceanographic data from the southern California area available in the literature. Summaries of historical oceanographic data by the Southern California Coastal Water Research Project (SCCWRP 1973) and the State Water Pollution Control Board (SWPCB 1959) were used to characterize oceanographic and turbidity conditions throughout the southern California area. Meteorological summaries from the National Weather Service provided information on rainfall, storms, and other meteorological conditions (NOAA 1980). In the past, stream flow data for the two creeks in the study area (San Onofre and San Mateo Creeks) were supplied by the United States Marine Corps, Water Resources Division. Unfortunately the stream gauge instrumentation was damaged by 1979 storms and no data is available on flow rates for 1980 in these creeks. Wave data from measurements at Oceanside were obtained from the Nearshore Research Group of the Institute of Marine Resources at Scripps Institute of Oceanography (IMR 1980). Upwelling indices, calculated from differences in barometric pressure from throughout the northeast Pacific Ocean, were obtained from the National Oceanic and Atmospheric Administration/National Marine Fisheries Service (Bakun 1980). Results of special turbidity studies conducted by SCE are also utilized in the analysis of turbidity.

METHODS

This section presents a synopsis of the methods used in the investigation of turbidity conditions. There were five basic types of turbidity measurements for this portion of the study including: 1) vertical profiles of percent light transmittance; 2) Secchi disc observations; 3) suspended and settleable solids analysis; 4) aerial color photography; and 5) continuous measurement of light intensity at the bottom. A detailed description of methods is presented in the Brown and Caldwell Procedures Manual for Environmental Surveillance at San Onofre (BC 1978). The methods and equipment utilized for turbidity measurements in conjunction with biological sampling are presented in the appropriate biological sections.

LIGHT TRANSMITTANCE PROFILES

Vertical profile measurements of percent light transmittance along a 1 m path length were used to document the natural spatial trends and variability of turbidity for Units 2 and 3 PMP stations, and to document vertical and horizontal extent of turbidity plumes from Unit 1. Vertical profiles of light transmittance were measured at 51 Unit 1 operational sampling stations and at 23 additional preoperational monitoring stations for Units 2 and 3 (Figures 2A-1 and 2A-2) during field surveys of 8 January, 13 March, 14 May, and 9 July 1980. The PMP program was terminated in September 1980, after two years duration. Since Unit 1 was offline and the PMP was terminated, light transmittance profiles during the 10 September and 5 November 1980 surveys were obtained only at the 34 stations required by the ETS program.

SECCHI DISC

Secchi disc observations provided an index of the amount of water clarity by determining the depth of extinction of reflected ambient light in the water column. Secchi disc data were used as an aid in determining the distribution of suspended solids and their effect on water clarity, and the transmission of downwelling light through the water column. Secchi disc data also provided measurements which were comparable with a large volume of historical Secchi disc data.

SUSPENDED AND SETTLEABLE SOLIDS

Suspended and settleable solids were measured at 42 stations (28 Unit 1 operational monitoring stations and 14 Units 2 and 3 preoperational monitoring stations) during the first four 1980 bimonthly surveys in order to supplement other turbidity data, and to relate light measurements to the actual amount of suspended material.

AERIAL PHOTOGRAPHY

Color aerial photographs were obtained to show the distribution of natural turbidity in the study area and to show the extent of turbid plumes from Unit 1 when present. These color photographs also presented a visual analysis of the effect of the turbid plumes on the aesthetics of the San Onofre area.

LIGHT INTENSITY AT BENTHIC STATIONS

Ambient light intensity reaching the bottom of the PMP hard bottom benthic stations was continuously measured to determine how temporal variations in turbidity affect the amount of light to benthic fauna and flora.

Continuous ambient light intensity in the photosynethic range was measured at the five paired PMP benthic stations. One of these locations is within the San Mateo kelp bed and two locations are in the San Onofre kelp bed, downcoast of the diffuser for Unit 2. Continuous temperature and the amount of sedimention were also measured at these locations. These measurements provided information on the variability of turbidity in time and space, and were used to determine how turbidity affected light intensity available to the benthic community. Light intensity was also measured onshore at the generating station to relate the amount of light intensity available at the water's surface to that at the ocean bottom.

RESULTS AND ANALYSIS

This section presents an analysis of 1980 results in order to fulfill the objectives of turbidity studies at San Onofre.

Turbidity measurements during 1980 were consistent with those of previous years, indicating the large variability in natural turbidity found in the nearshore coastal environment. Turbidity conditions ranged from extremely turbid to clear and were heavily influenced by seasonal fluctuations in rainfall, waves, and winds. The greatest variations in turbidity occurred as localized natural phenomena.

TEMPORAL TRENDS AND VARIATIONS

The penetration of natural light to the ocean bottom was measured at five paired hard-bottom benthic stations from 1 January through 2 October 1980. Results of these measurements are presented on Figure 2B-8. Also presented are simultaneously recorded bottom water temperatures.

Ambient light intensity reaching the water surface as measured onshore, followed a seasonal cycle during 1980, with lowest light intensities (1000 micro-Einsteins/m^2sec) during the winter months and highest (greater than 2000 micro-Einsteins/m^2sec) during the summer months. Ambient light intensity decreased during storms and when coastal low clouds and fog were present.

Maximum daily light intensities reaching the ocean bottom at benthic stations followed a complex pattern during 1980. Light intensities were generally less than 50 micro-Einsteins/m^2sec during the first few weeks of January 1980. After 12 January, light intensities dropped to below 10 micro-Einsteins/m^2sec until early March. Beginning in March light intensity fluctuated in a cyclic manner, with rises and falls varying from one to three weeks in duration. Maximum periods of light intensity were observed during the first and third weeks in July at most stations. Light intensity dropped to near zero at all stations on several occasions, each of varying duration. General decreases of less than one weeks duration occurred on the following dates; 1 April, 21 April, 28 April, 12 May, 24 May, 11 June, 29 June, 12 August, and 10 September. Longer term light intensity decreases, lasting from 7 to 21 days, occurred from 2 July through 15 July, 20 July through 2 August, and 20 August through 9 September.

An attempt was made to correlate the observed light intensities to natural oceanographic and meteorological phenomena. The dominant natural phenomena which affected bottom light intensities, in order of relative importance, were: 1) rainfall, 2) wave intensity, 3) upwelling and local winds, and 4) ambient surface light intensity. Records of these parameters during 1980 are presented on Figure 2B-9.

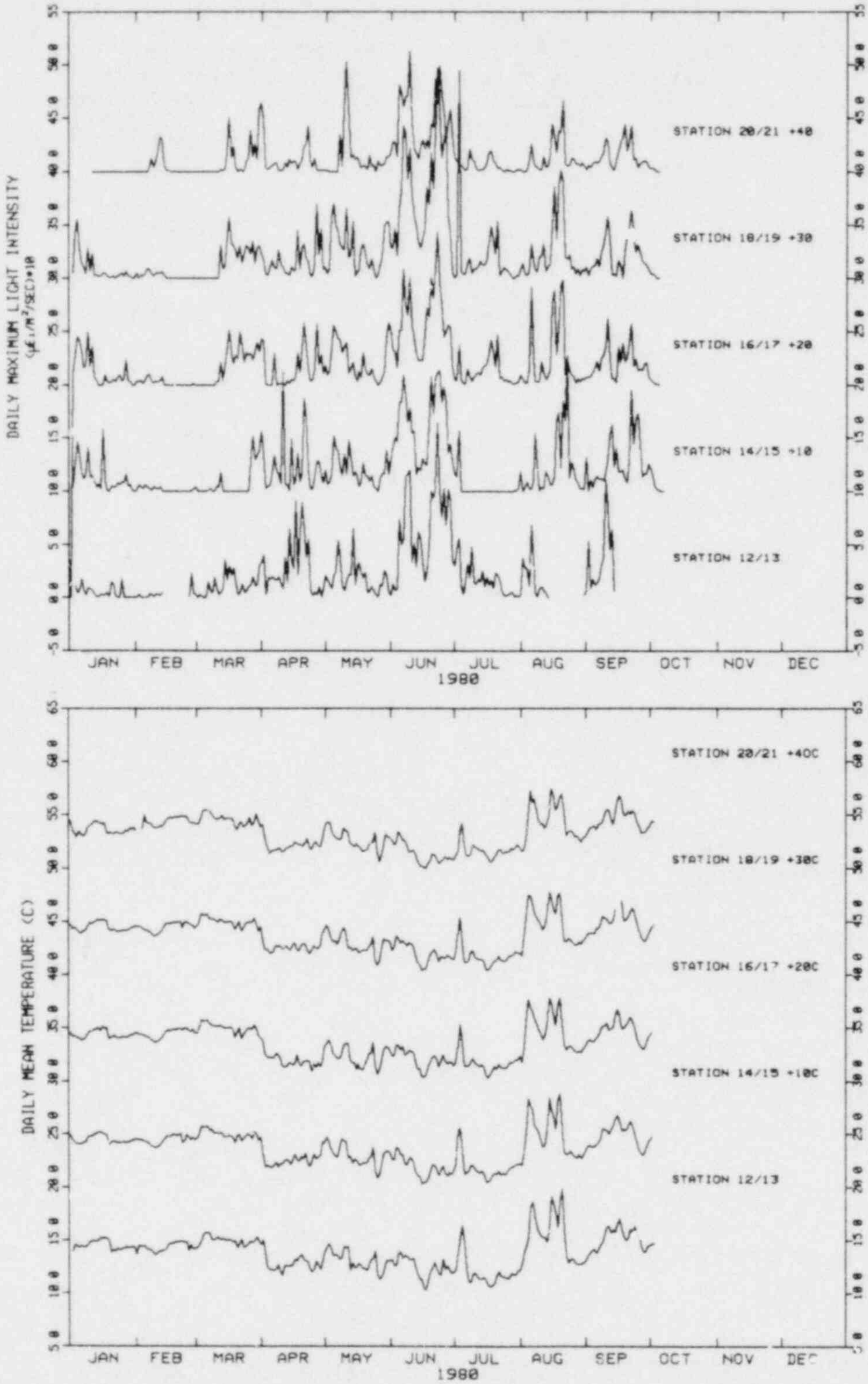

Figure 2B-8. Daily maximum light intensity and daily mean temperature at selected PMP benthic cobble stations during 1980.

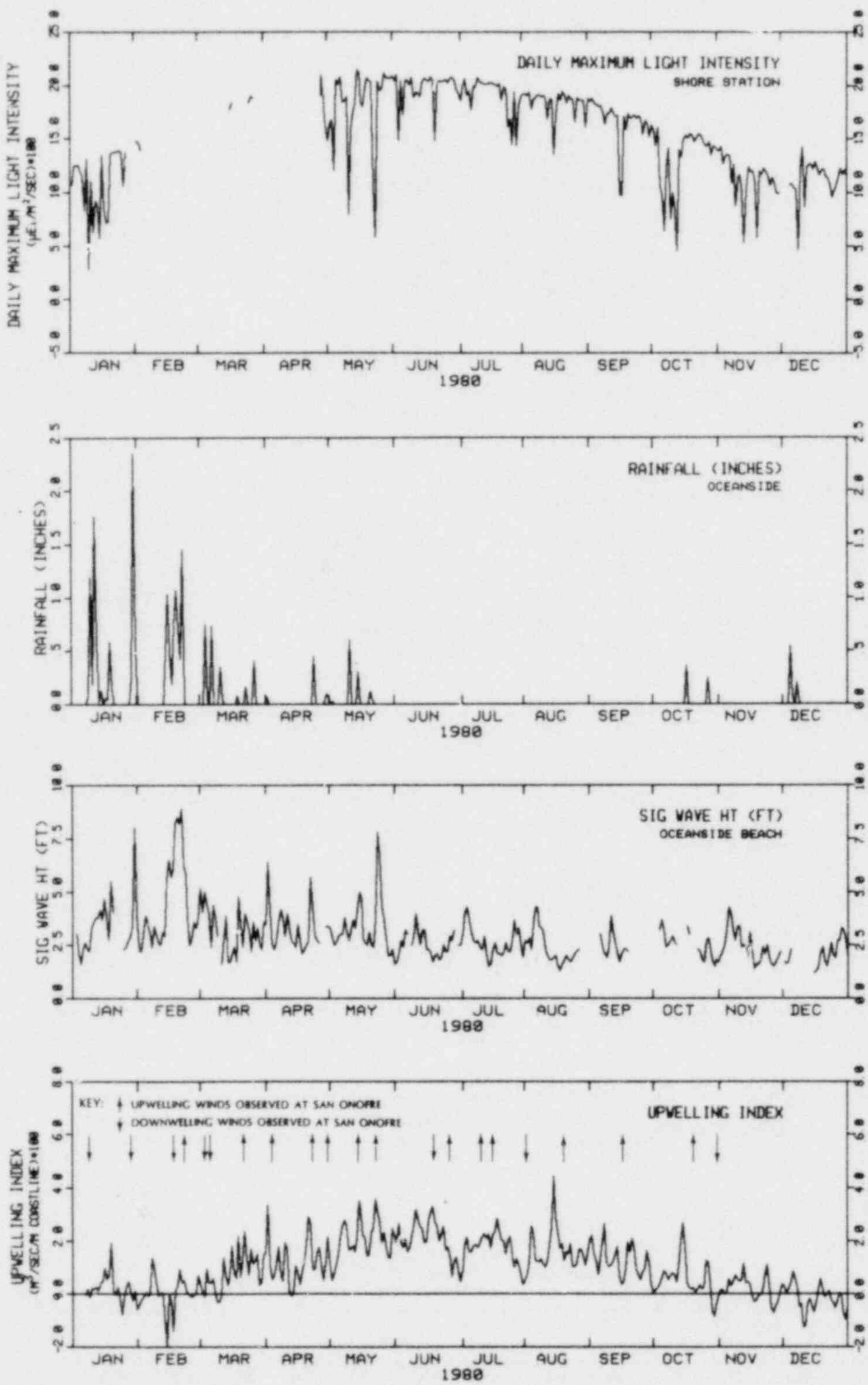

Figure 2B-9. Ambient light intensity, rainfall, significant wave heights, and upwelling indices near San Onofre during 1980.

Rainfall was the phenomenon which most directly affected ocean bottom light intensity. Decreases in light intensity at all stations were recorded during occurrences of rainfall and subsequent storm water runoff. Periods of greatest total rainfall and longest duration of rainfall corresponded to longer periods of reduced bottom light intensities.

Storms during January, February, and March produced a total of over 17 inches of rain in the first 70 days of 1980 at Oceanside Marina located 27 km downcoast of San Onofre. A simultaneous decrease in light intensity was observed throughout the entire study area which lasted through 11 March 1980. Shorter periods of rain were observed in late April (0.6 inches) and mid-May (1.1 inches), which corresponded to light intensity decreases of several days each. No measurable rainfall was recorded between May and September.

The wave energy impinging on the coastline is another important factor affecting light intensities. In general, wave energies were greatest from January through April 1980. During periods when maximum significant wave height was greater than approximately 4 feet, major decreases in bottom light intensity were observed. These decreases were apparent on the following dates: 13-19 January, 29 January, 13-22 February, 29 February, 3 March, 18 March, 1 April, 21 April, 13-15 May, 23-24 May, 3-4 July, and 5-6 August 1980.

Periods of decreased wave action correspond to increased light intensity. During mid-April, early May, early and late June, and late August 1980, sustained periods of wave heights of less than 4 ft corresponded to periods of maximum recorded light intensity values. Sustained periods of relative calm allow finer grains to settle out of the water column, which results in increased light intensity at the bottom.

Upwelling is another phenomenon which affects light intensity. Upwelling is a process by which nearshore surface waters are pushed offshore by sustained alongshore winds, and colder bottom waters are drawn towards the surface. In southern California, winds which blow downcoast can create upwelling if they are of strong enough velocity for sustained periods. Upwelling indices, calculated for the area offshore of San Diego (33°N 118°W) are presented on Figure 2B-9.

During 1980, upwelling followed a seasonal cycle, with maximum intensities occurring in May and June. Upwelling winds were persistent from roughly March through October in southern California. Periods when upwelling indices of greater than 200 m^3/sec/100 m of coastline persisted for 2 to 3 days correlated with long period decreases in light intensity of 1-10 April, 18-21 April, 5-9 May, 12-24 May, 11-20 June, 5-26 July, and 10-17 August 1980. This decreased light intensity is probably due to increased wave intensity associated with these winds and the upwelling of more turbid bottom waters to surface waters in the nearshore area. Localize periods of downwelling, due to winds from the southeast on 17 June and 2 August resulted in increased light intensity at the bottom for periods of 10 and 2 days, respectively.

Light intensity and temperature records are highly coherent among stations, which indicates that the upwelling phenomenon is occurring over an area much larger than the San Onofre study area. During local upwelling periods, bottom temperature decreases as much as 2-3°C in one day were recorded throughout the study area. Upwelling events were persistent on approximately the same time scale as the winds creating the upwelling. When upwelling decreased, light intensity and temperature records returned to their natural values within several days.

Ocean bottom light intensity corresponds only slightly to surface ambient light intensity. Ambient light intensity generally decreased when storm were

present. Other decreases occurred on overcast or foggy days. The relationship between decreased surface ambient light and bottom light intensities was not apparent, however.

The effect Unit 2 cooling water system on light intensity was also investigated. There was no apparent relationship between pump flow through the Unit 2 diffuser and benthic light intensities, even at the benthic station located within 300 m of the Unit 2 outfall diffuser. One of the four circulating water pumps for Unit 2 was generally operating from March through September (see Chapter 1).

SPATIAL TRENDS AND VARIATIONS

The most dominant feature of turbidity data collected at San Onofre was the natural decrease in surface water turbidity with distance offshore. This was due to surface waters being further removed from the primary source of turbidity, the sediments. The yearly mean surface light transmittance increased from approximately 5% at inshore A-line stations to approximately 40% at offshore M-line stations as illustrated on Figure 2B-10. A similar increase in light transmittance was observed at a depth of 4 m (13 ft). The yearly mean depth of Secchi disc visibility increased with distance offshore from approximately 5 m (16 ft) at inshore stations to nearly 8 m (26 ft) at offshore stations. Total

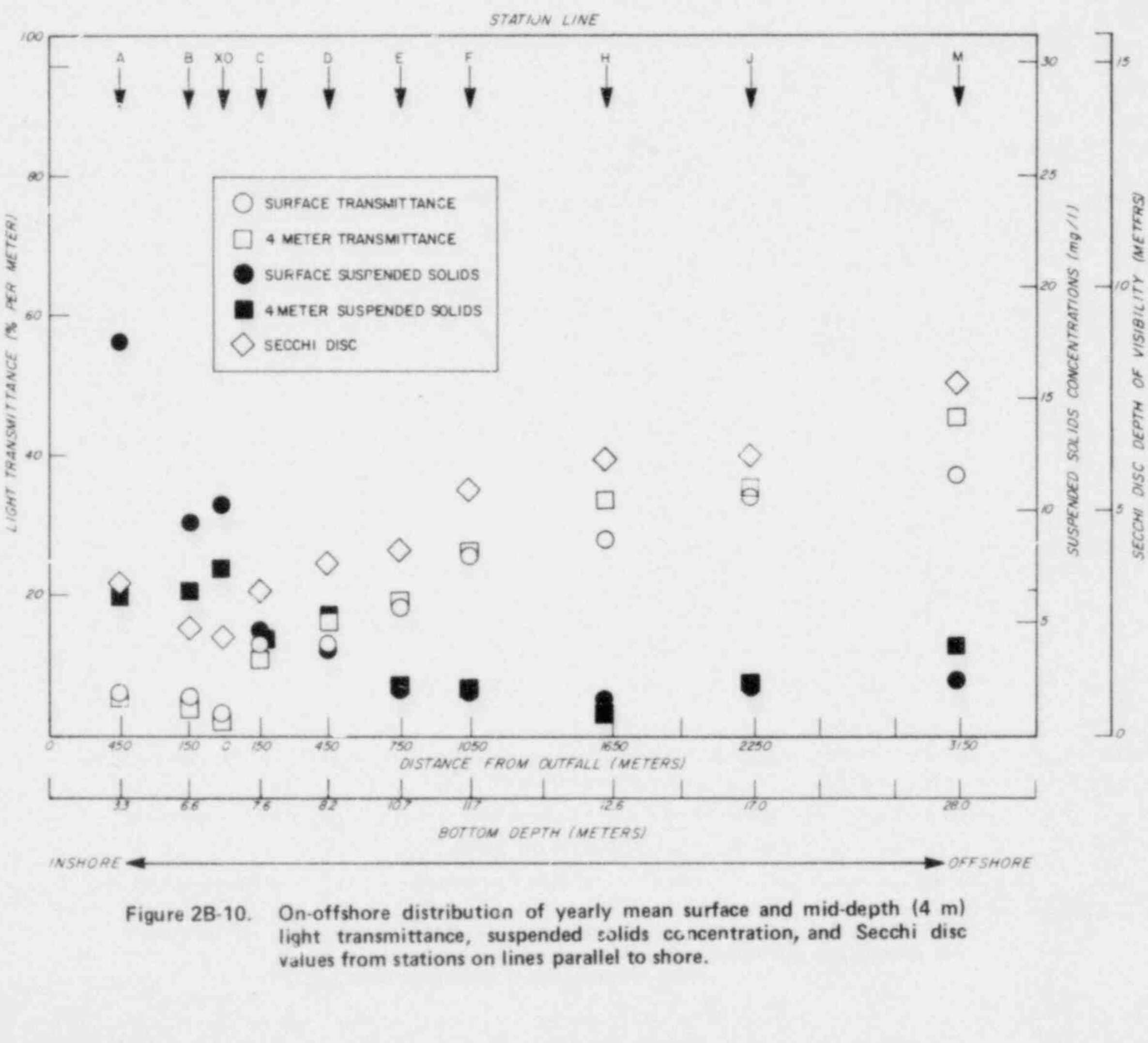

Figure 2B-10. On-offshore distribution of yearly mean surface and mid-depth (4 m) light transmittance, suspended solids concentration, and Secchi disc values from stations on lines parallel to shore.

suspended solids decreased from nearly 7 mg/liter along the inshore A-line stations to less than 3 mg/liter along the offshore M-line stations.

This trend of decreasing turbidity with distance offshore was apparent by comparing Figures 2B-11 and 2B-12. Yearly means of light transmittance were between 10 and 15% at stations along the C-line (9 m: 30 ft of depth), and between 32 and 38% at stations along the J-line (20 m: 66 ft of depth).

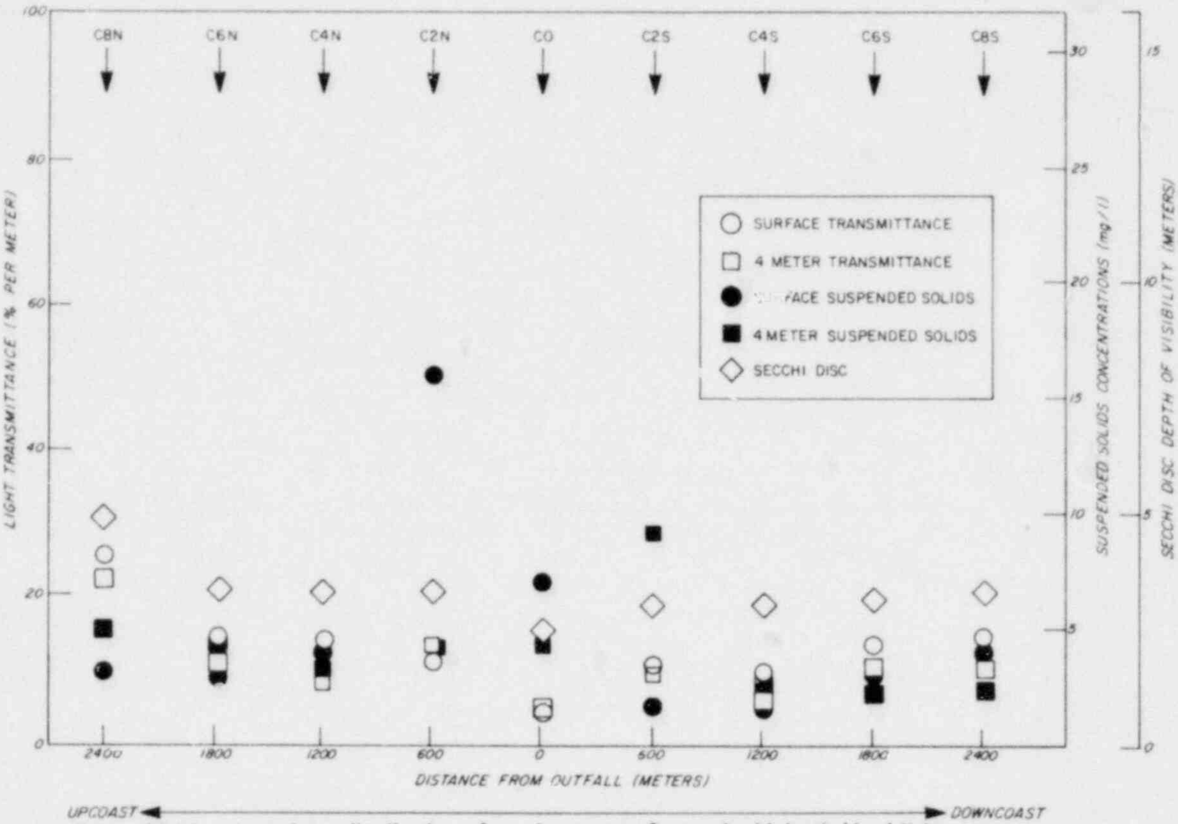

Figure 2B-11. Longshore distribution of yearly mean surface and mid-depth (4 m) light transmittance, suspended solids concentration, and Secchi disc values from stations in 8 m of water.

The longshore distribution of turbidity is illustrated by yearly mean light transmittance values from bimonthly surveys presented in Figures 2B-11 and 2B-12. During these surveys, light transmittance generally decreased with distance downcoast though only significantly between stations 600 m upcoast and 1200 m downcoast (2000 and 4000 ft, respectively) of the discharge. Light transmittance was approximately 5% less at Station C2S than at Station C2N. This trend was less apparent further downcoast and among stations in deeper water.

Turbidity generally increased with depth except during periods when heavy rainfall was not accompanied by wave-induced mixing.

Spatial variations of turbidity at the San Onofre study area are well documented by bimonthly profile and Secchi disc data presented in Volume II of this report (SCE 1981b). The natural variability of turbidity in the San Onofre study area was large. Significant differences in turbidity were observed with distance offshore, with turbidity generally greatest in the nearshore area where changing bottom topography caused varying amounts of breaker activity.

The survey area means of surface light transmittance for Units 2 and 3 stations were highest in January (65% transmittance) and lowest in July (17%

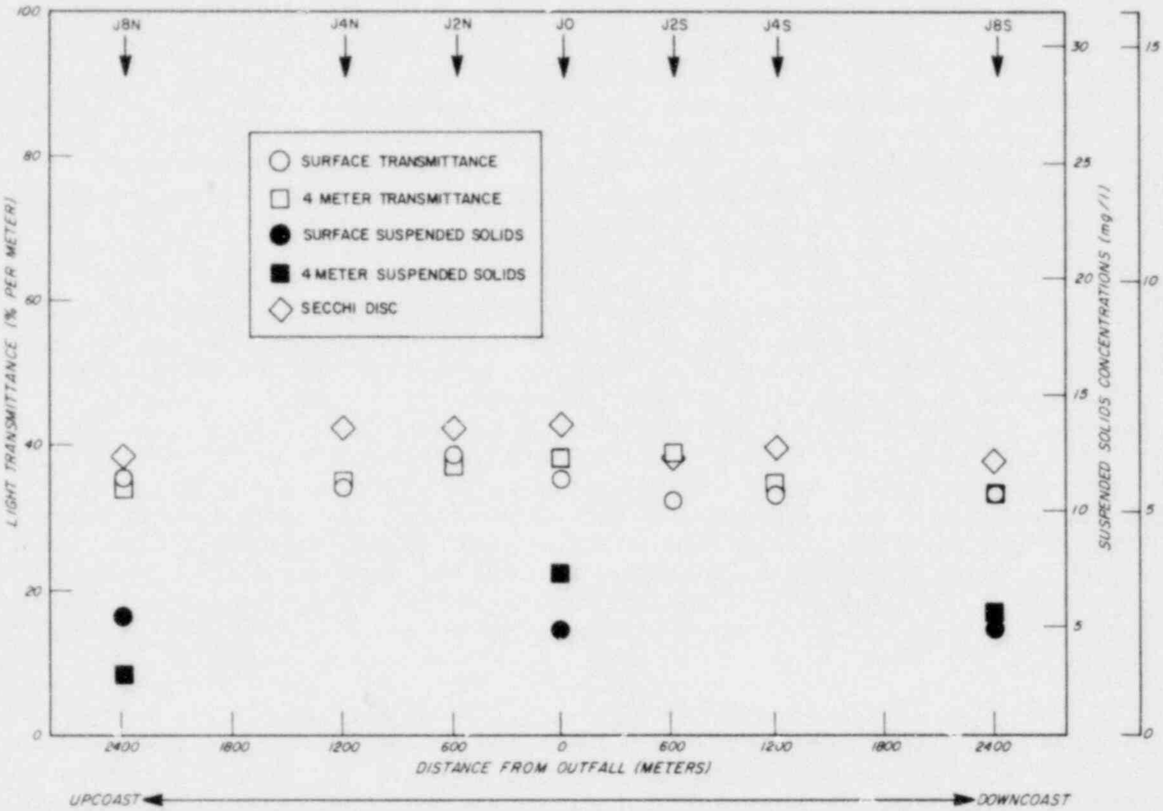

Figure 2B-12. Longshore distribution of yearly mean surface and mid-depth (4 m) light transmittance, suspended solids concentration, and Secchi disc values from stations on 17 m of water.

transmittance). The 8 January survey, was conducted just prior to the first significant rain storm of the winter of 1979-1980 and waters in the offshore study area were very clear. Therefore, the largest range in light transmittance at the surface (49%) was observed in January. The largest standard deviation of light transmittance ±15% from the mean of Units 2 and 3 stations was also observed in January. The lowest mean surface light transmittance and standard deviation was observed during the 9 July survey, when the mean was 19% and the standard deviation was ±6%. Similar patterns were observed at 4 m (13 ft) of depth.

At Unit 1 sampling stations a similar pattern was observed. Highest mean percent light transmittance, largest range, and greatest standard deviation were observed during 8 January survey, and the lowest of these statistics occurred during the 9 July survey.

INFLUENCE OF UNIT 1 ON TURBIDITY

During the 8 January bimonthly survey, there was natural stratification of turbidity with depth. At stations in 9 m (30 ft) of depth, natural turbidity varied between 21 and 22% light transmittance at the surface to less than 10% near the bottom. A turbid surface plume was created by Unit 1, and extended 1800 m (6000 ft) upcoast to 1200 m (4000 ft) downcoast of the discharge. Light transmittance was depressed by as much as 30% in the offshore area of this turbid plume, where ambient light transmittance would have been approximately 40%.

Turbidity caused by waves which resuspend bottom sediments in the near-shore area had the greatest affect on water clarity in the area of the Unit 1

discharge. Significant wave heights of approximately 4 feet during the 13 March, 9 July, and 5 November surveys, created enough turbidity throughout the water column within the Unit 1 study area to mask turbid plumes due to circulation of cooling waters. During these surveys, light transmittance at stations in 9 m (30 ft) of water generally decreased from between 1 and 22% at the surface to less than 5% near the bottom. Aerial photographs presented in Volume II (SCE 1981b), show that wave turbulence generated significant turbidity plumes in the area 1800 m (6000 ft) upcoast and downcoast and 1800 m offshore of the station. Unit 1 did not produce a noticeable turbid plume during these surveys.

Unit 1 water circulation pumps were operating at approximately 0.04% of their normal rate during the bimonthly surveys of 14 May and 10 September 1980. At this flow rate, no turbidity within the study area could be attributed to the discharge of Unit 1 cooling waters. The lowest survey mean light transmittance occurred during the 14 May survey. Mean transmittance was slightly higher during the 10 September survey. Light transmittance at stations in 9 m (30 ft) of depth ranged from 0 to 18% at the surface and from 0 to 25% at mid-depth (4 m: 13 ft) during the 14 May survey. Light transmittance values and ranges at these stations were slightly higher during the 10 September survey. During these surveys, turbidity was significantly affected by natural phenomena, such as winds in excess of 10 mph, significant wave heights of 3 to 5 ft, precipitation of almost one inch within one week prior to the May survey, and abundance of plankton throughout the water column.

During 1980, the absence of cooling water flow through Unit 1 during the time of greatest nearshore turbidity indicates that the influence of Unit 1 cooling water upon turbidity within the nearshore environment was less than that of natural processes. It was also evident that the natural variability of turbidity within the nearshore waters was greater than variations caused by the Unit 1 discharge.

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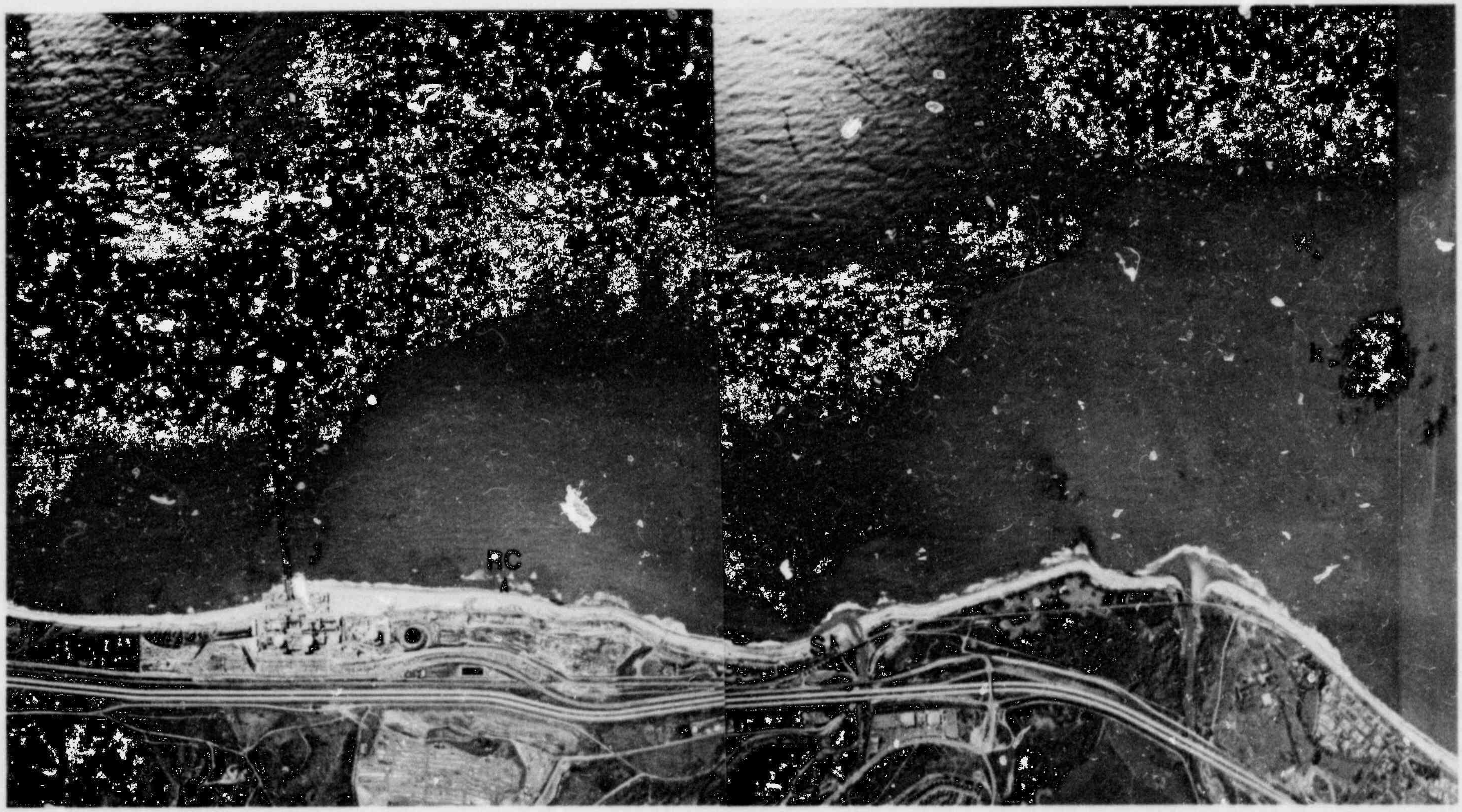

Plate 1. January 31, 1980, San Onofre inactive.

Due to SONGS inactivity, no discharge plume exists. The high level of natural turbidity is due to high river discharge at San Onofre and San Mateo Creeks. The large river discharge volume has inundated the sand spits that normally form at the river mouths during periods of low river flow (see subsequent photographs). Sediment from San Onofre Creek hugs the downcoast shore (S) under the influence of wave action before dispersing offshore near the SONGS Plant. Turbidity caused by rip currents (RC) is evident. A density front (DF) associated with the turbid plume can be detected at various locations offshore. Movement of the plume upcoast is discerned by the turbid wake (W) associated with the San Mateo kelp bed (K). Turbidity upcoast from San Mateo Point and also at the San Onofre kelp bed is relatively minor.

Plate 2. February 23, 1980, San Onofre in full operation.

Substantial turbidity is seen as a result of sediment input (S) at San Onofre and San Mateo Creeks. Again, river discharge hugs the coast as it proceeds in the downcoast direction until reaching the San Onofre vicinity. Turbid plumes associated with rip currents (RC) are evident. A turbid mass of water proceeds offshore as defined by the density fronts (DF). A nonturbid plume exists at the San Onofre outfall indicating the non-turbid nature of the water at the intake depth and location. The creation of this non-turbid plume at the outfall (O) implies that only the surface water layer is highly turbid.

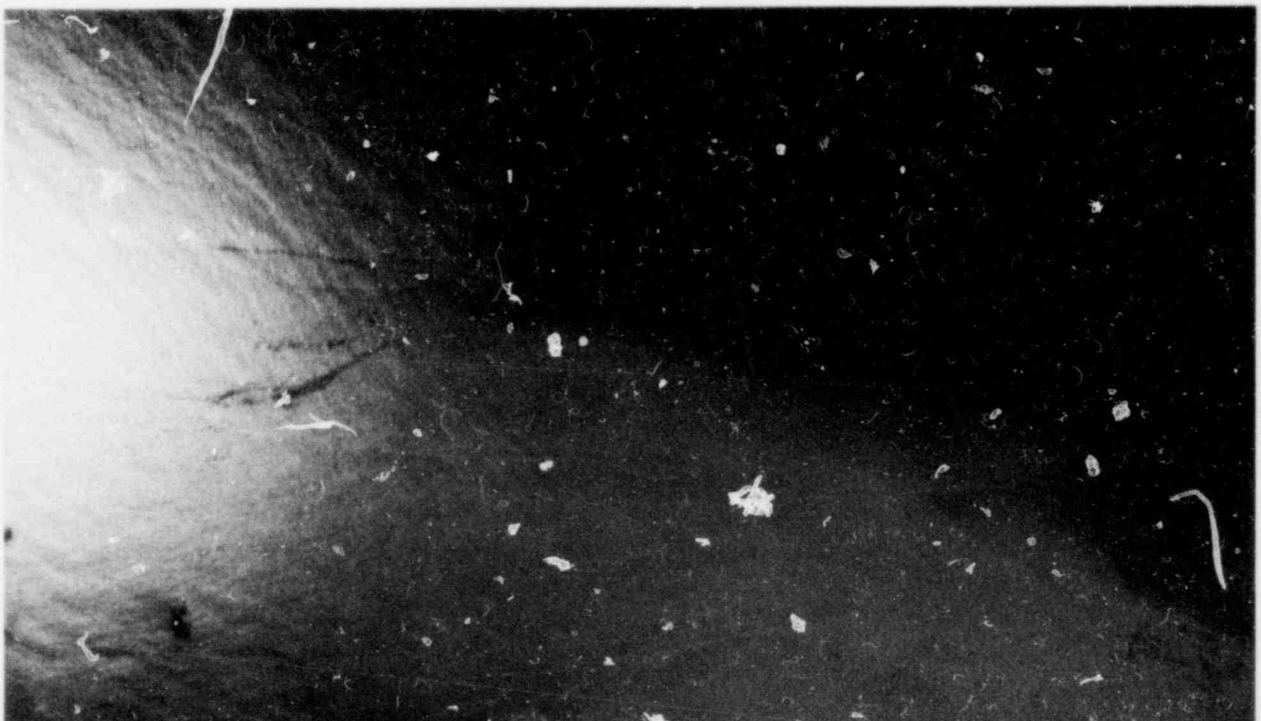

Plate 3. March 9, 1980, San Onofre fully operational.

As seen in previous photographs, the turbid water discharged by the rivers (S) moves downcoast within the surf zone until it is dispersed offshore near San Onofre. The San Onofre outfall (O) is discharging a turbid plume of characteristic color in the upcoast direction. Thus, the wave-induced current within the surf zone and the current at the outfall location are moving in opposite directions. The large turbid plume generated by the river discharge and rip current (RC) processes merges with the smaller plume of the outfall. The turbid zone, in general, seems to be contained between the San Onofre outfall and San Mateo Point.

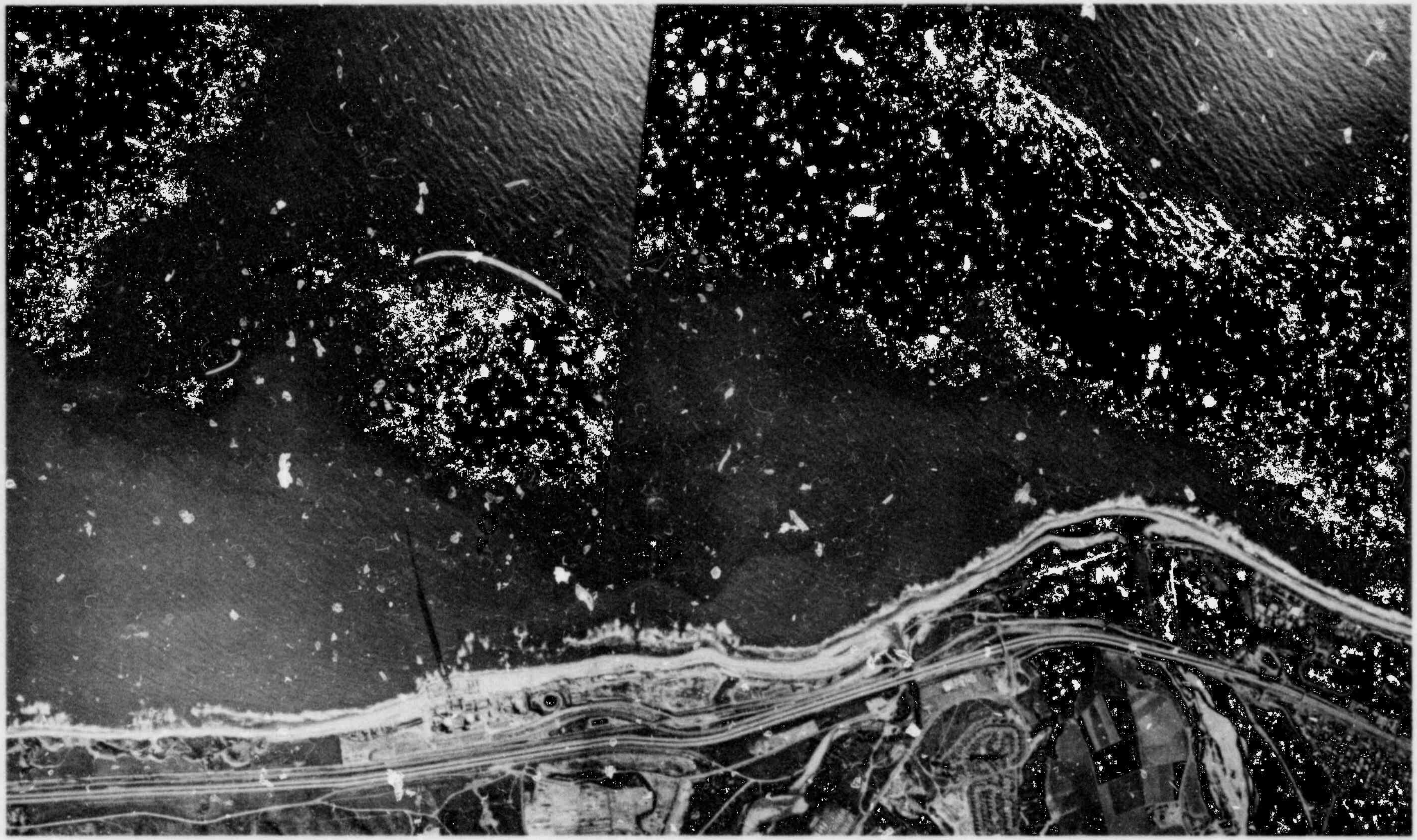

Plate 4. April 2, 1980, San Onofre fully operational.

A turbid water mass associated with surf zone and rip current (RC) processes is evident with intense turbidity at San Mateo Point and just upcoast of the San Onofre pier. The outfall (O) is visible as a small turbid streak directed downcoast. The width of the surf zone increases just upstream of the San Onofre pier due to the existence of the bathymetric bulge at this location. The level of turbidity is very low upcoast of San Mateo Point. Much of the turbidity that exists downcoast of San Mateo Point is generated by wave-induced resuspension within and near the surf zone at both San Mateo Point and the San Onofre bulge. The kelp beds (K) are visible but are not within the turbid plume as defined by the density front (DF).

Plate 5. July 10, 1980, San Onofre pumps only, no heat.

The general level of surface turbidity is low relative to the previous photographs. A turbid plume associated with the bulge is seen just off the shore. Rip currents (RC) nearshore are observed. A turbid plume from the San Onofre outfall (O) is evident, however, due to the lack of heated discharge, this surface expression is devoid of thermal effects. The San Onofre kelp bed is seen offshore.

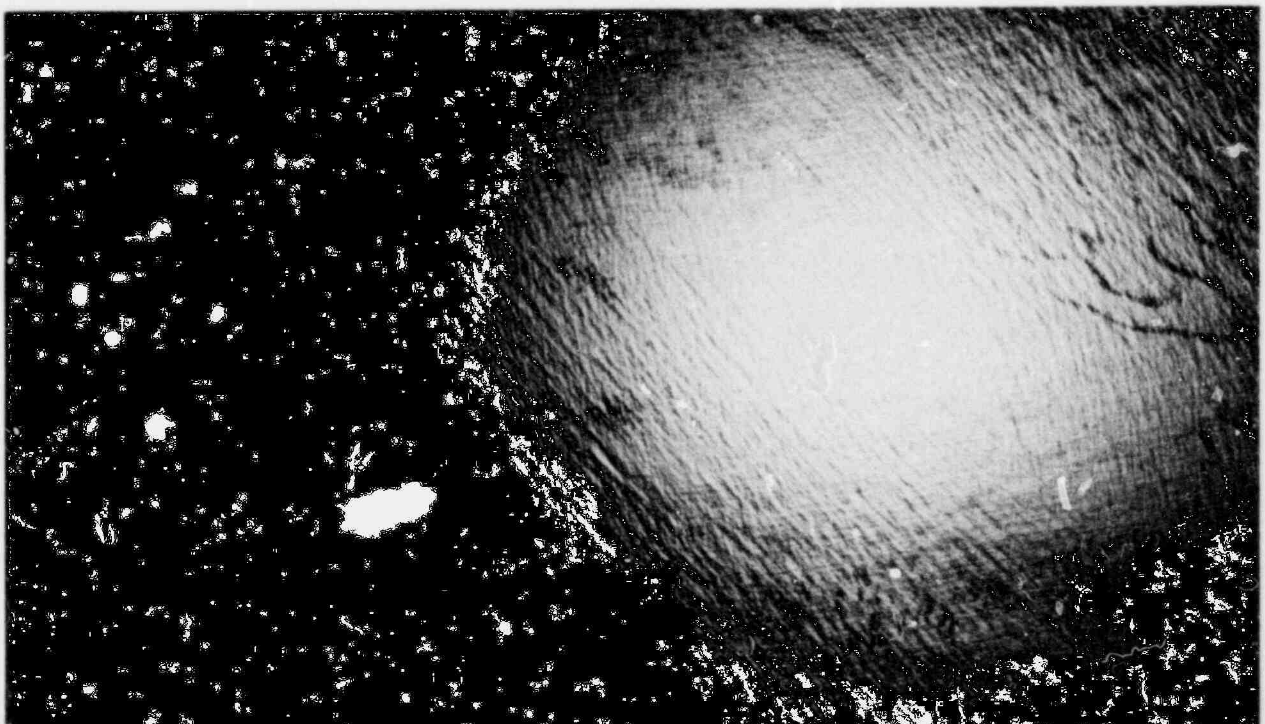

Plate 6. July 17, 1980, San Onofre pumps only, no heat.

Very little surface turbidity is seen in this photograph. Surf zone turbidity (RC) is at a low level. The turbidity associated with the unheated discharge of the outfall (O) is barely visible. The kelp bed (K) is seen offshore.

CHAPTER 2C

WATER QUALITY

INTRODUCTION

The major water quality characteristics which were measured during the San Onofre monitoring study included temperature, salinity, density, dissolved oxygen, pH, water transparency, nutrients, and heavy metals. The results of temperature and turbidity studies are reported in Chapters 2A and 2B. This chapter pertains to dissolved oxygen concentration (DO), hydrogen ion concentration (pH), and heavy metals concentrations in the receiving waters and sediments. Salinity and density data were used only in support of the other studies conducted for San Onofre and are not discussed in detail in this report.

During 1980, water quality characteristics of dissolved oxygen, hydrogen ion concentration, and specified heavy metals were investigated and evaluated in the San Onofre area primarily to complete the two-year receiving water baseline study for Units 2 and 3. These studies provide a predischarge data base of water quality characteristics which can be compared to studies during operation of Units 2 and 3 to determine if these units significantly affect water quality. The secondary objective of the 1980 water quality study at San Onofre was to continue to increase the established data base on the operational effects of Unit 1, and to assure natural dissolved oxygen and pH levels were maintained.

Water quality studies met all objectives and requirements of the Environmental Technical Specifications (ETS) program for Unit 1 and the Preoperational Monitoring Program (PMP) for Units 2 and 3 established by the Nuclear Regulatory Commission (NRC), as well as monitoring required by the National Pollutant Discharge Elimination System (NPDES) permit for Units 1, 2, and 3, issued by the California Regional Water Quality Control Board, San Diego Region (CRWQCB, SDR).

This chapter presents: 1) a pertinent summary of data collected by SCE studies in 1980; 2) an analysis of data to meet objectives; and 3) a description of water quality characteristics, their interaction with generating station activities, and a perspective of water quality conditions in the study area and the southern California area

Previous volumes of this year's annual report have presented all basic data obtained in SCE studies. Volume I presents a summary of data required by regulatory agencies, and was submitted to the appropriate agencies on 31 March 1981 (SCE 1981a). Volume II contains all basic raw data collected for SCE programs during 1980, including the basic regulatory-required data and additional supplemental data obtained in order to fulfill objectives of the study (SCE 1981b).

BACKGROUND

In order to put 1980 studies in perspective, the following section presents background information on water quality data collected at San Onofre during previous years, and then describes similar studies during 1980. A brief history of water quality studies conducted at San Onofre is presented in Table 2C-1.

Table 2C-1. Time history of water quality measurements at San Onofre.

Water Quality Studies	Types of Data Collected	Dates	Instrumentation	Frequency	Locality/ Stations	Depths Sampled
Major Programs						
Marine Environmental Monitoring						
Unit 1 Preoperational	Dissolved oxygen	1967-1968	Winkler titration	Bimonthly	5 stations	Surface
	Hydrogen ion concentration	1967-1968	Polarographic pH meter	Bimonthly	5 stations	Surface
	Coliform bacteria	1967-1968	Laboratory incubation	Bimonthly	5 stations	Surface
	Currents	1967-1968	Current droques			
Unit 1 Operational	Dissolved oxygen	1968-1972	Winkler titration, Martek dissolved oxygen probe	Bimonthly	3 stations	Surface
	Hydrogen ion concentration	1968-1972	Polarographic pH meter, Martek pH probe	Bimonthly	3 stations	Surface
	Coliform bacteria	1968-1972	Laboratory incubation	Bimonthly	3 stations	Surface
	Current measurements	1968-1972	Current droques, current meters			
Environmental Technical Specifications						
Unit 1	Dissolved oxygen	1975-1980	Martek dissolved oxygen probe	Bimonthly	3 stations	Surface
	Hydrogen ion concentration	1975-1980	Martek pH probe	Bimonthly	3 stations	Surface
	Heavy metals	1975-1978	SCUBA diver collection, atomic absorption spectrophotometer analysis	Quarterly	4 stations	Mid-depth, sediments
		1978-1980	SCUBA diver collection, atomic absorption spectrophotometer analysis	Bimonthly	4 stations	Mid-depth, sediments
	Currents	1978-1979	In-situ current meters	Bimonthly, 25 hr period	Station C2N	1 meter depth
Preoperational Monitoring Program						
Units 2 and 3	Dissolved oxygen	1978-1980	Martek dissolved oxygen probe	Bimonthly	4 stations	Surface
	Hydrogen ion concentration	1978-1980	Martek pH probe	Bimonthly	4 stations	Surface
	Heavy metals	1978-1980	SCUBA diver collection, atomic absorption spectrophotometer analysis	Bimonthly	5 stations	Mid-depth, sediment
	Currents	1978-1980	In-situ current meters	Bimonthly	Station H2N	1 and 7 meter depth
Special Studies						
Unit 1 Operational	Chlorine residual and demand	1975-1977	Amperometric titration	Bimonthly	6 stations plus inplant	Surface
Units 2 and 3 Preoperational	Total and residual chlorine	1980	Amperometric titration	3 times during 1980	8 stations	Surface

HISTORICAL STUDIES

In the spring of 1967, a water quality sampling program was initiated as part of the Marine Environmental Monitoring Program (MEM) required by CRWQCB to monitor the effect of Unit 1 on receiving waters. Surface water samples were taken in the vicinity of the outfall for determination of dissolved oxygen

concentrations. Natural ambient levels of DO and pH were determined from samples collected at the control station downcoast of the Unit 1 discharge.

Specifications relating to DO and pH were based on results of earlier research conducted throughout the southern California bight by the Allan Hancock Foundation. Historically, surface dissolved oxygen concentrations have ranged from 4.3 to 12.6 mg/* near San Onofre, with lowest concentrations in winter and highest concentrations during spring (Allan Hancock Foundation 1965; SCCWRP 1973). The natural pH range for the San Onofre study area, based on data measured from 1967 to 1973, has been defined as 7.3 to 8.5. Allan Hancock Foundation (1965), reported a range of surface pH in the waters near San Onofre from 7.5 to 8.6, with an average of 8.1. Similar results were reported by SCWPCB (1959).

Beginning in 1975, water quality measurements were obtained as a portion of the ETS monitoring program. The specifications for DO and pH in this program were identical to those established by the Water Quality Control Plan for Ocean Waters of California. The Water Quality Control Plan states that the discharge shall not, at any time, depress dissolved oxygen concentrations of receiving waters more than 10% from that which occurs naturally, as measured with respect to a suitable control station, and that the generating station shall not cause pH to vary by more than 0.2 units from that which occurs naturally.

Sampling technique and analysis under the MEM program (1967-1975) consisted of five dissolved oxygen and pH sampling stations, with subsequent analysis by Winkler titration (Strickland and Parsons 1972) and a Corning Model 10 pH meter, respectively. In 1975, under the ETS program, dissolved oxygen and pH sampling was conducted bimonthly at 3 stations. In May 1978, the PMP was initiated and included four additional stations for dissolved oxygen and pH sampling as presented in Table 2C-1. From 1977 through 1980, vertical profile measurements of DO and pH were collected simultaneously with temperature and turbidity profiles.

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

1980 STUDIES

Water quality studies during 1980 were similar to previous years for the first four bimonthly surveys. Vertical profile measurements of dissolved oxygen and pH were obtained at 74 sampling stations along with temperature, light transmittance, salinity, and density profile information (Figures 2A-1 and 2A-2). In August 1980, bimonthly water quality studies for Units 2 and 3 PMP were terminated after completion of the two-year data base. Studies of the operational effects of Unit 1 were continued in accordance with ETS requirements during the September and November surveys. This resulted in measurements of DO and pH at 34 stations.

Heavy metal water column and sediment samples were collected bimonthly and analyzed for copper, chromium, nickel, iron, and titanium concentrations. After the bimonthly survey in July 1980, the PMP program was terminated, as the required two-year preoperational data base had been obtained. Since Unit 1 was not operational after April 1980, the Unit 1 studies were reduced to collect data only at required stations.

Results of previous studies have been extensively documented in previous annual reports. Formal requests to delete ETS requirements were submitted to the NRC in October 1980 based upon the accomplishment of the objectives within the mandated scope.

DISCUSSION

Results of water quality parameters measured at San Onofre were typical of the southern California nearshore marine environment. Dissolved oxygen, pH, and heavy metals concentrations were measured in the San Onofre study area to document background conditions prior to operation of Units 2 and 3 and to determine effects of the Unit 1 discharge on water quality.

Factors affecting nearshore water quality characteristics include: 1) the interaction of other water quality characteristics such as temperature, salinity, density, and nutrients, and the effects of advective and nonadvective processes on the distribution of these properties; and 2) biological activity in the region, especially by planktonic organisms. Advective processes (currents) produce flux of mass and of other properties by direct motion of seawater. Nonadvective processes, like diffusion, produce a flux in properties but not of mass. The interaction of all these factors can cause large changes in the water quality characteristics of the area.

DISSOLVED OXYGEN

The dissolved oxygen concentration observed at any given time is affected by the various sources and sinks of oxygen, and advection and diffusion processes. The major sources of oxygen are the atmosphere and photosynthesis. The major sinks of dissolved oxygen are respiration by marine organisms and the oxidation of organic and inorganic material. Surface waters are normally at saturation level due to the immense source of oxygen in the air and mixing by surface waves. The solubility of oxygen is dependent upon temperature, salinity, and barometric pressure. Since salinity is fairly uniform throughout the southern California area, temperature has the greatest effect on the solubility of oxygen. Oxygen is more soluble in colder waters, and less soluble in warmer waters.

Plankton blooms affect the vertical distribution of dissolved oxygen. Phytoplankton often increase mid-depth dissolved oxygen concentrations during daylight hours by release of oxygen to the water as a by-product of photosynthesis. During the past five years, these plankton blooms were often observed during the March and May bimonthly surveys in the offshore study area for Units 2 and 3. Blooms of zooplankton are often responsible for a sharp decrease in dissolved oxygen with depth.

Prominent changes in vertical stratification of dissolved oxygen become more evident in the warming trends of the summer months. As the surface water layer is warmed, stratification of the water column increases. This creates a density difference between waters above and below the thermocline which limits mixing between oxygen-rich surface waters and oxygen-depleted waters below the thermocline, resulting in a rapid decrease of DO with depth below the thermocline. Stratification of dissolved oxygen was most evident in measurements taken during the May survey, where DO decreased from 9 mg/liter in surface waters to between 4 and 5 mg/liter in bottom waters at downcoast stations which did not have plankton blooms.

During periods when intense plankton blooms were absent, a gradual decrease in dissolved oxygen concentration was observed with increasing depth. The

vertical dissolved oxygen gradient was usually greater at Units 2 and 3 sampling stations than at the inshore Unit 1 stations due to the increased depth offshore. During spring and summer, density stratification contributes to the vertical dissolved oxygen gradient by inhibiting the mixing of surface and bottom waters. During the winter there is little or no density stratification with depth and DO is relatively uniform throughout the water column.

Upwelling conditions can over-ride density gradient boundries when strong offshore winds from the west-northwest force warm surface water offshore. The displaced surface water mass is replaced by the underlying deep nutrient-rich bottom water which wells up through the water column. The biological and water quality characteristics (such as nutrients, turbidity, DO, pH, COD, etc) in this upwelled cool bottom water can be significantly different from the displaced surface water mass. For example, two days prior to the 13 March 1980 survey, upwelling indices (Bakun 1980) show signs of upwelling offshore of San Onofre.

Satellite imagery reveal increased upwelling and decreased surface temperatures offshore of San Onofre between 12-16 March 1980. Continuous temperature records at San Onofre also indicate a cooling trend in the water column. These processes coupled with phytoplankton blooms between 5 and 10 m of depth increased dissolved oxygen concentrations in the offshore area.

Surface dissolved oxygen concentrations were not significantly different during bimonthly surveys at either inshore or offshore sampling stations. During the last six years of monitoring, dissolved oxygen concentrations in the vicinity of San Onofre have always been typical of nearshore waters of southern California.

Historically, waters neighboring the San Onofre region contain dissolved oxygen concentrations ranging from 4.3 mg/liter in winter to 12.6 mg/liter in summer (Hancock 1965). Spatial variability was mostly controlled by naturally occurring processes, especially plankton blooms, although there was an apparentally small scale influence of localized entrainment in the vicinity of the diffuser for Unit 2 due to circulating water flow.

Dissolved oxygen concentrations were not reduced by more than 10% due to the operation of Unit 1, and are therefore in compliance with ETS, NPDES, and SWQCB requirements.

HYDROGEN ION CONCENTRATION

The hydrogen ion concentration (pH) in southern California coastal waters varies in a very narrow band around a mean of approximately 8.1. Natural ranges for pH in the San Onofre area have been defined as 7.3 to 8.5, based on information gathered from 1967 to 1973 (Allan Hancock Foundation 1975). The pH of seawater is determined by the bicarbonate/carbonate/carbon dioxide balance in a natural seawater buffer system. Changes in pH within the natural range are due mainly to photosynthesis and respiration of marine organisms, which alter the balance of carbon dioxide in the buffer system. Low pH values are reflected in high concentrations of carbon dioxide and low concentrations of oxygen. It is usual to find high concentrations of carbon dioxide and lower pH values where respiration is the dominant process. Thus, a high degree of correlation is expected between pH, DO, and photosynthesis.

Vertical profile measurements taken at San Onofre often show vertical stratification of pH with depth, with higher surface values and a general decrease in pH with depth. This stratification is related to the vertical stratification of dissolved carbon dioxide and oxygen as previously discussed. Decreased dissolved oxygen concentrations are reflected by decreased pH values.

Surface pH was within the normal range previously observed in the vicinity of San Onofre. Surface pH was not altered by more than 0.2 units due to the operation of Unit 1 and therefore is in compliance with ETS, NPDES, and SWQCB requirements. There were no observed spatial variations among required sampling stations offshore nor between inshore and offshore sampling stations.

HEAVY METALS

Heavy metals (such as copper, chromium, nickel, iron, and titanium) are normal constitutents of receiving waters and ocean bottom sediments. Heavy metals are derived from natural sources (weathering of pre-existing rock) and man-influenced sources. The movement of heavy metals from a source to the site of deposition is complex, and involves physical, chemical, and biological factors. Heavy metals are important to marine life; at low concentrations, many are essential to plant productivity, while at high concentrations, they can be inhibitory or toxic.

Heavy metals concentrations in mid-depth receiving water and ocean bottom sediment samples have been determined at four required Unit 1 (inshore) stations for the past six years, and for two years at five Units 2 and 3 preoperational (offshore) stations. Results of the heavy metals monitoring for 1980 were presented in Volume II of the annual Operation Report (SCE 1981a).

Receiving Water Heavy Metals

Natural factors which increase concentrations of heavy metals in the water column include: 1) surface runoff from rainfall and river runoff; 2) currents which transport heavy metals from other areas; 3) upwelling, which brings heavy metals to the study area from deeper offshore waters; and 4) resuspension of sediment heavy metals during periods of high physical mixing between the sediments and water column. The natural factors which decrease heavy metals concentrations in the water column include: 1) heavy metals adhering to inorganic and organic particles which fall out of suspension in the water column (precipitation); 2) assimilation by marine biota; and 3) current transport away from the study area. Unit 1 and the construction of Units 2 and 3 may provide other factors influencing the concentrations of heavy metals in the study area.

Receiving water heavy metals samples were analyzed for total copper, chromium, iron, nickel, and titanium from 1976 to 1980. Prior to 1976, samples were analyzed for dissolved heavy metals only. The analysis for total heavy metals does not include filtration of samples to remove suspended particulates, as does the dissolved heavy metals analysis, and is therefore sensitive to the total amount of suspended solids in the water sample. Heavy metals tend to adhere to organic and inorganic particles in the water column, so that samples containing larger amounts of particulates may have higher concentrations of heavy metals. Of those heavy metals analyzed, iron is the most sensitive to the presence of particulates, and copper is only somewhat sensitive. Chromium, nickel, and titanium are usually not affected.

The concentrations of iron have generally followed the pattern of turbidity in the San Onofre area since 1976. Increased iron concentrations were usually observed during winter months when rainfall and increased wave action increased the amount of suspended material in the water column.

No persistent increase in receiving water concentrations of copper, chromium, or nickel has been observed for the past six years. Concentration levels of titanium have been consistently low and uniform for the past three years of study.

A measurable increase in receiving water iron concentration has been observed in yearly mean values for 1978, 1979, and 1980 throughout the study area, including the Unit 1 and Units 2 and 3 control stations 6700 m (22,000 ft) downcoast. Since the increase of iron concentrations occurred throughout the San Onofre study area, this increase is not directly attributable to any operational influence of the generating station.

The general increase in water column iron concentrations throughout the study area during bimonthly surveys of the past three years, correspond to a general increase in turbidity observed for the same period (see Figure 2B-4) The highest receiving water iron concentrations were usually observed at the Unit 1 discharge station during the past four years. This station is the most inshore heavy metals sampling station and generally has higher turbidity than the other Unit 1 sampling stations. High turbidity in the area of the Unit 1 discharge is due primarily to the influence of the following four factors as discussed in the Turbidity chapter (Chapter 2B): 1) the shoreline bulge and offshore seabed off San Onofre, 2) the downcoast eddy from the San Mateo headlands; 3) entrainment of bottom waters by the Unit 1 discharge; and 4) offshore construction for Units 2 and 3.

The higher iron concentrations observed at the Unit 1 discharge station may also have been due to Unit 1 operation and the construction for Units 2 and 3. A temporary steel trestle for offshore construction of the seawater circulating system for Units 2 and 3 was utilized from 1977 to 1980. This trestle may have contributed to higher receiving water iron concentrations in the area of the Unit 1 discharge through corrosive oxidation and scaling of ferrous metals.

Sediment Heavy Metals

In evaluating heavy metals in marine sediments, the origin, movement, erosion, and deposition of the sediments must be considered. Each of these components is influenced by natural phenomena, such as climate, topography, regional geology, and oceanographic conditions. The horizontal and vertical distribution of heavy metals in ocean sediments are the result of several actions and interactions which relate to the origin and evolution of marine sediments.

Seasonal variation of heavy metal concentrations offshore (Units 2 and 3) in benthic sediments became apparent during parts of 1980. This seasonal variation followed changes observed in sediment grain size distribution. For 1980, the majority of grain sizes observed in the sediments for the offshore stations were of a phi size of 3.5 and higher, representing very fine grain sediments. However, the sediment grain size distributions measured at Stations J2S and J4S in March were significantly different, having high percentages of granular sand (phi sizes of 1.0 to -1.5). This indicated that localized erosion had occurred at these stations prior to the survey.

Wave energy is high during the winter months and is responsible for mass transport of large volumes of coastal sand to offshore areas. Significant wave energy prior to and during the 13 March survey was probably responsible for the erosion of fine grain sediments at Stations J2S and J4S.

Finer grain size particles have large surface area to volume ratios and therefore provide for more absorption of heavy metals from the surrounding seawater. This is why good correlation between grain size and heavy metals concentration was observed. The heavy metal concentrations associated with coarse grain size sediments in March at Stations J2S and J4S show generally lower concentrations of all heavy metals.

Temporal and spatial trends for inshore (Unit 1) stations are not as easily discernable as for offshore stations (Units 2 and 3) due to increased turbulence in the wave zone. There is a general increase in heavy metals concentrations in the sediments during the summer when wave affects on the sediments are generally less.

The on-offshore trends of ocean bottom heavy metals concentrations correspond to the increased effect of waves on sediments in shallower water. Higher wave action at the shallower Unit 1 stations keeps colloidal sediment particles suspended within the water column. These light weight particles remain suspended until favorable conditions allow their settlement to the bottom. Favorable conditions of this nature usually exist in offshore waters, which are less subject to wave action on the bottom. Upon settlement to the ocean bottom, the fine grain particles consolidate.

Discharge pump flow rates for Unit 1 were near maximum during the January, March, July, and September bimonthly surveys, with the exception of a half pump load in May and absent pump flow in November. Data from the Unit 1 discharge (Station X0), show that in November, when pump flow was absent, the percentage of small, finer colloidal particles increased at this station. The discharge station generally had significantly larger grain sizes than the downcoast control station. However, during November, the discharge station had finer grain size than the downcoast control station. This was probably the result of no circulating flow for a few weeks prior to sampling and lower wave activity.

The fine grain sediments, which are stirred up into the water column by wave action, may be entrained to surface waters by the cooling water flow and transported out of the discharge area by currents. Wave energy is usually greater in the area of the discharge due to waves shoaling as they encounter the protruding shoreline and the turbulent discharge bubble. During the rest of the year, when pump flow existed for several days prior to sampling, somewhat lower heavy metals concentrations and coarser grain sizes were observed at the discharge (Station X0).

No persistent measurable increase in sediment concentrations of copper, chromium, iron, or nickel were observed during the last six years of heavy metal monitoring. Also there have been no persistent increases in sediment titanium concentration during the last three years.

Since there has been no measurable consistent increase in heavy metals concentrations in the ocean bottom sediments during the past six years, the operation of Unit 1 has not effected the concentrations of heavy metals in the environment.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

APPROACH

The approach for 1980 studies was to obtain measurements during bimonthly surveys as required by the regulatory agencies and to obtain additional water quality information that would be helpful to the oceanographic and biological studies at San Onofre. The additional measurement of vertical profiles of salinity, density, dissolved oxygen, and pH simultaneously with temperature and turbidity profiles provided detailed information of water quality characteristics

and identified various water masses which enter the San Onofre area. These water quality profile measurements were also used to identify the vertical distribution of plankton and their effect on water characteristics.

DATA SOURCES

In addition to information collected by SCE at San Onofre during the past 15 years, other data sources were incorporated to provide useful background information on water quality characteristics at San Onofre. The data sources utilized include: 1) published historical data summaries pertaining to oceanographic conditions in the Southern California Bight; 2) meteorological summaries for California; 3) published historical reports of oceanographic/ biological conditions in the San Onofre region; and 4) calculated upwelling indices.

Historical oceanographic data summaries published by the State Water Pollution Control Board (SWPCB 1954), Southern California Coastal Water Research Project (SCCWRP 1973), and the Allan Hancock Foundation (Hancock 1965) were researched to provide information on natural oceanographic conditions and constituents throughout the southern California area. Climatological data from the Naval Weather Service Department and the National Oceanic and Atmospheric Administration (NOAA 1980) were used in assessing influence of meteorological conditions on the San Onofre region. Upwelling indices, calculated from barometric pressures from throughout the northeast Pacific Ocean, were obtained from NOAA/National Marine Fisheries Service to evaluate the effects of upwelling on water quality characteristics (Bakun 1980). Results of other portions of 1980 studies conducted by SCE were also utilized in the analysis of dissolved oxygen, hydrogen ion, and heavy metals concentrations.

METHODS

This section presents a synopsis of the methods used in the study of dissolved oxygen, hydrogen ion concentrations, and heavy metals. Methods of data collection included: 1) vertical profiles of dissolved oxygen and pH, 2) Winkler titration of dissolved oxygen, and 3) atomic absorption spectrophotometry for heavy metals. More detailed descriptions of methods are presented in the Brown and Caldwell Procedures Manual for Environmental Surveillance at San Onofre (BC 1978).

DISSOLVED OXYGEN AND HYDROGEN ION CONCENTRATION

Vertical profile measurements of dissolved oxygen (DO) and hydrogen ion concentration (pH) were taken at 51 Unit 1 operational monitoring stations and 23 Unit 2 and 3 preoperational monitoring stations (Figures 2A-1 and 2A-2) during the field surveys of 8 January, 13 March, 14 May, and 9 July 1980. During the 10 September and 5 November surveys, DO and pH profiles were taken only at 34 Unit 1 stations in accordance with ETS requirements and temperature and turbidity profiling. Measurements of surface DO and pH at Unit 1 monitoring Stations C0, X0, and C22S were required bimonthly by ETS Section 3.1.1.a.(3) and ETS Section 3.1.1.a.(7), respectively. Measurements of surface water DO and pH at Units 2 and 3 monitoring Stations J2S, J2N, J4S, and F22S satisfied PMP requirements.

HEAVY METALS

Monitoring of Unit 1 heavy metals concentrations in San Onofre receiving waters and ocean bottom sediments was conducted in compliance with ETS Section 3.1.1.a.(2) and NPDES Permit No. CA0001228 (CRWQC, SDR Order No. 76-11). Units 2 and 3 monitoring was conducted in compliance with PMP requirements. Samples were

collected bimonthly at Unit 1 Stations X0, D4N, D4S, and C22S and at Units 2 and 3 Stations J0, J2S, J4S, J4N, and J22S (Figures 2A-1 and 2A-2). All samples were analyzed for chromium, copper, nickel, iron, and titanium. The PMP heavy metal sampling was terminated after July 1980 as the required two-year data base had been established. Heavy metals monitoring for ETS was changed to quarterly surveys after July 1980, hence, no samples were collected during the September survey.

RESULTS AND ANALYSIS

This section presents results of 1980 measurements of dissolved oxygen, hydrogen ion concentration, and heavy metals.

DISSOLVED OXYGEN

Surface concentrations of dissolved oxygen were relatively uniform over the entire San Onofre study area with the exception of the 13 March and 10 September surveys. Units 2 and 3 (offshore) stations generally had higher dissolved oxygen concentrations, percent saturation, and spatial variation in March. Surface dissolved oxygen concentrations at offshore stations ranged from a maximum of 10.3 mg/liter in March to a minimum of 7.9 mg/liter in January and May. Spatial variability as greatest in March, when DO concentrations ranged from 8.3 to 10.3 mg/liter in the offshore study area, and least in January, when DO concentrations ranged from 7.9 to 8.2 mg/liter.

Unit 1 operational (inshore) stations generally had highest surface dissolved oxygen concentrations and percent saturation in March, when surface dissolved oxygen concentrations ranged from 8.6 to 10.0 mg/liter. Greatest spatial variation was observed in May, when surface DO concentrations ranged from 7.9 to 10.6 mg/liter. Lowest DO concentrations at the inshore stations were observed in September (7.1 mg/liter). Least spatial variation occurred in November, when surface DO concentrations ranged from 8.3 to 8.6 mg/liter among inshore stations.

HYDROGEN ION CONCENTRATION

Hydrogen ion concentration (pH) varied only slightly at both inshore and offshore stations. Values of surface pH ranged from 8.1 to 8.4 units. Highest pH values were observed in March and May, and lowest in July and September. There was little spatial variability in either the inshore or offshore study areas, and no distinct on-offshore or upcoast-downcoast trends were noted.

HEAVY METALS

Results of receiving water heavy metals analaysis are presented first, followed by results of ocean bottom sediment analysis.

Receiving Waters

The range, mean, and standard deviation of heavy metals in the receiving waters and sediments at Units 2 and 3 stations during the past three years are presented in Table 2C-2.

Yearly means of offshore Units 2 and 3 receiving water heavy metals concentrations for 1980 were relatively low for most metals and varied little between sampling stations. Nickel concentrations generally ranged from less than 0.001 mg/liter to 0.010 mg/l with the exception of the maximum concentration of 0.074 mg/liter which was measured at Station J4N in May. Copper

Table 2C-2. Summary of maximum, minimum, and standard deviation of heavy metals concentrations in receiving water and ocean bottom sediments for operational stations from 1978-1980.

PREOPERATIONAL UNITS 2 AND 3

RECEIVING WATER (mg/l)

Metal	Item	J0	J2N	J2S	J4N	J4S	J22S
		Sampling Station					
Copper	Min/Survey	0.001/Mar,Nov '79	0.007/May '78	0.0007/May '78	0.001/May '78	0.001/May,Jul '78	0.001/Jul '80
	Max/Survey	0.19/May '79	0.007/May '78	0.018/Sep '79	0.011/Jul,Nov '79	0.011/Jul,Nov '79	0.10/Jul '79
	Mean	0.027	0.007	0.0065	0.0062	0.005	0.0071
	Std Dev	0.058	0.0	0.0050	0.0050	0.004	0.0062
Chromium	Min/Survey	0.0003/Jul '78	0.0006/May '78	0.0004/May '78	0.0007/Nov '78	0.0008/May '78	0.0007/Sep '78
	Max/Survey	0.011/Jul '79	0.0006/May '78	0.007/Jul '79	0.005/Jul '79	0.006/Jul '79	0.006/Jul '79
	Mean	>0.0026	0.0006	>0.002	>0.002	>0.0018	>0.002
	Std Dev	0.003	0.0	0.0017	0.002	0.0014	[illegible]
Iron	Min/Survey	0.004/Sep '78	0.028/May '78	0.04/Mar '79	0.005/Nov '78	0.02/Nov '78	0.005/Nov '78
	Max/Survey	0.22/Nov '79, Jul '80	0.028/May '78	0.30/Jan '80	0.27/May '79	0.35/May '79	0.26/Jan '79
	Mean	0.12	0.028	0.13	0.12	0.13	0.13
	Std Dev	0.08	0.0	0.09	0.09	0.09	0.08
Nickel	Min/Survey	<0.001/Mar '79	0.0005/May '78	0.0004/May '78	0.0005/May '78	0.0007/Nov '76	<0.001/Jan-Jul '80
	Max/Survey	0.022/May '79	0.0005/May '78	0.026/May '79	0.074/May '80	0.02/Nov '79	0.013/May '79
	Mean	0.012	0.0005	>0.01	>0.01	>0.006	>0.008
	Std Dev	0.019	0.0	0.02	0.02	0.006	0.015
Titanium		All measurements <0.1					

SEDIMENTS (mg/kg)

Metal	Item	J0	J2N	J2S	J4N	J4S	J22S
		Sampling Station					
Copper	Min/Survey	3.6/Mar '80	3.5/May '78	1.2/Mar '80	2.9/Mar '80	0.7/May '80	1.7/May '80
	Max/Survey	7.3/Jul '79	3.5/May '78	6.6/Jul '79	8.9/May '78	7.0/Mar '79	5.3/May '79
	Mean	5.2	3.5	4.7	4.6	3.98	3.71
	Std Dev	1.12	0.0	1.62	1.50	1.54	0.84
Chromium	Min/Survey	12.0/Sep '78	12/May '78	10/May '78	11/Jul '78	7.6/May '78	8.3/Sep '78
	Max/Survey	21.0/May '79	12.0/May '78	23/Mar '79	23/May '78	21/Jan '80	24/May '80
	Mean	18.0	12	16.9	15.4	14.3	14.8
	Std Dev	3.16	0.0	3.65	3.67	4.3	3.77
Iron	Min/Survey	6900/Jul '78	5800/May '78	1240/Mar '80	5600/Nov '78	2270/Mar '80	4300/Nov '78
	Max/Survey	12200/Jul '79	5800/May '78	11800/Mar '79	13000/May '78	10200/Jul '79	8180/May '79
	Mean	9247.5	5800	8019.3	8325.7	6629.3	6607.1
	Std Dev	1899.1	0.0	2804.9	2077.6	2273.7	1142.2
Nickel	Min/Survey	5.6/Mar '80	5.3/May '78	1.3/Mar '80	3.2/Mar '80	2.9/May '78	3.5/Nov '78
	Max/Survey	11/May '79	5.3/May '78	9.7/May '79	12/May '78	10/Mar '79	7.9/May '79
	Mean	8.2	5.3	7.8	7.0	6.6	6.4
	Std Dev	1.6	0.0	1.5	2.1	2.0	1.1
Titanium	Min/Survey	240/Jul '78	540/May '78	124/Mar '80	210/Jul '78	190/Jul '78	180/Jul '78
	Max/Survey	1130/May '80	540/May '78	1150/Mar '79	1130/May '80	1160/Mar '79	1140/May '80
	Mean	805.3	540	657.2	601.8	570.5	593.3
	Std Dev	211.6	0.0	312.8	285.4	338.9	288.1

concentrations ranged from 0.001 mg/liter to 0.006 mg/liter. During 1980, chromium and titanium in the receiving waters were usually less than the detection limit.

Iron concentrations in receiving waters at PMP stations ranged from 0.06 mg/liter to 0.23 mg/liter. These iron concentrations were similar to values observed during the previous year and historical nearshore data from unfiltered samples.

The range, mean, and standard deviation of heavy metals at the Unit 1 (inshore) stations during the last three years are presented in Table 2C-3. Receiving water copper concentrations for inshore sampling stations in 1980 ranged from 0.001 mg/liter to 0.021 mg/liter with a yearly mean of 0.005 mg/liter. The maximum copper concentrations in receiving waters occurred at the discharge in November. During other surveys, copper concentrations at the discharge were similar to other stations. Chromium concentrations at inshore stations were always close to the detection limit, with a maximum value of 0.003 mg/l at Station D4S.

Yearly mean and maximum concentrations of iron in the inshore receiving waters were both highest at the point of discharge (Station X0). Iron concentrations ranged from 0.09 mg/liter to 0.71 mg/liter. Receiving water iron

Table 2C-3. Summary of maximum, minimum, and standard deviation of heavy metals concentrations in receiving water and ocean bottom sediments for preoperational stations from 1978-1980.

UNIT 1 - OPERATIONAL

RECEIVING WATER (mg/l)

Metal	Item	X0	C22S	D4N	D4S
Copper	Min/Survey	0.0007/Mar'78	0.001/Jan,Nov '79	0.0004/May '78	0.0008/May '78
	Max/Survey	0.066/Jul '79	0.013/Mar '79	3.2/Jan '80	0.12/May '79
	Mean	0.0093	0.004	0.006	0.009
	Std Dev	0.017	0.003	0.006	0.01
Chromium	Min/Survey	0.0003/Sep '78	<0.001/Jan,Jul'80	0.0004/Sep '78	0.0001/May '78
	Max/Survey	0.008/Jul '79	0.014/Jul '79	0.005/Jan '79	0.011/Jul '79
	Mean	>0.0021	>0.0048	>0.0019	>0.0026
	Std Dev	0.0019	0.0096	0.0014	0.0026
Iron	Min/Survey	0.005/Nov '78	0.0089/Nov '78	0.0047/Nov '78	0.018/Nov '78
	Max/Survey	1.2/Jan '79	0.34/Jan '79	0.36/May '80	0.40/Sep '80
	Mean	0.34	0.14	0.16	0.17
	Std Dev	0.30	0.10	0.11	0.12
Nickel	Min/Survey	0.0008/May'78	0.0012/May'78	0.0006/May'78	0.0003/May '78
	Max/Survey	0.048/Nov '79	0.029/Nov '79	0.078/Nov '79	0.017/May '79
	Mean	0.009	>0.008	0.012	>0.007
	Std Dev	0.01	0.01	0.017	0.006
Titanium		All measurements <0.1			

SEDIMENTS (mg/kg)

Metal	Item	X0	C22S	D4N	D4S
Copper	Min/Survey	3.3/Jul '80	1.0/Jan '79	0.025/Jun '79	1.2/Nov '80
	Max/Survey	8.2/Mar '79	5.9/Jul '78	8.8/Mar '80	5.4/Jul '78
	Mean	4.9	3.67	5.5	5.2
	Std Dev	1.33	1.24	1.95	4.94
Chromium	Min/Survey	8.0/Sep '78	3.0/May '79	9.2/Mar '78	6.0/Nov '80
	Max/Survey	17.0/May'80	23.0/May '80	25.0/May '80	44.0/Mar 80
	Mean	13.6	12.9	14.3	16.98
	Std Dev	2.55	4.71	4.98	8.76
Iron	Min/Survey	6400/Sep '78	1160/May '79	5190/Jan '80	2000/Nov '80
	Max/Survey	14400/Mar '79	9000/Jul '78	11900/Jul '80	28800/Mar '8[illegible]
	Mean	8713.5	6190.5	9505.9	8241.8
	Std Dev	2023.5	2143.3	3455.5	5771.1
Nickel	Min/Survey	4.0/Jul '80	2.9/May '78	4.8/Nov '79	3.9/May '78
	Max/Survey	11.0/Mar '79	11/Jul '78	13/May '80	28/Mar '80
	Mean	7.2	6.1	7.9	8.5
	Std Dev	2.0	2.0	2.7	5.4
Titanium	Min/Survey	270/Sep '78	171/Jan '79	210/Jul '78	210/Nov '78
	Max/Survey	1000/Mar '79	969/May '80	1240/May '80	1190/May '80
	Mean	485	541	638.5	624.4
	Std Dev	281.2	217.4	294.7	315.6

concentrations at the discharge were higher than those at the control station during all but the July survey. Maximum concentrations of iron, occurring at the discharge, were three times greater than those measured at Stations C22S, D4N, and D4S.

Concentrations of nickel in the receiving water ranged from less than 0.001 mg/liter to 0.015 mg/liter, with a yearly mean of 0.006 mg/liter. Maximum nickel concentrations occurred at Station D4S during two surveys (10 March, 8 July) and this station also had the greatest yearly mean concentration.

All receiving water titanium concentrations were less than the detectable limit (0.1 mg/liter) for all sampling stations.

Ocean Bottom Sediments

The range, mean, and standard deviation of heavy metals in the sediment at Units 2 and 3 stations during the last three years are presented in Table 2C-2. Sediment copper concentrations from offshore stations for Units 2 and 3 ranged from 0.7 to 6.1 mg/kg with a yearly mean of 3.7 mg/kg for all stations combined. Concentrations of copper were slightly higher in January and July than during other months. Chromium concentrations ranged from 7.9 to 24 mg/kg, with an annual mean of 17 mg/kg.

Ocean bottom sediment iron concentrations in the offshore study area ranged from 1240 to 10,000 mg/kg, with a yearly mean of 7300 mg/kg. Sediment concentrations of nickel ranged from 1.3 to 9.9 mg/kg, with an annual mean of 6.6 mg/kg. Titanium concentrations ranged from 201 to 1140 mg/kg, with a yearly mean of 750 mg/kg. Sediment concentrations of chromium, iron, nickel, and titanium were all lowest during March, and were similar during other months.

The range, mean, and standard deviation of heavy metals in the ocean bottom sediment at Unit 1 stations during the last three years are presented in Table 2C-2. Sediment copper concentrations ranged from 1.2 to 24 mg/kg. The highest value occurred at Station D4S in March, and is nearly three times larger than ar[illegible] for 1980. The annual mean copper concentration was 5.8 mg/kg. Ch[illegible]trations ranged from 6 to 44 mg/kg, with an annual mean of 18 mg[illegible]nt iron concentrations ranged from 2000 to 28,800 mg/kg, with an annual mean of 9880 mg/kg. Nickel concentrations ranged from 4.0 to 28 mg/kg, with an annual mean of 9.0 mg/kg. Concentrations of titanium in the sediments ranged from 352 to 1240 mg/kg, with a yearly mean of 752 mg/kg.

The maximum concentrations of copper, chromium, iron, and nickel in the inshore study area were all observed at Station D4S in March. Concentrations of these metals were similar during the remaining surveys in 1980. Concentrations of all sediment heavy metals at inshore stations were usually greater at Stations D4N and D4S than at Stations X0 or C22S.

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CHAPTER 2D

SEDIMENTOLOGY

INTRODUCTION

This chapter describes marine geological conditions near the San Onofre Nuclear Generating Station (Figure 2D-1) and discusses the results of 1980 marine sediment monitoring to determine effects resulting from construction and dredging operations associated with placement of offshore cooling water conduits and related structures for San Onofre Units 2 and 3 (Figure 2D-1). The program also provides preoperational sedimentology data. The sediment monitoring program was conducted in conjunction with the biological infaunal studies described in Chapters 4A and 5A. The study met regulatory requirements for the Construction Monitoring Program (CMP).

The purpose of the present 1980 sediment monitoring was to 1) assess the effects of sand dispersal during and after construction and dredging operations associated with the addition of San Onofre Units 2 and 3 to the existing generating facility, and 2) to provide information on physical variables previously identified as being major factors influencing the distribution and abundance of benthic organisms.

Sedimentological investigations were conducted in both the intertidal and subtidal nearshore environments adjacent to San Onofre. Data collected during 1980 are presented in the summary data report (SCED 1981a) and the comprehensive data report (SCE 1981b).

BACKGROUND

PREVIOUS STUDIES

Environmental studies of San Onofre intertidal and subtidal areas began in the fall of 1963 and have continued through the construction and operation of San Onofre Unit 1 (Table 2D-1). Early studies of the San Onofre area referred to the sedimentary environment as sandy or cobble in the context of infauna or epiflora substrates. No granulometric analyses were reported; the sand/cobble ratio was reported for 1964, 1965, 1967, 1968, 1969, 1970 and 1971. The sediment at benthic Station A 2000 ft offshore and 2800 ft upcoast of the outfall was reported to have abundant or little sand compared to cobble. Alternatively, only the presence or absence of cobble was noted at benthic Stations B through F and the Barn kelp and San Mateo kelp benthic stations. In 1972 and 1973, grain size analyses were obtained for 8 sets of samples from 19 offshore stations.

The existence or absence of sand substrate was noted when benthic (subtidal) and intertidal samples were collected for the Marine Environmental Monitoring and San Disposal Monitoring programs (Lockheed Center for Marine Research [LCMR] 1974, 1975, 1976). Mean percentages of sand at eight stations, two zones, and the three kelp stations were reported monthly between April 1975 and November 1977 (LCMR 1977).

The first formal sedimentological studies under the Construction Monitoring Program (CMP) began in 1976 and continued until 1980. In 1980, one sandy

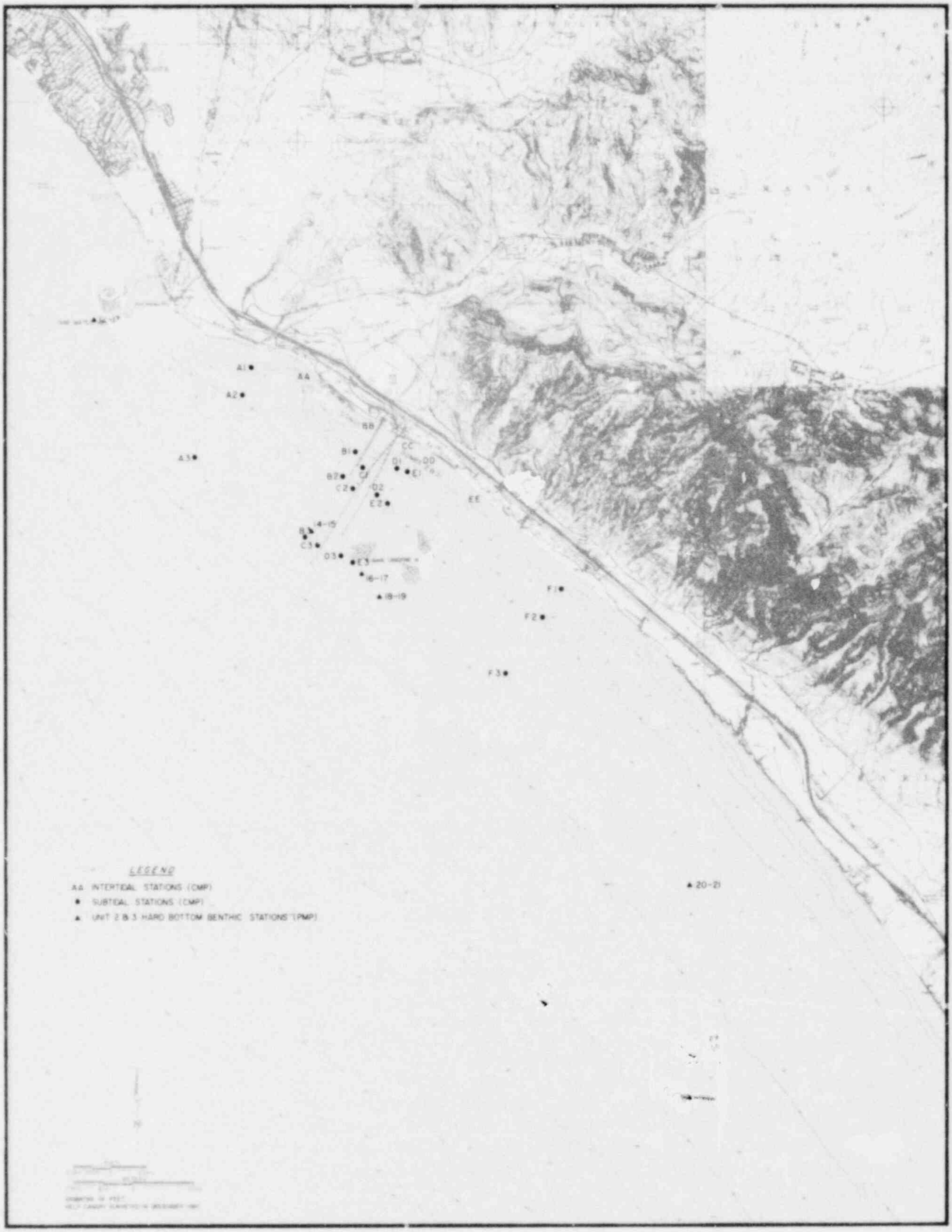

Figure 2D-1. Sediment stations.

Table 2D-1. Chronological history of SCE-sponsored studies producing sedimentological information at the San Onofre site.

Major Programs	Date	Frequency	Locality	Replicates	Type of Data Collected
Marine Environmental Monitoring					
Unit 1 Preoperation	1963-66	Semiannual	Offshore SONGS	Visual observations of substrate type	10 intertidal surveys, 21 intertidal surveys. Sand cobble ratio at benthic
Unit 1 Operation	1966-72	"	Unit 1.	"	Station A; presence or absence of sand or cobble at benthic Stations B-F, Barn kelp and San Mateo kelp.
Unit 1 Operation	1972	Mar, Apr, Jun, Aug, Oct	Offshore SONGS Unit 1	Diver-obtained grab samples	Granulometric analyses of sediments at 19 benthic stations.
"	1973	Jan, Apr, Jun		"	"
Marine Environmental Monitoring	1974	4/yr	Offshore	Visual observations	Mean % of sand at 8 stations in 2
Semiannual Operating	1975	"	SONGS	of substrate at	benthic zones and 3 kelp stations
Sand Disposal Monitoring	1975	Apr, Sep, Dec	Units 2 & 3.	benthic (subtidal) intertidal stations	"
"	1976	Feb, Apr, Sep, Dec		"	"
Construction Monitoring Program (CMP)	1976-77	4/yr at 18 benthic stations	"	Core samples obtained by diver offshore (18 sed-	Granulometric analyses of sediment samples, intertidal and subtidal, plus organic and carbonate carbon
CMP and Preoperational monitoring Program (CMP) of Units 2 and 3	1978	and 5 intertidal stations		iment traps, 66 benthic grain size, 114 benthic carbon)	content on subtidal only.
"	1979	"		and hand coring on the beach (175	"
"	1980	"		intertidal grain size/quarter)	"

intertidal biological survey was conducted (February). Concurrent with biological sampling, five replicate sediment samples were collected at seven intertidal levels, from five stations. Grain size distribution characteristics were determined for these samples. In addition, beach profiles were recorded for each station at the time of sampling. Since offshore dredging was completed in March 1980, no additional quarterly surveys were performed.

In 1980, benthic infaunal surveys were conducted in March and June. Biological and sedimentological samples were collected at 18 stations with replication dependent on water depth. Sediment samples were analyzed for grain size and organic carbon content. In addition, monthly collections from sedimentation traps were analyzed for the same time period. Since offshore dredging was completed in March and all offshore trestle structures has been removed by April, the last quarterly survey was conducted in June.

As part of the Preoperational Monitoring Program (PMP) LCMR recorded certain physical/chemical environmental data including sediment accumulation with their Benthic Sensing Package (BSP) at selected stations. The BSP data and results are presented in Chapter 5B.

HISTORY OF CONSTRUCTION

Preparation of the construction site for San Onofre Units 2 and 3 was initiated in March 1974. The construction site is located adjacent to and southeast of San Onofre Unit 1.

Two contiguous trestles were constructed from July through December 1976 for the installation of the Unit 2 intake and discharge conduits. The trestles extended approximately 1006 m offshore from the onshore staging area. 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 San Onofre Unit 3. The trestles seaward of the intake structure of Unit

3 were removed in 1979; the remaining portion of the Unit 3 trestle on the discharge side was removed between 11 March and 30 April 1980 and the portion on the intake side was removed between 4 September and 5 December 1980.

During San Onofre Units 2 and 3 site preparation, approximately 1,739,923 m^3 of spoil material was excavated from the bluff adjacent to San Onofre 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 and is being used for shop and office locations during plant startup and testing. 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-2). 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-2).

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 (19.6 ft) and 9 m (29.5 ft) isobaths (Figure 2D-2).

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) to compensate for interruption of the natural sand transport path by the construction laydown pad on the beach.

Table 2D-2. Volume and disposition of disposed sand (m^3) 23 March 1977 through January 1980.

Month	Offshore Conduit/ Backfill Placement	Beach Placement	Nearshore
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		
1980			
Jan	8,492		

The final dredging activity consisted of a small amount of material (8,492 cubic yards) deposited in January 1980 on the south side of the Unit 3 discharge structure terminus at a depth of 15 m (49.2 ft).

A summary of the dredge material displacement at San Onofre during 1977 to May 1980 is presented in Table 2D-2 with the quantity, location, and time of placement shown in Figure 2D-2.

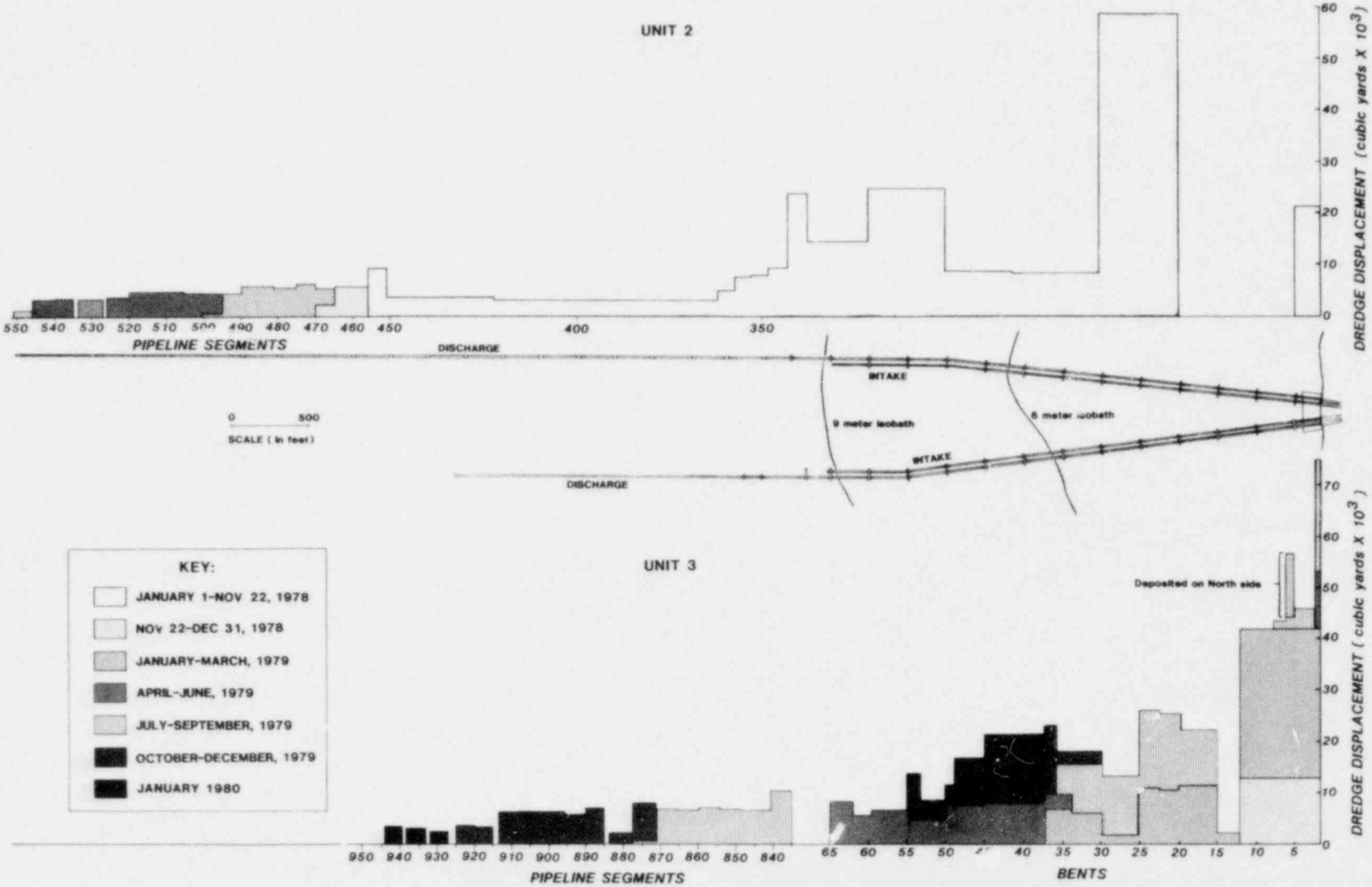

Figure 2D-2. Dredge spoil displacement quantities along San Onofre Nuclear Generating Station Units 2 and 3, discharge, and intake structures.

MARINE GEOLOGICAL SETTING

The San Onofre 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 San Onofre 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 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

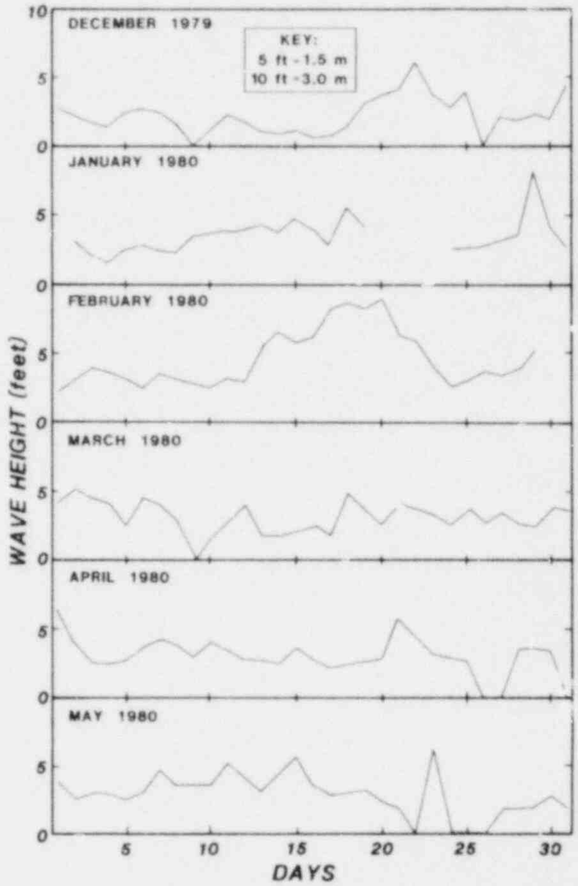

Figure 2D-3. Daily maximum significant wave height in the vicinity of the San Onofre Nuclear Generating Station site from December 1979 through May 1980.

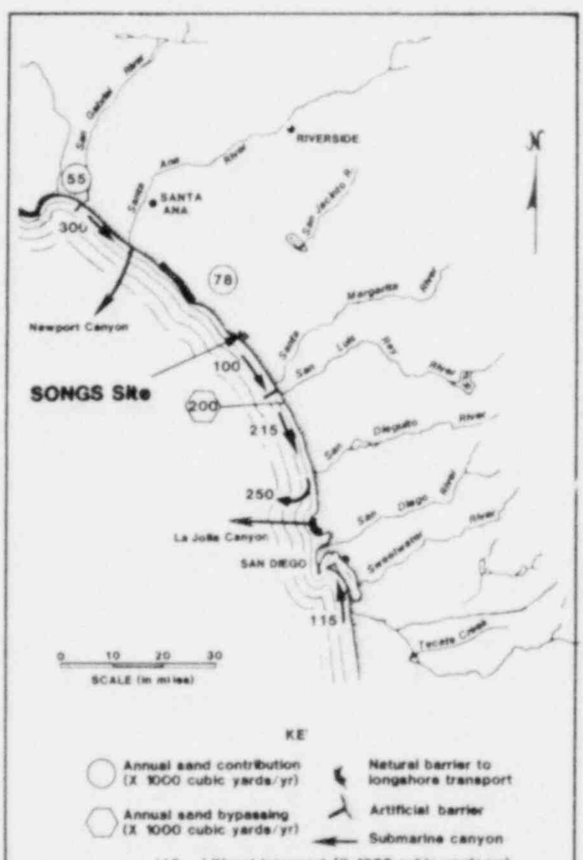

Figure 2D-4. Rates of longshore transport of sand in the SONGS area (State of California 1977).

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. The rock in the bluffs and cliffs are soft tertiary marine sandstones that weather to provide an 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 fine sediments 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 (32.8 ft), 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 tractively shoreward 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 of 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 San Onofre. 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 San Onofre 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.

DISCUSSION

INTERTIDAL ZONE

Beach Profile

Beach profile mesurements in 1980 indicated that the impoundment of beach sand continued at the construction pad. A wide beach formed just upcoast of the pad and sediments changed little during the year. Most impounded material was effectively removed from transport by beach drift (lateral tractive transport of sand in the swash-backwash zone). Downcoast of the pad beach stability was reduced, and erosion and accretion modified the intertidal zone in response to changes in the direction of wave attack. Most changes in the intertidal zone probably related to natural seasonal and episodic changes in the littoral environment.

Beach Sediment Characteristics

Granulometric and statistical analyses of intertidal sediments sampled in 1980 permitted the characterization of active processes in the intertidal regime. Sediment properties developed by the analyses were typical of the intertidal environment. The groin effect of the construction pad was evident in its stabilization of statistical measurements of the sediments upcoast of the pad.

Analysis of intertidal sediment statistics for 1979 established the existence of four major intertidal sediment facies:

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

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.

Such subtle distinctions in sediment type were not discernible in the February 1980 intertidal sediment samples. A coarse-to-medium sand existed at the lowermost elevation on all transects except CC. Sediments along Transect AA were particularly rich (5 to 27%) in gravel. These sediments probably represent Facies II, III, and IV. No representative of the fine grained sediment facies (I) were found.

Apparently, winter storms reworked the beach sands and removed the fine fraction leaving behind coarser sediment than was observed in December 1979. The finest sediment (a medium sand with average mean grain size of about 1.25 phi) was found in Transect BB just upcoast of the construction pad. It is likely that this sediment represents entrapment of beach drift by the pad.

Only one effect associated with construction at the San Onofre site was evident: The extremely small variation of sediment statistics at Transect BB, upcoast of the San Onofre 2 and 3 construction pad, was attributed to the groin effect of the pad. Sediment at Transect BB was impounded by the pad and therefore was not subject to the free littoral transport that occurred elsewhere near the site.

THE SUBTIDAL ZONE

Sedimentation Rates and Changes in Sea Floor Elevation

The sedimentation rate was generally highest and most variable at inshore (6 m, 19.6 ft) stations, and lowest and least variable at offshore (15 m, 49.2 ft) stations. Intermediate stations (9 m, 29.5 ft) exhibited intermediate rates. Sedimentation rates were substantially higher in 1980 than in 1979. Sediment rates apparently 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.

Changes in sea floor elevation were often greater than those indicated by the sedimentation in the traps positioned a meter or so above the sea floor, indicating the sea floor erosion and accretion were caused by material moving laterally along the bottom below the traps, presumably by the tractive effect of passing waves. Most of the changes in sea floor elevation appear to have been caused by winter storms.

The subtidal sediment facies identified in the 1978 and 1979 studies were recognized in the 1980 study results. The differences noted in the present study were caused by the use of mean versus sorting plots rather than factor analysis to discriminate facies.

A general trend in the facies distribution was for fine sand facies to occupy most inshore stations except at the upcoast Transect AA. Also, the occurrence of relict sediment at Stations E3, C2, and D3 suggest that little sediment was being introduced at those sites. This is consistent with the outer limit of the littoral zone being between the 20 and 30 ft isobaths.

No effects of construction or of trestle removal was evident in the distribution of subtidal sediment facies in March and May 1980.

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The measurement of inorganic carbon (carbonate) in subtidal sediments was valuable as a discriminator of relict sediments. Organic carbon content of subtidal sediments, though probably important to the benthic infauna, provided no

direct information regarding natural or artificial processes active in the subtidal zone. Extreme values of organic carbon content, not previously observed, were measured in 1980.

This concludes the overall discussion. Detailed 1980 methods and results are presented in the sections that follow.

APPROACH

To detect and evaluate the effects of construction for Units 2 and 3 on intertidal and subtidal sediments at San Onofre, evidence of anomalous sediment conditions attributable to construction effects was sought. 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 used were:

1. Mean Grain Size. This statistic summarizes 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 asymmetry 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 Kg = 1.00. Platykurtotic curves (Kg < 1.00) suggest the incomplete fusion of two or more distinctly different sediment types. Values of Kg > 1.00 are leptokurtotic and thus indicate the relative absence of size extremes resulting from selectivity in transport and reworking of sediment deposits.

METHODS

Sediment characteristics of the intertidal and subtidal areas adjacent to San Onofre were sampled during one quarterly survey in 1980 (SCE 1981 a-b).

Thirty-five intertidal sampling stations along 5 transects and 18 subtidal stations along 6 transects were established (Figure 2D-1). Sampling was initiated in December 1976, four months prior to commencement of dredging, and continued quarterly through May 1980. The results, analysis, and interpretations presented herein are based on data collected during quarterly surveys conducted in 1979 and 1980. The results of prior sediment studies were presented in 1978, 1979 and 1980 annual reports (MBC 1978; SCE 1979, 1980).

Because intertidal and subtidal environments at San Onofre were seen to be distinctly different, with easily distinguishable abiotic and biotic characcteristics, 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 were conducted along five permanently established transects perpendicular to the shoreline (Figure 2D-1). 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 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 2.4 m) tidal elevation (from MLLW) at each transect was located by surveying from permanent reference marks of known elevation.

During the 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 (0.3 m) elevation intervals from +6 ft (1.8 m) 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 from 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 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).

Grain size data were 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 were 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 subtidal infaunal surveys conducted by divers using SCUBA equipment. During each survey, permanent stations were occupied at the 6, 9, and 15 m (19.6, 29.5, and 49.2 ft, respectively) isobaths along each of six transects were occupied (Figure 2D-1). Three transects were located upcoast and three downcoast at prescribed distances from a reference transect running midway between the cooling water conduits of San Onofre 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.

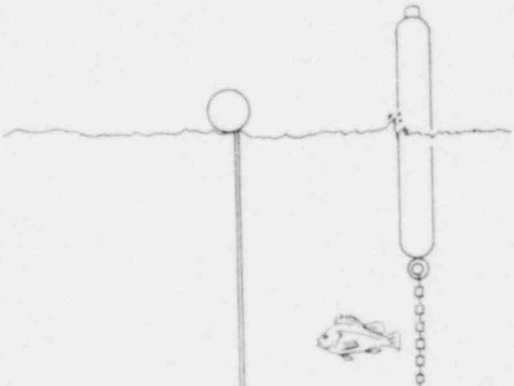

Figure 2D-5. Subtidal sediment trap and monument construction.

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 (20.4 in) long and with a diameter of 10.6 cm (4.2 in). A funnel, recessed 4.5 cm (1.8 in) below the top of the trap with a 3.0 cm (1.2 in) opening at its bottom, was installed to prevent 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.

Organic Carbon Analysis

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 and 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 $C\text{-}CO_3$ 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).

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 San Onofre site to allow recognition of anomalous sediment conditions caused by construction activities.

RESULTS AND ANALYSES

The results of measurements and analyses of the geomorphic and sedimentological properties of the San Onofre 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 San Onofre 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 (774.3 ft), 629 m (2063.7 ft), and 1187 m (3894.5 ft) (Figure 2D-1).

Topographic profiles were measured at each transect in December 1979 and in February 1980. Data obtained from beach profile measurements are presented in Table 2D-3. The profiles were plotted (Figure 2D-6) to show the changes in beach morphology during successive measurements.

The profiles indicated that little change from beach erosion or accretion occurred at the San Onofre site except at Transect CC where the greatest change in beach profiles occurred.

The changes in the profiles (Figure 2D-6 and Table 2D-3) from November 1979 to January 1980 represent minor adjustments to the wave and wind regime during the winter season. The changes in beach profiles from November 1978 to January 1980 (Figure 2D-7) are characterized by accretion at Transect BB and to a lesser extent at Transects AA and DD. Transect EE showed the least change and Transect CC showed most change at the berm and backshore, unlike the other transects.

Summarizing changes at the study site, the shore advanced upcoast (especially immediately upcoast) of the construction pad and retreated slightly at Transect EE. In addition, the beach also retreated just downcoast of the pad. Considerable advance occurred at Transect DD, 629 m (2063 ft) 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 San Onofre site (Transects AA and EE) showed relatively little change in area from November 1978 to January 1980.

Table 2D-3. Beach characteristics.

	Beach		Upper Beach Slope		Lower Beach Slope		Beach		Upper Beach Slope		Lower Beach Slope	
	Profile Area (ft^2)	Width (ft)	Cotangent of Slope	Degrees	Cotangent of Slope	Degrees	Profile Area (ft^2)	Width (ft)	Cotangent of Slope	Degrees	Cotangent of Slope	Degrees
1979			Transect AA						Transect DD			
Feb	-*	-	-	-	1.9	27.8	-	-	-	-	1.3	37.6
May	883.2	246.1	36.4	1.6	9.1	6.3	1126.4	380.6	7.4	7.7	20.4	2.8
Aug	855.7	311.7	18.9	3.0	15.1	3.0	777.3	252.6	8.1	7.0	11.3	5.1
Nov	909.5	347.8	26.6	2.2	14.9	3.8	977.7	347.8	8.6	6.6	17.2	3.3
1980 Feb	817.3	259.2	30.8	1.9	12.6	4.5	889.2	236.2	7.7	7.4	10.3	5.6
1979			Transect BB						Transect EE			
Feb	-	-	-	-	2.7	20.3	-	-	-31.4	-1.8	1.5	33.7
May	1580.1	465.9	97.4	0.6	13.9	4.1	568.6	193.5	-31.4	-1.8	9.1	6.3
Aug	1617.2	456.1	148.1	0.4	11.6	4.9	668.3	246.1	-263.7	-0.2	10.6	5.4
Nov	1652.9	459.3	102.9	0.6	16.9	3.4	608.6	190.2	-40.9	-1.4	7.2	7.9
1980 Feb	1666.4	511.8	182.8	0.03	11.7	4.9	593.5	200.1	-32.0	-1.79	9.1	6.3
1979			Transect CC									
Feb	-	-	-	-	1.9	27.8						
May	967.2	278.9	10.9	5.2	10.0	5.7						
Aug	1336.0	452.8	17.4	3.3	16.2	3.5						
Nov	753.9	253.9	9.7	5.9	15.0	3.8						
1980 Feb	1084.0	298.6	13.4	4.3	9.5	6.0						

*not measured

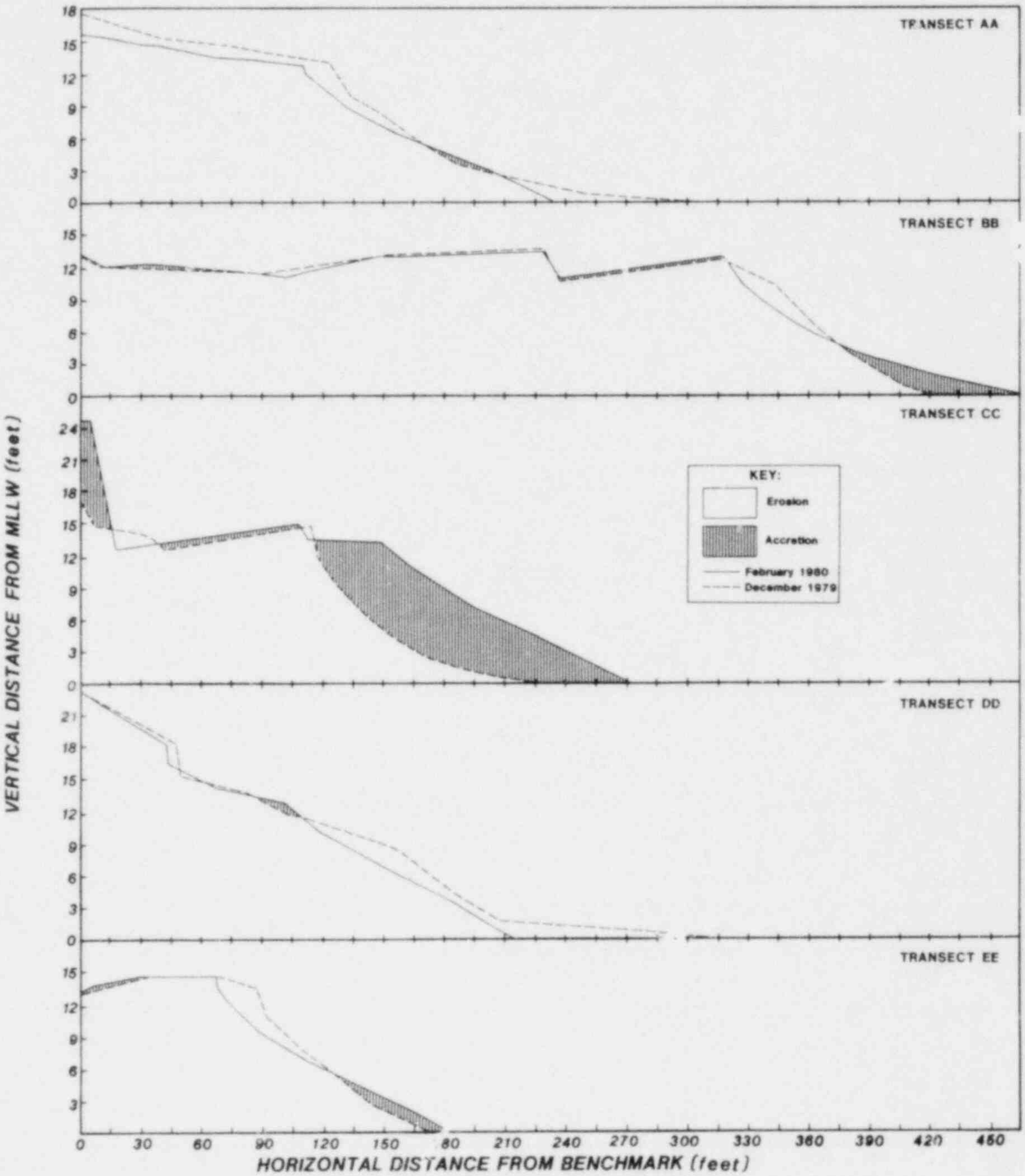

Figure 2D-6. Beach profiles at intertidal transects.

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

3. Profile BB, just upcoast of the site, showed the least change in area from May 1979 to January 1980; the change from November 1978 to January 1980 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.

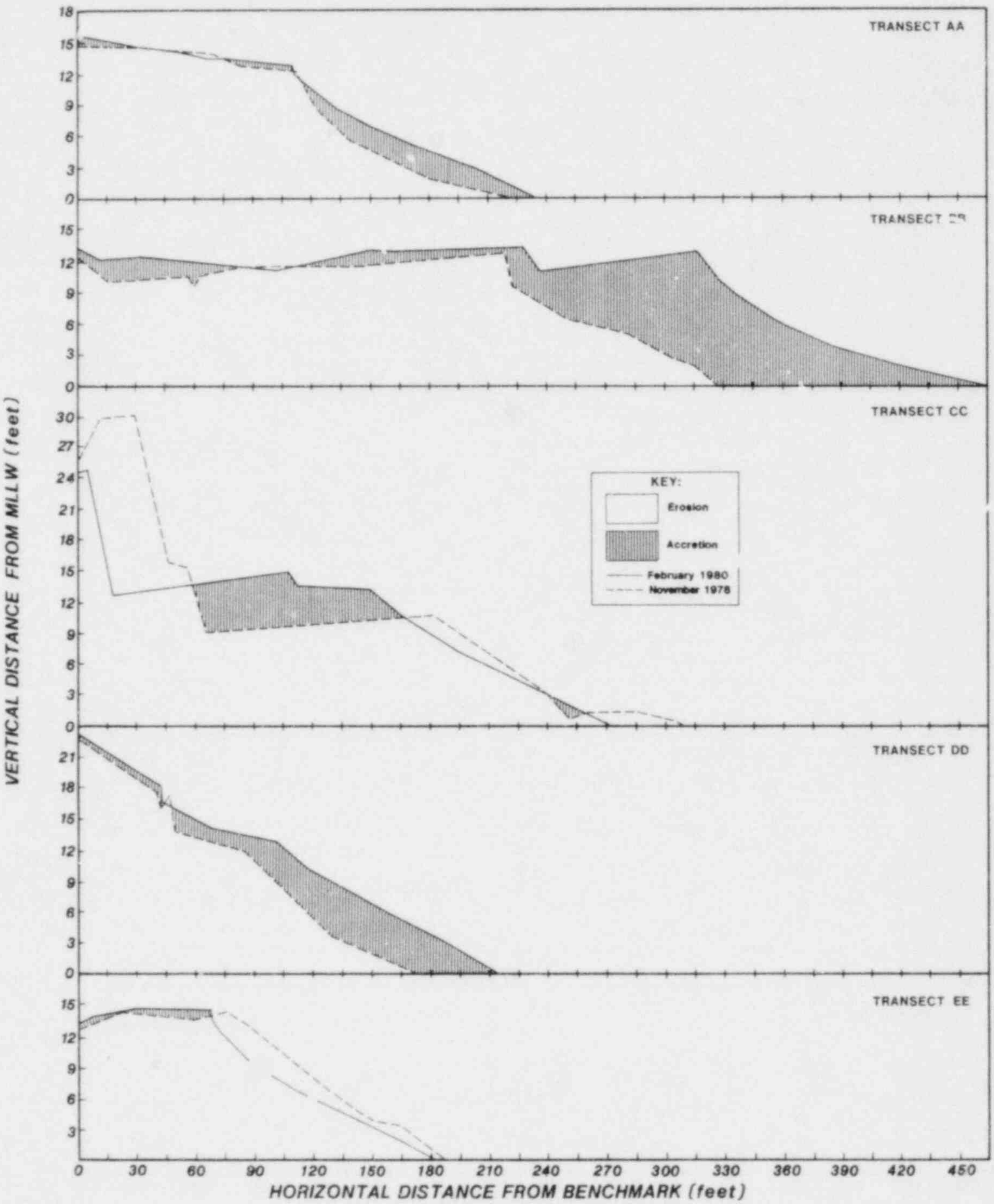

Figure 2D-7. Annual changes in intertidal beach profiles.

Beach Sediment Characteristics

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 from December 1979 to

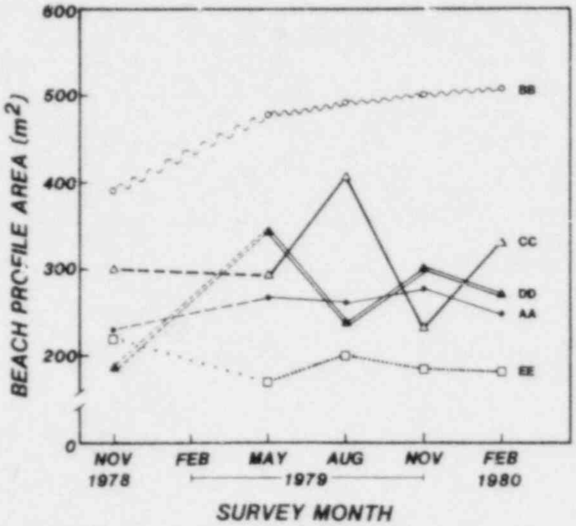

Figure 2D-8. Changes in intertidal beach profile areas.

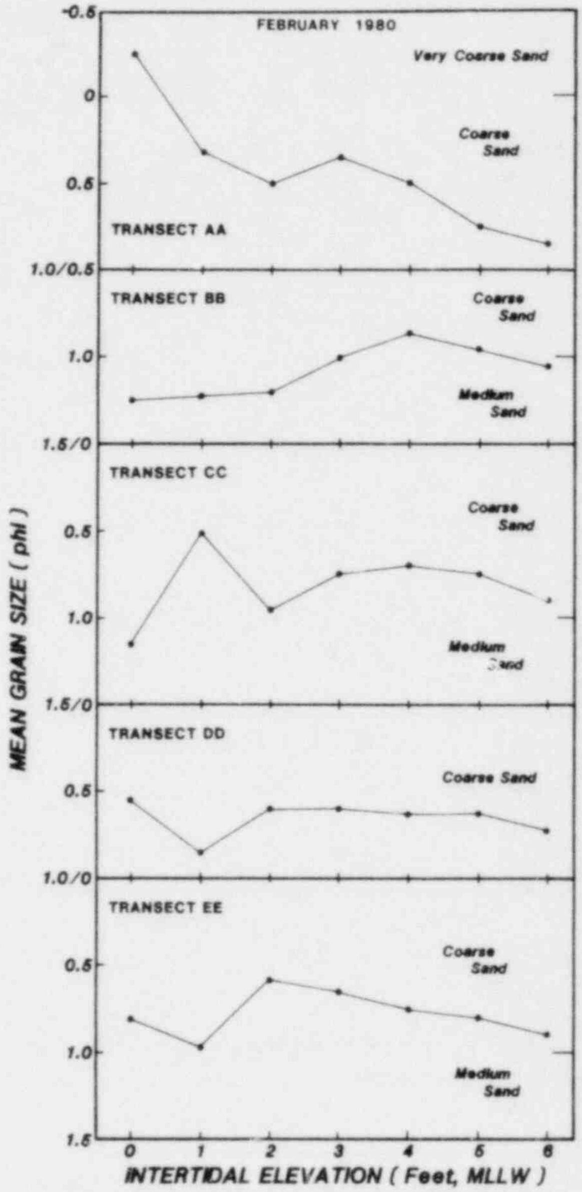

Figure 2D-9. Mean grain size profiles by level.

February 1980, while Transect AA sediments 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), where the sediments 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 only reached by waves during high tides or periods of high waves (usually the winter). There was no tendency for coarser mean grain sizes to occur at high beach elevations in 1980. This phenomena was observed in 1979, however, thus conforming to the expectation that coarse sediments would be transported and deposited at high beach elevations by high winter waves.

Comparing February 1980 data with that taken in December 1979 showed that the mean grain size at upper beach elevations did not change appreciably. At lower elevations; however, the mean sediment grain size became coarser. This may be associated with storms (waves 5 ft high or greater) that occurred in December 1979, January 1980, and February 1980.

The gravel content (grain diameter exceeding 2 mm, or -1 phi) of sediment samples (Figure 2D-10) indicated that variability in mean grain size at Transect AA was caused by the presence of gravel in February 1980, but not in December 1979. 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.

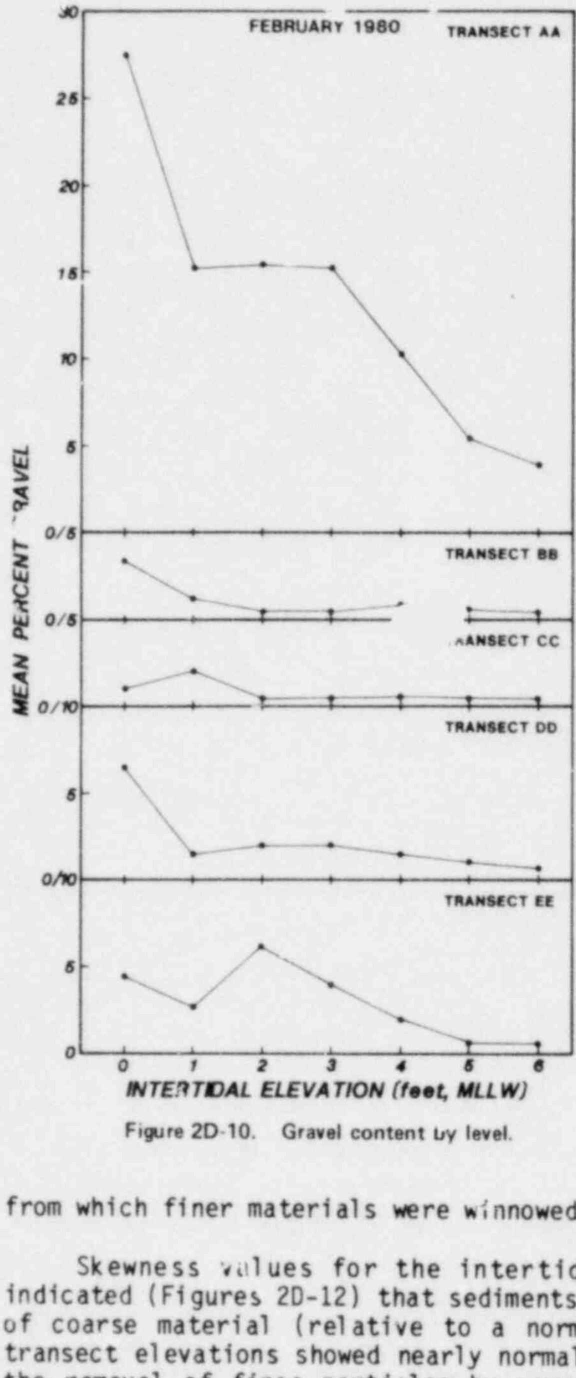

Figure 2D-10. Gravel content by level.

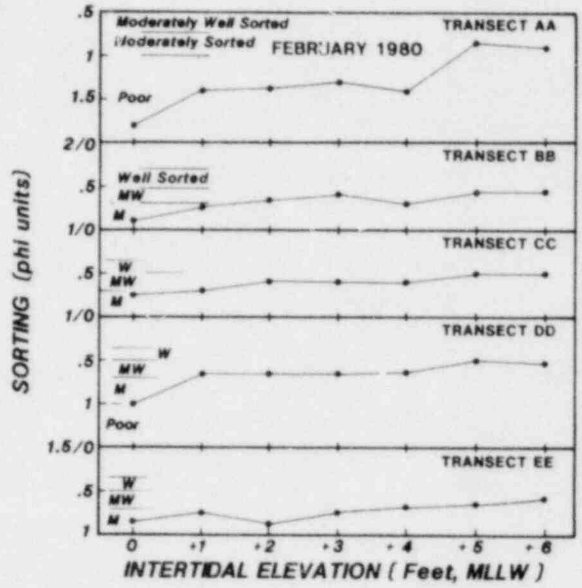

Figure 2D-11. Sorting values by level.

Sorting (Figure 2D-11) exhibited by the intertidal sediment samples varied most at Transect AA in February 1980. Sediments from other transects changed little with elevation and were moderately to moderately-well sorted. Transect BB showed the least variation in sorting with elevation and time (compared to 1979 data). Generally, sorting appeared to be somewhat improved with elevation above the transect. In all cases the lowest sorting was found at the 0 ft elevation. Sorting varied inversely with gravel content, suggesting that gravel was introduced at Transect AA in relatively unsorted sediments rather than representing residual sediments from which finer materials were winnowed by wave action.

Skewness values for the intertidal sediments sampled in February 1980 indicated (Figures 2D-12) that sediments at low tidal heights contained an excess of coarse material (relative to a normal population). Sediments at the higher transect elevations showed nearly normal distributions. This was consistent with the removal of fines particles by wave action (winnowing). Sediment samples in February 1980 were more skewed to the coarse particle size than observed in December 1979. Skewness values of the sediments at all transects except AA were within the range of values measured in 1979; the skewness of the sediments at Transect AA tended to be slightly lower in value than measured in sediments there in 1979. An excess of coarse material (winnowing of fines) seems to have occurred at all elevations on Transect AA.

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. Kurtosis tended to vary with elevation on Transects DD

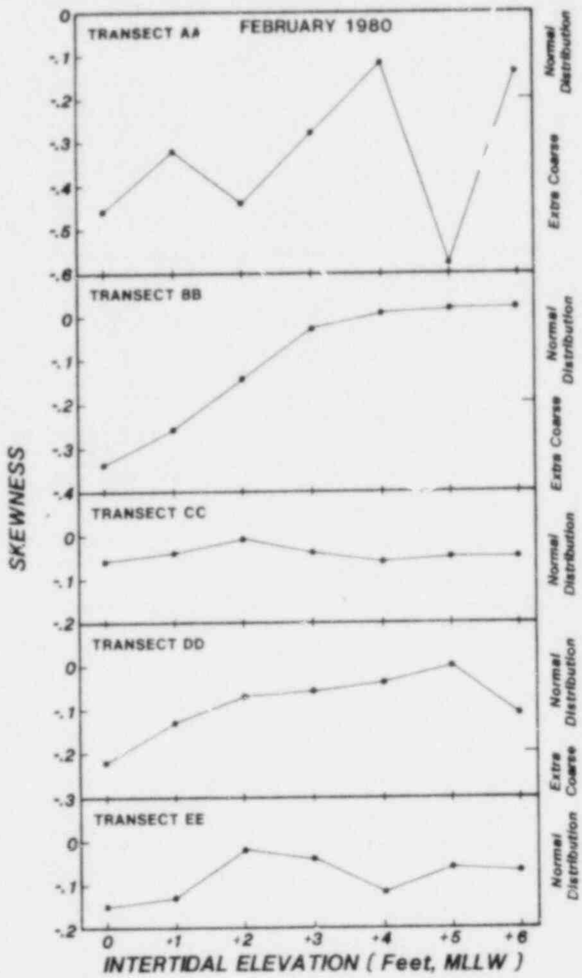

Figure 2D-12. Skewness values by level

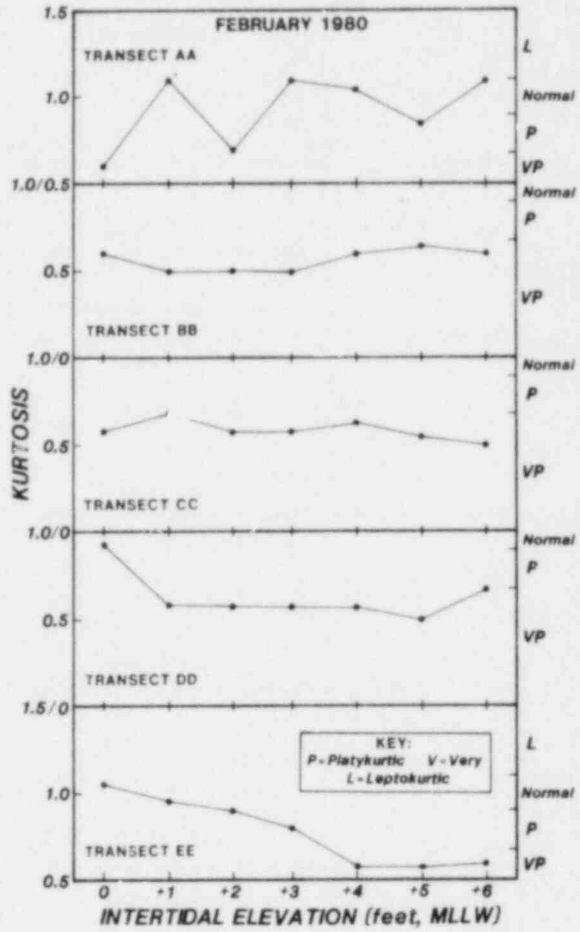

Figure 2D-13. Kurtosis values by level

and EE such that the sediments at high elevations had excesses of both extreme coarse and fine sizes. This also corresponded to the effects of winnowing at the strand and indiscriminant deposition of all suspended load toward the berm. The sediments along Transects BB and CC showed no such trend; they were characterized by excess extreme sizes at all elevations. No distinct trend in kurtosis was evident at Transect AA.

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-14. The lower curves in Figure 2D-14 represent elevations of the seafloor measured with reference to a fixed elevation on each trap.

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-14.

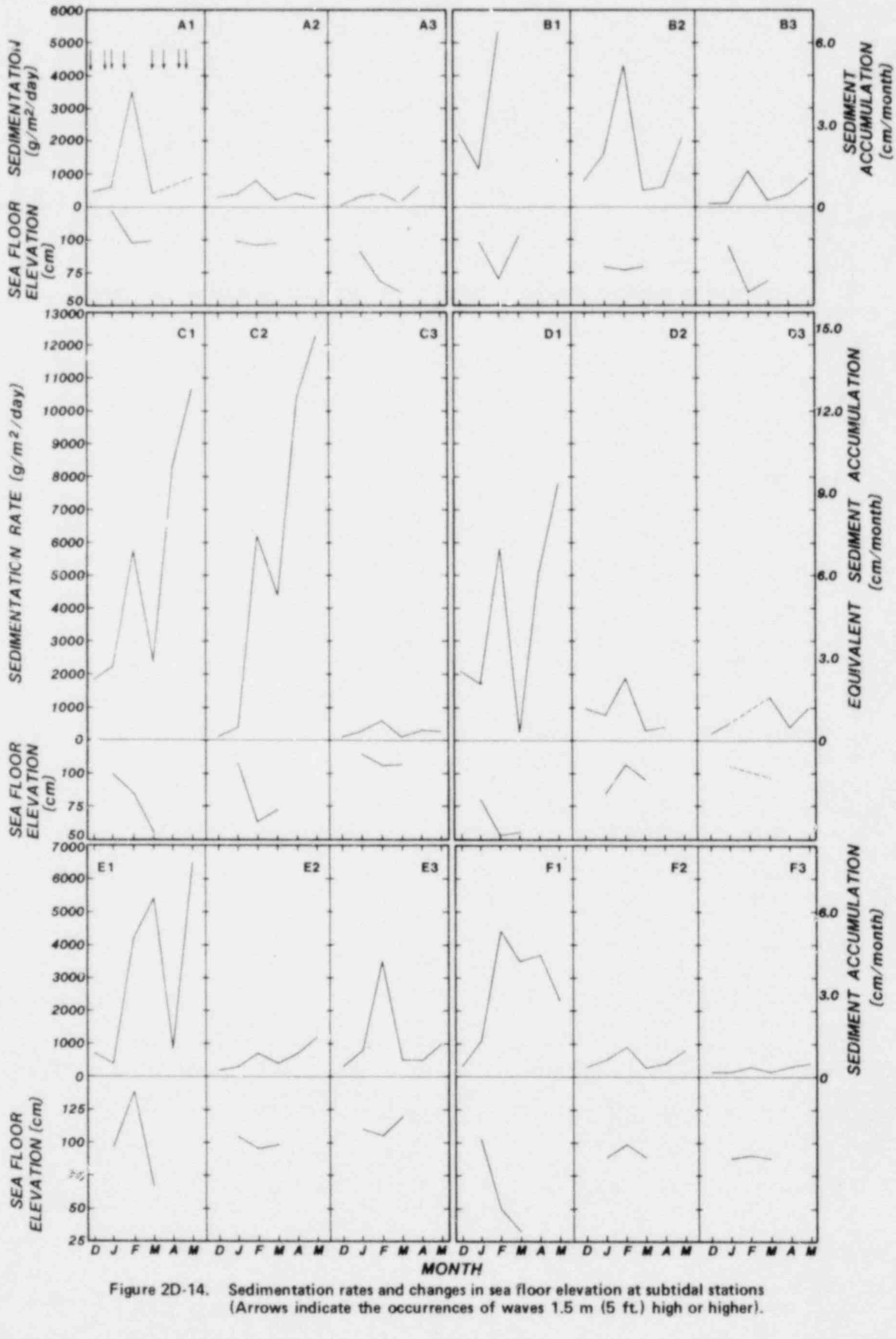

Figure 2D-14. Sedimentation rates and changes in sea floor elevation at subtidal stations (Arrows indicate the occurrences of waves 1.5 m (5 ft.) high or higher).

Table 2D-4. Net change in sea floor elevations, January to March 1980.

Station	Net Change (cm)	Station	Net Change (cm)
A1	-24	D1	-25
A2	- 2	D2	9
A3	-30	D3	- 9
B1	5	E1	-53
B2	1	E2	- 7
B3	-21	E3	10
C1	-41	F1	-70
C2	-36	F2	1
C3	- 8	F3	0

The net change in sea floor elevations is shown in Table 2D-4. Overall effect of erosion was probably caused by winter storms.

The occurrence of high (>5 ft) waves at the study site is shown in Figure 2D-14. No consistent correlation between storm waves and sedimentation rate or change in sea floor elevation was detected. An epoch of high sedimentation was measured at inshore stations (6 m) in February 1980, but no pattern of occurrence was suggested.

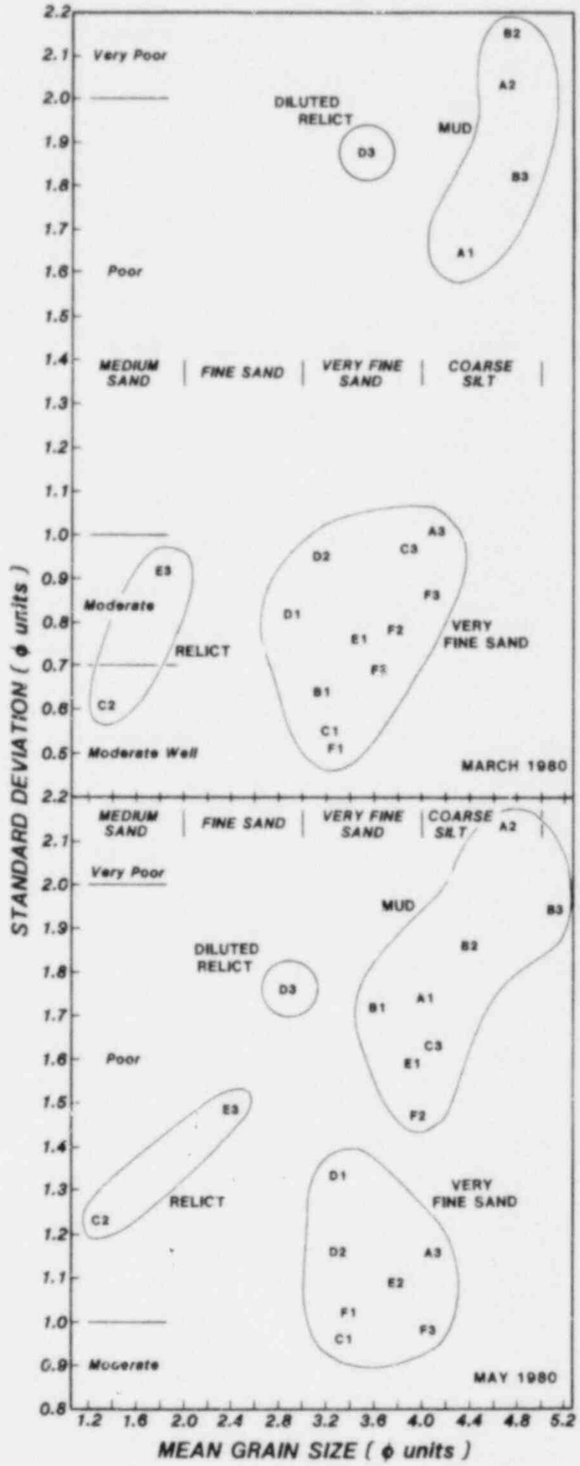

Figure 2D-15. Sorting versus mean plot of March and May 1980 intertidal sediment samples.

Subtidal Sediments

Grain size data obtained for subtidal sediments were plotted on a mean grain size versus sorting coordinate set to investigate sediment facies relationships comparable to those developed in the 1978 and 1979 studies (SCE 1980).

Four sediment facies from sediment samples collected in the subtidal zone during 1978 and 1979 were also recognized in the 1980 subtidal sediments. These facies were:

1. A variable facies of fine to very fine sand usually found at shallow (6 m) or occasionally deeper (9 m) water depths. This facies is the lower right cluster of samples of Figure 2D-15.

2. A mixed facies of mud, i.e. of silt and fine sand. This facies tended to occur at all depths and was characterized by poor sorting. This is the upper right cluster on the mean grain size versus sorting plots (Figure 2D-15).

3. A facies of coarse silt that tended to coalesce with Facies 2 and usually occurred at the deepest (9 m) stations. Only sample D3 appeared to resemble this facies; however, D3 was strongly bimodal and probably represented a relict sample diluted with fines. Facies 2 and 3 are most likely indistinguishible on the mean grain size versus sorting plots.

4. A facies of medium to coarse polymodal sand interpreted to be of relict origin. This was represented by samples E3 and C2 (Figure 2D-15).

The only samples that persistently retained sediment of the same facies in both 1979 and 1980 were E3, C2, and D3 (relict sediments) and C1, D1, D2, and F1 (shallow, fine sand facies).

The facies at each sample location persisted in most cases; however, the nature of the sediments changed from March to May 1980. Moderately sorted sediments became poorly sorted and the moderately well-sorted sediments became only moderately sorted. This was interpreted as a response to fine materials being introduced into the area between March and May. This probably represented a return of finer sediments after the cessation of winter storms.

OTHER PHYSICAL AND CHEMICAL MEASUREMENTS

Sediment Organic and Carbonate Carbon

Samples collected from the upper 2 cm (0.8 in) of bottom sediments were analyzed for total and carbonate carbon ($C-CO_3$). Total carbon is a general indicator of faunal or secondary productivity. The difference between total carbon and $C-CO_3$ represents organic carbon, a measure organic nutrients available for benthic organisms. 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 $C-CO_3$ values may range substantially higher than sediment organic carbon values.

Organic carbon values in contemporaneous sediments showed little variation over a range from 0.05 to 1.65%; most values were near 0.15% (Table 2D-5) but quite high (>1.0) vaues occurred in samples B1 and B2. There was no tendency for the deepest (finest) sediments to have the highest values at each transect. Most carbonate carbon values in contemporaneous subtidal sediments also showed little variation over a range of 0 to 0.19%. There was no tendency for the deepest stations to yield the highest values.

The relict sediments at Station E3 and D3 showed dramatically higher values of carbonate carbon but not of organic carbon.

The extreme values of organic carbon and of carbonate carbon measured in March and May 1980 were considerably higher than those measured in 1979. No samples had both kinds of carbon in extreme percentages. Apparently relict sediments were not sites for the concentration of organic materials.

Table 2D-5. Results of subtidal sediment carbon analysis (mean of replicates).

Station	Mar	May	Station	Mar	May
A1	.23/.08	.14/.03	D1	.11/.0+	.05/.05
A2	.38/.08	.62/.08	D2	.11/.08	.06/.16
A3	.23/.05	.24/.05	D3	.13/2.04	.07/1.45
B1	1.09/.10	1.65/.12	E1	.12/.0+	.06/.04
B2	1.12/.19	.26/.08	E2	.14/.07	.09/.06
B3	.28/.08	.33/.07	E3	.13/.73	.08/.78
C1	.13/.02	.09/.03	F1	.28/.05	.08/.02
C2	.16/.18	.05/.04	F2	.70/.06	.33/.06
C3	.06/.11	.15/.16	F3	.62/.05	.10/.04

NOTE: Values in body of table are: % organic carbon/% carbonate carbon

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CHAPTER 3

PLANKTON

INTRODUCTION

The plankton studies reported in this chapter were under investigation during 1980 primarily to complete data collection for the two-year Preoperational Monitoring Program (PMP). This study was designed to establish baseline information on plankton which can be compared to conditions that occur after San Onofre Units 2 and 3 become operational. A second objective was the continuation of the Unit 1 operational effects study. The studies conducted in 1980 met regulatory objectives and requirements of the Environmental Technical Specifications (ETS), Preoperational Monitoring Program (PMP), and National Pollution Discharge Elimination System (NPDES).

The purpose of this chapter is to 1) describe the species composition, distribution, and abundance of plankton inhabiting the receiving waters offshore of the generating stati ; 2) present a summary of data collected during 1980 pertinent to the evaluation of baseline data for the PMP and the Unit 1 effects for the ETS and NPDES; 3) analyze this data to meet the objectives of the PMP, ETS, and NPDES; and 4) develop a perspective of the planktonic communities and populations offshore of San Onofre relative to those found in other areas of the Southern California Bight.

All 1980 SCE biological and physical data used in this analysis were presented in Volumes I and II of the Annual Operating Report, San Onofre Nuclear Generating Station (SCE 1981a,b). Volume I, which includes a brief summary of only regulatory required data, was submitted to the requiring agencies on 31 March 1981 (SCE 1981a). Volume II contains all basic raw data collected for the SCE programs to meet the objectives in 1980 including the basic regulatory required data and additional supplementary data (SCE 1981b).

BACKGROUND

HISTORICAL REVIEW (1964-1979)

Table 3-1 shows a brief history of San Onofre plankton studies. The present plankton studies in the San Onofre area have developed from a qualitative preoperational examination of plankton in 1964, followed by quantitative preoperational and operational semiannual Marine Environmental Monitoring (MEM) plankton studies conducted for Unit 1 between 1965 and 1975 for the California Regional Water Quality Control Board, San Diego Region (Table 3-1). The scope of these early plankton studies included collection of surface (0-2 m (0-5 ft)) zooplankton samples with a net and surface phytoplankton with whole-water samples. The data collected from 1965 to 1972 were summarized and reviewed by Barnett (1973), Enright and McGowan (1973), and Dodson (1973). This review revealed that there was an increase in abundance of many zooplankton taxa during periods of Unit 1 operation at all stations, including "controls". This increase was hypothesized to have been "due to natural dynamic fluctuations in the zooplankton populations or caused by the nuclear plant discharge operations" (Barnett 1973, Enright and

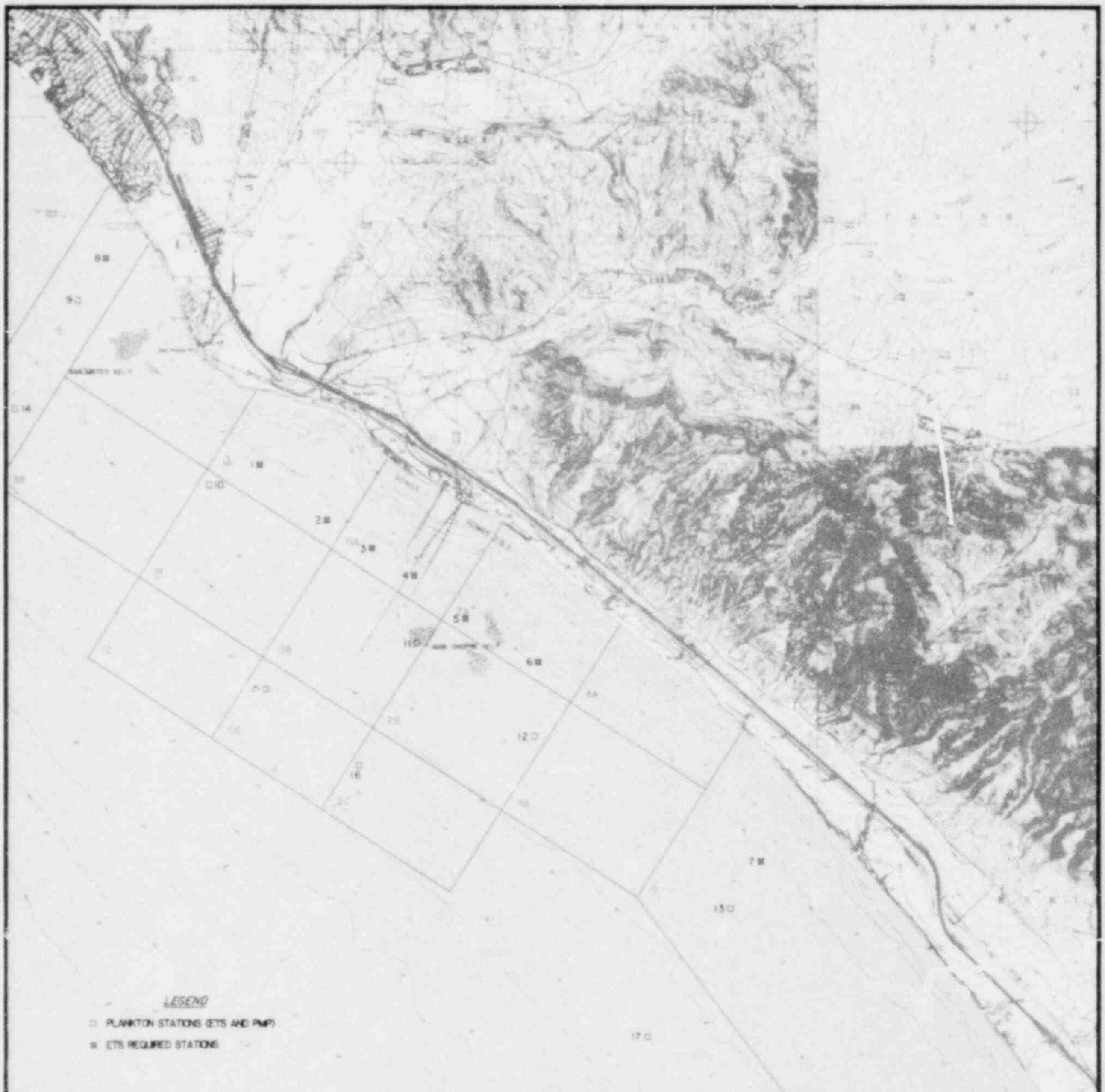

Figure 3-1. ETS and PMP plankton receiving water station locations at San Onofre Nuclear Generating Station.

Table 3-1. Synopsis of SCE plankton studies conducted offshore of San Onofre from 1963 through 1980.

	No. of Surveys • Year	Total No. of Surveys	Sampling Gear	No. of Stations	No. of Depth Strata	No. of Replicates	Type of Data Collected
Zooplankton							
MARINE ENVIRONMENTAL MONITORING (MEM) PROGRAM							
Unit 1 Preoperational Plankton Study 1965-1966	2	1	1/2-m 333 μ mesh net	3	1	1	A
Unit 1 Transitional Plankton Study 1967	2	1	1/2-m 333 μ mesh net	3	1	1	A
Unit 1 Operational Plankton Study 1968-1969	2	3	1/2-m 363 μ mesh net	5	1	1	A
Unit 1 Operational Plankton Study 1970-1975	2	11	1/2-m 363 μ mesh net	5	1	1	B
ENVIRONMENTAL TECHNICAL SPECIFICATIONS (ETS)							
Unit 1 Plankton Study mid-1975 to mid-1980	6	19	pump with 202 μ mesh	7	2	1-2	B
Unit 1 Plankton Study mid-1978 to mid-1980	6	12	pump with 202 μ mesh	7	2	6	C,D
Unit 1 Plankton Study mid-1980	6	3	pump with 202 μ mesh	7	2	1	C
PREOPERATIONAL MONITORING PROGRAM (PMP)							
Units 2 & 3 Plankton Study mid-1978 to mid-1980	6	12	pump with 202 μ mesh	10	2	6	C,D
MARINE REVIEW COMMITTEE (MRC)							
Unit 1 Environmental Effects, Units 2 & 3 Baseline Data and Predicted Operational Effects 1976-1980	12-24	59	pump with 202 μ mesh	5	3-6	1	C,H
Phytoplankton							
MARINE ENVIRONMENTAL MONITORING (MEM) PROGRAM							
Unit 1 Preoperational Plankton Study 1965-1966	1	2	whole water sample	2	1	1	E
Unit 1 Transitional Plankton Study 1967	1	1	whole water sample	2	1	1	E
Unit 1 Operational Plankton Study 1968-1975	1	7	whole water sample	2	1	1	E
ENVIRONMENTAL TECHNICAL SPECIFICATIONS (ETS)							
Unit 1 Plankton Study 1975-1978	6	19	whole water sample	7	2	1-2	F,G
Unit 1 Plankton Study 1978-1980	6	12	whole water sample	7	2	6	G
Unit 1 Plankton Study 1980	6	3	whole water sample	7	2	1	G
PREOPERATIONAL MONITORING PROGRAM (PMP)							
Units 2 & 3 Plankton Study 1978-1980	6	12	whole water sample	10	2	6	G
MARINE REVIEW COMMITTEE (MRC)							
Unit 1 Environmental Effects, Units 2 & 3 Baseline Data and Predicted Operational Effects 1976-1980	12-24	59	glass fiber filtered	5	3-6	1	G,H

A - Abundance estimates, identification to genus or higher
B - Abundance estimates, identification to species (began in 1972)
C - Identification and enumeration of selected species
D - Zooplankton dry weight biomass determined for each sample
E - Species list and cell counts
F - Relative abundance of phytoplankton species
G - Chlorophyll a and phaeopigment concentrations
H - Nutrients

McGowan 1973). Variability in abundance between stations decreased during operational periods. This was attributed to the turbulent mixing produced by the discharge (Barnett 1973). Phytoplankton species composition and cell numbers were similar between San Onofre and control stations (Dodson 1973) and variability in abundance at all stations decreased during operational periods (Enright and McGowan 1973). These studies continued until 1975. Analysis of the results indicated that relative abundance did not differ significantly between stations and attributed variations in abundance between sampling periods to natural fluctuations in zooplankton abundance.

The NRC required ETS study began in May 1975 with the establishment of seven stations spaced at increasing distances upcoast and downcoast from the San Onofre Unit 1 intake/discharge line (Figure 3-1). This study was designed to assess area-wide effects rather than nearfield intake/discharge effects. This program assessed the state of plankton resources upcoast and downcoast of San Onofre along the 10-m isobath. Results of these studies indicated no measurable effect of Unit 1 operation on these plankton resources over several years of study. 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. This program monitored plankton resources from the same area as the ETS program as well as areas further offshore and upcoast from the generating station. Monitoring data for Unit 1 was continued and preoperational baseline data was gathered for future assessment of Units 2 and 3 operations on plankton.

1980 STUDIES

The combined PMP and ETS plankton sampling (three days of sampling at 17 stations (Figure 3-1) on Day 1, and 14 stations on Days 2 and 3) was conducted on a bimonthly sampling basis from January through May 1980. At this time the two-year PMP was completed. The ETS portion of this sampling (one day of sampling at 7 stations) was continued on a bimonthly basis for the remainder of 1980. This resulted in three combined PMP-ETS and three ETS sampling periods. Temperature and percent light transmittance measurements, current estimates, and weather observations were also collected during all surveys.

Unit 1 was out of operation throughout much of 1980 due to steam generator problems, and was operational during only the January and March 1980 plankton surveys. Since the ETS operational objectives have been met and extensively documented in previous annual reports, formal requests to delete the ETS plankton requirements were submitted to the NRC in February 1980 based upon accomplishment of the objectives within the mandated scope. However, regulatory delays in Nuclear Plant licensing matters have prevented change or termination of the operational studies since the Three Mile Island incident and no NRC response had been received by the end of 1980.

DISCUSSION

Physical and chemical factors in shallow, nearshore marine environments 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 ... range from 13

to 17°C (35.4 to 62.6°F). Surface water temperatures in the summer may be 17 to 22°C (62.6 to 71.6°F), while temperatures at a depth of 10 m (33 ft) are two to three degrees cooler (IRC 1973, LCMR 1976d, SCE 1979a). Nutrients are distributed in a 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 (50- 51 ft) (SCE 1979c). Turbidity is due to suspended particles of sediment and organic detritus, as well as plankton. Turbidity in the San Onofre area increases both nearshore and nearbottom (LCMR 1976d, SCE 1979a). High turbidity in inshore coastal waters is largely due to increased turbulence and wave action stirring up and suspending bottom materials (Raymont 1963). Current speed offshore of San Onofre typically ranges from 5 to 40 cm/s (2.0 to 15.7 in./sec) and averages 10 cm/s (3.9 in./sec). These coastal currents vary in direction and speed as a result of winds and tides (EQA and MBC 1973).

SPATIAL AND TEMPORAL PATTERN OF ZOOPLANKTON DISTRIBUTION

Total Zooplankton Abundance

Total abundance of organisms is a useful gross measure of spatial and temporal changes of population size, although it does not take into account the taxonomic composition of the community.

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 have shown 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 boundary conditions (i.e., gradients of nutrients, temperature, salinity, light, temperature, food source), (2) advective effects (wind induced transport and turbulence), (3) behavior (social) patterns, (4) reproductive rates, and (5) factors determined by competition.

The vertical distribution of total zooplankton abundance in 1980 was somewhat different from the general pattern seen in the San Onofre study area over the last five years. In 1980, the total zooplankton abundance was greater in the upper stratum than the lower for all surveys except November. This pattern is the reverse of what has generally existed in the previous years around San Onofre (LCMR 1977, 1978; SCE 1979, 1980e). The vertical distribution of total zooplankton in 1980 appears unrelated to any physical or biological factor which would help explain this trend. The vertical stratification of zooplankton was most obvious at the 30-m (98-ft) stations for the combined ETS-PMP surveys and was distinct only during September for the ETS surveys. A partial explanation for the 1980 pattern of vertical distribution is that some taxa such as Podon polyphemoides, Penillia avirostris, and acantharians, which occur seasonally and tend to be more numerous in the upper stratum, were more abundant in 1980 than in previous years.

Upcoast-downcoast transect differences showed no distinct pattern during 1980 with the exception of the consistently lower abundance recorded at San Mateo Point stations. The lower abundance during the March survey was responsible for the only statistically significant transect difference during 1980. The lowest zooplankton abundances for the January and May surveys also occurred at the San Mateo Point stations. A similar pattern was also observed for 1978 and 1979 combined ETS-PMP surveys (SCE 1980e). Since these stations were studied only for the combined program, no data beyond the two-year combined program are available.

A pattern of decreasing abundance with increasing distance from shore was characteristic for all three combined ETS-PMP surveys of 1980. This pattern is one which emerged early in the combined ETS-PMP studies and has been a consistent feature since its inception in 1978 (SCE 1979d, 1980e). Similar onshore-offshore gradients of abundance have been reported from the San Onofre area by MRC studies (MRC 1979) and are a general feature of neritic zooplankton communities (Raymont 1963). Such patterns are attributable to greater food sources nearshore. In the San Onofre study area this is exemplified by the corresponding gradient of decreasing chlorophyll a concentration with increasing distance from shore.

The 1980 seasonal pattern of abundance, with peaks in May and September, shows characteristics of several previous years. The occurrence of a spring maximum (March or May) is a feature of all previous years. A secondary fall peak was also detected in some previous years. In previous 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.

Zooplankton Biomass

Biomass measurements of zooplankton are based on the mass of the organisms present, not on the number of the organisms present, as are abundance values. The pattern exhibited by zooplankton biomass reflects the pattern described for total abundance and is consistent with results of the two-year combined ETS-PMP study. This is expected as long as the proportion of organisms of various sizes remains about the same. If the proportion of either very large or very small organisms changes, biomass will also change, even though the total abundance remains about the same. Over the period of the combined ETS-PMP study, zooplankton biomass showed a seasonal pattern in which surveys with high total abundance generally contained high biomass. Differences in the pattern of biomass and total abundance among surveys may be attributed to differences in the size of organisms. Similar to the results for total abundance, the onshore-offshore pattern of biomass distribution for the entire two year ETS-PMP study generally exhibited a gradient of decreasing biomass with increasing distance from shore. Vertical stratification also corresponded to zooplankton abundance over the entire two-year study, with the 30-m stations showing the greatest difference between strata. No consistent upcoast-downcoast biomass differences were detected for the San Onofre area over the two-year period.

Select Taxa

The rank order of select taxa in 1980, and annual mean abundance, is presented in Table 3-2 together with similar data for previous years. Year to year comparisons of rank order abundance reveal that the select taxa did not undergo any major shifts in relative abundance that have not been observed before. The differences which did occur reflect seasonal abundance peaks that seem to recur without any evident periodicity. For example, *Podon polyphemoides* and *Corycaeus anglicus* were more abundant in 1980 than most previous years due to the large abundance of each species during one survey. This elevated the annual mean abundance of these taxa.

All of the designated select taxa occurred in plankton samples during 1980. Since numerical abundance and widespread temporal occurrence were among criteria used to designate select taxa, it would be unusual for any select taxon to be absent on all surveys. Three of the select taxa were absent from one or more

Table 3-2. Rank order of abundance of select taxa collected off San Onofre, from 1975 to 1980.

Taxa	Rank						Annual Mean (no./m³)					
	75†	76	77	78††	79	80§	75†	76	77	78††	79	80§
Acartia spp. copepodites	1	1	1	1	1	1	2105	797	1005	613	817	1473
Acartia tonsa	5	3	3	4	3	5	98	480	164	195	365	331
Penilia avirostris	§§	2	4	8	11	14	§§	523	151	84	43	10
Paracalanus parvus copepodites	3	9	2	2	2	2	127	89	2153	514	546	556
Sagitta spp.	2	7	5	9	6	6	148	98	118	72	239	319
Corycaeus anglicus	7	4	9	6	7	3	60	165	62	159	235	472
Cyphonautes larvae	8	6	6	10	8	9	56	102	114	72	129	172
Paracalanus parvus	9	5	8	3	4	7	55	108	87	209	333	295
Labidocera trisponos copepodites	4	8	10	7	9	10	110	98	56	92	106	106
Podon polyphemoides	10	10	7	5	13	4	21	75	94	167	21	436
Euterpina acutifrons	6	11	11	11	10	11	63	64	52	63	69	42
Clausocalanus spp.	§§	§§	§§	§§	5	8	§§	§§	§§	§§	298	179
Oithona oculata	§§	§§	§§	§§	12	13	§§	§§	§§	§§	31	21
Cypris larvae	§§	§§	§§	§§	14	12	§§	§§	§§	§§	14	34

† 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.

§ First three surveys ETS-PMP, second three ETS only.

§§ Taxon not present or not a major contributor to total in these years.

surveys: Podon polyphemoides (September and November); Penilia avirostris (March, May, and July); and Oithona occulata (July). Two of these, P. polyphemoides, and P. avirostris have exhibited seasonal occurrence in the San Onofre area in previous years (SCE 1979d, 1980e; LCMR 1976d, 1977, 1978) and the 1980 pattern is consistent with this. Oithona occulata is not usually abundant and its absence in July probably reflects the decreased sampling effort accompanying the conclusion of the combined ETS-PMP study.

The increased abundance of some taxa such as Paracalanus parvus and Clausocalanus spp. during 1978-1980 may be attributed to adoption of the PMP sampling design, which included stations farther offshore where these taxa comprise a greater proportion of the community.

The results of the combined ETS-PMP studies conducted from mid-1978 through mid-1980 agree with other studies of zooplankton in the San Onofre area (MRC 1979). The onshore-offshore zonation of species described by the MRC studies is consistent with the patterns exhibited by select taxa in the combined ETS-PMP studies, even though the ETS-PMP study area did not extend as far offshore. Like the chlorophyll, biomass, and total abundance, the distribution and abundance of certain taxa, and the onshore-offshore zonation, may also be affected by periodic oceanographic events that causes changes in the water mass structure along the coast (SCE 1980e).

SPATIAL AND TEMPORAL PATTERN OF PHYTOPIGMENT DISTRIBUTION

Chlorophyll a

Chlorophyll a exhibited a general pattern of seasonal, vertical, onshore-offshore distribution, and upcoast-downcoast varition that was similar to general patterns observed during previous years and reported for the Southern California Bight. These patterns appear to be governed by local weather and oceanographic events.

The seasonal pattern of chlorophyll a seen during 1980 represents a classic pattern observed in temperate coastal waters of southern California. This pattern has generally been present throughout studies off San Onofre (Figure 3-2). The presence of a winter low which increases to a late spring and early summer high, then declines, is consistent with general local nutrient cycles. The spring bloom is consistent with general patterns of spring upwelling which become less frequent or cease during the summer. The nutrient rich, upwelled water provides nutrients for the phytoplankton and as the upwelling stops and nutrients are depleted, the phytoplankton and, therefore, chlorophyll a levels decline.

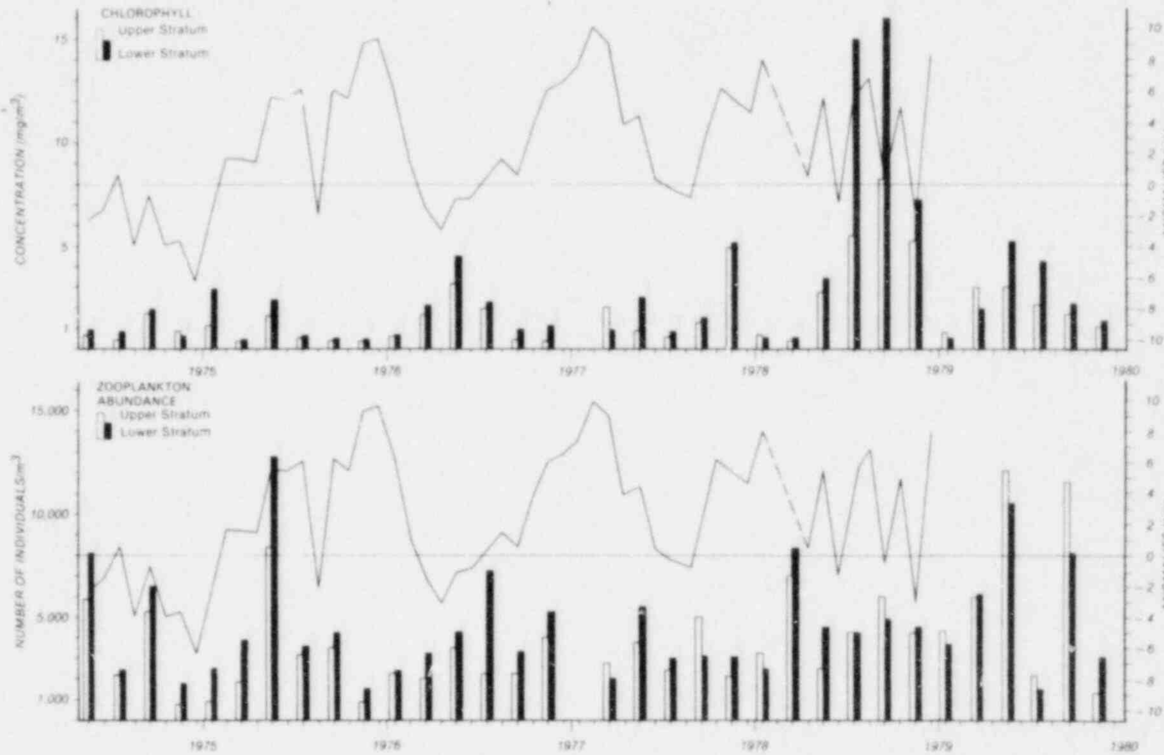

Figure 3-2. Mean chlorophyll a and total zooplankton abundance by depth stratum for each ETS and PMP survey from 1975 through 1980 with monthly mean anomalies in sea surface height shown through 1979. PMP studies were initiated in July 1978 and completed in May 1980.

The seasonal periodicity of phytoplankton peaks offshore of San Onofre over long time periods, based on over five years of chlorophyll a data, appears also to be closely related to certain oceanographic events. Tont (1976) has shown diatom biomass, a major component of phytoplankton populations, to be correlated to sea surface anomalies. Sea surface anomalies are short term deviations of mean sea level from the long term (approximately 50 years) 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. Negative sea level anomalies bring nutrients into the coastal zone and can result in diatom blooms. Chlorophyll a data from the San Onofre region shows a relationship to this parameter. The annual peak(s) in

chlorophyll a concentration (September 1975, January 1976, May 1977, November 1978, and July and September 1979) occurred during or immediately following periods of relatively low sea level values (SCE 1980b). 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.

The pattern of depth distribution of chlorophyll a in 1980 was consistent with that of previous years' ETS and PMP results and with the findings of other investigators (SCE 1980e; Barnett & Sertic 1978). Depth differences were smallest or absent during periods of low chlorophyll a concentration and tended to be significant when chlorophyll a concentrations were highest. This pattern corresponds to general physical and chemical oceanographic events characteristic of southern California coastal waters. Generally well mixed waters present during late fall through early spring are nutrient depleted and result in low concentrations of chlorophyll a in both upper and lower strata with little or no difference between the two. In spring and summer, the establishment of a thermocline and vertical gradient of increasing nutrient concentrations with depth, combine to cause stratification of phytoplankton during this period. This stratification is usually characterized by a subsurface chlorophyll maximum (Cullen and Eppley 1981).

Since the beginning of the ETS San Onofre plankton monitoring programs in 1975, chlorophyll a concentrations have generally been greater in the lower stratum than in the upper stratum (SCE 1980e). 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), which results in more chlorophyll a in the phytoplankton cells. 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 chlorophyll a concentrations with increased distance from shore was generally observed in both depth strata for 1980 ETS-PMP surveys. The difference was usually greatest between the 30-m stations and all inshore stations. The significant differences in chlorophyll a concentration among isobaths observed for 1980 ETS-PMP surveys correspond to the general pattern observed for the 1979 surveys, and for the three surveys incorporating an inshore/offshore sampling design during 1978. The persistent onshore-offshore gradient of chlorophyll a occurred in each survey and is characteristic of most nearshore marine environments. This pattern has been shown to occur throughout the Southern California Bight (Eppley, Sapienza, and Renger 1978) including nearby areas upcoast (Dana Point) and downcoast (Del Mar) of San Onofre. Previous studies (Barnett and Sertic 1978; Barnett et al. 1980) have also demonstrated an onshore-offshore gradient of chlorophyll a concentration in the San Onofre area; therefore, there is no reason to expect that this is other than a natural and persistent phenomenon. A partial explanation for higher chlorophyll values nearshore may be a function of increased turbidity nearshore (SCE 1980b) causing lower light levels, and not necessarily greater abundances of phytoplankton. Phytoplankton cells are known to compensate for low light by increasing the amount of chlorophyll per cell (Odum, McConnell, and Abbott 1958).

The lack of meaningful patterns among upcoast-downcoast transects in the combined ETS-PMP surveys and lack of any clear patterns in the upcoast-downcoast variability during the ETS surveys, indicates that any such observed variability is probably attributable to patchiness in the natural phytoplankton populations.

In other regions, patchiness in the distribution of phytoplankton over areas similar in size to the San Onofre study area has been shown to be responsible for much of the observed variability.

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 of phaeopigment concentration during 1980 was similar to that present for chlorophyll a although the amplitude of fluctuation over the course of the year was very small. The generally low phaeopigment concentration, which is proportional to chlorophyll a concentrations over the year, may be attributed to the lack of any significant sources of phaeopigment in the water column other than the normal amount present in the normal cycle of synthesis and degradation that occurs in cells. The absence of any high value of phaeopigment concentration shows that no unhealthy phytoplankton populations were encountered. No significant depth, isobath, or transect variations were present for phaeopigment concentration during 1980. The pattern that existed may be attributed almost entirely to its reflection of existing chlorophyll a concentrations.

Phytopigment Fluorescence Ratio

Phytopigment fluorescence ratios for phytoplankton samples collected off San Onofre reveal that phytoplankton populations in the study area are in a healthy state. 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 2.2. A ratio of approximately 1.7 is regarded as typical of healthy phytoplankton stocks since even healthy populations have some phaeopigment present (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 without grazing by herbivores. The mean ratios determined for San Onofre phytoplankton seldom declined below 1.5 and averaged between 1.6 and 1.7 most of the year. The presence of occasional ratios below 1.7 during the year probably reflects the fact that phaeopigment 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. This background phaeopigment may artificially lower the ratio observed in field studies. The slightly higher ratios seen for 15- and 30-m (50- and 100-ft) isobaths for the combined ETS-PMP surveys may be attributed to somewhat higher phaeopigment concentrations at the inshore stations resulting from suspended detrital plant material. Seasonally, the pattern of phytopigment ratio corresponds to that of chlorophyll a. This may be attributed to more actively growing cells in the phytoplankton community during periods of optimal growth. The ratio of phytopigment fluorescence indicated that phytoplankton stocks were in a healthy condition during all 1980 surveys.

PLANKTON DISTRIBUTION IN RELATION TO OCEANOGRAPHIC PROCESSES

The relatively high variance due to differences between days in zooplankton and phytoplankton abundance seen in the San Onofre data (SCE 1979d, 1980e) represents one end of a spectrum of variability in time that extends to years and in space that ranges in horizontal scale from meters to the area encompassing the Southern California Bight and California Current.

The nearshore environment of the Southern California Bight in general, and the San Onofre area in particular, while having a fauna and flora differing from

that of the region beyond about 10 km (6.2 mi) (MRC 1979), is influenced by offshore physical and biotic factors present having a wide range of time and space variability. The evidence for this is mostly circumstantial. The strength of flow of the California Current varies on time scales of seasons to several years (Hickey 1979; Chelton 1980). This affects the net input of nutrients (Bernal and McGowan, in press; Shulenberger and Haury, in prep.) and plankton (Bernal 1979; Wickett 1967) into the Bight via the Southern California Eddy (Brinton 1976; Owen 1980) and the seasonally occurring California Counter Current. This latter current can have a considerable effect on coastal biota throughout the Bight because it is a relatively nearshore feature with direct connections with both the offshore portions of the California Current and warmer waters to the south. Intrusive water masses and eddies (Bernstein et al. 1977; Owen 1980) with horizontal scales of hundreds of kilometers add variability in the current with time scales of weeks to months. The importance and magnitude of smaller phenomena with shorter period (weeks or less) fluctuations have been shown by several studies (e.g., Tont and Platt 1979).

Direct evidence for the connection between the nearshore and offshore regions is limited. Work in the Southern California Bight by the Institute of Marine Resources (Scripps Institution of Oceanography) is providing evidence of the link between variations in the very nearshore physical conditions and the nutrient and productivity status for the entire Bight. Reid et al. (1958) has shown the relationship between sea surface temperatures measured at Scripps Pier (La Jolla) and both the mean temperature and standing stock of zooplankton over wide regions of the California Current.

A study by Bernal (1979) of the zooplankton biomass over the California Current between 1949 and 1969 showed five long term (several months to several years), discrete extremes. Lack of time-extensive nearshore studies prevents meaningful comparison to these data. However, variations of plankton volumes taken in Santa Monica Bay from 1957 to 1970 showed trends similar to those for zooplankton biomass measured during the same period off southern California (Anonymous 1973).

The documentation of the relationship between nearshore and offshore oceanographic conditions is essential to the understanding of both long and short term changes in the nearshore region. Otherwise, permanent alterations of nearshore conditions due to anthropogenic causes cannot be distinguished from long term, quasi-periodic changes common to the California Current. The same is true for understanding shorter term changes and in establishing accurate means for seasonal and shorter period conditions. For example, Tont (1981) stresses the fact that northwesterly winds and the resultant nearshore upwelling (time scales of days to weeks) need not generate diatom blooms if the upwelled water had previously been advected in from nutrient-poor subtropical or offshore regions. Such anomalous water can be of large extent (hundreds of km) and would be expected to affect wide areas, including nearshore regions such as San Onofre, for weeks to months.

SAN ONOFRE UNIT 1 EFFECTS

During much of 1980 Unit 1 was not operational due to steam generating problems. This affords an opportunity to consider the ETS objectives in terms of nearly six consecutive years of monitoring studies, ending with four consecutive plankton surveys during which the unit was not operational. Comparison of data collected during the period while the unit was not operational showed no differences in composition, distribution, or abundance of any plankton variable between 1980 and previous years when the unit was operational most of the year.

A review of over 10 years of data gathered as part of the MEM, ETS, and PMP studies conducted off San Onofre and conclusions drawn by independent MRC studies has shown that the operation of Unit 1 has not significantly affected the plankton resources of the San Onofre area.

UNITS 2 AND 3 PREOPERATIONAL BASELINE OBJECTIVES

Successful completion of the Preoperational Monitoring Program in June 1980 provided additional data on the nature and extent of plankton resources in the vicinity of San Onofre. Both phytoplankton and zooplankton were found to exhibit normal spatial and temporal variation in the study area. The most distinct and persistent patterns were the vertical stratification of organisms with greater abundance or concentrations of zooplankton most often in the lower depth stratum, and onshore-offshore gradients in which abundance or concentration of zooplankton or phytopigment declined with distance from shore. Upcoast-downcoast distribution showed no consistent or distinct patterns when significant differences were detected. Temporal variation showed general gross recurrent patterns on a seasonal basis. Considerable variation was frequently observable among the three days of a single survey and may be attributed to the patchiness and temporal variability inherent to plankton populations as they are slowly moved along the coast by local currents.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

METHODS

A detailed description of station locations and field and laboratory methodology is given in combined ETS and PMP procedures (LES 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 are arranged in three longshore transects, each transect being oriented parallel to the coastline. Each transect includes stations located directly offshore of San Onofre Unit 1 and upcoast and downcoast stations. Eight stations (Stations 1-8) lie along the 10-m (30-ft) isobath, five stations (Stations 9-13) lie along the 15-m (50-ft) isobath, and the remaining four (Stations 14-17) lie along the 30-m (100-ft) isobath. The ETS stations (Stations 1-7) are located upcoast, downcoast, and directly offshore of Unit 1 along the 10-m isobath. The required PMP stations (Stations 10-13) are similarly located on the 15-m isobath (Figure 3-1).

Biological samples collected at these stations included zooplankton samples and whole-water samples for analysis of chlorophyll *a* and phaeopigment concentration. These were collected concurrently from two strata within the water column at each station by use of a plankton pump system. The upper stratum extends from the surface to the 5-m (16-ft) depth for the stations located along the 10-m isobath, and from the surface to the 8-m (26-ft) depth at stations along the 15- and 30-m isobaths. The lower stratum encompasses the depth interval from 5 to 10 m at the stations located on the 10-m isobath and from 8 m to the bottom for the deeper stations. Within each of these strata, samples were stepwise integrated by obtaining 0.33 m^3 (11.6 ft^3) of water at each 1-m (3.3-ft) depth interval within a stratum. Zooplankton samples were concentrated by filtering the water sampled

by the pump through a 202-μm mesh plankton net. A 450-ml (1-qt) whole-water sample was 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 were collected from each stratum at each station. The first replicate was taken as the pump intake was lowered and the second as it was raised. This procedure was repeated on three days within a seven day period for each bimonthly survey during January, March, and May, except that inshore Stations 2, 3, and 5 were not sampled on the second and third days. During the remaining surveys, non-replicated sampling was conducted on only one day at the seven ETS stations.

Physical data were collected concurrently with biological sampling. Temperature and percent light transmittance measurements were taken at 1-m intervals using a Martek XMS temperature-transmissivity unit. During 1980, transmissivity-depth profiles were obtained at selected stations during the January, March, and May surveys. No transmissivity profiles were taken during the remaining surveys. Temperature-depth profiles were obtained each time a station was sampled. Gross current speed and direction of flow was estimated by deployment of a sub-surface drogue for a measured length of time (15 min to 1 h) while each station was occupied. Meteorological information, including cloud cover, wind, and sea conditions, were obtained each time a station was occupied.

Plankton surveys were conducted on 8, 10, and 13 January; 10-12 March; 15, 17, and 18 May; 19 July; 16 September; and 5 November 1980. During the January, March, and May surveys all 17 stations were sampled in accordance with the combined ETS and PMP sampling design. The two-year PMP terminated in June 1980, therefore, surveys during July, September, and November were conducted only at Stations 1-7 in accordance with the ETS.

LABORATORY

Phytoplankton populations were assessed by determining phytopigment concentrations from whole-water samples. These samples were glass-fiber filtered, ground in acetone, and examined with a Turner Model 111 fluorometer for the determination of chlorophyll *a* and phaeopigment concentrations (Yentsch and Menzel 1963, Strickland and Parsons 1972).

Assessment of zooplankton populations was 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 was numerically abundant, based on three years of ETS data, and is a major component of the species composition and trophic structure of the zooplankton community offshore of San Onofre (LCMR 1978). 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 was found to comprise more than 30% of the samples during a survey, it was also enumerated. Generally, zooplankton abundances were sufficiently high that sample abundances were estimated from subsamples obtained with a Stempel pipette. When abundances were very low a Folsom plankton splitter was used and aliquots of the whole sample were enumerated.

Zooplankton biomass was measured for each zooplankton sample collected during the January, March, and May surveys. Biomass samples were filtered and dried at 60°C (140°F) for 24 h prior to weighing (Lovegrove 1966).

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. Unless otherwise stated, all statistical differences noted in the results section were at the $P \leq 0.05$ level. Onshore-offshore and upcoast-downcoast distributions of zooplankton abundance, biomass, chlorophyll a, 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 the results of analysis of data obtained during the three combined ETS-PMP surveys and three ETS surveys conducted during 1980 are presented. Each of the biological parameters examined for these studies is considered in terms of general spatial and temporal patterns revealed by the analyses. The following subsections present figures and tables which summarize important results of statistical testing, along with general trends in the magnitude and distribution of the abundance and concentration data. Salient features of each survey's data are noted, results of the ANOVA tests are presented, and attention is called to general temporal trends. Unless otherwise stated, statistical significance is at the $P \leq 0.05$ level.

The ANOVA design used for hypothesis testing for the three combined ETS-PMP surveys takes into account the following important spatial variables: isobath on which stations were located, depth stratum from which samples were collected, and onshore-offshore orientation. The last factor considers upcoast versus downcoast patterns, and treats onshore-offshore lines of stations as transects. For purposes of hypothesis testing, stations were grouped into five transects as depicted in Table 3-3. The factor "transect", measuring variation amoung groups of onshore-offshore aligned stations, revealed fewer instances of significance than other main effects measured. An important feature of the ANOVA design employed is the testing of fine-scale temporal variation. This was done using duplicate samples collected a few minutes apart on the same day and nesting them

within days. Between day variation was then used to test the primary factors. The fact that nearly every analysis conducted showed a significant difference between days of the survey demonstrates the highly transitory nature of the nearshore planktonic populations off San Onofre. This feature was present for all of the biological parameters studied and indicates that patchiness, as well as temporal patterns of distribution, may greatly affect the interpretation of data collected on a single day.

Table 3-3. 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

ZOOPLANKTON

Total zooplankton abundance, dry weight biomass, and abundance of select taxa were examined for the zooplankton community offshore of San Onofre. Dry weight biomass of zooplankton was conducted only for the three combined ETS-PMP surveys. Mean total zooplankton abundance and biomass for the 1980 surveys are summarized in Figure 3-3 by isobath and depth stratum.

Total Abundance

Overall mean total zooplankton abundance by survey exhibited a seasonal pattern with one low and two peaks of high zooplankton abundance. Mean total abundance was lowest in July and highest in May. The second seasonal peak, slightly smaller than the May maximum, occurred in September. Figure 3-3 shows a pattern of gradual increase in mean total zooplankton from January through May, followed by the July minimum, the second peak in September, and a decline in November.

Results of analysis of variance for total zooplankton abundance are presented in Table 3-4. Mean total abundance was significantly greater in the upper stratum than the lower during January. In March and May the analyses were complicated by significant interaction between the depth and isobath factors. Study of the interactions indicates a general pattern of greater abundance in the upper stratum, obscured by an onshore-offshore gradient of total abundance. Figure 3-3 indicates that the general pattern of greater abundance in the upper stratum is most evident at the 30-m stations. This general depth pattern also was present in the July and September ETS surveys.

Mean total zooplankton abundance for the three combined ETS-PMP surveys showed a pattern of decreasing abundance in an onshore-offshore direction proceeding from 10- to 15- to 30-m stations. This was significant in January, but obscured by interaction with the depth factor in March and May. Study of the interaction supports this general pattern as being significant, but obscured because of depth differences.

In March the San Mateo Point transect had significantly lower mean abundance than the other four transects, which were not significantly different from one another. This pattern was also present in the other two combined ETS-PMP surveys

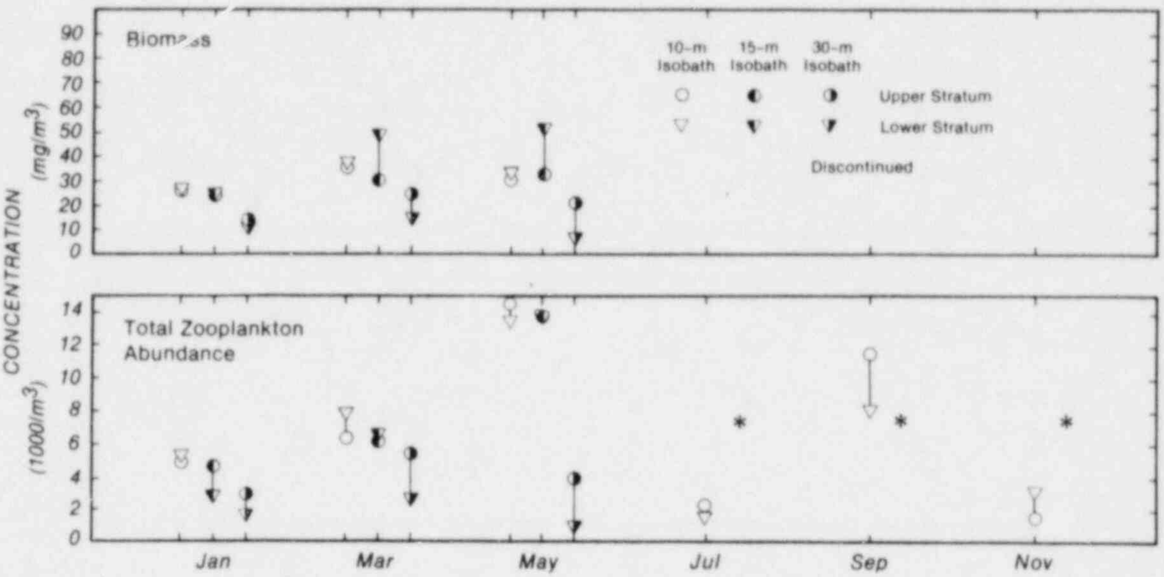

Figure 3-3. Arithmetic means of total zooplankton abundance and concentration of dry weight biomass observed during 1980. Asterisk (*) indicates discontinuation of deep strata (PMP) sampling.

Table 3-4. Results of analysis of variance ($P \leq 0.05$) and Duncan's multiple range tests† for 1980 ETS-PMP total zooplankton data.

Source	Survey Jan	Survey Mar	Survey May
Main Effects			
Depth (D)	U>L	††	††
Transect (T)	n.s.	2 3 1 4>5	n.s.
D x T	n.s.	n.s.	n.s.
Isobath (I)	10>15>30	††	††
D x I	n.s.	§	§§
T x I	n.s.	n.s.	n.s.
D x T x I	n.s.	n.s.	n.s.
Day	**	n.s.	n.s.
Nested Effects			
Duplicate	n.s.	n.s.	**
Day x Duplicate	n.s.	n.s.	n.s.

n.s. Not significant ($P > 0.050$)

** $P \leq 0.01$

† Duncan's test results are presented if the ANOVA result was significant ($P \leq 0.05$). Factors are arranged in order of decreasing values from left to right. Factors connected by underlines are not significantly different ($P > 0.05$).

†† Main effect complicated by significant interaction of the depth and isobath factors.

§ 10L 10U 15L 15U 30U > 30L

§§ 10L 10U 15L 15U > 30U > 30L

although not strong enough to be statistically significant. No general patterns of upcoast-downcoast difference was noted for the three ETS surveys. The latter did not include a station at San Mateo Point. A significant difference in total abundance was detected only in January for the three combined ETS-PMP surveys of three days duration.

Dry Weight Biomass

Zooplankton dry weight biomass determinations were conducted for the three combined ETS-PMP surveys. The seasonal pattern depicted in Figure 3-3 indicates that biomass was lowest in January with approximately equal values measured in March and May.

Results of analysis of variance are presented in Table 3-5. No clear patterns were detected because the significant interaction of the depth factor, with both isobath and transect in January and March and with isobath in May, obscured the relationship of biomass and any of these factors alone. Study of the interactions indicates that biomass was generally greater at the 10- and 15-m stations than at 30-m stations and only at 30-m stations were depth differences significant, with the greater biomass occurring in the upper stratum. No discernible pattern was evident from examination of the interactions involving transect as a factor. No significant difference between biomass and any factor examined were detected in May. In March and May, significant differences were detected among biomass values measured for different days of a survey.

Table 3-5. Results of analysis of variance ($P \leq 0.05$) and Duncan's multiple range test for 1980 ETS-PMP zooplankton biomass data.

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

(U) Upper; (L) Lower; (10) 10-m, (15) 15-m, (30) 30-m stations
n.s. Not significant ($P > 0.050$)
* $P \leq 0.05$
† Main effect complicated by significant interaction.
†† The results of the Duncan's multiple range test did not indicate any meaningful pattern.
††† 10U 10L 15U > 15L 30U > 30L
§ 15L 10L 10U 15U 30U 30L
§§ 15L 10L 10U 15U > 30U > 30L

Abundance of Select Taxa

The mean survey abundance of each of the select taxa studied is presented in Table 3-6. Seasonal patterns of abundance of most taxa fluctuated in the same general pattern as the total zooplankton. This was especially true of the taxa most frequently predominant in the samples, Acartia spp. copepodites, Acartia tonsa, Paracalanus parvus, and P. parvus copepodites. A few taxa were much more abundant at certain times of the year, comprising a greater relative percentage of the zooplankton at that time than during the remainder of the year. Clausocalanus spp. was more abundant in January than in other surveys, Corycaeus anglicus was more abundant in March and September, Podon polyphemoides was more abundant in May and July, and cyphonautes larvae were more abundant in July and November.

Table 3-6. Mean abundance of select taxa (no/m^3) by survey for 1980.

Select Taxa	Jan	Mar	May	Jul	Sep	Nov	Annual Mean Total
Acartia spp. copepodites	475.0	608.3	2,350.8	156.2	4,654.6	590.6	1,472.6
Acartia tonsa	150.3	302.9	357.4	6.0	1,007.0	160.6	330.7
Penillia avirostris	0.2	-	-	-	20.3	40.6	10.2
Paracalanus parvus copepodites	618.2	970.0	1,031.4	138.4	281.8	298.4	556.4
Sagitta spp.	69.2	535.5	638.4	12.3	623.5	32.5	318.6
Corycaeus anglicus	281.8	1,223.1	345.2	18.8	942.1	23.3	472.4
Cyphonautes larvae	164.2	230.3	27.8	211.5	177.5	222.8	172.4
Paracalanus parvus	248.0	569.9	278.5	245.8	394.5	31.5	294.7
Labidocera trispinosa copepodites	89.6	234.2	206.9	22.8	67.1	16.9	106.2
Podon polyphemoides	7.1	0.1	2,380.5	228.6	-	-	436.0
Euterpina acutifrons	41.0	100.3	65.6	7.9	14.9	24.6	42.4
Clausocalanus spp.	836.9	38.4	16.7	11.9	69.9	97.4	178.5
Oithona occulata	84.1	1.2	0.5	-	0.8	39.3	21.0
Cypris larvae	4.3	64.8	10.7	83.5	3.8	33.7	33.5
Other copepods	189.6	90.7	113.0	128.0	43.7	291.4	142.7
All other taxa combined	626.2	1,000.2	3,445.9	686.3	1,542.8	298.9	1,266.7
Total Zooplankton	3,885.8	5,969.9	11,269.3	1,958.0	9,844.3	2,202.5	5,855.0

Examination of results of analysis of variance for the three combined ETS-PMP surveys, and study of results of ETS data indicates only a few distinctive trends among the select taxa over the entire year. Two taxa, cypris larvae and Euterpina acutifrons, were consistently more abundant in the lower depth stratum. Podon polyphemoides tended to be more abundant in the upper stratum. No consistent upcoast-downcoast variation was detected and this factor usually was not significant. No taxon was generally more abundant at the 30-m stations and the abundance of most select taxa usually was greatest at the 10- and 15-m stations than at the 30-m stations.

PHYTOPLANKTON

Chlorophyll a and phaeopigment concentrations, and the ratio of phytopigment fluorescence were measured to monitor the magnitude and distribution of phytoplankton populations. Mean values of the variables are presented for each survey by isobath and depth stratum in Figure 3-4.

Chlorophyll a

A distinct seasonal pattern of phytoplankton abundance was indicated by chlorophyll a concentrations. The mean concentration was lowest for the January

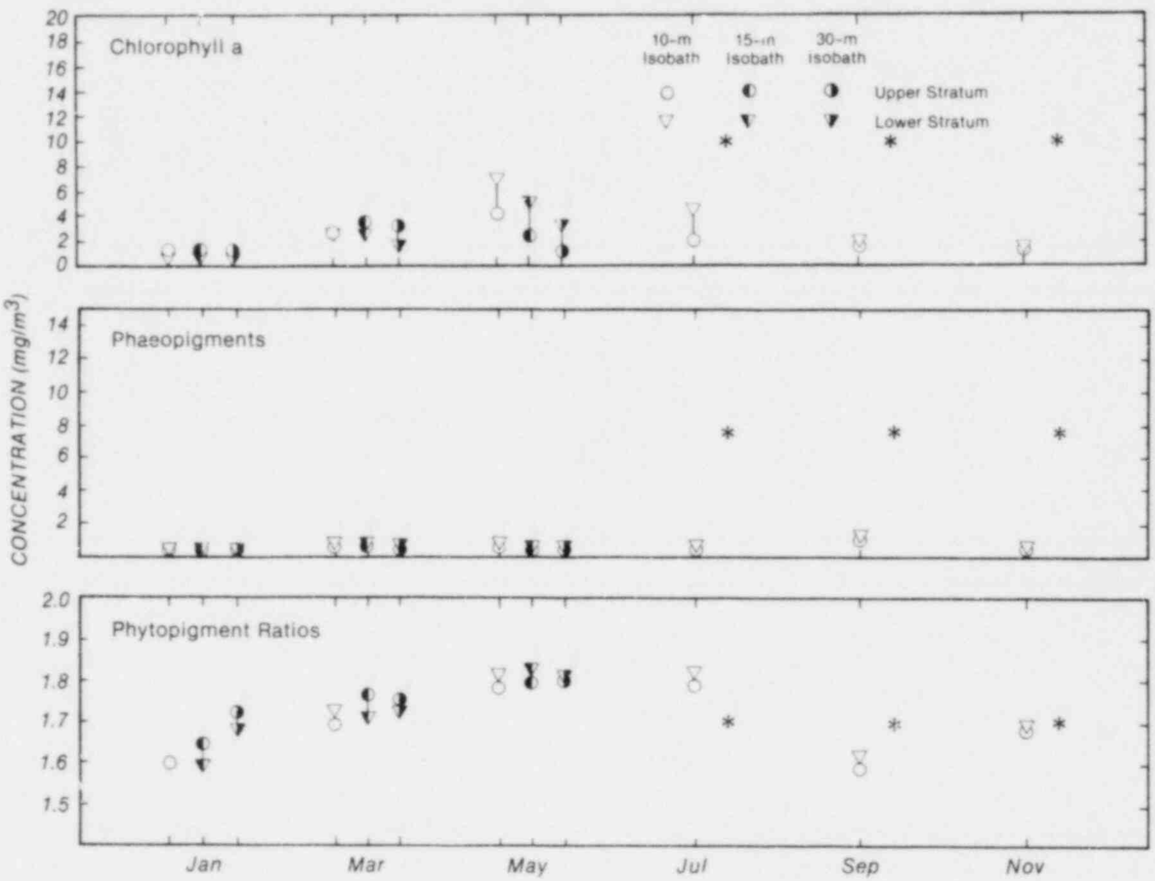

Figure 3-4. Arithmetic means of concentrations of chlorophyll *a*, phaeopigments, and phytopigment observed during 1980. Asterisk (*) indicates discontinuation of deep strata (PMP) sampling.

survey and greatest for the May survey. Overall mean chlorophyll a concentrations increased sharply from the January minimum to the May maximum, then gradually declined through the remainder of the 1980 surveys.

Results of analysis of variance (ANOVA) on chlorophyll a data for the three combined ETS-P ? surveys are shown in Table 3-7. Chlorophyll a concentrations during January and March were not significantly different between upper and lower depth strata. In May, significantly ($P \leq 0.05$) greater chlorophyll a concentrations were measured from the lower depth stratum along all three isobaths. Inspection of data for ETS surveys reveals a distinct depth difference in July with much greater chlorophyll a concentrations present in the lower depth stratum. This pattern was also evident in September and November, but differences between strata were not great. Differences in chlorophyll a concentration among the three isobaths were not significant in January or March. In May, significantly different concentrations of chlorophyll a were present on each isobath, with a gradient of decreasing concentration moving away from shore. Significant difference in chlorophyll a concentration among transects occurred only during the May survey. Results of Duncan's test showed no pattern to this difference. No clear patterns of distribution of chlorophyll a concentration among stations was evident for the three ETS surveys. For the combined ETS-PMP surveys significant differences among days within a survey were detected in March. A significant interaction between days and duplicate samples occurred for the January survey.

Table 3-7. Results of analysis of variance ($P \leq 0.05$) and Duncan's mutliple range tests for 1980 ETS-PMP chlorophyll *a* data

Source	Survey: Jan	Survey: Mar	Survey: May
Main Effects			
Depth (D)	n.s.	n.s.	L>U
Transect (T)	n.s.	n.s.	4 5 3 1 2
D x T	n.s.	n.s.	n.s.
Isobath (I)	n.s.	n.s.	10>15>30
D x I	n.s.	n.s.	n.s.
T x I	n.s.	n.s.	n.s.
D x T x I	n.s.	n.s.	n.s.
Day	†	***	n.s.
Nested Effects			
Duplicate	†	n.s.	n.s.
Day x Duplicate	**	n.s.	n.s.

n.s. Not significant ($P > 0.050$)

* $P \leq 0.05$

** $P \leq 0.01$

*** $P \leq 0.001$

† Main effect complicated by significant interaction with duplicate samples.

Phaeopigment

The seasonal pattern of phaeopigment concentration observed during 1980 is summarized in Figure 3-4. The lowest overall survey mean occurred in the combined ETS-PMP survey of January, and the highest phaeopigment concentration occurred in the ETS survey of September. The mean phaeopigment concentrations for the remaining four 1980 surveys had mean phaeopigment concentrations which were similar in magnitude and showed no clear seasonal trends.

Results of the analyses of variance of the phaeopigment data are presented in Table 3-8 for the three combined ETS-PMP surveys. No significant difference in phaeopigment concentration between depth strata, among the three isobaths, or among the five transects were detected. In both January and March, phaeopigment concentrations among the days within the survey were significantly different. The phaeopigment concentrations measured during the three ETS surveys showed no consistent pattern among the stations.

Phytopigment Fluorescence Ratio

The ratio of fluorescence of phytopigments before and after acidification was used as a measure of the general physiological state of the phytoplankton community off San Onofre. The results of these determinations are summarized by depth stratum and isobath on Figure 3-4 for each survey. The seasonal cycle of phytopigment fluorescence generally reflects the pattern described for chlorophyll a concentration. The lowest ratios were recorded in January and September, and the highest in May and July. Depth patterns of phytopigment fluorescence ratios indicate only slight differences to be present, but a consistent trend is

Table 3-8. Results of analysis of variance (P ≤ 0.05) and Duncan's multiple range tests for 1980 ETS-PMP phaeopigment data.

Source	Survey		
	Jan	Mar	May
Main Effects			
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.
Isobath (I)	n.s.	n.s.	n.s.
D x I	n.s.	n.s.	n.s.
T x I	n.s.	n.s.	n.s.
D x T x I	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. Not significant ($P > 0.050$)
* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

evident. At 10-m stations the ratio was slightly greater in the lower stratum at both the 15- and 30-m isobaths was greater in the upper stratum in January and March, but greater in the lower stratum in May. For combined ETS-PMP surveys, an onshore-offshore trend was distinct only in January when the ratio increased proceeding from 10- to 15- to 30-m stations. Ratios were about the same at all isobaths in March and May. Inspection of data revealed no distinct or consistent upcoast-downcoast patterns with respect to phytopigment ratios.

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CHAPTER 4

INTERTIDAL

INTRODUCTION

The communities inhabiting the narrow boundary between land and sea which s 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 San Onofre Nuclear Generating Station. Although both communities must deal with the same rigors imposed by their intertidal presence, the species composing the two communities differ considerably. In consequence, they are discussed separately below.

CHAPTER 4A

SANDY INTERTIDAL

INTRODUCTION

The sandy intertidal habitat at San Onofre was sampled in February 1980 to complete the monitoring program associated with the construction of the Units 2 and 3 outfall structures. Actual construction of the structures was completed in 1979, but related activities (i.e. removal of pier bents) continued into early 1980. A special study will eventually be conducted to follow return of the beach configuration to normal following removal of the construction laydown pad and its seawall. The 1980 sandy intertidal studies met all objectives and requirements of the Constuction Monitoring Program (CMP). The objectives of this chapter are to: 1) present a summary of sandy intertidal data collected in 1980, 2) analyze this data to meet objectives, and 3) describe the sandy intertidal resources, and placing their interaction with station activities in perspective.

Data collected in the single 1980 sandy intertidal survey were presented in both the Summary and Comprehensive Data Reports (SCE 1981a,b).

BACKGROUND

HISTORICAL REVIEW

Table 4A-1 shows a brief history of San Onofre sandy intertidal studies.

Evaluation of the intertidal environment in the vicinity of San Onofre began in 1963 providing baseline data prior to Unit 1 operation. Sampling of the sandy intertidal biota was conducted 31 times with a variety of methods between 1963 and 1972. These efforts, part of the Marine Environmental Monitoring Program

Table 4A-1. Chronological history of SCE-sponsored sandy intertidal studies at the San Onofre site.

Major Programs	Date	Sampling Gear	Number of Surveys	Tidal Heights Sampled	Locations	Replicates	Type of Data Collected
Marine Environmental Monitoring							
Unit I Preoperational	1964-66	scoop	6 (Transect 5.5) 10 (Transects 1,2,3,4,5)	low and mid tide	6 transects within 1600m of Units 2 & 3 conduit	Maximum of 2 spatial	Presence and qualitative abundance estimates. Site description and photographs.
Unit 1 Operational	1967-74	shovel excavation	17 (Transect 5.5) 18 (Transects 1,2,3,4,5)	"	"	None	Presence and quantitative abundance estimates. Site description and photographs. Emerita size/frequency.
Sand Disposal Study							
Predisposal	1974	core tubes	1	variable low intertidal	5 transects from 900m N to 9400m S of Units 2 & 3 conduit centerline	5 spatial 3 temporal	Species counts, Emerita size/frequency. Site description.
Post disposal	1974-76	"	8	"		"	"
Construction Monitoring Program							
Construction	1976-80	core tubes	14	0 to +6' (MLLW)	5 transects within 1900m of Units 2 & 3 conduit centerline	5 spatial	Species counts, Emerita size/frequency, grain size sediments, beach profiles, temperature

(MEM) were reviewed in detail by Given (1973). Sampling during the MEM involved screening of small samples of sand (between 1 and 8 liters in volume) through a 1 mm mesh screen to separate out any infaunal organisms. Although attempts were made to identify beach inhabitants by surface inspection within prescribed areas (1/16 m^2 in January 1968), this proved less satisfactory than excavation, and was discontinued. Beginning in May 1967 and continuing to the end of the MEM, sampling consisted of excavation of 1 m^2 quadrats to a depth of 8 cm at two intertidal positions along each transect. Samples were taken at low water and halfway between low tide and the previous high tide mark. Tidal heights of the samples were not determined. Sampling under the MEM continued until 1974.

Intertidal sampling continued in 1974 as part of the Sand Disposal Study (SDS) to evaluate the effects of Units 2 and 3 construction. During the SDS sampling was uniform and consisted of five lines of samples collected at 2 m (6 ft) intervals from the low tide line of the survey day. Five replicate cores were collected along each line at 5 m (15 ft) intervals. Four of the five lines were located at or below low water for the day. This procedure was repeated at each station on three consecutive days during each quarterly survey. Tidal heights of the samples were not determined. As construction activities moved offshore, the SDS evolved into the CMP. The EMP program involved sampling at five stations. A transect line at each station was divided into seven intertidal heights at one-foot intervals from +0.0 ft to +6.0 ft. Five replicate biological and geological samples were collected at each intertidal level. Replication was determined previously in a special study sponsored by SCE. After field screening organisms and sediments were returned to the laboratory for identification and grain size analysis respectively. At the time of sampling beach profiles were recorded to assess changes in beach configuration. The MEM sampling transects were not quite the same as those occupied in later studies, but at least one transect (MEM 4, SDS 2, CMP BB) has been located in the same place since 1963. All three programs were conducted in accordance with California Regional Water Quality Control Board-San Diego Region (CRWQCB-SDR) requirements in force at the time.

1980 SAMPLING

Only a single sandy intertidal sampling was conducted in 1980 since offshore construction ended and the CMP was completed after the first quarter (Table 1-1). As in previous CMP monitoring surveys, five transects (Figure 4A-1) were occupied. Beach profiles and sediment grain size samples were taken with the biological samples. Geophysical aspects of the sandy intertidal have been discussed in Chapter 2D of this volume.

DISCUSSION

The sandy intertidal habitat at San Onofre is relatively dynamic. Regular annual cycles of sand accretion and removal alternately cover and expose areas of cobble in the lower part of the intertidal zone. The biota of this hard substrate is addressed in the second part of this chapter. Much of this accretion and removal represents transport of sand from subtidal areas onto the beach by summer long-period swells, and its removal by short-period storm waves during the winter. Superimposed on this onshore-offshore cycle is longshore littoral drift; movement of sediments along the coast by persistent nearshore curents. This lateral transport moves an estimated 100,000 to 200,000 cubic yards of sediment past the San Onofre site towards Oceanside each year (SCE 1980).

The organisms which inhabit this unstable habitat are well adapted to life in a heavily stressed environment. All are highly mobile, and most are able to

Figure 4A-1. Intertidal transect locations.

migrate in response to the twice daily rise and fall of the tide. Sampling of the intertidal community in the MEM and SDS programs was therefore tied to an ephemeral condition (i.e. "low tide") rather than a known tidal elevation with respect of Mean Lower Low Water (MLLW) datum. This was replaced with a height stratified sampling regime for the CMP to examine the vertical distribution of the sandy beach fauna (SCE 1979, 1980).

The only consistent member of the community over the entire period since sampling began in 1963 has been the sand crab Emerita analoga. Emerita has been the most abundant organism, as well as the most frequently encountered. Its population exhibited a seasonal abundance cycle, with heavy spring settlement of pelagic larvae. Few adults survive into the following spring. This species forms the major energy pathway connecting the sandy intertidal fauna with other portions of the nearshore marine ecosystem. Adult Emerita are choice prey of several surf-zone fishes including California corbina. They are one of the commercially harvested invertebrates used as fish bait, and as such are a currently exploited resource. Frey (1971) reported a commercial catch of roughly four tons in 1967, almost double the 1963 total.

Much of the energy fixed by Emerita is probably channeled into reproduction. Each female may produce thousands of eggs per brood, and may carry up to 5 broods per season in southern California (Efford 1969). The large number of larvae released are pelagic for approximately four and one-half months (Efford 1970). Mortality through predation during this period is undoubtedly severe, and the larvae serve as a food resource for planctivorous fishes.

The other members of the sandy intertidal community are similarly related to the remainder of the marine ecosystem through predation on adults in situ and on exported pelagic larvae by water column and benthic predators. Sandy intertidal organisms are dependent in turn on the import of suspended particulate matter and plankton on which Emerita and several other intertidal forms feed.

Many intertidal species are strongly dependent on the nature of the sediments they inhabit (SCE 1980), and tend to be patchily distributed. Sand crabs, in addition to sediment-related patchiness, are strongly aggregative (Efford 1965). As a result, samples taken from sandy beaches frequently contain no organisms. During the MEM several of the sandy intertidal sampling sites were termed "sand deserts"; a reflection of the low population density observed there. In the SDS program the majority of the samples produced no organisms, producing data matrices not suitable for analysis. In the CMP program the size of each replicate was increased considerably to capture more organisms. This strategy was generally successful, although during the winter quarter, when the sand crab population was at its lowest ebb, few of the samples contained organisms.

The aggregating habit of sand crabs has tended to place perceived patterns of distribution around San Onofre in doubt. A multivariate analysis based on the 1979 CMP data (SCE 1980) identified patterns of community distribution related to beach configuration (i.e. width, slope) and sediment grain size. Despite this, the community in an area obviously modified physically by presence of the sand impoundment structure (lay-down pad) was not different than that observed at other San Onofre sites. In the MEM Given 1973, Parr 1973) and in the SDS (Lockheed Aircraft Services 1974 and other subsequent reports) no consistent patterns of community distribution were observed. Similarly, in CMP data (MBC 1978, SCE 1979, 1980, this report) no consistent trends have been evident. The composition of the intertidal biota seemed determined by extrinsic factors (i.e. relative "goodness" of the recruitment year as a function of long-term hydrographic and meteorological trends) or by variations in sampling efficiency (whether a patch of organisms was hit or missed). Coe (1956) examined at length long-term records

of several intertidal and shallow subtidal organisms, concluding that major population changes were usual, arhythmic, and produced by complex interactions of a wide variety of factors. A series of recent investigations based on plankton recorder data over a 25-year period (Colebrook 1978a,b; Reid 1977, 1978) has indicated connections with very large scale meteorological events and trends, as well as smaller scale atmospheric anomalies (Colebrook, Reid, and Coombs 1978), and both zooplankton and phytoplankton distribution and abundances. Such connection may also be found in the eastern Pacific, once data are suitably analyzed. Present analyses of sandy intertidal community distribution at San Onofre indicate little or no involvement of the generating station. The actual cause and effect relationships are not known, but no adverse affect on the sandy intertidal community has thus far been demonstrated. The community at San Onofre remains quite similar to that observed on similar beaches throughout the southern California bight (Straughan 1977).

The sparsity of the sandy intertidal fauna in general, and the low population levels typical of the San Onofre vicinity in February, severely limits the interpretation of 1980 data. The implication that a real difference exists between the community upcoast of the sand impoundment structure and that downcoast from it is not consistent with the conclusions of previous analyses based on a much broader data base. Nothing in the February 1980 collection suggests that the community was substantively different in winter 1980 when compared with previous winter surveys.

The presence of the construction laydown pad at San Onofre does serve as a physical impediment to long-shore sand transport. As such, it has modified the structure of the beach, particularly on its upcoast side. Previous multivariate analysis, however, failed to demonstrate that the sandy intertidal community was seriously affected by these physical modifications. Thus, patterns discerned from February 1980 data appear to be caused by sampling artifacts rather than reflective of construction activity effects.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

APPROACH

Monitoring of the sandy intertidal environment and community in 1980 was comparable in design and scope to that performed under the CMP beginning in 1976. Results of the February 1980 survey will be examined via classification analysis, and the distribution of organisms compared with historical data. The analysis and interpretation of 1980 data will be considerably less than in the 1979 report (SCE 1980) since only one survey was conducted.

In addition to the data collected in 1980, comparative CMP data from 1979 (SCE 1980), 1978 (SCE 1979), and 1976-1977 (MBC 1978) will be examined. Since data presented and discussed in these reports were collected using the same field methods, they are directly comparable.

METHODS

Prior to the initiation of each intertidal survey, the +8 ft tidal elevation for 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).

of several intertidal and shallow subtidal organisms, concluding that major population changes were usual, arhythmic, and produced by complex interactions of a wide variety of factors. A series of recent investigations based on plankton recorder data over a 25-year period (Colebrook 1978a,b; Reid 1977, 1978) has indicated connections with very large scale meteorological events and trends, as well as smaller scale atmospheric anomalies (Colebrook, Reid, and Coombs 1978), and both zooplankton and phytoplankton distribution and abundances. Such connection may also be found in the eastern Pacific, once data are suitably analyzed. Present analyses of sandy intertidal community distribution at San Onofre indicate little or no involvement of the generating station. The actual

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

Grain size distributions were determined by three complementary 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.

Data Analysis

Classification analysis consisted of two types of analysis. First, stations were classified by their species composition and abundance (normal analysis), resulting in the grouping of similar stations. Secondly, species were classified by their occurrence and abundance at individual stations, which clustered species with similar distribution patterns (inverse analysis). In both analyzes, the flexible sorting strategy (β =.25) was used to generate dendrograms from a Sørenson's QS similarity matrix. Prior to the analyses, raw data were square root transformed to reduce the effect of extremely skewed data points, and standardized as a percentage of each species' maximum abundance (Smith 1976).

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.

RESULTS/ANALYSIS

Sandy intertidal sampling was performed between 13-15 February 1980. Community density was low as in previous winter collections. A total of 175 cores yielded only 74 individuals representing 6 species (Table 4A-2), an average of roughly 88/m^2. The sand crab Emerita analoga constituted the majority of individuals taken for the entire survey, and along each transect except BB. All

the species recorded in February 1980 had been collected in one or more previous surveys at San Onofre.

Table 4A-2. Sandy intertidal transect summary table for 1980 collections.

	Transect AA	Transect BB	Transect CC	Transect DD	Transect EE	All Transects
February 1980						
Number of Species	2	3	4	3	3	6
Number of Individuals	7	5	14	22	26	74
Number of Emerita	6	2	11	19	20	58
% Individuals: Emerita	85.7	40.0	78.6	86.4	76.9	78.4
Species Diversity (H')	0.18	0.46	0.33	0.21	0.28	0.32

A regular pattern of increase in the number of species collected per transect with approach to the trestle centerline was observed in the February 1980 data. The number of species was small, however, and the pattern may have been an artifact of the low density. The increased total number of individuals and number of Emerita per transect with increasing distance from Transect BB (Table 4A-2) was probably a true attribute of the community, and not an artifact of low community density.

Table 4A-3. Rank, percent of collection total, and percent replicate occurrence of sandy intertidal species, February 1980.

Rank	Species	%	Cum %	% Occur
1	Emerita analoga	78.4	78.4	22.3
2	Hemipodus borealis	14.9	93.3	6.3
3	Excirolana linguifrons	2.7	96.0	1.1
4	Lumbrineris zonata	1.4	97.4	0.6
4	Microspio acuta	1.4	98.7	0.6
4	Excirolana kincaidi	1.4	100.0	0.6

Of the six species encountered, three were represented by a single specimen, and the fourth by two specimens. Only the community dominant Emerita and the subdominant polychaete Hemipodus occurred in more than 5% of the replicates. Together, these two species constituted over 90% of the 1980 collection (Table 4A-3). These same species have ranked first and second in winter surveys of the community since 1977 (MBC 1978; SCE 1979, 1980) although their percentage contribution increased from 69% in March 1977 to 93% in February 1980.

Community distribution patterns were examined with classification analysis (Figure 4A-2). The five pooled replicates at each level of each transect were considered a "station" in the normal analysis, resulting in 35 stations for classification. Station and species groups were serially designated with numbers and letters, respectively. A letter denoting month of collection (F for February) was added to each group to conform with previous usage.

The February 1980 normal analysis defined six groups of stations. Group 1F (16 members) consisted of stations from all five transects that contained only Emerita. The three stations in Group 2F were characterized by Emerita and one of the constituent species of Group BF. All three stations in Group 3F were upcoast of the construction laydown pad and contained only the subdominant worm Hemipodus. Group 4F (5 stations) members had both Emerita and Hemipodus, but no other species. The six Group 5F stations contained no organisms, while the two high intertidal stations in Group 6F contained only the isopod Excirolana linguifrons.

Group formation was not closely related to tidal height in most cases, although Group 6F contained only high intertidal sites. No station group was restricted to a single transect, but distributional trends related to the structure. All but two of 21 stations downcoast of the structure supported Emerita, and the two where it was absent were in the high intertidal zone of Transect CC. It is along the back beach above transect CC that excavated

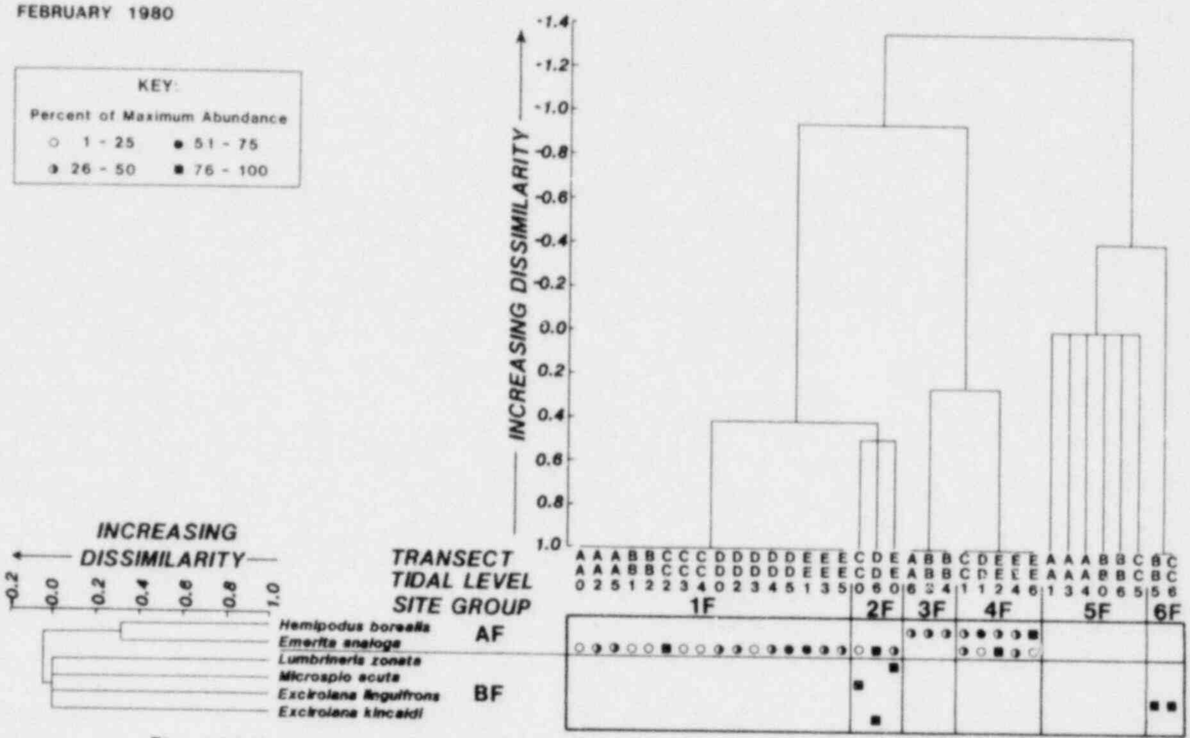

Figure 4A-2. February 1980 station and species classification with resultant two-way table.

materials were temporarily stored. In contrast, only 5 of 14 stations sampled upcoast of the trestle line contained Emerita. It is probable that only a single Emerita collected upcoast was part of an overwintering population since the vast majority of individuals were in the 0-5 or 5-10 mm size classes (Figure 4A-3). As mentioned previously (SCE 1980) these small individuals reflect sporadic low-level recruitment outside the main March-June settlement period.

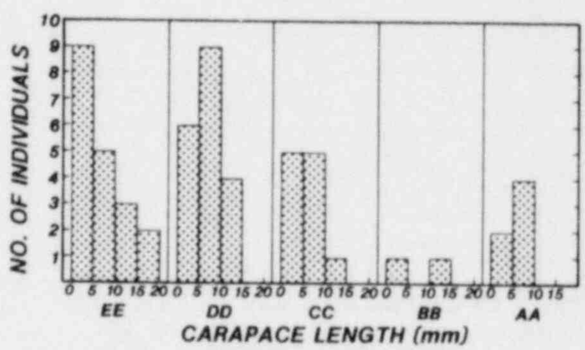

Figure 4A-3. Emerita size-frequency by transect, February 1980 survey.

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CHAPTER 4B

INTERTIDAL COBBLE

INTRODUCTION

The intertidal study was conducted during 1980 primarily to provide qualitative information used to maintain continuity with previous required studies and is not conducted to meet regulatory requirements. This chapter presents a historical summary of studies conducted in the San Onofre cobble areas and a brief characterization of this intertidal environment (Plate 4B-1). Data collection and analysis methodologies are described and the results and analysis of 1980 data are presented. The 1980 results are compared to results of previous San Onofre intertidal studies and discussed in relation to possible effects of San Onofre Unit 1 operation. The 1980 biological data used in this Analysis Report are contained in the Annual Operating Report, San Onofre Nuclear Generating Station, Volume II, Comprehensive Data Supplement (SCE 1981b).

BACKGROUND

HISTORICAL REVIEW (1963-1979)

Studies of intertidal sand and cobble biota have been conducted in the vicinity of San Onofre since 1963 (Table 4B-1). The studies were usually conducted quarterly during daylight low tides. The early studies varied considerably using quadrats ranging from 0.04- to 1-m^2 (0.43- to 10.8-ft^2) area, sampling different locations, and using different sampling designs. Results of the early qualitative Marine Environmental Monitoring (MEM) 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 San Onofre Unit 1.

Studies continued from 1973 to 1975 in compliance with California Regional Water Quality Control Board, San Diego Region requirements for the San Onofre Unit 1 MEM (LCMR 1974b,c, 1975f), and San Onofre Units 2 and 3 Sand Disposal Monitoring Program (SDMP; LCMR 1974a, 1975a,b,c,d,e, 1976a, b). The SDMP combined both sand beach and rocky cobble intertidal data collection to investigate possible effects resulting from sand disposal and construction activities of San Onofre Units 2 and 3. In November 1974, coordination of environmental monitoring programs resulted in formation of the San Onofre Unit 1 Environmental Technical Specifications (ETS) Program that fulfilled both California Regional Water Quality Control Board National Pollution Discharge Elimination System (NPDES) 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 (Figure 4B-1). Station locations were based on (1) available similar substrata and habitat types, (2) historical extent of the surface water thermal

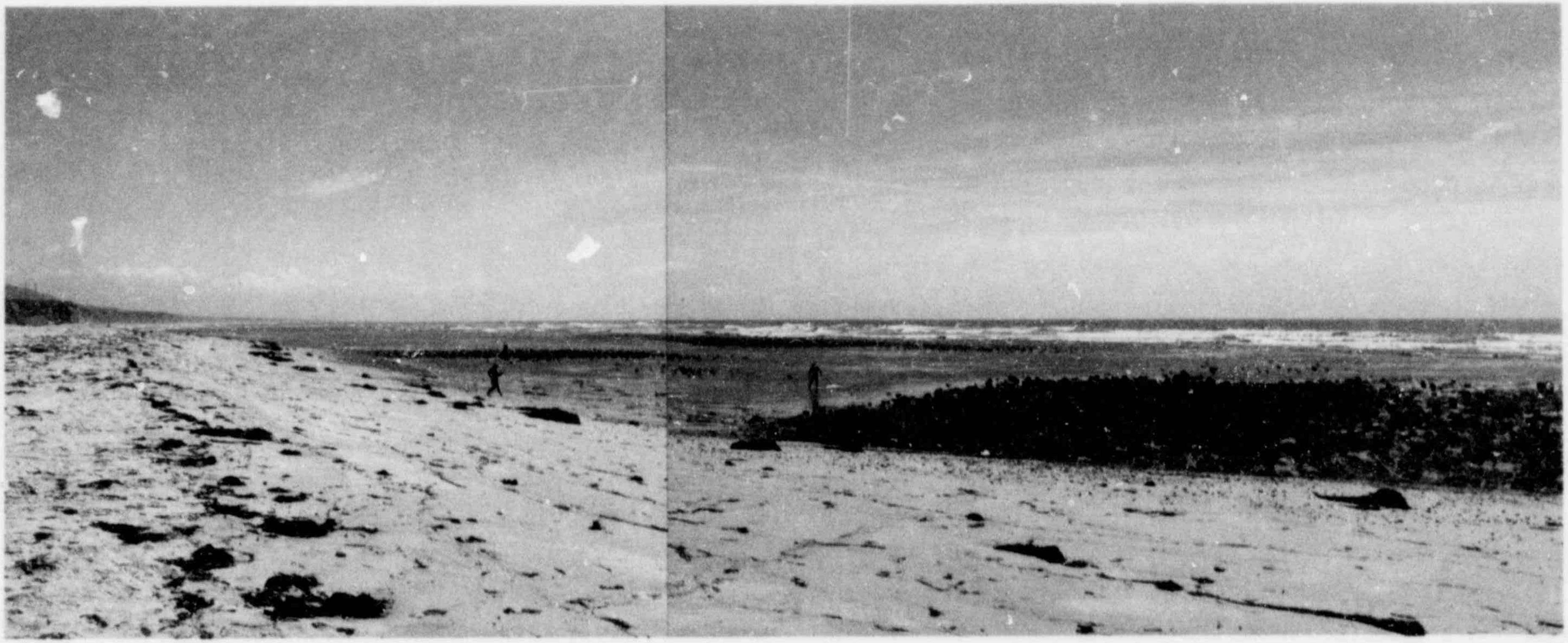

Plate 4B-1. Rocky and sandy intertidal habitats in the vicinity of the San Onofre Nuclear Generating Station.

Table 4B-1. Synopsis of SCE rocky cobble intertidal studies conducted offshore of San Onofre from 1963 through 1980.

	No. of Surveys per Year	Total No. Total No. of Surveys	Quadrat Size	Quadrats/ Station	No. of Stations	Sampling Design	Type of Data Collected
MARINE ENVIRONMENTAL MONITORING (MEM) PROGRAM							
Unit 1 Preoperational Sampling							
1963	1	1	-	-	1	-	A
1964	2	2	$0.1m^2$	4	1	Random toss quadrats	B
1964	1	1	$0.04m^2$	3	1	Quadrats sampling	B
1965, Jan	1	1	$0.06m^2$	3	1	Quadrats sampling	B
1965, April	1	1	-	-	2	-	A
1965	1	1	0.25, 0.5 or $1.0m^2$	3-5	2	Uniform (5-m) intervals	B
Unit 1 Transitional Sampling							
1966	4	4	$1.0m^2$	2-4	2	Random intervals	B
1967	4	4	$1.0m^2$	-	2	Uniform (5 or 10-m) intervals	B,J
Unit 1 Operational Sampling							
1968-1973	3-4	20	$1.0m^2$	-	2	Uniform (5 or 10-m) intervals	C
1974	4	3	$1.0m^2$	1-9	3	Uniform (5 or 10-m) intervals	C,K
SAND DISPOSAL MONITORING PROGRAM							
1974-1975	4	3	$1.0m^2$	2	2	Quadrats near MLLW	C,D,I,K
1975-1976	4	6	$1.0m^2$	1-9	3	Uniform (5 or 10-m) intervals	C,D,I
ENVIRONMENTAL TECHNICAL SPECIFICATIONS							
1975-1977	4	10	$0.25m^2$	3	5	Fixed quadrats & fixed 2-m wide hand transect	C,D,E,G,I
INTERIM OBSERVATIONAL PROGRAM							
1978-1980	3-4	11	$0.25m^2$	3	5	Fixed quadrats	H,E,F,I,D

A - Qualitative observations
B - % cover or number; ID to generic level
C - % cover or number; ID to species level
D - Beach measurements
E - % sand
F - % rock
G - Temperature
H - % cover or number of two most abundant taxa
I - Photographs
J - Excavation, to 5 in. Sporadic 13 cm (5 in) digs in cobble quadrats
K - $0.1\text{-}m^2$ dig samples to approximately 20 in depth. Sieved through 1-mm mesh screen. Infaunal organisms identified to species and counted.

field of the San Onofre 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. Each station consisted of permanent markers defining a band transect encompassing intertidal ecological zones 3 and 4 (Ricketts and Calvin 1971) and three 0.25-m^2 quadrats parallel to the sand and cobble contact line in ecological zone 4. All flora and fauna were identified and either counted or their percent cover estimated in the quadrats while only larger organisms were recorded in the 2-m (6.6-ft) wide band transect. Results of this study indicated that human activities such as clamming and tidepooling, the natural processes of sand and cobble movement, and the seasonal variability of populations were the major factors in changes in the intertidal environment.

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 San Onofre Unit 1. This, in conjunction with the conclusions of previous studies that there were no detectable effects resulting from the operation of San Onofre 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. The Observational Intertidal Study, 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 permanent station locations used during the ETS study.

1980 STUDY

Intertidal surveys were conducted quarterly at the ETS stations during 1980 except during the third quarter when there were no acceptable daylight low tides. Information collected during 1980 included percent sand and exposed bare rock, percent cover of the two most abundant organisms in each fixed quadrat, photographs of each fixed quadrat, distance and magnetic heading from the center quadrat to the sand and cobble contact line, and general observations.

DISCUSSION

The intertidal cobble habitat in the vicinity of San Onofre is limited to relatively small rocky areas interspersed among the larger areas of sand beaches (Plate 4B-1). In these areas, cobble occupies the lower ecological zones (3 and 4) and is conspicuous only during low tides. The areas at Stations 1 and 2, upcoast of Unit 1 (Figure 4B-1), have generally exhibited the largest expanses of cobble during past studies. The cobble habitats immediately upcoast (Station 3) and downcoast (Stations 4 and 5) of Unit 1 exhibit smaller expanses of cobble than Stations 1 and 2. The downcoast habitats have steeper beaches and generally have a mixture of cobbles and boulders thinly covering a bedrock base.

The cobble habitats upcoast of Unit 1 (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.

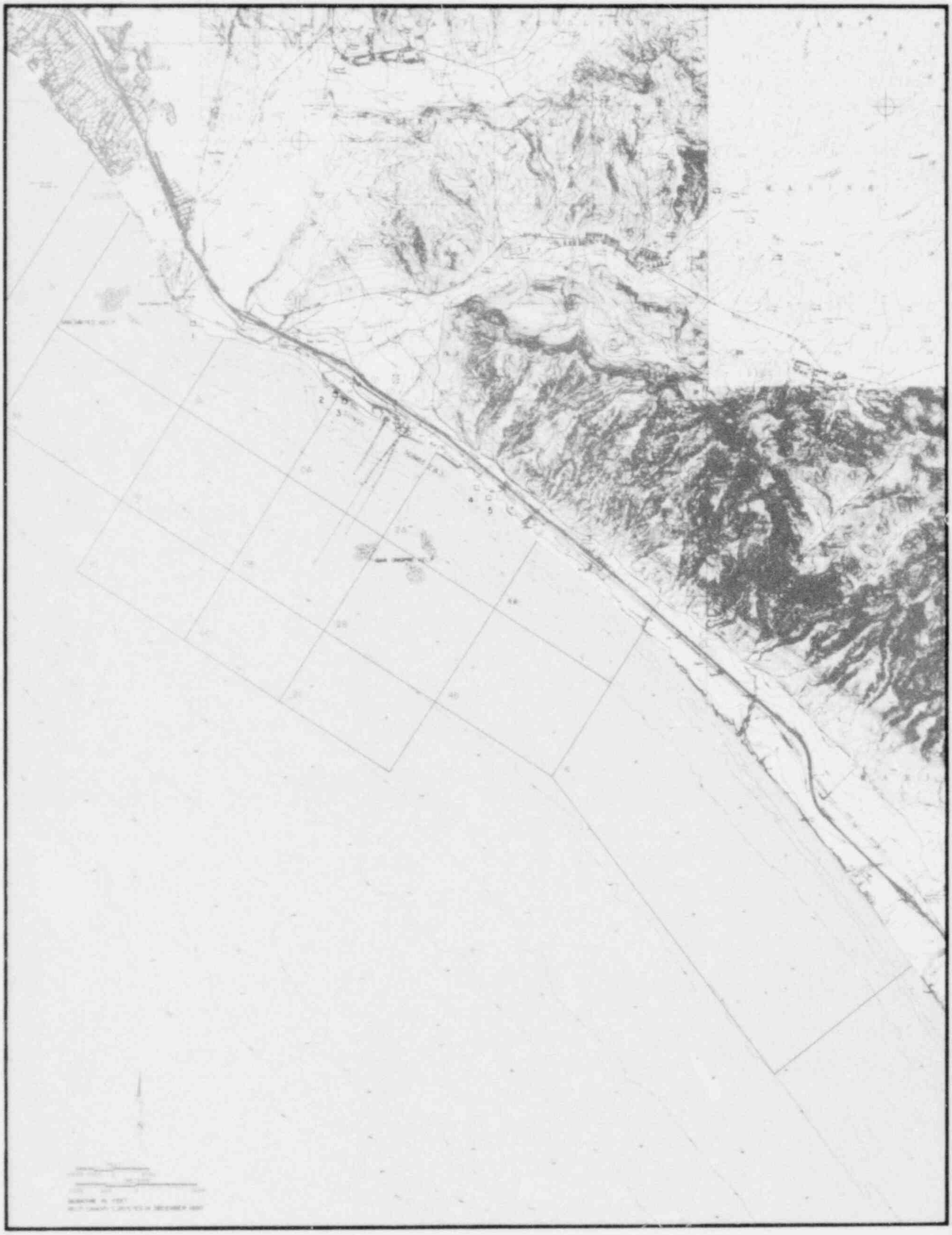

Figure 4B-1 ETS intertidal station locations at San Onofre Nuclear Generating Station.

Changes in density or percent cover of the abundant intertidal organisms observed generally exhibited recognizable seasonal trends. Variations in the abundance of a species within a station 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 has consistently been greatest during the summer months. This was also true in 1980 when a total of eight taxa were observed in June. The minimum number of abundant taxa observed during a survey was seven taxa in March and December. The number of different abundant taxa recorded during summer was greater due to the establishment of the green algae Enteromorpha spp. on previously bare cobble surfaces. This species colonizes 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 1980 data with historical data from the San Onofre 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; SCE 1980e).

Data for all stations during all surveys indicate that percent sand cover in the fixed quadrats was generally higher during winter surveys and lower during summer surveys excluding the unnatural disturbances at the downcoast stations during 1980 and the mild weather conditions prior to the December 1980 survey. The high percentage of sand cover noted in March 1980 at Station 1 was due to the diversion of San Mateo Creek from a naturally formed channel behind the beach berm during severe storm run-off. This channel extended about 0.5 km (0.3 miles) south and terminated at a small point of land, while sediment laden waters flowed across the cobble patch where Station 1 fixed quadrats were located. The cobble patch was covered with sand to depths approaching 1 m (3.3 ft). At other stations during the same period there was no general increase in the percentage of sand cover.

Sand accretion and burial of intertidal cobble areas has frequently been noted in reports in the San Onofre area since 1963. This process is probably significant in defining or limiting the populations of intertidal organisms (McKnight 1969; Connell 1972; SCE 1979b, 1980e). Organisms such as erect and crustose coralline algae and Zonaria farlowii are able to persist in areas affected by 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 the control area upcoast of San Onofre (Station 1) in 1980, is followed by decreasing abundance of macrobiota (MBC 1978). This phenomenon was obvious in the study area as indicated by the reduced percentage of biota in quadrats with increasing sand cover (SCE 1981b).

The extension of the intertidal sand areas over the cobble beds immediately upcoast of Unit 1 may also 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, 1980e). The sand accumulation immediately upcoast of the pad is a consequence of a temporary structure obstructing normal longshore drift. The effect may extend upcoast as far as the station 610 m (2,001 ft) upcoast of the Unit 1 discharge line. The intertidal sand as indicated by the sand and cobble contact line never covered the quadrats during 1980 as it did during December of 1978 and 1979 (SCE 1979d, 1980e), but remained more extensive than it was during surveys conducted prior to the construction of the laydown pad.

As sand cover is reduced through transport of winter sands or shifts in longshore current, new areas of cobble surface are usually exposed to settlement and growth of intertidal organisms during the spring and summer (Emerson 1975) as at the upcoast control station between March and June 1980. Photographs of fixed quadrats taken during the March 1980 survey showed the presence of small cobble with uncolonized surfaces exposed. Less bare cobble surfaces were present during the June survey, except in the newly exposed cobble area at the upcoast control station, indicating that much of the area .xposed by decreased sand cover and shifted cobble had been colonized, by species such as Ulva and Enteromorpha.

Substratum instability may also be a major process affecting the distribution and abundance of intertidal biota. The high number of different abundant taxa observed between intertidal stations and seasons 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 the overturning of cobbles. Similar results have been observed in other studies (Osman 1977, 1978) which indicated that intermediate sized cobble of 1 to 10 dm^3 (0.04 to 0.35 ft^3) are stable enough to establish a community, but not stable enough to allow a few taxa to establish dominance. This seemed to be the situation near San Onofre.

Changes in cobble patches over a long time period have also been observed in the intertidal stations. Among the more notable changes has been the general erosion of portions of some cobble patches both in area and elevation. Following the extensive excavation of two of the fixed quadrats in the downcoast cobble patch closest to Unit 1 between the June and November 1978 surveys, a small channel formed which emptied across an intertidal sand flat about 20 m (66 ft) upcoast of the fixed quadrats. By the December 1980 survey, most small loose cobble had been moved out of that channel, which was about 2 m (7 ft) wide and down to bedrock. The channel now has affected all three fixed quadrats, with changes in the biota a consequence of shifts in cobble substrata, currents, and percent sand on the channel bottom.

The cobble patch at the station 2,300 m (7,546 ft) downcoast also seems to be lower as indicated by increasing exposure of the corner markers of the fixed quadrats which are located on the high part of the cobble patch. Similar observations were made at the station 850 m (2,789 ft) upcoast during the February 1978 survey (SCE 1979b). Subsequent observations have indicated that the general cobble level at this station has returned to the level seen during previous years.

Clamming or digging activity observed during 1980 showed an increase over observed activity in 1979 and was comparable with the activity noted in years prior to 1979 (Parr 1973; LCMR 1977b; SCE 1979d, 1980e). Severe local storms and associated terrestrial runoff during 1978 and 1979 have been implicated in reduced clam populations in the San Onofre area (Williams 1979), and were probably responsible for the reduced clamming activity during 1979. During 1980, however, human intervention and excavation activity was noted during all surveys, resulting in considerable localized disturbance of the habitat and associated biota in some areas. Recolonization of biota in the disturbed areas at Stations 3, 4, and 5 was not 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,e).

Other unnatural disturbances of biota occurred at the downcoast stations during 1980, when mats composed mostly of fishing line with some electrical wire, fabric, and firehose fragments caught on corner markers of quadrats of the downcoast stations. The scouring action of the mats resulted in exposure of higher

percentages of bare rock and reduced biotal coverage. The mats were removed during each survey, however, they reoccurred throughout the year, indicating that the areas were used for surf-fishing, probably during periods of higher tides.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

METHODS

FIELD

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

Station locations are shown in Figure 4B-1. Station 1, 3.1 km (1.9 mi) upcoast of the San Onofre Unit 1 discharge line, is outside the 1°F (0.6°C) 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 (2.69-ft^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 were employed to survey the dominant macroorganisms living on the surface of the substrata at each station. Biologists visually estimated 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 were 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 were taken during each survey using natural light. All field work was conducted in daylight during low tides of at least -0.18 m (-0.6 ft) MLLW.

Surveys were conducted on 13 and 14 March, 14 and 15 June, and 19 and 20 December. There were no daylight low tides suitable for sampling during the third calendar quarter.

RESULTS

A qualitative description of the 1980 biological and physical data is presented for each station. The mean percent sand and mean percent bare rock are presented in Figures 4B-2 and 4B-3, respectively.

INTERTIDAL COBBLE STATION 1 - REFERENCE STATION

Observations recorded during the three 1980 surveys revealed that the major human activity in the area was surfing. No excavations were noted near the fixed quadrats and no clammers were observed in the area. Activities of tidepoolers resulted in some habitat disturbance (e.g., turning over cobbles) in this intertidal cobble area.

Percent sand cover in the fixed quadrats ranged from 1 to 7% during the June and December 1980 surveys, and was 100% in all quadrats during the March survey.

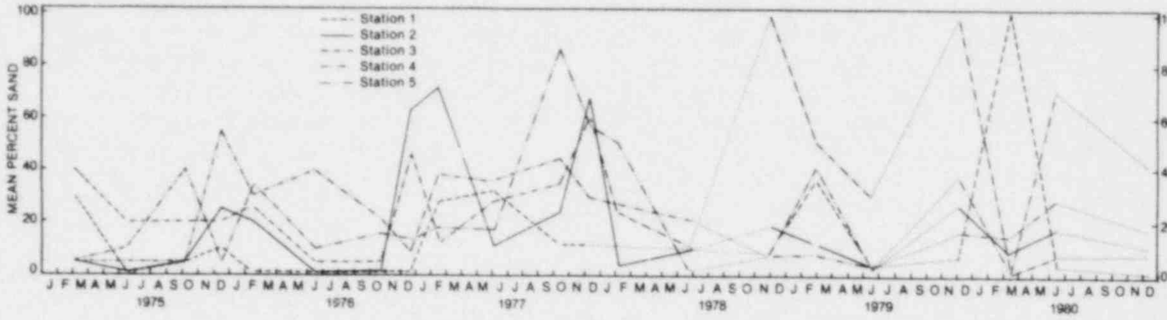

Figure 4B 2. Mean percent sand present at ETS intertidal cobble stations from October 1976 to December 1980. Intermittent data is indicated by a dotted line (. . . .).

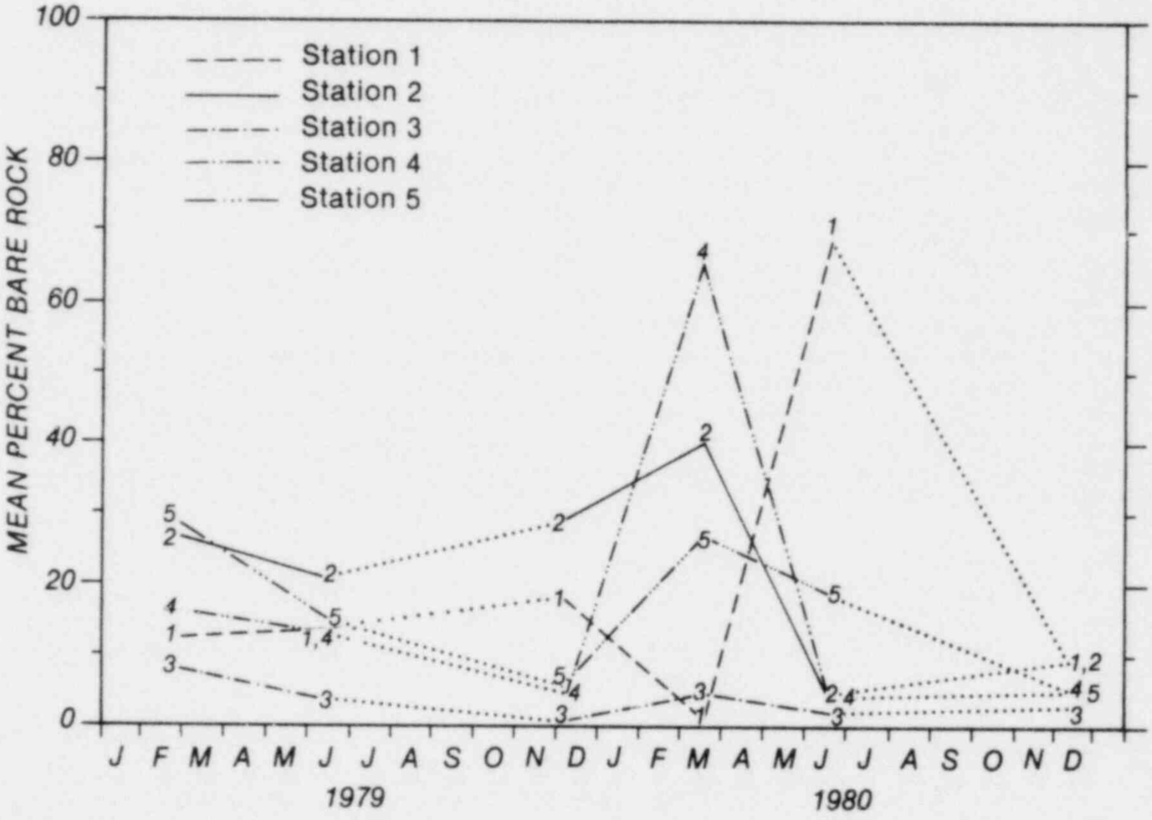

Figure 4B-3. Mean percent bare rock exposed at intertidal cobble station fixed quadrats from 27 February 1979 to 19 December 1980. Intermittent data is indicated by a dotted line (. . . .).

The sand and cobble contact line was 11 m (36 ft) and 26 m (85 ft) shoreward of the fixed quadrats during the June and December sampling periods but 12 m (39 ft) offshore during the March sampling period. Percent bare rock in the quadrats ranged from 70-80% during the June survey and from 1 to 2% during the December survey.

The most abundant taxa, based on percent cover, in the fixed quadrats during 1980 were a turf complex of small algae, Parvosilvosa (Neushul and Dahl 1967), and a chlorophyte alga Enteromorpha spp. During two of the three surveys, the erect coralline algae Corallina/Haliptylon complex was abundant in one quadrat. The red algae Gelidium/Pterocladia complex was one of the two most abundant taxa in one quadrat during the December survey.

INTERTIDAL COBBLE STATION 2

No excavations were noted in the vicinity of the fixed quadrats during the 1980 surveys, but clamming activity was noted in the area during the June survey. The main human activity observed was tidepooling. Surfing and sport fishing activities were also noted. The mean percent sand cover was low during all surveys, with individual quadrats exhibiting a range from 2 to 25% sand cover. More surface area of bare cobble was exposed during the March and December surveys. The sand and cobble contact line was 28 m (92 ft) shoreward of fixed quadrat 2 in December, 9 m (30 ft) closer than during the March survey, and 5 m (16 ft) closer than during the June survey.

Zonaria farlowii, Sargassum spp., and the erect coralline algae complex Corallina/Haliptylon were usually among the two most abundant taxa in the Station 2 quadrats during 1980. Enteromorpha spp. was one of the two most abundant taxa in all three quadrats only during the June survey. The two algal complexes, Parvosilvosa and Gelidium spp., were abundant in the December survey. The crustose alga Ralfsia spp. was reported as abundant in one quadrat during the March 1980 survey.

INTERTIDAL COBBLE STATION 3

Clamming activities were noted during the three 1980 surveys and tidepooling, fishing, and surfing activities were observed in the cobble area during the June survey. Percent sand cover in the fixed quadrats varied from 0 to 15% during the 1980 surveys. The sand and cobble contact line was about 7 m shoreward of fixed quadrat 2 during the December survey and was within 2 to 3 m (7 to 10 ft) of quadrat 2 during the March and June surveys. Bare rock varied from 1 to 5% exposure during the 1980 surveys.

The Corallina/Haliptylon complex and Parvosilvosa were most frequently among the two most abundant taxa in the fixed quadrats during all three surveys. The chlorophyte algae Enteromorpha spp. was one of the two most abundant algae during the June survey. Zonaria farlowii was one of the two most abundant algae only in one quadrat in the March 1980 survey.

INTERTIDAL COBBLE STATION 4

No clammers were noted during the 1980 surveys, however, overturned boulders and cobble, and exposed bedrock were evident in fixed quadrats 2 and 3 as in 1979 (SCE 1980e), possibly indicating that some continuing natural process and/or clamming or tidepooling activity had occurred. Additional disturbance was caused by mats of fishing line, wire, and cloth, and a piece of firehose that pivoted on the corner markers and abraded the substrata. During the 1980 surveys, the percent sand cover in the quadrats varied from 1 to 85%. The high sand cover estimates were primarily composed of a thin layer of sand over bedrock in the excavated quadrats. Percent bare rock varied from 20 to 85% during the surveys, with the highest percentages of exposed rock occurring in disturbed quadrats 2 and 3. The sand and cobble contact line was approximately 2, 12, and 11 m shoreward of fixed quadrat 2 during the March, June, and December surveys, respectively.

The Corallina/Haliptylon and Parvosilvosa complexes were usually the most abundant algae during all three surveys. Phyllospadix spp. and unidentified crustose coralline algae were recorded among the two most abundant taxa in the fixed quadrats during the March 1980 survey. Endocladia spp. was abundant in one quadrat during the June survey. Percent biotal cover ranged from 4 to 14% in quadrats where the mats of debris were caught on the corner markers.

INTERTIDAL COBBLE STATION 5

Excavations indicating clamming activity were noted in the cobble area during the 1980 surveys. Surfing and tidepooling activities were observed in the vicinity of Station 5 during the December and March surveys. The sand and cobble contact line ranged from approximately 7 to 12 m (23 to 39 ft) shoreward of fixed quadrat 2 during the 1980 surveys. Fixed quadrat 3 had been disturbed apparently from some excavation prior to the December survey. A continuing general erosion of the cobble bed was indicated by increasing exposure of the corner markers of all three fixed quadrats. At the time of the March sampling, fixed quadrat 2 was being scraped by a mat of nylon line and wire which was pivoting on the corner markers of the quadrat. The percent bare rock was higher in this disturbed quadrat than in the other quadrats, varying over the year from 4 to 45%.

The Corallina/Haliptylon complex was one of the two most abundant algae in all quadrats during all surveys ranging from 5 to 35% cover. Parvosilvosa increased in percent cover in all fixed quadrats from March to December until it covered from 20 to 45%, while Phyllospadix spp. decreased in percent cover from 50 to 10% in fixed quadrat 1 over the same period.

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CHAPTER 5

SUBTIDAL

INTRODUCTION

The sea floor off San Onofre Nuclear Generating Station 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 dobble or cobble/boulder mixtures are interspersed with the softer sediments throughout the San Onofre offshore area. In consequence, the subtidal biota is composed of both species adapted 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 benthic infaunal community was under investigation primarily to assess potential environmental effects resulting from San Onofre Units 2 and 3 construction activities. In addition, the data gathered functionally provide a preoperational data base for future comparison with data collected during plant operation. The studies met the regulatory requirements set forth by the California Regional Water Quality Control Board-San Diego Region (CRWQCB-SDR) for a Construction Monitoring Program (CMP).

This chapter presents: 1) a synthesis of data collected during 1980 under the CMP; 2) analyses and interpretation of the data; 3) discussion of biotic composition and distribution in relation to San Onofre construction and operation; and 4) provides a comparison with benthic communities outside the immediate San Onofre area for perspective.

Data collected during the 1980 field efforts was presented in summarized form (SCE 1981a) and in a comprehensive report (SCE 1981b).

BACKGROUND

A brief chronological history of environmental studies examining benthic infauna at San Onofre is presented in Table 5A-1.

Marine Environmental Monitoring (MEM) of benthic communities examining both rocky and sandy habitats in the vicinity of San Onofre began in 1963 and continued under this program until 1973 (Environmental Quality Analysts and Marine Biological Consultants 1973, Lockheed Aircraft Service 1974). The studies were performed semiannually except for three per year in 1969 and 1970. Surveillance was primarily accomplished through diver observations at six stations and was semiquantitative with identification of surficial organisms on rock and sand substrate and abundance estimates (visibility permitting). With the exception of substrate records, physical/chemical features of the organisms habitat remained largely unexplored. Methods changed slightly through the years with a major modification, the addition of limited (3 replicates) infaunal core sampling, occurring in 1969. This change provided the first detailed examination of the sediment infaunal community. The data collected generally provided long-term surveillance records with continuity of time and sampling locations.

In 1974 the San Disposal Monitoring (SDM) program was initiated (Table 5A-1) and continued through 1976 (MBC 1975, 1977). The monitoring program complied with specifications set forth by the CRWQCB-SDR order No. 71-6. Studies performed under this program were designed to assess effects of sand spoil disposal resulting from bluff excavation related to construction activities for San Onofre Units 2 and 3. The number of stations sampled was five, of which three were composed of sand substrate. Biological core replication was also increased from three under MEM to four per station. No sediment substrate samples for grain size or organic carbon were collected. This program continued during the initial

Table 5A-1. Chronological history of SCE-sponsored benthic infaunal monitoring at the San Onofre site.

Major Programs	Date	Method	Freq.	Locality	Replicates	Type of Data Collected
Marine Environmental Monitoring				Offshore		
Unit I Preoperational	1963-Aug 1966	Diver Observation	2/yr	Unit 1	-	Diver observations, semiquantitative, macro-species identification, substrate records, no samples collected.
Unit 1 Operational	1967-69	"	"	6 stations	-	
	1969-73	" and core samples	"		3 biological core tubes/station	" and addition of infaunal sampling by coring sieve and identification in laboratory.
Sand Disposal Monitoring Program						
Predisposal surveys	1974	Diver	4/yr	Offshore	4 biological	Benthic infaunal sampling by coring substrate
1st Postdisposal	1974	cores	"	Units 2&3	cores/station	records, surficial identification. Lab identifica-
2nd	1974-75	"	"	3 Stations	"	tion of organisms >1.0 mm, enumeration size fre-
3rd	1975	"	"	"	"	quency of dominant species, no grain size or
4th	1975	"	"	"	"	carb[illegible] data.
5th	1976	"	"	"	"	"
6th	1976	"	"	"	"	"
7th	1976	"	"	"	"	"
8th	1976	"	"	"	"	"
Construction Monitoring Program (CMP)	1976-77	"	"	Offshore Units 2&3 18 stations including upcoast-downcoast reference areas.	Core samples 3 biological 1 grain size 1 carbon/station.	Infaunal core sampling, identification, enumeration and biomass, substrate grain size and carbon samples, sediment trap data, water clarity and temperature.
CMP and Preoperational Monitoring Program	1978 1979 1980	"	"	"	Min 5, max 12 biological box cores. Min 3, max 4 grain size. Min 3, max 8 sediment organic samples.	" and increase replication of biological and sedimentological samples

construction phases for Units 2 and 3, and was replaced by the Construction Monitoring Program (CMP) once offshore dredging began.

In 1976 when offshore dredging activities associated with construction of San Onofre Units 2 and 3 began, the Construction Monitoring Program (CMP) was initiated. This program, mandated by the CRWQCB-SDR for quantitative monitoring and reporting, examined the environmental effects of dredge and construction related sand dispersal on the benthic infaunal community (Figure 5A-1). A new sampling array with 18 stations offshore Units 2 and 3 as well as upcoast and downcoast was established. Originally three biological, one grain size, and one sediment organic carbon sample were collected at each station. The program was improved through 1977-1978 with biological and physical/chemical replication determined by state-of-the-art methods. Infaunal sampling at a station ranged from 5 to 12 replicates depending on station depth. Grain size replication ranged from three to four samples per station and organic carbon from three to eight replicates per station, again depending on station depth.

1980 STUDIES

This report presents data and discussions resulting from surveys performed under the CMP during March and June 1980. These were the final two surveys conducted since offshore construction activities ceased in March 1980.

DISCUSSION

The San Onofre sublittoral zone is composed of both rocky and sandy benthic habitats. The sandy soft bottom environment is extensive and supports a

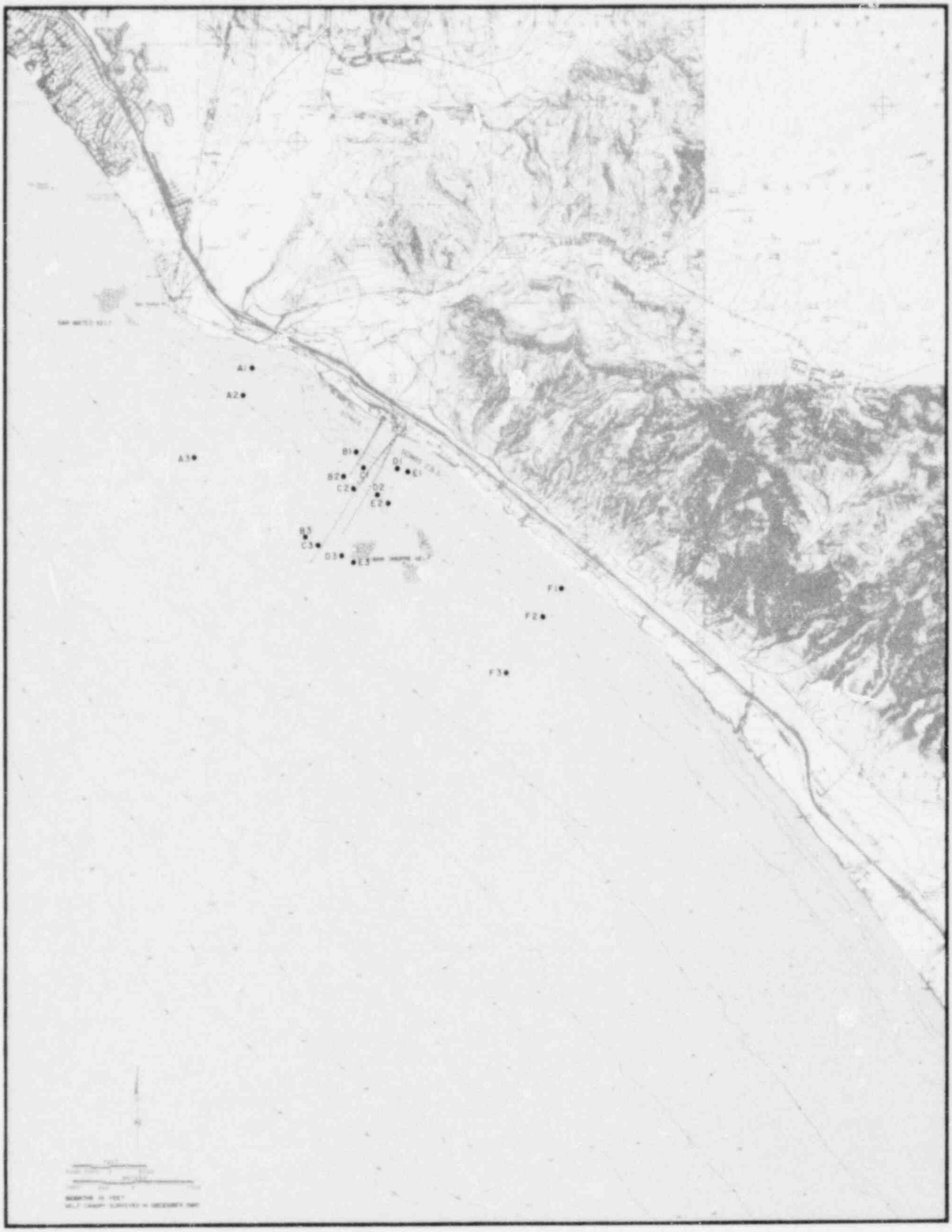

Figure 5A-1. Station locations.

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 sediment grain size they live in or consume (Gray 1974, Johnson 1971, Lie and Kisker 1970). McCave (1974) also suggests that 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). Since dredging and other construction related activities (and structures) can modify the sediment environment, the benthic infauna may be affected. Community composition and distribution features are key factors to monitoring changes in benthic infauna since shifts in numbers of species and individuals through time and space usually occur in response to natural or man-induced environmental alteration.

NUMBER OF SPECIES AND INDIVIDUALS OF THE BENTHIC INFAUNAL COMMUNITY

The number of species and number of individuals are interrelated community parameters. These features were examined at San Onofre quarterly on a station by station basis during 1979 and 1980. 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 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 affected by construction of Units 2 and 3 or operation of Unit 1, was the greater number of species in deeper water. These results were evident in 1978 and 1979 and persisted through 1980 (Figure 5A-2) (SCE 1979, 1980). This pattern is characteristic of exposed open coast environments in the southern California bight such as San Onofre (Lie and Kisker 1970, Diener and Parr 1977).

The mean number of species at reference and treatment stations was very similar throughout the year. There was, however, generally lower numbers of species recorded from stations upcoast of San Onofre compared to downcoast stations (Figure 5A-2).

During previous surveys (SCE 1979, 1980) Stations A1 and E3 (see Table 5A-2 for depth conversions metric to feet and station abbreviations) exhibited marked shifts in species composition and numbers of individuals. In 1979, Station A1 was radically modified by storm runoff exposing underlying rock substrate while sweeping soft sediments seaward. This resulted in periods with no "infaunal community" at this site. These results were not repeated in 1980 and data

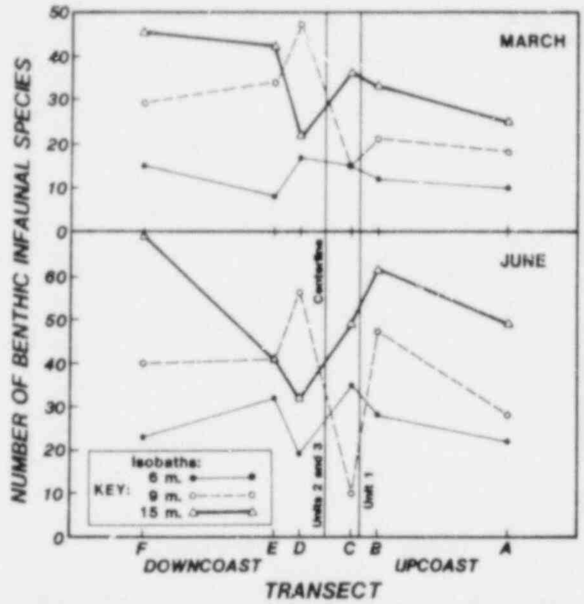

Figure 5A-2. Number of benthic infaunal species by depth, station, and survey period.

obtained suggest the species composition at Station A1 is comparable to that of other 6 m isobath stations. Station E3 also did not appear to undergo the changes in community composition or abundance recorded during earlier surveys.

A pronounced seasonal pattern of change in the number of species was found in previous years (SCE 1979, 1980) and was again apparent in 1980. The greatest number of species were found during the June survey. Within a season, the 15 m isobath stations were consistently the most diverse while inshore stations always supported the fewest number of species.

Patterns of species diversity were revealed in data from each quarterly survey (Figure 5A-2). Patterns of higher and lower numbers of species upcoast and downcoast of Units 2 and 3 and the discharge of Unit 1 recorded during 1978 and 1979 (SCE 1979, 1980) were still evident.

The mean number of individuals/liter recorded by depth during the quarterly surveys is shown in Figure 5A-3. Trends in the annual mean number of individuals/liter were fairly consistent between stations on the same transect with abundances near the construction area either higher or lower than reference areas. Individual survey plots of mean number of individuals/liter for each station (Figure 5A-3) reflected a pattern similar to that observed for numbers of species. Treatment stations on the 9 and 15 m isobaths upcoast and downcoast of the dredgeline supported elevated numbers of individuals/liter compared to reference stations. This pattern was less evident at the 6 m stations. Reference stations on the same isobath generally contained similar annual mean numbers of individuals/liter, suggesting limited effects from construction or operation.

Table 5A-2. Station depth abbreviations.

Depth (m)	Depth (ft)	Transects					
6	19.7	A1	B1	C1	D1	E1	F1
9	29.5	A2	B2	C2	D2	E2	F2
15	49.2	A3	B3	C3	D3	E3	F3

The two community parameters discussed above are interdependent and strong similarities in their distributional patterns were expected. There appeared to be a relationship between biotic patterns and sediment patterns (see Chapter 2D, Sedimentology). 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 limited replacement downcoast of this area. Thus, patterns in numbers of species and individuals previously noted, resulted from substrate modification associated with construction activities. It is anticipated that these effects will not persist since the barriers to normal longshore transport have been removed and all dredging was completed. 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 may in part represent species life history adaptations to the environment. Dynamic environments of low predictability, such as many in the southern California bight, 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 at San Onofre (which exhibited high substrate dynamism) would be considered opportunists.

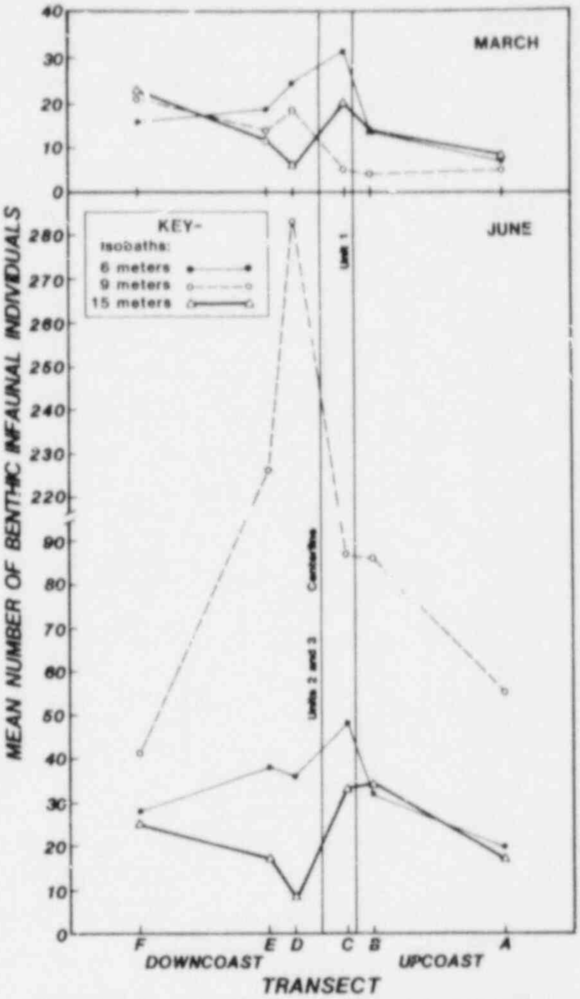

Figure 5A-3. Number of benthic infaunal individuals/liter by depth, station and survey period.

Additional factors associated with substrate stability can influence observed biotic patterns by affecting larval recruitment. Many species colonize from meroplanktonic recruits transported into the San Onofre 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 (i.e. near the trestle structures) of accretion and erosion as well as operation of Unit 1 (i.e.near the discharge and intake structures).

PATTERNS IN BENTHIC INFAUNAL COMMUNITY DISTRIBUTION

Classification analysis of benthic infaunal data revealed several types of community distributional patterns. All patterns were similar to the results from 1978 and 1979 (SCE 1979, 1980) and included: 1) clusters of stations whose communities varied along a depth gradient, 2) groups of species whose distribution and highest abundance characterized specific isobaths, and 3) presence of several ubiquitous species.

Normal analyses of data from both surveys revealed a distinct onshore-offshore pattern of station similarity which corresponded to the depth gradient (Table 5A-3, Figures 5A-4 and 5A-5). The results indicated that most stations on an isobath (both reference and treatment stations) had similar faunal assemblages

Table 5A-3. 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

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.

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 slightly, displayed a high degree of internal consistency in the presence and abundance of dominant community members.

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 B9 and C9 in station Group 1 of the March survey, Station A1 in station Group 1 in the June 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. This phenomenon was apparently short-lived, since stations which shifted group affinities returned to their depth group in subsequent surveys. Major substrate differences in sediment size and grain size distribution appear correlated with the observed biological differences (Chapter 2D, Sedimentology). The biological differences probably represent responses to this habitat modification.

The species groups determined from the inverse classification had abundance patterns characterizing the various stations which persisted through the year. However, between surveys, as some species additions and disappearances occurred between surveys the communities were modified slightly. Since a large number of species were 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-4 through 5A-5).

The inshore 6 m isobath stations were characterized by species groups with few species. Many of these species are regular inhabitants having been recorded at the same stations in 1978 and 1979 (SCE 1979, 1980). 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 bicuspidatus and Euhaustorius washingtonianus; and the cumacean Leptocuma forsmani.

Species which were restricted to the 9 and 15 m isobath stations during most seasons or which occurred in their highest relative abundances at these stations included: the polychaete Amastigos acutus, Owenia collaris, Mediomastus ambiseta, Mediomastus acutus, Nephtys cornuta franciscana, Chaetozone setosa, and Eusigalion spinosum; the ostracod Euphilomedes carcharodonta; the cumacean Oxyurostylis pacifica; the mollusks Tellina modesta, Periploma discus, and Yoldia scissurata; the amphipod Photis macrotica and the ophiuroid Ophiophragmus urtica.

Most of the species encountered in the subtidal benthic collections displayed a definite distributional pattern and occured in assemblages which characterized distinct depth regimes. Some species, however, were ubiquitous in

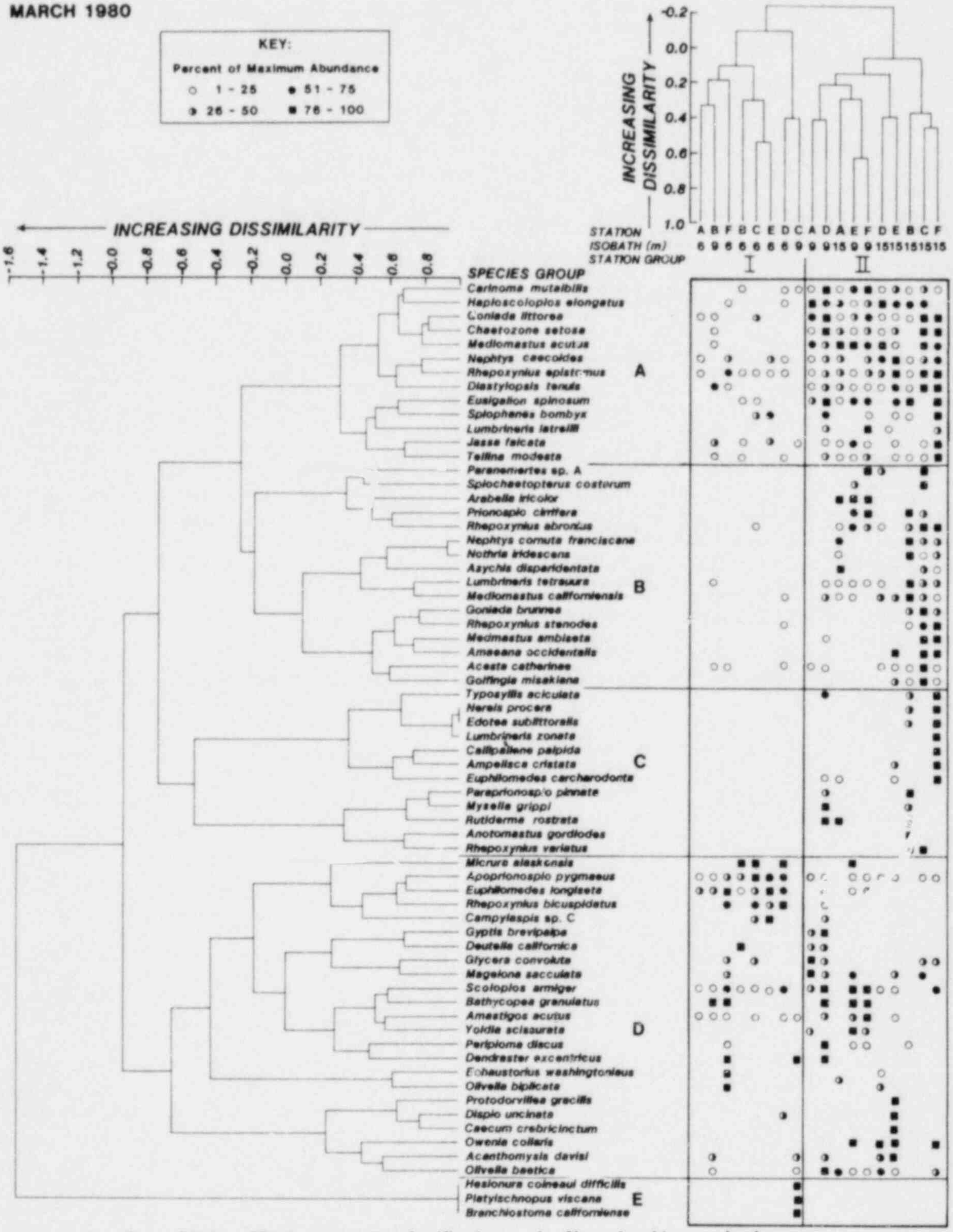

Figure 5A-4. March community classification results. Normal and inverse dendrograms with resultant two-way table.

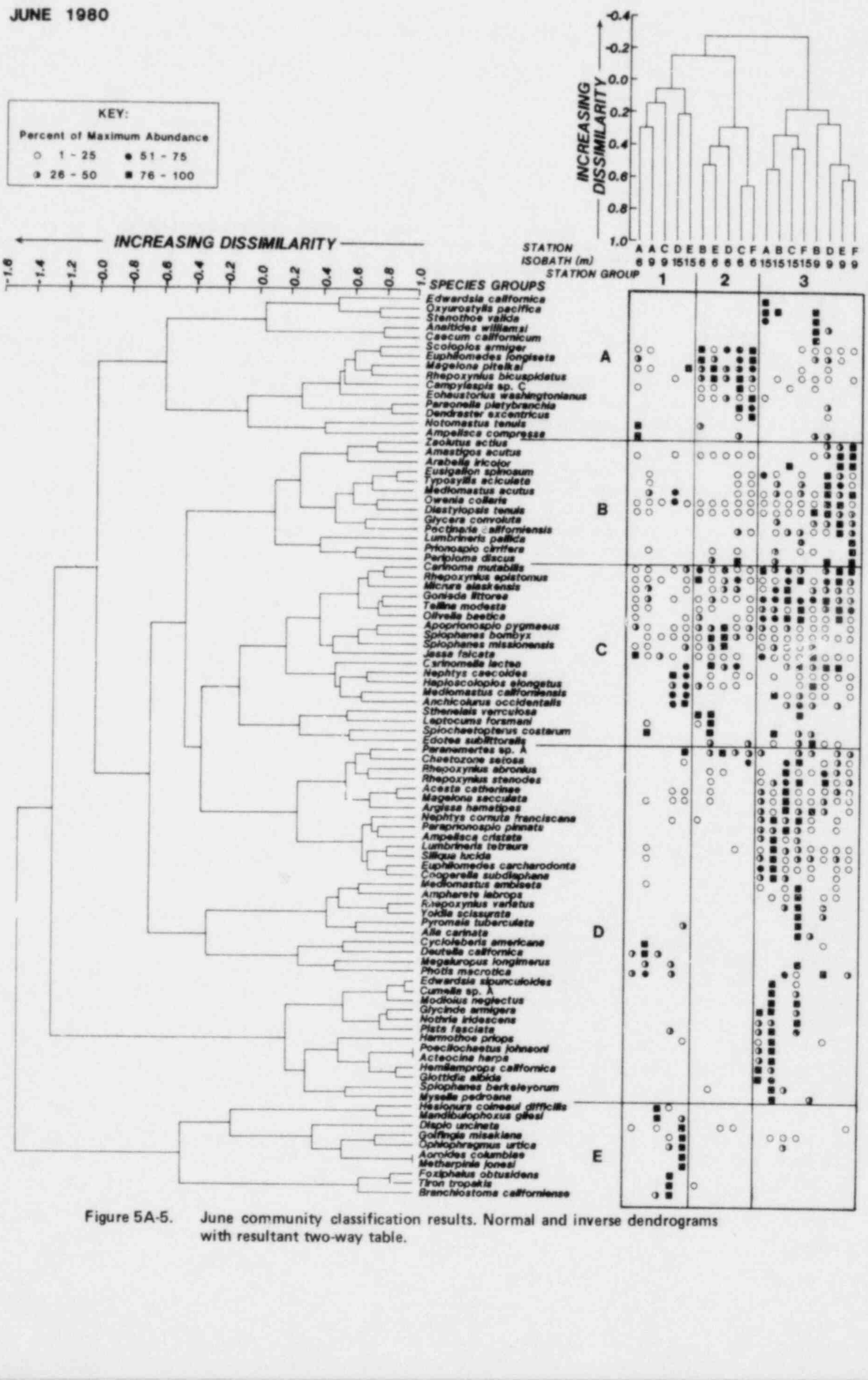

Figure 5A-5. June community classification results. Normal and inverse dendrograms with resultant two-way table.

the study area, although they may have occurred in high abundance at only one depth. Among these species were: the polychaetes Spiophanes bombyx, Amastigos acutus, and Spiophanes missionensis: the mollusk Tellina modesta; and the amphipod Rhepoxynius epistomus.

The restricted patterns of distribution exhibited by many of the species discussed above was not coincidental. Many occur throughout the southern California bight and have been reported as inhabitants of similar microhabitats (MBC 1980, 1981a-c). Their site-specific distribution patterns are determined by physiological, food, and other microhabitat features. 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).

In general, community composition and distributional patterns appear to have been influenced by depth, sediment composition, sedimentation, and the organic carbon content of the sediments. Depth was the only factor which was not influenced by San Onofre Units 2 and 3 construction and Unit 1 operation. Community analyses suggested that distributional patterns of characteristic benthic species were not permanently altered by San Onofre construction and operation activities. However, community parameters such as diversity, and number of individuals, were modified at stations immediately adjacent (within 236 m) upcoast and downcoast of the San Onofre Units 2 and 3 construction compared with reference stations. The effects presumably were caused by the impediment of longshore sediment transport. Effects of construction activities on the benthic infauna are not expected to persist now that construction-related trestles and other structural impediments have been removed.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

APPROACH

Biological collections were made at stations located on six permanent transects. Two of the transects were established as reference areas, one upcoast and one downcoast, of the construction site. The remaining four treatment transects flank the dredging axis for intake and diffuser lines.

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 CMP is to define the extent and severity of any impact 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) by Unit 1 are also considered here.

Environmental effects associated with construction of Units 2 and 3 or with operation of Unit 1 or both may be indicated by population or community characteristics which differ markedly from the "normal" characteristics exhibited by organisms in reference areas. The data gathered during this investigation were analyzed at various levels of complexity to determine any effects. 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, species numbers or numbers of individuals between treatment and reference stations?
   b. changes in benthic infaunal community distribution patterns normally associated with the area offshore San Onofre?

DATA SOURCES

Data discussed in this report were obtained primarily from two sources. The two quarterly surveys performed during 1980 and previous studies of the same program during the period 1976-1979 (MBC 1977, 1978, 1979).

METHODS

Data were collected during two quarters, March and June 1980. 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 the dredging and conduit emplacement route (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 conduits may 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.

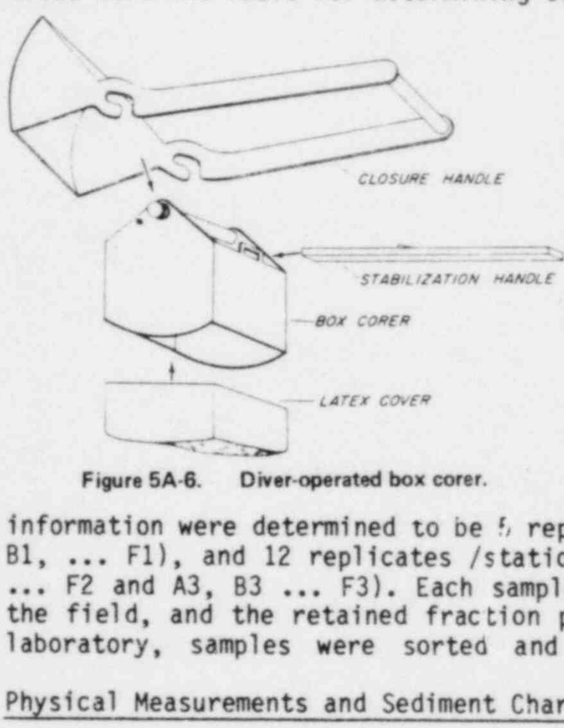

Figure 5A-6. Diver-operated box corer.

BIOLOGICAL SAMPLING

At each station replicate 1 liter 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-6).

The number of core samples necessary to adequately represent the infaunal biota was determined from a test collection and from analysis of 1977 data using information loss, species accumulation, and percent detectible change measures as criteria. Optimum levels of effort and information were determined to be 5 replicates/station along the 6 m isobath (A1, B1, ... 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-seawater. In the laboratory, samples were sorted and the species identified and enumerated.

Physical Measurements and Sediment Characteristic

At each station, sediment stake heights (i.e. 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 determination and grain size analysis were collected adjacent to the biological samples at each station. 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 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 1974). Calculations for mean phi, skewness, kurtosis, and other sediment descriptive characteristics followed standard formulae based on moment measures (Folk 1974) (see Chapter 2D, Sedimentology).

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 spatial and temporal patterns of species numbers and numbers of individuals. Multivariate analytical techniques were employed to synthesize community distribution patterns.

Multivariate Techniques. 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 that 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 common 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 two individuals.

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 dendrogram. 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 analyses, data were square root transformed and standardized by the species maximum to reduce the excessive influence of abundant species (Smith 1976).

RESULTS

1980 RESULTS

The infaunal community surveyed during this program was highly variable among stations in terms of species composition and abundance. Over 14,800 infaunal organisms were collected during the two surveys including 318 taxa representing 12 phyla. The total number of individuals ranged from a low of 2,409 in March to 12,480 in June. The total number of taxa recorded by survey followed a similar trend and increased from a low of 193 in March to a high of 259 in June. The majority of taxa were identified to species; however, some taxa were identified at higher levels of classification. The number of taxa is an approximation of the true number of species because it includes both overestimations and underestimations. Some specimens cannot be identified to species because of immaturity, or fragmentation during sampling which results in overestimation through introduction of "artificial" taxa (e.g. Tellina sp.). These small clams were probably juveniles of T. modesta that had not developed the anatomical characteristics which 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 89% of all the taxa collected (Table 5A-4). 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 1 liter samples collected at that station. (All station abbreviations and depth conversion from metric to feet are presented in Table 5A-2 for convenience.) Since the optimal sample size was previously determined, the cumulative species diversity value reflected the total diversity at a station.

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 collected per station during each survey are listed in Table 5A-5 and are graphically presented in Figure 5A-2. The

Table 5A-4. Phyletic composition of the benthic infaunal community.

Phylum	Number of Taxa	Percent
Annelida	128	40.25
Arthropoda	104	32.70
Mollusca	50	15.72
Echinodermata	9	2.83
Cnidaria	9	2.83
Nemertea	7	2.20
Chordata	3	0.94
Phoronida	2	0.63
Ectoprocta	2	0.63
Sipunculoidea	2	0.63
Nematoda	1	0.31
Brachiopoda	1	0.31
Total Taxa	318	
Total Phyla	12	
Total percent		≈100

number of species generally increased with increasing depth. The mean number of species at all stations increased between the March and June surveys.

The mean number of species collected at 6 m reference stations ranged from a low of 12.5 during March to a high of 22.5 species in June. The mean number of species at 6 m treatment stations ranged from a low of 13.0 in March to a high of 36.0 in June. The mean number of species at 9 m reference stations ranged from 23.5 in March to 34.0 in June, while 9 m treatment station means ranged from 26.8 in March to 38.5 in June. The mean number of species recorded for the 15 m reference stations ranged from 35.0 in March to 44.0 in June, and treatment station values were 33.3 and 45.8 for March and June, respectively.

Annual mean number of species for all reference stations located on the 6 m isobath was 17.5, while the annual mean at treatment stations was 20.8. The annual mean number of species collected at 9 m isobath reference stations was 28.8 and that for treatment stations was 33.9. At the 15 m isobath reference stations, the annual mean number of species was 39.5, while the treatment stations on the same isobath had a mean of 29.0.

NUMBER OF INDIVIDUALS

The mean number of individuals/liter at a station generally increased between March and June (Table 5A-6, Figure 5A-3). When annual isobath means for reference and treatment areas are considered, the mean number of individuals/liter was greater at the mid-depth (9 m) stations. The annual mean values at the reference stations were highest (30.5 individuals/liter) at the 9 m station

Table 5A-5. Number of benthic infauna species by station and survey period.

Isobath	Station	Survey: March	Survey: June	Mean
6 m	A	10	22	16.0
	F	15	23	19.0
Reference $\bar{X}$		12.5	22.5	17.5
	B	12	28	20.0
	C	15	35	25.0
	D	17	19	18.0
	E	8	32	20.0
Treatment $\bar{X}$		13.0	26.0	20.75
9 m	A	18	28	23.0
	F	29	40	34.5
Reference $\bar{X}$		23.5	34.0	28.75
	B	21	47	34.0
	C	15	10	12.5
	D	47	56	51.5
	E	34	41	37.5
Treatment $\bar{X}$		26.75	38.5	33.86
15 m	A	25	19	22.0
	F	45	69	57.0
Reference $\bar{X}$		35.0	44.0	39.5
	B	33	61	47.0
	C	36	49	42.5
	D	22	32	27.0
	E	42	41	41.5
Treatment $\bar{X}$		33.25	45.75	29.0

Table 5A-6. Number of benthic infauna individuals/liter by station and survey.

Isobath	Station	Survey: March	Survey: June	Mean
6 m	A	7	20	13.5
	F	16	28	22.0
Reference $\bar{X}$		11.5	24.0	17.75
	B	14	32	23.0
	C	32	48	40.0
	D	25	36	30.5
	E	19	38	28.5
Treatment $\bar{X}$		22.5	38.5	30.5
9 m	A	5	55	30.0
	F	21	41	31.0
Reference $\bar{X}$		13.0	48.0	30.5
	B	4	86	45.0
	C	5	87	46.0
	D	19	293	156.0
	E	14	226	120.0
Treatment $\bar{X}$		21.0	173.0	89.25
15 m	A	8	17	22.5
	F	23	25	24.0
Reference $\bar{X}$		15.5	21.0	23.25
	B	14	34	24.0
	C	20	33	31.5
	D	6	8	7.0
	E	12	17	14.5
Treatment $\bar{X}$		13.0	23.0	69.25

and declined to 23.3 and 17.8, respectively, for the 15 and 6 m stations. The annual mean number of individuals/liter at the treatment stations ranged from 89.3 at the 9 m stations to 30.5 at the 6 m stations.

The mean number of individuals/liter at the 6 m reference stations ranged from 11.5 in March to 24.0 in June. The mean values at the treatment stations ranged from 22.2 individuals/liter in March to 38.5 in June. The mean number of individuals/liter collected at the 9 m reference stations ranged from 13.0 in March to 48.0 in June, while treatment station values were 21.0 and 173.0, respectively for March and June. Reference stations from the 15 m isobath contained mean numbers of individuals/liter of 15.5 in March and 21.0 in June. The treatment station values ranged from 13.0 in March to 23.0 in June.

PATTERNS IN BENTHIC INFAUNAL COMMUNITY DISTRIBUTION

Intercommunity similarity analyses were performed separately for each survey period using classificatory techniques (Clifford and Stephenson, 1975).

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 similar distribution patterns among stations. The two-way coincidence tables summarize faunal distributions with symbols (Table 5A-3) representing relative abundances based on the maximum abundance for each species.

The site groups which result from the normal analysis are labelled with arabic numerals for easy reference in subsequent discussions of the similarity analysis results (Figures 5A-4 and 5A-5). 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-4 and 5A-5).

March Data Classification

The normal classification dendrogram from March contained one primary division resulting in two groups (Figure 5A-4). The two groups corresponded to "shallow stations" and "deeper stations." Station Group 1 was composed primarily of 6 m (Table 5A-2) isobath stations from Transects A through F, however, 9 m isobath stations from Transects B and C also clustered in this group. Station Group 2 included the remaining 9 m stations (A, D through F) and all 15 m transect stations (A through F).

The inverse analysis from March produced five species groups (A though E, Figure 5A-4). Species Group A occurred at most 9 and 15 m isobath stations in high relative abundance. Species in this group included Mediomastus acutus and Haploscoloplos elongatus. Some of these species including Rhepoxynius epistomus and Nephyts caecoides were found at the shallower stations of Group 1 but in low relative abundance. Species of Group B had a distribution similar to those of Group A. These species including Rhepopxynius abronius, Lumbrineris tetraura, and Mediomastus californiensis were found at most 9 and 15 m stations in medium to high abundance, however, their presence was rare in the shallow stations. No representives from species Group C were found at 6 m isobath stations, but selected species including Typosillis aciculata and Nereis procera were found in high abundances at particular 15 m stations (e.g. Station F). Species from Group D were ubiquitous to all depths with scattered representation among the transects. Their relative abundances were variable, but for individual species such as Scoloplos armiger and Amastigos acutus high relative abundances were

common. Hesionura coineau difficilis, Platyischnopus viscana, and Branchistoma californiense composed species Group E and were only found at the 9 m station of Transect C.

June Data Classification

The normal classification for the June data resulted in the formation of three station groups roughly corresponding to the various isobaths sampled (Figure 5A-5). Station Group 1 was composed of a mixture of stations from all depths, including the 6 m station from Transect A, 9 m stations from Transects A and C, and the 15 m isobath stations from Transects D and E. The 6 m isobath Stations B through F comprised station Group 2. The remaining 9 and 15 m isobath stations formed station Group 3.

Inverse analysis of the June data resulted in the formation of five species groups (A through E, Figure 5A-5). Species from Group A characterized the 6 m stations in high relative abundance, and occurred in some deeper stations in lower numbers. Among the species in this group were Magelona pitelkai, Rhepoxynius bicuspidatus, and Eohaustorius washingtonianus. Group B species were found at most 9 and 15 m isobath stations in high and medium abundances. However, some of these species including Mediomastus acutus and Owenia collaris were found in lower abundances at many 6 m isobath stations. Species from Group C were generally ubiquitous to stations at all depths. Their relative abundances also varied among the stations with many exhibiting slightly higher numbers at 9 and 15 m stations. Group C species included Goniada littorea, Micrura alaskensis, Apoprionospio pygmaeus, and Haploscoloplos elongatus. The 9 and 15 m stations were characterized by high and medium relative abundances of Group D species. Species from this group were rare at shallow stations, and when found were in very low numbers. These species included Argissa hamatipes, Nephtys cornuta franciscana and Paraprionospio pinnata. Species Group E contained animals which were confined to individual stations representing various depths. Several were found only at the 15 m stations from Transects D and E including Goldfingia misakiana, Ophiophragmus urtica, and Foxiphalus obtusidens.

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CHAPTER 5B

SUBTIDAL COBBLE - UNITS 1, 2, AND 3

INTRODUCTION

The hard benthos studies reported in this chapter for the area offshore the San Onofre Nuclear Generating Station (SONGS) were under investigation in 1980 primarily to complete the two-year Preoperational Monitoring Program (PMP). This program provides baseline data for 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 subtidal cobble habitats. Secondary objectives included continuation of subtidal studies for the Environmental Technical Specifications (ETS) and National Pollution Discharge Elimination System (NPDES) to determine the operational effect(s) of Unit 1 on the near-field benthic marine environment. These investigations were also designed to assess the environmental effects of sediment dispersal on the near-field cobble habitats within the San Onofre Kelp forest during construction and dredging operations for the Units 2 and 3 intake and diffuser-discharge conduit systems. This study meets the regulatory requirements for the ETS program, the Construction Monitoring Program (CMP), the PMP, and the NPDES.

The purpose of this chapter is to present analyses and interpretations of the 1980 and previous years' data pertinent to each of the study elements and objectives and to describe the benthic environment offshore of San Onofre. The 1980 biological and physical oceanographic data used in this analysis report were presented in the Annual Operating Report, San Onofre Nuclear Generating Station, Volumes I and II (SCE 1981a,b). Volume I, which includes a brief summary of only required regulatory data, was submitted to the requiring agencies on 31 March 1981 (SCE 1981a). Volume II contains all basic raw data collected for the SCE programs to meet the 1980 objectives including the basic regulatory required data and additional supplementary data (SCE 1981b). Additional data collected for each study element during previous years was used to identify general temporal patterns or trends.

BACKGROUND

HISTORICAL REVIEW (1963-1979)

Benthic biological studies of the marine environment at San Onofre began in 1963 and consisted of periodic monitoring studies which were basically qualitative (Table 5B-1). These became more quantitative as sampling methods improved. An independent evaluation of the Marine Environmental Monitoring studies from 1964 through 1971 was presented by Given (1973) and Scanland (1973). They concluded that the artificial substratum and relief associated with the Unit 1 discharge structure increased the numbers and species of benthic organisms 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 (2,001 ft) downcoast of the discharge, were buried by sand and covered with a fine layer of silt after the generating station

Table 5B-1. Synopsis of SCE hard bottom subtidal studies conducted offshore of San Onofre from 1963 through 1980.

Program	Total No. of Surveys	No. of Samples per Year	No. of Stations	Sampling Area (m^2)	No. of Sampling Areas/Station	Type of Data Collected
MARINE ENVIRONMENTAL MONITORING (MEM) PROGRAM						
Preliminary Survey 1963	1	†	†	†	†	A
Unit 1 Preoperational Benthic Sampling 1964-1966	6	1-2	9	†	†	A
Unit 1 Transitional Benthic Sampling 1966-1967	2	2	4-6	†	†	A
Unit 1 Operational Benthic Sampling 1968-1975	12	2	7-9	1	3	B
SAND DISPOSAL MONITORING PROGRAM (SDMP) 1974-1976	9	4	5	4	2 random, 2 fixed	B
ENVIRONMENTAL TECHNICAL SPECIFICATIONS (ETS) 1975-1980	23	4	11 (3)	10	10 fixed	C
CONSTRUCTION MONITORING PROGRAM (CMP) 1976-1980	15	4	2 (2)	10	10 fixed	C
PREOPERATIONAL MONITORING PROGRAM (PMP) mid-1978 to mid-1980	8	4	10 (8)	6, 0.125	1 fixed, 4 random	D
BENTHIC SENSING PACKAGES (BSP) mid-1979 to mid-1980	NA	continuous	5††	NA	NA	E
MARINE REVIEW COMMITTEE (MRC) Kelp Transect Studies 1979-1980	6	3	13	300	NA	F
INTERIM KELP PROGRAM (IKP) Preliminary Survey 1980	1	3	6	720, 36, 30	12 random, 6 fixed, 3 fixed	G

† Undefined
†† At PMP stations
A - Qualitative observations with estimates of abundance of flora and fauna to species level over an undefined area.
B - Visual estimates of % cover or abundance of flora and fauna to species level in a defined area.
C - Quantitative estimates of % sand, % rock, % cover of flora and fauna to species level, and abundance of solitary invertebrates and kelp by visual estimation, also temperature and visibility estimates. Number in parentheses denotes number of kelp forest stations.
D - Quantitative estimates of % sand, % rock, % cover of flora and fauna to species level, and abundance of kelp and macroinvertebrates by point contacts technique (300 points in fixed, 60 points in random). Also, temperature and visibility estimates. Number in parentheses denotes number of kelp forest stations.
E - Estimates of total organic carbon and sediment deposition, temperature, and light penetration.
F - Estimates of kelp and dominant grazer abundance, nutrients, temperature, light penetration, sedimentation rates at San Onofre Kelp.
G - Estimates of % sand, % rock, abundance of dominant kelp and grazer species at San Onofre Kelp. (12 random 10-m^2 circular plots are sampled at each site, 6 6-m^2 quadrats at each PMP site, and 3 10-m^2 transects at ETS and CMP sties, all located in the San Onofre Kelp forest).

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).

Semiquantitative data were collected from 1963 until March 1975 when the existing Environmental Technical Specifications program was initiated. This program implemented permanent survey stations distributed in distinct zones and kelp beds (Figure 5B-1), taxonomic standardization, and consistent methods for 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 biological effects immediately adjacent to the Unit 1 discharge (very near-field effects), but emphasizes monitoring a larger area near Unit 1 for potential far-field spatial and/or temporal effects on organisms in these subtidal cobble-boulder habitats (Figure 5B-2). Therefore, no ETS stations occur closer than 500 m (1,640 ft) from the Unit 1 discharge. The results, analyses, and interpretation of yearly benthic survey data from 1975 to 1979 (LCMR 1976d, 1977, 1978, SCE 1979d, 1980e) have not identified or suggested any long-term spatial or temporal biological effects associated with the operation of Unit 1. Similarly, the CMP data collected during nine quarterly surveys conducted from December 1976 to December 1978 (MBC 1978, SCE 1979d) did not identify any changes in the San Onofre Kelp forest macrobiota that could be associated with diffuser-discharge conduit construction for San Onofre Units 2 and 3.

In terms of immediate near-field effects, Osman (1978) reported an increase in invertebrate larval settlement on artificial hard substrata within 50 m (164 ft) of the Unit 1 discharge relative to areas further away. This increase was attributed to alteration of natural currents by the hydrodynamic entrainment of surrounding water. This entrainment exposed the near-field hard substrata to greater densities and subsequently greater settlement of larvae than would normally be expected under natural conditions.

Collection of physical and chemical data (continuous light, continuous temperature, sedimentation, and total organic carbon) was accomplished from August 1979 to September 1980. These data documented the natural variations associated with these parameters in the vicinity of each PMP benthic station.

1980 STUDIES

Winter storms prevented the majority of the PMP, ETS, and CMP stations from being sampled during the first quarterly survey period (January-February). The Benthic Sensing Packages were operational at each PMP station-pair and effectively documented near bottom conditions (light attenuation, temperatures, sediment flux) during this period.

The three remaining quarterly ETS surveys (10-m^2, 108-ft^2 transects at 13 stations; 5 located in 3 kelp forests) were completed on schedule. The second PMP benthic survey (6-m^2, 64.6-ft^2 quadrats at 10 stations; 6 located in 2 kelp forests) was completed in June 1980. Collection of BSP data was terminated in August 1980.

Since the Unit 1 ETS operational objectives have been met and extensively documented in previous annual reports, formal requests to delete the ETS benthic

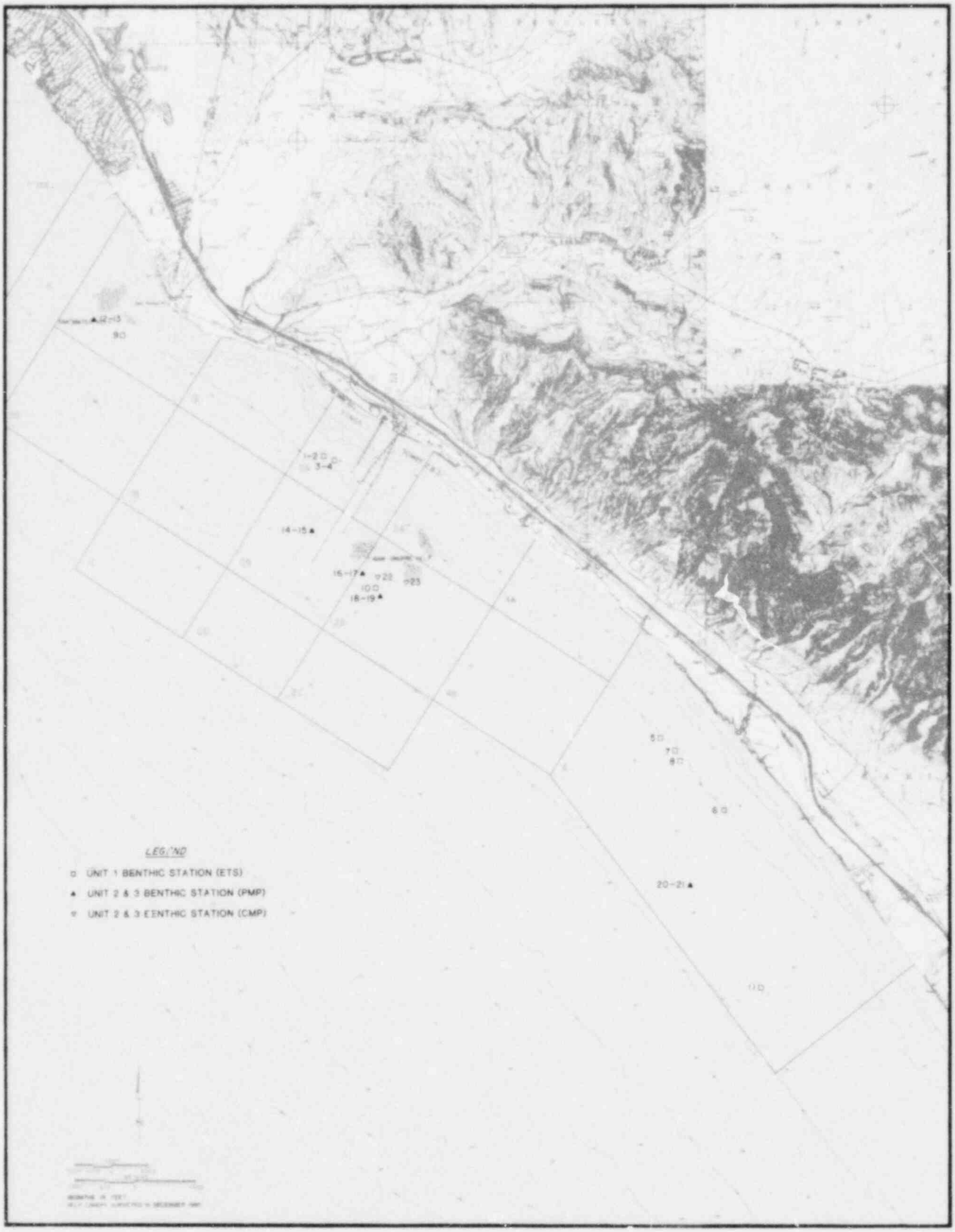

Figure 5B-1. ETS, CMP, and PMP benthic station locations at San Onofre Nuclear Generating Station.

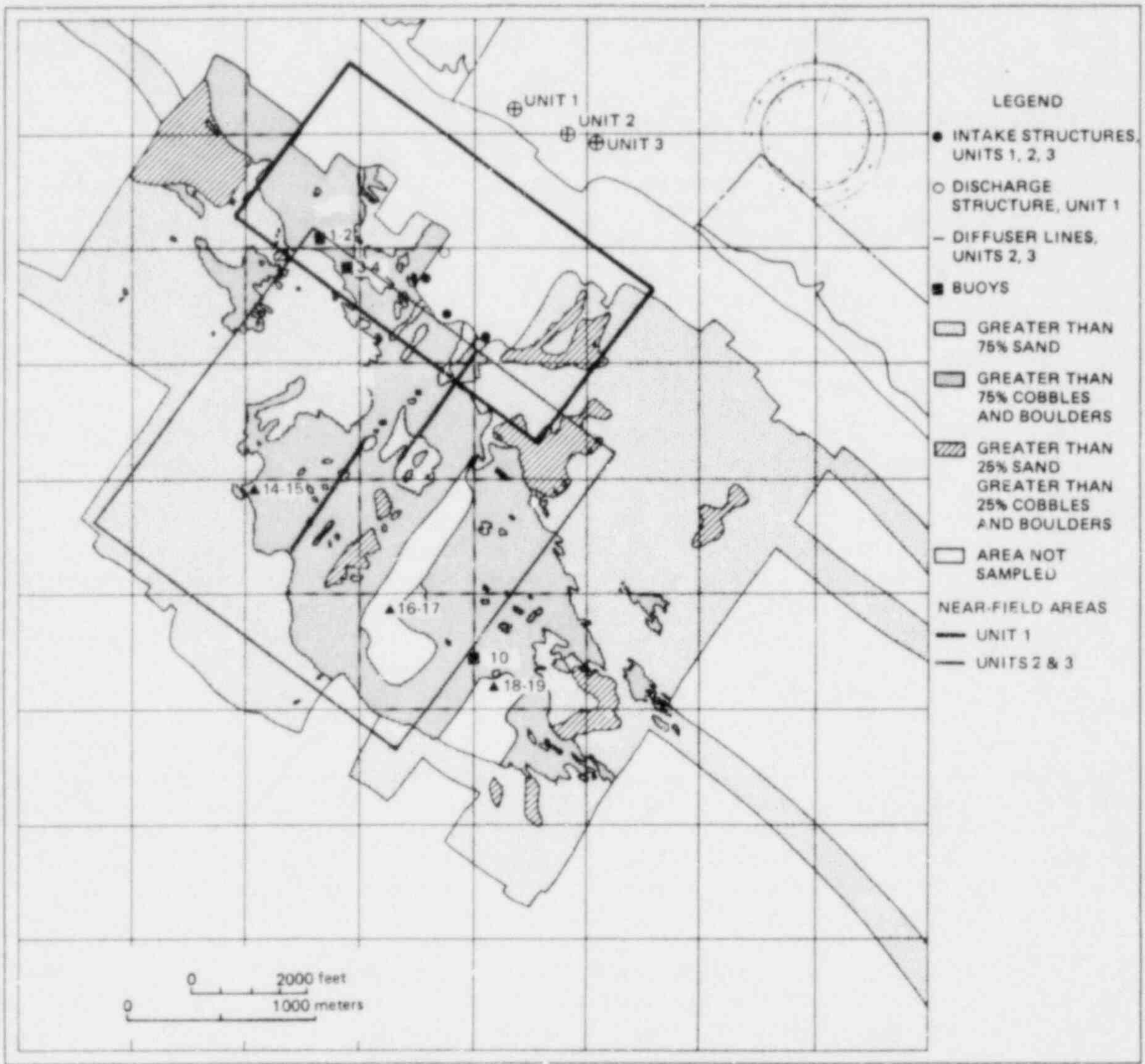

Figure 5B-2. Distribution of substrata types in the vicinity of the San Onofre Nuclear Generating Station (after IRC 1978).

requirements were submitted to the NRC in October 1980 based upon accomplishment of the objectives within the mandated scope. However, regulatory delays in Nuclear Plant licensing matters have prevented change or termination of the operational studies since the Three Mile Island incident and no NRC response had been received by the end of 1980. Unit 1 was out of operation throughout much of 1980 due to steam generation problems. Construction which could have affected the benthic communities under study was essentially completed in 1979 and the regulatory study requirements were officially suspended in March 1980. The two-year PMP study was completed in June 1980 as the objectives (i.e., a two-year baseline study to provide information to evaluate the operational effects of Units 2 and 3) had been met.

Following completion of the PMP in June, an Interim Kelp Program (IKP) was initiated in December to monitor kelp density, and physical and biological factors associated with kelp recruitment and growth in the San Onofre Kelp forest. Diving biologists sample organisms within random 10-m^2 circular plots, located at permanent sites previously sampled during the ETS, CMP, and PMP studies in the San Onofre Kelp forest. For sampling details see the Methods section of this chapter.

DISCUSSION

Analysis of all ETS, PMP, and CMP subtidal data collected from 1975 to 1979 revealed that no significant environmental effects could be associated with the operation of Unit 1 or the construction of Units 2 and 3 (SCE 1980e). Although Unit 1 was not operational after April 1980, spatial and temporal changes of benthic communities were within the range of variation noted during previous years. Detailed interpretation of the monitoring data suggests that the benthic community in the vicinity of the San Onofre Nuclear Generating Station is strongly influenced by physical factors related to natural nearshore dynamics.

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 San Onofre is quite varied with respect to substrata composition. On hard substrata, the natural processes of accretion and erosion of sand or silt can alter associated biological populations (Connell 1972, Given 1973, Valentine 1973). The greatest proportion of hard substrata offshore of San Onofre is unconsolidated cobble and boulder with isolated areas of exposed bedrock and sandstone. The nearshore substratum within the San Onofre study area, from 5 km (3.1 mi) upcoast to 10 km (6.2 mi) downcoast, consists of a heterogeneous mixture of boulder, cobble, and sand. The proportions of boulder, cobble, and sand vary with location (IRC 1978). The San Mateo Point region 5 km upcoast of Unit 1 consists of relatively stable cobble and boulder substratum from the 18-m (59 ft) isobath to the shoreline (Figure I-3, LCMR 1978). In contrast, the Don Light area 8 km (4.9 mi) downcoast from Unit 1 is largely sand with isolated patches of cobble occurring on the 10 to 12-m (33- to 39-ft) isobath (IRC 1978; Figure I-5, LCMR 1978). The area directly offshore of San Onofre is a mixture of all three substrata types (IRC 1978; MBC 1978; Figure 5B-2).

HARD BENTHOS MARINE BIOLOGICAL SETTING, 1975-1980

Hard substrata habitats offshore of San Onofre have been studied, in detail, on the inshore 10-m (33-ft) isobath (the approximate depth of the Unit 1 point source discharge) within three major kelp forests (San Mateo, San Onofre, Barn), and on the offshore 12- to 14-m (39- to 46-ft) isobath (the approximate depth of the Unit 2 diffuser-discharge). This distribution of sampling sites has been used to evaluate and compare within the limits of the overall program, the long term

spatial and temporal effects of the Unit 1 discharge system on the hard substrata environment as well as to study representative portions of the three major kelp forests in the San Onofre area. Sampling sites on the 12- to 14-m isobath have been studied to collect representative data on preoperational conditions in the nearfield San Onofre Kelp forest as well as at farfield study sites. The general results, significant ecological observations recorded at these sites between 1976 and 1980, and the conclusions associated with these studies are reviewed below.

Inshore Cobble Habitats

The inshore cobble habitat has typically exhibited the greatest temporal and spatial differences in community structure of all sampling sites since 1975 (LCMR 1976d, 1977, 1978; SCE 1979d, 1980e). The differences associated with the inshore cobble habitat have been most pronounced between stations located in Zone 0A near the Unit 1 discharge and Zone 6, downcoast of the Unit 1 discharge. Comparison of data collected between zones, until 1978, consistently revealed that Zone 0A supported a greater diversity of organisms, principally because of a greater number of red algae (LCMR 1978). In contrast, filter and suspension feeding invertebrates were the dominant organisms sampled in Zone 6 (LCMR 1978). These characteristic differences in community structure were maintained between 1975 and 1977, and were directly related to the distribution and composition of hard substrata (LCMR 1978). Hard substrata in Zone 0A consisted of movable cobbles and boulders and always exhibited greater percent occurrence than the low relief sandstone and clay substrata typical of the Zone 6 area (LCMR 1978). Stations in Zone 0A were located on a comparatively large expanse of cobbles and boulders in contrast to the stations in Zone 6 which were surrounded by sand. Apparently localized turbidity associated with nearby sand plains in conjunction with the lack of movable cobbles (that may physically disturb areas and create unihabited space) resulted in the Zone 6 habitats being dominated by sessile invertebrates (sensu Osman 1977; LCMR 1978; SCE 1979d).

During the first quarter of 1978 unusually severe storms and terrestrial runoff resulted in dramatic and catastrophic alterations to the nearshore cobble habitat (SCE 1979d, 1980e). At least two stations in both zones were buried with sand and have remained covered since 1978 (Table 5B-2; SCE 1979d, 1980e). This resulted in the localized extinction of a substantial number of invertebrate and algal communities. The rapid burial of the inshore as well as the offshore cobble communities resulted in the mass mortality of at least one motile invertebrate, the chestnut cowry, *Cypraea spadicea* (SCE 1979d).

The inshore study area has exhibited a transient nature varying from cobble to sand and, in one instance, back to cobble as a consequence of sand accretion and erosion (SCE 1979d, 1980e, 1981b). These areas, however, have exhibited a relatively stable nature before and after periods of major disturbances (i.e., storms). Although biological interactions may be important factors regulating community structure (Connell 1972; Dayton 1971, 1973), establishment, maintenance, and persistence of the inshore cobble habitat in this study area is most assuredly regulated by sometimes short term, unpredictable physical factors (i.e., oceanographic and meteorological conditions) associated with sand movement (sensu Valentine 1973).

During this six year study period, although a few changes in the marine environment within a locally restricted area have been related to construction and operation of Unit 1 (Given 1973; Parr and Diener 1978; Osman 1978), this study has never identified any long-term far-field ecological effects associated with Unit 1 activity (LCMR 1975, 1976d, 1977, 1978; SCE 1979d. 1980e).

Table 5B-2. Percent hard substrata estimates recorded at each permanently established ETS benthic station from 1976 to 1980.

ETS Station Number	1976 Jan	1976 May	1976 Aug	1976 Oct	1977 Feb	1977 Apr	1977 Jun	1977 Nov	1978 Jan†	1978 May	1978 Jul	1978 Oct
1	95.5	92.7	93.0	85.0	86.9	79.8	65.4	83.1	n.s.	84.0	79.1	91.8
2	94.7	76.0	87.3	86.0	85.5	73.5	64.0	69.0	n.s.	91.9	82.5	17.0
3	90.8	83.0	n.s.	65.5	72.0	64.0	74.5	68.2	n.s.	0.0††	0.0	0.0
4	91.5	79.0	78.0	43.0	50.0	69.0	64.5	56.4	n.s.	n.s.††	0.0	0.0
5	55.5	52.1	31.5	41.5	46.5	52.5	41.5	53.8	n.s.	n.s.††	7.1	24.1
6	75.0	74.5	64.0	61.5	62.5	73.5	75.0	78.4	n.s.	n.s.††	43.8§	33.4
7	46.0	30.2	38.0	33.0	23.5	13.5	27.8	32.7	n.s.	n.s.††	0.0	0.0
8	67.1	63.7	44.0	49.5	65.5	70.9	66.5	62.1	n.s.	n.s.††	72.0§	64.0
9 (SMK)	95.2	96.7	93.2	87.0	94.7	92.3	94.0	91.3	90.9	93.0	94.7	94.9
10 (SOK)	68.1	75.0	49.1	37.5	57.5	53.0	53.5	46.1	n.s.	46.0	48.7	73.0
11 (BK)	65.5	74.5	69.7	53.0	80.0	72.5	76.5	78.8	n.s.	n.s.††	74.7§	68.5

ETS Station Number	1979 Feb	1979 Apr	1979 Jul	1979 Oct	1980 Jan†	1980 May	1980 Jul	1980 Oct
1	99.5	94.4	92.3	87.0	n.s.	86.0	75.7	80.5
2	64.0	46.0	42.5	23.3	n.s.	95.4	68.5	70.8
3	0.0	9.0	0.0	0.4	0.3	0.1	0.3	0.0
4	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0
5	11.5	7.5	22.0	21.7	21.2	0.0	0.0	0.3
6	57.8	52.5	31.0	43.0	52.0	56.0	40.0	56.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	46.0	50.0	70.0	68.5	n.s.	39.5	57.5	59.0
9 (SMK)	91.4	91.5	95.0	95.5	92.8	96.6	92.0	94.0
10 (SOK)	71.0	81.0	53.5	58.0	n.s.	82.5	77.0	85.5
11 (BK)	70.4	68.0	74.1	66.5	71.0	81.5	74.0	75.3

n.s. Not sampled
† Storm period
†† Stations buried with sand
§ Station lost and reestablished

Kelp Forest and Offshore Cobble Habitats

San Mateo, San Onofre, and Barn Kelp forests have been shown to be spatially and temporally different during the past six years of study (SCE 1979d, 1980e). Specific differences are associated with substrata composition, biological interactions, and kelp canopy expansion and contraction (SCE 1979d, 1980e). An important factor associated with the characteristic features of each kelp forest is substrata composition and stability. Comparison of substrata composition at all kelp forests has shown the San Mateo Kelp forest to be remarkably stable exhibiting the most hard substrata with the least amount of variability since 1976 (Table 5B-2; LCMR 1977, 1978; SCE 1979d, 1980e). Substrata composition at Barn Kelp forest was also relatively stable until January 1978 when this station was buried by sand (Table 5B-2; SCE 1979d). After another Barn Kelp station was established during July 1978 in the same vicinity, the new station continued to show substrata stability similar to the previous Barn Kelp site (Table 5B-2; SCE 1980e). Consequently, the composition and stability of the substrata at the San Mateo and Barn Kelp forests apparently contributes to the greater diversity and more equitable distribution of organisms at these stations in comparison to the San Onofre Kelp forest (LCMR 1977, 1978; SCE 1979d, 1980e, 1981b).

Substrata composition and stability at San Onofre Kelp has exhibited major changes including increases and decreases of approximately 30% sand cover per square meter between some quarterly surveys (SCE 1979d, 1980e).

Substrata instability at San Onofre, in contrast to San Mateo and Barn Kelp forests, is apparently related to the unique substrata composition characteristic of the site (see Substrata Stability and Sediment Movement). Substrata at San Onofre Kelp is composed of low relief cobbles and boulders and there are substantial sand lenses (ripple-pods, sensu Henry 1976) in the vicinity that frequently result in sand scouring (SCE 1979d, 1980e).

The high abundance of unidentified crustose coralline algae noted at this station in comparison to the other kelp stations indicates a functional adaptation to unstable areas which are periodically subjected to sand scour and/or burial (SCE 1980e). For example, encrusting coralline algae may undergo burial for three to four months and still exhibit a pinkish color indicative of health (SCE 1979d). Also, if hard substrata are available after substantial sand scouring, coralline 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 characteristically dominated by crustose coralline algae have been exposed to some type of physical or biological disturbance. Similar observations regarding frequent sand scouring and crustose coralline algal abundance have been made at the Del Mar Kelp forest located approximately 50 km (31 mi) downcoast of the San Onofre Kelp forest (Rosenthal, Clarke, and Dayton 1974; Grigg 1975).

All kelp forests in the study area have exhibited canopy expansion and contraction; however, the San Onofre canopy has shown the most dramatic fluctuations since 1971 (Chapter 7, Figure 7-2). Although dramatic changes in canopy areal exent may be related to temporal changes in water column temperature and nutrients (Chapter 7), successful Macrocystis recruitment to hard, stable substrata and its subsequent development, given a suitable bottom environment (absence of scour, burial, sufficient light), will also affect canopy configuration.

The conspicuous absence or low abundance of kelp plants at the offshore San Onofre Kelp stations since the 1977 sampling period may also be related to instability of the substrata (LCMR 1978; SCE 1979d, 1980e). The presence of fine 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 the San Onofre Kelp station as well as offshore cobble Station-pair 18-19 have been subject to more sand scour than other kelp stations (SCE 1979d, 1980e), it is hypothesized that recruitment of Macrocystis has been inhibited by the physical microenvironment (sand scour).

The instability of small cobble may also result in mortality of juvenile Macrocystis plants as described in SCE 1980e. Comparison of composition and distribution of substrata at each kelp forest suggests that factors associated with the physical movement of silt (turbidity), sand, or cobbles have been a primary mechanism regulating community structure at the San Onofre Kelp forest between 1975 and 1980.

Offshore Cobble Habitats

Similar to the kelp forest stations, the offshore cobble stations also exhibit distinct differences among sites. However, these differences do not appear to be related as strongly to substrata dynamics as differences among the kelp forest stations. With the exception of the burial of a large portion of Station-pair 20-21, substrata composition at the offshore cobble stations has

remained relatively stable (SCE 1979d, 1980e, 1981b). The principal difference among these sites is the dominance of sessile invertebrate cover over algal cover at Station-pair 12-13 in the San Mateo Kelp forest. This dominance pattern is reversed at the remaining sites in the San Onofre Kelp forest. These relationships have persisted since 1979 (SCE 1980e), although storms substantially reduced overall foliose algal cover at all offshore cobble stations during the 1980 sampling period (see Physical Factors, Light).

Light appears to be a significant factor associated with community structure at Station-pair 12-13. This is suggested by the substantial reduction of algal cover as the San Mateo Kelp forest canopy expanded over the sampling site in 1979 (SCE 1980e). Community structure at stations located in the San Onofre Kelp forest, however, appears to be related to a combination of factors including light, physical disturbance, and possible predation by the white urchin, Lytechinus spp. (SCE 1979d, 1980e).

The location of the offshore cobble stations in deeper water than most of the other sampling sites suggests that, at least in this study area, light intensity in concert with biological factors becomes more important to community structure as depth and physical stability of the environment increase. Factors that tend to moderate physical instability (depth, stationary hard substrata) or reduce the heterogeneity of the environment (presence of or total absence of a dense kelp canopy) apparently result in reasonably predictable and sensitive biological communities. This generalization is supported by the dramatic temporal and spatial physical changes in community structure at cobble sites on the 10-m (33-ft) isobath in comparison to moderated biological changes at the kelp forests and the offshore cobble habitats during storm periods in 1978 and 1980. The general exception to this was the burial and loss of sampling sites at Barn Kelp and Station-pair 20-21. The burial of these sites located on the 12- to 14-m (39- to 46-ft) isobaths approximately 14 km (8.7 mi) and 8 km (4.9 mi) downcoast of the San Mateo and San Onofre Kelp forests, respectively, is further evidence of significant oceanographic processes operating over a comparatively short distance within the overall study area.

PHYSICAL FACTORS

Substrata Stability and Sediment Movement

The hard bottom benthic stations are located on the 10-m (ETS stations) and the 14-m (PMP stations) isobaths, and are distributed within the 16-km (9.9 mi) distance between the San Mateo and Barn Kelp forests (Figure 5B-2). Considering the distribution of these stations with regard to depth and distance from shore, five years of quarterly substrata composition data (LCMR 1977, 1978; SCE 1979d, 1980e), and the significant aspects of meteorological conditions during this period, there is substantial evidence that offshore (depths 10-14 m) sediment movement in the vicinity of San Onofre is considerably more dynamic than generally recognized.

In comparison to the sand movement phenomena at San Onofre, results of a three-year investigation measuring changes in sand level on the La Jolla shelf (depths of 6-21 m, 20-69 ft)concluded that although seasonal changes in sediment deposition and erosion were evident on the 9.1-m (30-ft) isobath, the maximum difference between summer and winter seasons was comparatively small (0.7 cm, 0.3 in.; Inman and Rusnak 1956). Similarily, an investigation studying patterns of sediment movement approximately 5 km (3.1 mi) north of La Jolla indicated that changes in sand level on the 10-m isobath did not undergo any significant net change during a five-year study period (Aubrey 1979). Other observations suggesting that insignificant changes in seasonal sediment accretion and erosion

are characteristic of depths > 10 m have also been reported for other areas of San Diego County (Berry 1977). Although these studies have evaluated seasonal patterns of erosion and accretion in the nearshore environment (depths < 10 m), they have also documented the relatively stable nature of offshore bottoms at depths ≥ 10 m.

Substrata composition recorded at the ETS subtidal benthic stations during the past indicates the study area offshore San Onofre has been a temporally dynamic as well as a heterogeneous assemblage of cobble, boulder, rockshelf, and sand (Table 5B-2). This dynamic state may be the result of abnormally severe storms with high rainfall which result in significant sand deposition over relatively large areas of hard substrata (cobble, boulder, rock shelf). Storm activity in the absence of high rainfall may result in substantial erosion of sand exposing underlying hard substrata.

Rainfall during 1976 and 1977 were representative of average years in San Diego County (Pryde 1977). During this period the general trend at most ETS stations was sand erosion during winter followed by slight deposition in the fall (Table 5B-2). During 1978, intense winter storms resulted in the southern California area receiving over twice as much rainfall during the first four months as would normally be expected during an average year (SCE 1979d). ETS Stations 3-8 and 11 were subjected to significant sand accretion apparently as a result of the abnormally high rainfall and subsequent runoff from San Mateo, San Onofre, and Las Pulgas Creeks. Subsequent surveys at these sites indicated that up to 1 m (3.3 ft) of sand was deposited over the sampling areas. Two of these stations located on the 10-m isobath (Stations 3 and 4) have remained nearly 100 percent sand since 1978. Greater than fifty percent of the hard substrata at Station 5 was buried as a result of the 1978 storms. During January 1980 severe storms buried the remaining portion of hard substrata at Station 5. Station 7 was 100 percent sand during 1979 (SCE 1980e). This station was lost during 1980 and has been assumed to be 100% sand based on 1979 sampling data (SCE 1980e). Stations 6 and 8, originally located near Station 7, were never found after extensive searches and were assumed to have been buried. Station 11 (Barn Kelp) located on the 14-m isobath was also lost as a result of the 1978 storms. Diving operations during early 1981 relocated the original Barn Kelp station. Sand in the station area was in the process of eroding with approximately 50% of the sampling area still buried. As detailed in the results, PMP Station-pair 20-21 located on the 14-m isobath was also the site of substantial sand accretion during 1980.

Considerable sand erosion over a relatively short period has been documented ETS Station 2 on the 10-m isobath (Table 5B-2). Percent hard substrata estimates at Station 2 during 1979 and 1980 reveal that high percentages of sand were transported out of the sampling area after the 1978 and 1979 October surveys. These observations seem paradoxical when considered with respect to substrata composition data at Stations 1, 3, and 4 (Table 5B-2), which are located nearby (Figure 5B-1). This region, however, is uncharacteristic of the general shoreline because of a slightly elevated seabed in the offshore slope in front of San Onofre where these stations are located (Figure 5B-3, Chapter 2 - Turbidity). Possibly, the location of these stations on this "bulge" differentially influences sediment movement depending upon winter storms, rainfall, and cre sediment discharge.

The substantial accretion and erosion of sand at the previously discussed sites is evidence that considerable sand movement between 10 m and 14 m does occur in the San Onofre vicinity. Analysis of this movement, at least from a five year perspective when unusually heavy rainfall occurred, suggests the offshore

movement of substantial volumes of sediment resulted from these storms. The accumulation of sediment in local vernal streams was probably substantial (Berry 1977) because of the atypically low rainfall during the nine to ten year period prior to the 1978 winter storms. Consequently, the contribution of stream bed sediment to the nearshore area may be considered unusual.

In the San Onofre vicinity, hard substrata is a prerequisite for Macrocystis development. The region between the 9- and 17-m (30- and 56-ft) isobaths on reasonably stable hard substrata represents a good habitat for the development of nearshore kelp forests in this area. This is demonstrated by the presence of the existing San Mateo, San Onofre, and Barn Kelp forests. The persistence of these kelp forests, however, is related to other variables including biological, physical, and chemical factors. However, the fact remains that without stable hard substrata, kelp forests will probably not establish and, in the event of substrata instability (sand scour, sand movement, burial, cobble movement), kelp forests may exhibit differential patterns of canopy expansion/contraction as well as recruitment and development of subcanopy populations.

Comparison of hard substrata estimates at San Mateo, San Onofre, and Barn Kelp forests since 1976 reveal that these areas are substantially different. San Mateo Kelp forest is situated on a rocky point consisting principally of cobbles and boulders which have been stable at least since 1975 (LCMR 1976d, 1977, 1978; SCE 1979d, 1980e; Table 5B-2). Substrata composition at Barn Kelp is principally basement rock composed of sandstone sheets. The substrata is generally stable in this area, however, a substantial lens of sand buried the original station during storms in 1978.

In contrast to the stable substrata associated with the San Mateo Kelp forest, substrata at the San Onofre Kelp station may be considered temporally dynamic and seasonally unstable (Table 5B-2). Although substrata estimates at Barn Kelp appear to be relatively consistent, this station was buried with sand and subsequently lost during 1978 (Table 5B-2). In contrast to the considerable variation during each year noted at San Onofre Kelp, the Barn Kelp station exhibited complete burial followed by an apparently slow process of erosion. Periods of maximum erosion and accretion at San Onofre have been associated with late fall and winter sampling periods, respectively (Table 5B-2). The influence of the 1978 storm on sand movement at the San Onofre Kelp station is clear as sand erosion was suppressed in spring 1978 in comparison to similar sampling periods in 1976, 1977, 1979, and 1980 (Table 5B-2).

The episodic movement of sediment generally observed between the 14- and 10-m isobaths and specifically within the San Onofre and Barn Kelp forests may be explainable by the Shelf Depositional Model hypothesized for the San Diego mainland shelf by Henry (1976). In this model, storms associated with "50 year floods" result in the flushing of creeks, rivers, and estuaries that deposit substantial volumes of sediment on the mainland shelf between the 15- and 90-m (49- and 295-ft) isobaths. Sediment accumulations up to 7 m (23 ft) thick have been recorded offshore of San Onofre (Henry 1976). Tractive movement of this sediment shoreward is facilitated by wave action. As the depth becomes shallower, the increased wave action moves a wedge of coarser sediment shoreward. In depths less than 20 m (66 ft) this sediment wedge begins to break up, both in thickness and lateral extension, and exposes the underlying bedrock. The remaining isolated, well sorted coarse sand components of the wedge are described as "ripple-pods". These ripple-pods are then transported over the bedrock and into the littoral zone. Eventually this sediment is transported by longshore movement to submarine canyons where it is lost to the nearshore environment (Henry 1976).

The demonstrated dynamic nature of the hard substrata in the San Onofre Kelp forest in time and space suggests that the entire San Onofre Kelp forest may be situated on an extensive plain of cobbles and boulders that may be periodically and patchily covered by ripple-pods. The influence of this possible geological setting on the subsequent development of kelp forest communities is not understood, however, the variable nature of the San Onofre Kelp forest must be closely associated with these predominant processess.

Light

The low light and Secci disc measurements recorded during the first five months of 1980 are directly related to the severe storms (SDCFCD 1980) during January, February, and March (Chapter 2). The turbidity resulting from the offshore transport of terrestrial sediment due to flooding of the San Mateo and San Onofre Creeks during this period, had a substantial impact on foliose algal cover, particularly at the offshor cobble stations located in the San Onofre Kelp forest. Although sand burial and subsequent anoxia eliminated substantial portions of hard benthos communities in other areas, reduced light intensity (turbidity), possibly below the compensation point of many algae, is probably the principal factor associated with the decrease (151%) of foliose algal cover at the PMP stations in the San Onofre Kelp forest between October 1979 and May 1980. In comparison, there was a 63% increase between October 1978 and April 1979 during a comparatively mild winter (SCE 1980e). Apparently turbidity and sand scour acted in concert to substantially suppress benthic algal growth and/or maintenance during this period. In contrast, sessile invertebrate populations increased in abundance (87%) at the same stations between October 1979 and May 1980 in comparison to a 1% increase between October 1978 and April 1979 (SCE 1980e). The simultaneous decrease of foliose algal cover and increase of sessile invertebrate cover demonstrates the possible significance and consequence of prolonged natural turbidity in the vicinity of the San Onofre Kelp forest.

Comparison of annual light regimes within the San Onofre Kelp forest, where mean light intensity was usually greatest of all the PMP benthic stations between 1978 and 1980, and San Mateo Kelp forest indicates there were substantial differences between canopy patchiness and density. A dense canopy over the sampling areas in the San Mateo Kelp forest (Station-pair 12-13 and Station 9) during 1979 (SCE 1980e)and the first half of 1980 appears to have been an important factor contributing to the maintenance of sessile invertebrate cover at these stations. The dominance of sessile invertebrates at these stations has been typical of the benthic community structure since 1978 (SCE 1979d, 1980e). The reduction in light intensity by overstory Macrocystis has been noted to inhibit the growth of understory algae in other studies resulting in the bottom flora appearing "conspicuously sparse" (Neushul 1971). 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 1975).

In contrast, foliose algal cover was the dominant component of benthic community structure at the offshore cobble stations in the San Onofre Kelp forest during 1979 (SCE 1980e) and the first half of 1980. Apparently, because of the patchy canopy associated with the San Onofre Kelp forest, there is a more heterogeneous distribution of the quality and quantity of light reaching the benthos than at San Mateo or Barn Kelp forests. Consequently, not only is benthic algal diversity greater in the San Onofre Kelp forest in comparison to San Mateo Kelp, algal cover is also substantially greater.

Although the various light patterns associated with canopy or subcanopy layering undoubtedly contribute to the diversity and growth of benthic algae in

the San Onofre Kelp forest, unless uninhabited space is available for algal spores to settle on, benthic algal diversity and cover will be comparatively low as in San Mateo and Barn Kelp. Provision of uninhabited space generally occurs as a result of disturbance, either physical (sand scour and erosion, cobble abrasion) and/or biological (predation, senescence, death). The dynamic nature of the substrata composition in the San Onofre Kelp forest has been discussed previously in this section (Substrata Stability and Sediment Movement) and previous years (SCE 1979d, 1980e). Although biological disturbances were not as evident during 1980 as in 1979, they are important (SCE 1980e) and are considered in a later section (Biological Responses to Physical Change).

Sedimentation and Total Organic Carbon

Sediment deposition at all sampling sites was influenced principally by wave action and secondarily by the distribution and composition of surrounding sand and cobble-boulder substrata. The comparatively high composition of sand surrounding Station-pairs 16-17 and 20-21 resulted in these sites showing comparatively high sedimentation during each sampling interval. In contrast, Station-pair 12-13, located in San Mateo Kelp and surrounded predominately by cobbles and boulders almost always exhibited lowest sediment deposition.

The composition of sediment deposited in the sedimentation collection chambers appears to depend primarily on the amount of nearshore oceanographic activity during the sampling periods. During the 1980 winter storm period, material sampled by the sedimentation chambers appears to have originated primarily from the vicinity of the sampling sites and secondarily from terrestrial runoff. During the benign oceanographic periods from September to December 1979 and May through October 1980, material that accumulated in the sedimentation chambers appears to have originated mostly from the water column rather than from the surrounding area.

This hypothesis is supported by the significant negative relationship between high sediment deposition and low TOC content at the BSP sites. In contrast, TOC content was relatively high at all sites except Station-pair 20-21 during periods of relatively low sedimentation. The fact that highest TOC estimates during the late spring and summer of 1979 and 1980 were associated with Station-pairs 12-13, 14-15, and 18-19 as opposed to lower values recorded at Station-pairs 16-17 and 20-21, suggests nearby Macrocystis plants may be responsible for the comparatively higher TOC estimates during these periods. This appears reasonable since a dense Macrocystis canopy was present over Station-pair 12-13 and scattered kelp canopies were present near Station-pairs 14-15 and 18-19.

The fact that maximum TOC estimates (March) followed maximum sediment deposition (February) may be the result of finer, organic rich material of terrestrial origin settling during March 1980. In contrast, TOC content during the period of highest sediment deposition (February 1980) was comparatively low. This was apparently associated with the collection of coarser, organic poor sediment suspended from the surrounding sand plains by storm waves. Visual appearance of sediment collected at Station-pair 20-21 during these contrasting sampling periods also supports this hypothosis. Finer, darker sediment was collected during the March sampling period as opposed to the coarser, lighter colored sediment collected during the February sampling interval.

BIOLOGICAL RESPONSES TO PHYSICAL CHANGE

The extreme biological responses to the physical environment are emphasized by occurrences at two stations between October 1979 and May 1980. Recruitment at

inshore cobble Station 2 in Zone 0A during the 1980 sampling period was associated with the erosion of the sand cover between October 1979 and May 1980 (SCE 1981b). Paradoxically, during the same period, inshore cobble Station 5 in Zone 6 underwent sand accretion that buried the remaining 21% of hard substrata.

The abundance of white coralline crust at Station 2 apparently reflects sand erosion between October 1979 and May 1980. The presence of white coralline crust probably represents the burial and subsequent death (anoxia, lack of light) of pink crustose coralline algae. Historical data at this station indicates burial of quadrats 6-10 occurred between July and October 1978 (SCE 1979d). The erosion of significant proportions of sand exposed the white, and presumably dead, crustose coralline algae. This uninhabited hard substrata was then colonized by the solitary tunicate, Chelyosoma productum, as evidenced by the high densities sampled during 1980 at Stations 1 and 2.

In contrast to the overall reduction of biological cover at Station-pair 18-19 noted during the 1980 sampling period, percent cover of the foliose red alga Rhodymenia spp. increased between October 1979 and May 1980. The development of Rhodymenia during an extended period of turbidity suggests it may be adapted to this type of environmental perturbation. Evidence for this hypothesis is suggested by examining its abundance in association with canopy and subcanopy kelps sampled at the offshore cobble and kelp stations since 1978 (SCE 1979d, 1980e, 1981b). The distribution of Rhodymenia has been positively correlated with the presence of either surface canopy (Macrocystis) or lower story subcanopy kelp (Pterygophora, Laminaria; SCE 1979d, 1980e, 1981b). Apparently these kelps modify the local environment, principally by the attenuation of light to levels resulting in a favorable habitat for Rhodymenia.

Between August 1978 and October 1979, Rhodymenia cover in the San Onofre Kelp forest was greatest at Station-pairs 14-15 and 16-17 where lower story kelps shaded portions of the benthos. In fact, greatest cover of this alga was consistently sampled at Station-pair 16-17 where highest Pterygophora cover was always recorded (SCE 1980e, 1981b). In contrast, Rhodymenia cover at Station-pair 18-19, where mean light intensity was greatest between the August 1979 and September 1980 sampling periods, was lowest among all offshore cobble stations sampled between August 1978 and October 1979 (SCE 1979d, 1980e). The pattern of decreasing Rhodymenia cover at all stations except Station-pair 18-19 may be associated with light intensity levels below minimum requirements. Extended turbidity conditions in conjunction with natural shading apparently reduced light intensity to below minimum requirements for Rhodymenia at all offshore cobble stations except Station-pair 18-19. In contrast, turbidity conditions at Station-pair 18-19 apparently reduced light intensity to a favorable level for growth. The fact that Rhodymenia cover exhibited a considerable increase at Station-pair 18-19 during a period of low light suggests a causative relationship between reduced light intensity (shaded environments) and growth. Although Rhodymenia appears adapted to shaded areas, there are probably other algae, possibly Pterygophora, that may also be adapted to periodic low light conditions.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

APPROACH

The various components of the hard benthos program (ETS, CMP, PMP) originated at different times for separate regulatory requirements and objectives.

Consequently, there are differences in design and methodology. In order to address the objectives of this report, data from all elements are considered.

Data analyses were oriented to identify the dominant and functionally important benthic organisms associated with the inshore cobble, offshore cobble, and offshore kelp habitats in the vicinity of San Onofre. Functionally important organisms are defined as those species of particular biological value because of their growth forms (encrusting, erect, solitary, colonial), possible adaptations to physical factors (sand scour, cobble movement, turbidity), or their trophic level (carnivore, grazer, primary producer). The abundances and distributions of these organisms are interpreted with respect to their functional adaptations to habitat type. The hypothesis that community structure is strongly influenced by the physical instability of the substrata in the area immediately offshore of San Onofre is examined by comparing the community structure and abundance patterns of dominant organisms in this area to that in areas of greater stability.

Benthic marine resources are defined as all subtidal macroorganisms occupying hard substrata to a depth of approximately 14 m (46 ft). A list of these macroorganisms and their relative importance with respect to the San Onofre area was presented and discussed in the Final Environmental Statement for San Onofre Units 2 and 3 (AEC 1973). The near-field vicinity of the Unit 1 discharge is defined as a rectangular area which extends approximately 1 km (0.6 mi) upcoast and downcoast of the Unit 1 discharge, and 0.5 km (0.3 mi) inshore and offshore of the discharge. This rectangle includes ETS Benthic Stations 1, 2, 3, and 4 (Figure 5B-2). 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-2). 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 Units 2 and 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, 33-39 ft) stations on the offshore isobath (12-14 m, 39-46 ft) 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 deposition, ambient bottom water temperature, and photosynthetically active radiation reaching the benthos near each pair of stations located on the offshore isobath (Chapter 2).

METHODS

BIOLOGICAL DATA COLLECTION

A total of 23 subtidal stations are sampled quarterly for the ETS, CMP, and PMP benthic studies. A map detailing the position of all stations with respect to San Onofre Units 1, 2, and 3 is presented in Figure 5B-1.

The ETS study includes eight cobble stations located on the nearshore (10-m, 33-ft) isobath and three kelp beds on the offshore (14-m, 46-ft) isobath. These eleven permanent stations, marked with surface buoys, were originally established in areas of comparable substrata in February 1975 (LCMR 1975). For identification purposes, the ETS inshore 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-1). 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. Two additional stations were established within the San Onofre Kelp forest for the CMP study (MBC 1978). These are located a short distance upcoast and downcoast of Station 10 (Figure 5B-1). 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).

Each permanent station for the ETS and CMP studies consisted of a band transect 10 m long and 1 m wide which was divided into ten, 1-m^2 (10.8-ft^2) quadrats. When visibility was adequate, marine biologists identified and enumerated solitary macroorganisms and made 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, the type of data (i.e., enumeration or percent cover) to be reported for each organism was standardized and indicated on preprinted plastic data sheets. The substratum characteristics and relief of each quadrat were described. Measurements of surface and bottom water temperatures, and observations of visibility and surge conditions were recorded. In addition, the following information was collected on giant kelp (Macrocystis) sporophytes within the band transects at the kelp stations: (1) number of stipes 2 m (7 ft) above the bottom on each individual kelp plant, (2) general condition of the kelp plants (e.g., tattered fronds), and (3) kelp growth (e.g., small new fronds with no fouling).

The PMP study was designed to collect baseline data on cobble communities biota located on the 14-m isobath offshore of the ETS kelp stations. The sampling design includes ten stations arranged in pairs distributed among two reference areas and the area near the Units 2 and 3 diffuser-discharge lines within the possible region of impact (Figures 5B-1, 5B-2). All stations were established on cobble-boulder substrata with similar relief and communities on approximately the 14-m isobath (IRC 1977, SCE 1979d, 1980e). This design is oriented at identifying and evaluating natural and/or discharge related changes associated with the cobble community prior to and after operation of Units 2 and 3. The labeling of the PMP offshore cobble stations is an extension of the ETS identification system with stations being numbered consecutively from upcoast to downcoast. 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-2). 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-1).

Each permanent PMP station is a rectangle measuring 2 m x 3 m (6.6 ft x 9.8 ft). Station-pairs are permanently marked with a surface buoy attached to an anchor block. Each 6.0-m^2 (64.6-ft^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). Collection of data utilizing this sampling technique was detailed previously (SCE 1979d, 1980e).

Benthic organisms at each offshore station were sampled in two ways to collect data on temporal abundance patterns and spatial distribution. To collect these data, diving biologists sampled each 6.0-m^2 station with 300 evenly distributed points. Four 0.125-m^2 (1.35-ft^2) square quadrats were randomly located within the 6.0-m^2 station area and sampled with 60 evenly distributed points to examine small, cryptic, clumped, or patchily distributed organisms. Data collected at each point included substratum type and macroorganisms present. Up to three organism levels, indicating layering in the community, were recorded. Data for both sampling methods were recorded 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 were enumerated. Surface and bottom water temperature, visibility, and surge conditions were recorded.

To effectively document the changing composition of substrata near the stations, a wide area reconnaissance was conducted at each station-pair. This included sampling four 30-m (98-ft) transects extending upcoast (300°), downcoast (120°), inshore (030°), and offshore (210°) from each station-pair. Each 30-m transect line was divided into 100 equal sections by numbered placards. After the transect line was positioned by the diver, the substratum under each placard was identified as boulder, cobble, or sand. For the PMP study the following functional definitions of substratum were employed for boulder and cobble. Boulder is defined as hard substratum which is immovable by natural current conditions and/or which measures 26 cm (10.2 in.) 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.

INTERIM KELP PROGRAM (IKP)

The IKP is an extension of the Unit 1 Environmental Technical Specification (ETS) and Units 2 and 3 Preoperational Monitoring Program (PMP) sampling designs and methodologies. Accordingly, six permanent stations including ETS Station 10; CMP Stations 22 and 23; and PMP Station-pairs 14-15, 16-17, and 18-19 (Figure 5B-2) are sampled three times annually.

At each of these permanent sampling sites, diving biologists collect the following data in accordance with established procedures. Individual *Macrocystis pyrifera* plants and the number of stipes associated with each plant $\geq$ 2 m (6.6 ft) tall are counted. Notes on the general condition of kelp plants are recorded. Additionally, the number of lower story brown algae (*Pterygophora californica*, *Laminaria farlowii*, unidentified juvenile laminoids) and urchins (*Strongylocentrotus* spp.) are counted within the designated sampling areas. Substrata composition within these sampling areas is subjectively described. General oceanographic observations on surface and bottom water temperatures, visibilities, and surge conditions are also noted. All data are recorded on preprinted plastic data sheets described in the procedures.

In addition to data collected at each fixed sampling site, between nine and twelve randomly located 10-m^2 (108-ft^2) circular plots within a 30-m radius of each permanent station are sampled. Within each circular plot the following sampling data are recorded on preprinted plastic data sheets. All *Macrocystis* plants are separated into three general classes based on plant height, juvenile plants (15-40 cm, 0.5-1.3 ft), subadult plants (41 cm-2 m, 1.3-6.6 ft), and adult plants (>2 m tall) and enumerated. Unidentified laminoids (5-15 cm, 2-6 in.) are also counted. In the case of high density aggregations, the density of plants < 40 cm (16 in.) tall are estimated by subsampling. The stipes of all plants > 2 m tall are counted. Additionally, the number of urchins (*Strongylocentrotus* spp.)

and lower story brown algae (Pterygophora and Laminaria) within each 10-m^2 sampli q site are counted. Percent composition of cobble, boulder, and sand are subjectively estimated at each site.

Organisms for all benthic surveys presented in this cl ter are defined as those living on the exposed portions of the hard substrata. Organisms are identified to the lowest taxon possible in the field using non-destructive sampling methods. Other organisms that were less common or that could not be specifically identified in the field were classified into higher taxonomic groups, such as unidentified hydroids or ectoprocts. Descriptive as well as functional growth-forms were also employed to identify taxa groups. For example, unidentified ectoprocts may be encrusting or erect. Another growth-form classification was the algal group of Parvosilvosa. This growth-form group included all minute algae forming dense patches of turf on hard substrata (Neushul and Dahl 1967).

Quarterly ETS surveys were conducted during 1980 from 24 January-10 February, 28 April-2 June, 24 July-17 August, and 23 October-3 November. Winter storms during January, February, and March resulted in unfavorable diving conditions; consequently only six ETS benthic stations were sampled during the first quarterly sampling period of 1980. As noted during 1979 (SCE 1980e) the area in the vicinity of ETS Station 7 remained covered with sand during the 1980 sampling period. Subsequently, no biological data were collected at this station during 1980. Construction Monitoring stations (CMP 22 and 23) were only sampled during the April-June period. The PMP benthic study was completed in June 1980. Although the PMP sampling periods were scheduled quarterly, only the second quarterly survey was completed during 1980. Only two PMP stations were sampled during the first 1980 sampling effort before it was terminated due to unfavorable diving conditions. The second quarterly sampling was conducted from 7 May-2 June 1980.

The data losses associated with the ETS and PMP first quarterly survey period were reported to the Nuclear Regulatory Commission (NRC) by means of a 30-day non-routine report submitted in March 1980 in accordance with Administrative Control Section 5 of the ETS.

During December 17-19 a preliminary Interim Kelp Program survey was conducted. During this sampling period only the randomly sampling component was conducted at ETS Station 10, CMP Stations 22, 23, and PMP Station-pairs 14-15, 16-17, and 18-19.

DATA ANALYSIS

Data collected during the 1980 sampling period were analyzed using nonparametric and parametric techniques. Associations between organisms were compared using Pearson's product-moment (r) and Spearman's rho (p) parametric and nonparametric correlation coefficients (Sokal and Rohlf 1969), respectively.

Three ETS stations (3, 4, and 5) were almost always 100 percent sand during 1980 (SCE 1981a) and Station ETS 7 was presumed to be 100 percent sand during 1980. These stations are not included in the analysis because the ETS prog am was not designed to sample sand habitats. That these stations were once cobbl habitats but are now covered with sand is ecologically significant, and th component of spatial and temporal variability is considered in the discussion.

RESULTS

The results are grouped into five categories based on sampling techniques and types of data collected. These categories include 1) meteorological and oceanographic observations, 2) qualitative field observations, 3) analysis of the inshore cobble and offshore kelp stations, 4) analysis of data collected at the offshore cobble habitats, and 5) analysis of density data for select organisms in the San Onofre Kelp forest. Presenting the results in this manner rather than by study element (i.e, ETS, CMP, PMP) provides the best understanding of the physical and biological environment in the study area.

METEOROLOGICAL AND OCEANOGRAPHIC OBSERVATIONS

Substantial precipitation (39.6 cm, 15.6 in.) occurred in the San Onofre area during the first three months of 1980. In the past 12 years, total rainfall during January through March exceeded this level only in 1978.

Bottom temperature, bottom transmissivity, and water column Secchi disc extinction depth were measured during bimonthly oceanographic data collection near benthic stations in the San Onofre area (SCE 1981b). Mean bottom temperatures were generally highest during the months of July and September (17.3°C, 63.1°F) and lowest during January (14.9°C, 58.8°F). Unusually warm mean surface (26.0°C, 78.8°F) and bottom (23.2°C, 73.7°F) temperatures were recorded between August 13 and 18 during the third quarterly ETS benthic survey (SCE 1981b). In general, temperatures varied little among stations within sampling periods. Bottom transmissivity ranged from 0 to 12% transmittance at most stations throughout 1980. It was noticeably greater at all oceanographic stations during the January survey in comparison to all subsequent surveys when bottom transmissivity was 1% or less. Secchi disc readings on the 10-m (33-ft) isobath were generally greater at stations downcoast of Unit 1 (6,710-7,320 m; 22,014-24,015 ft) than at those near the discharge (610 m; 2,001 ft upcoast). Greatest vertical water clarity was observed during September and October 1980 on the 10-m isobath.

Results of continuous light, sedimentation rate, and total organic carbon (TOC) data collected at each Preoperational Monitoring Program (PMP) Benthic Sensing Package (BSP) site since August 1979 are presented in Chapter 2 and summarized in this section. Light intensity at all stations was lowest from December 1979 through February 1980 and highest during June. The substantially depressed light levels recorded during the winter period were a direct result of winter storms. During the thirteen month study period, mean light measurements were greatest at Station-pairs 14-15, 16-17, and 18-19, all located in San Onofre Kelp.

Distinct increases in sedimentation rates were apparent beginning in December 1979 and continuing through January 1980 when peak sedimentation rates were recorded at all station-pairs (Figures 5B-3 and 5B-4). These maximum values recorded during the 1979 and 1980 winter period were correlated with the high rainfall measured at the same time. Relatively high sedimentation rates at Station-pairs 16-17 and 20-21 continued through March 1980 (Figures 5B-3 and 5B-4).

Highest and lowest sedimentation rates, measured in grams/centimeter^2/day (g/cm^2/d), were recorded at Station-pair 20-21 (4.84 g/cm^2/d) during February 1980 and at Station-pair 12-13 (0.02 g/cm^2/d) during December 1979, respectively (Figure 5B-3). Minimum and maximum mean sedimentation rates for the study period were recorded at Station-pairs 12-13 (0.07 g/cm^2/d) and 20-21 (0.54 g/cm^2/d). Mean sedimentation rates for the study period at Station-pairs 14-15, 16-17, and 18-19, located in San Onofre Kelp, were 0.15, 0.31, and 0.15 g/cm^2/d, respectively.

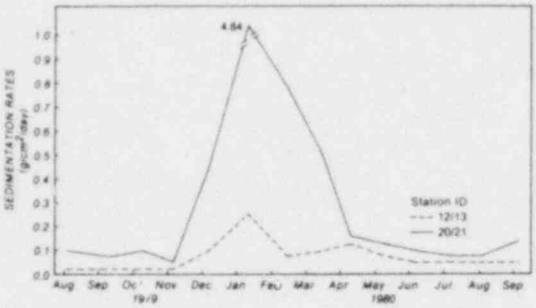

Figure 5B-3. **Mean sedimentation rates ($g/cm^2/d$) measured at Benthic Sensing Package (BSP) sites located near Station-pairs 12-13 and 20-21 from August 1979 to September 1980.**

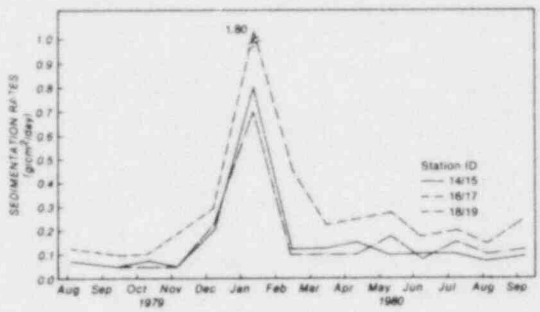

Figure 5B-4. **Mean sedimentation rates ($g/cm^2/d$) measured at Benthic Sensing Package (BSP) sites located near Station-pairs 14-15, 16-17, and 18-19.**

Distinct increases in TOC estimates were also apparent during the March 1980 sampling period (Figures 5B-5 and 5B-6). Mean TOC estimates were greatest in March and lowest in January and February for all stations during the thirteen month study period. Mean TOC estimates for all stations combined during November and December 1979 were less than during the 1980 summer period (June through August). Total organic carbon estimates during these periods were generally highest at Station-pairs 12-13 and lowest at 20-21 (Figures 5B-5 and 5B-6). Estimates of TOC from stations in San Onofre Kelp were more variable throughout the study period with mean estimates usually bracketed by the values recorded at Station-pairs 12-13 and 20-21 (Figures 5B-5 and 5B-6).

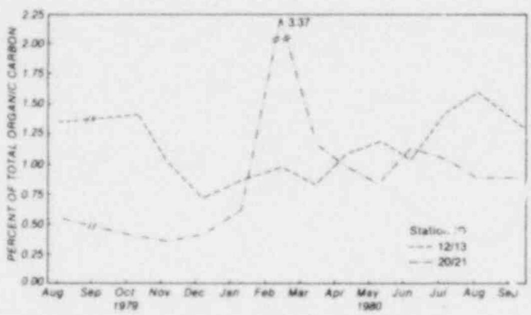

Figure 5B-5. **Mean percent total organic carbon (TOC) measured at Benthic Sensing Package (BSP) sites located near Station-pairs 12-13 and 20-21 from August 1979 to September 1980.**

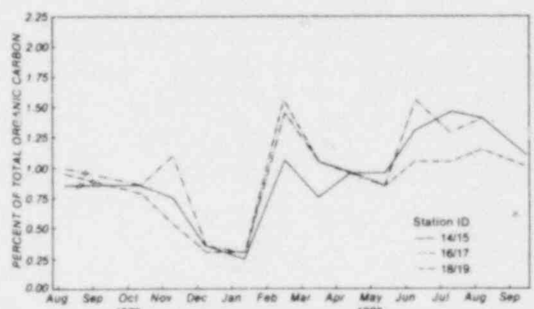

Figure 5B-6. **Mean percent total organic carbon (TOC) measured at Benthic Sensing Package (BSP) sites located near Station-pairs 14-15, 16-17, and 18-19 from August 1979 to September 1980.**

The periods of peak TOC estimates were not coincident with peak periods of sediment accumulation. Analysis of sedimentation rates and TOC estimates during identical sampling periods (Figures 5B-3 through 5B-6) reveals an inverse relationship among Station-pairs 12-13, 14-15, and 18-19 where high volumes of sediment were inversely correlated with low TOC estimates. High sedimentation rates showed a significant negative correlation with low TOC estimates during the 1979 and 1980 study period at these stations ($n = 24$; $P \leq 0.01$). In contrast, correlation between sedimentation rates and TOC estimates were not as great at Station-pair 16-17 ($P = 0.08$) with no relationship indicated at Station-pair 20-21 ($P = 0.99$).

FIELD OBSERVATIONS

Observations by field biologists documented comparatively unusual kelp canopies and fouling of kelp blades during the 1980 study period (SCE 1981a). The San Mateo Kelp canopy was unusually dense above Station 13 during January. During October and November, the canopy at Barn Kelp was sparse, consisting of scattered Macrocystis plants. During this period, some of the holdfasts of kelp plants in the vicinity of the Barn Kelp transect appeared dead and/or decaying. Unusually high mean surface and bottom temperatures (23.0°C, 73.4°F and 17.8°C, 58.4°F; respectively) were recorded during July and August. During this period dense hydroid and ectoproct fouling on attached and drifting blades of Macrocystis, Pterygophora, and Laminaria was also observed. Heavily fouled drift Macrocystis blades were observed in the ETS band transect at San Mateo Kelp during this period. The dense fouling communities on drift Macrocystis blades suggest these blades were originally a component of the surface canopy.

Recruitment of algae and sessile invertebrates was noted at inshore and offshore cobble and kelp stations. Juvenile brown algae (Cystoseira/Halidrys) were noted at Station 6 during January. Juvenile anthozoans (Muricea californica) and solitary tunicates (Chelyosoma productum, Styela montereyensis) were noted at various stations during May and August. Unidentified laminoids (possibly juvenile Macrocystis) were observed at San Mateo Kelp during October.

INSHORE COBBLE AND OFFSHORE KELP STATIONS

Substrata Composition

Inshore cobble stations not characterized as sand habitats during the 1980 study period were ETS Stations 1, 2, 6, and 8. As in 1979 (SCE 1980e), percent cover estimates of hard substrata (cobble, boulder, rock shelf) were most similar between stations within zones. These estimates were always greater in Zone 0A than in Zone 6 and averaged 79.4% and 51.4% during 1980, respectively. Although no distinct seasonal variations were evident at these stations, significant sand erosion occurred at Station 2. Mean percent sand cover at this station decreased from 76.7% to 4.6% between the October 1979 and May 1980 sampling periods (SCE 1980c, 1981b).

Estimates of hard substrata percent cover at the kelp stations averaged 93.9% at San Mateo Kelp, 81.6% at San Onofre Kelp, and 75.5% at Barn Kelp during 1980; and 45.2% and 74.0% during the April-June survey at CMP Stations 22 and 23, respectively. Estimates were consistently highest for San Mateo Kelp and showed the least variability. Seasonal variation was not demonstrated at any kelp station during the 1980 study period. There were, however, increases in hard substrata averaging 10% at San Onofre and Barn Kelp between October 1979 (SCE 1980e) and May 1980 (SCE 1981b).

Abundant Taxa

The five most abundant enumerated and percent cover taxa and/or taxa assemblages observed at the inshore cobble stations during 1980 are defined as the abundant organisms (Tables 5B-3 and 5B-4). In general they are non-motile and represent both the numerically dominant and functionally important organisms associated with the inshore cobble habitat.

Abundant enumerated taxa at the inshore cobble stations included one alga and 14 invertebrate taxa (Table 5B-3), which accounted for 90% of all individuals enumerated. Maximum number of individuals were recorded during July in both zones

Table 5B-3. 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 each 1980 survey.

	Stations 1 and 2†			Stations 6 and 8			
Abundant Taxa	May	Jul	Oct	Jan	May	Jul	Oct
Anthopleura artemisia	0.1	0.2	0.1	0.0	0.0	0.0	0.0
Astrangia spp.	0.3	0.0	0.1	0.0	0.8(5)	0.8	1.0(5)
Chelyosoma productum	97.5(1)	249.6(1)	147.9(1)	0.6	8.8(1)	9.0(2)	0.1
Cystoseira/Halidrys	1.0(5)	0.9(5)	1.0	5.7(1)	1.8(4)	1.8(4)	1.8(3)
Diopatra ornata	3.9(3)	2.2(4)	4.6(3)	2.0(5)	3.5(3)	5.1(3)	8.1(2)
Kelletia kelletii	0.5	0.1	0.2	0.0	0.4	0.1	0.3
Molgula spp.	0.0	0.0	0.0	2.2(3.5)	0.0	0.0	0.0
Muricea californica	2.[illegible](4)	2.3(3)	3.2(4)	2.2(3.5)	8.3(2)	9.1(1)	9.0(1)
Muricea fruticosa	0.[illegible]	0.0	0.2	0.1	0.7	0.8	0.7
Onuphid, unident.	0.2	0.4	0.0	4.0(2)	0.[illegible]	0.2	1.5(4)
Patiria miniata	0.3	0.2	0.0	0.0	0.0	0.2	0.0
Sabellaria cementatium	0.2	0.0	1.3(5)	0.1	0.0	0.0	0.0
Sabellarid, unident.	0.2	0.0	0.1	0.6	0.1	0.2(5)	0.6
Spiochaetopterus costarum	0.2	0.5	0.5	0.6	0.4	0.9	0.7
Styela montereyensis	4.6(2)	8.4(2)	6.4(2)	0.4	0.3	0.3	0.8
Total number of individuals††	112.0	266.0	168.0	19.0	26.0	31.0	25.0
Total individuals, top five taxa§	109.0	263.0	163.0	16.0	23.0	25.0	21.0
Percent (%)§§	97.3	98.9	97.0	84.2	88.5	80.6	84.0

† Stations 1 and 2 were not sampled during the January survey due to poor visibility and winter storms.
†† Estimates based on 20 m^2 of sampling area.
§ Total number of individuals accounted for by the five most abundant taxa.
§§ Percent represented by the five most abundant taxa.

Table 5B-4. 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 each 1980 survey.

	Stations 1 and 2†			Stations 6 and 8			
Abundant Taxa	May	Jul	Oct	Jan	May	Jul	Oct
Acrosorium uncinatum	1.0	3.6(4)	2.2	0.0	0.0	0.0	0.0
Balanus spp.	1.4	0.9	2.9	1.8	2.6(5)	2.5(5)	1.9
Bryopsis corticulans	0.0	0.0	0.0	0.0	3.4(3)	0.0	0.1
Bryopsis hypnoides	0.0	0.0	0.3	2.5	2.4	4.7(3)	6.6(3)
Corallina/Haliptylon	0.6	0.5	0.6	11.7(1)	4.6(2)	4.8(2)	3.9(4)
Crustose corallines, unident.	5.6(3.5)	8.4(2)	3.2(5)	2.9(4.5)	1.0	0.6	1.6
Ectoprocts, unident. (encrusting)	8.9(1)	4.2(3)	22.0(1)	0.2	2.9(4)	2.7(4)	16.8(2)
Ectoprocts, unident. (erect)	2.8	2.9(5)	6.5(2)	5.2(2)	5.1(1)	9.3(1)	24.1(1)
Euherdmania claviformis	0.5	0.2	1.0	0.7	0.7	0.5	1.2
Hydroids, unident.	5.6(3.5)	1.8	3.9(3)	0.8	0.4	1.8	3.8(5)
Leucilla nuttingi	0.4	0.8	0.6	0.6	0.7	0.5	0.9
Parvosilvosa	7.4(2)	20.1(1)	3.5	5.0(3)	2.2	1.3	3.7
Pterocladia/Gelidium	0.6	0.2	0.4	2.9(4.5)	1.1	1.2	1.1
Rhodymenia spp.	4.4(5)	2.0	3.7(4)	1.2	0.8	1.2	0.6
Rhodophytes, unident.	0.5	1.7	0.7	2.3	1.1	0.6	0.6
White coralline crust	2.9	0.0	0.7	0.0	0.3	0.1	0.0
Total biological cover††	47.0	52.0	54.0	51.0	32.0	34.0	69.0
Cover, abundant taxa§	32.0	39.0	39.0	28.0	19.0	24.0	55.0
Percent (%)§§	68.1	75.0	72.2	53.9	59.4	70.[illegible]	79.7

† Stations 1 and 2 were not sampled during the January survey due to poor visibility and winter storms.
†† Estimates based on 20 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.

with the greatest number of organisms consistently observed at Stations 1 and 2 (Zone OA) during 1980. Comparison of the total number of individuals of abundant taxa recorded in each zone indicated that statistically greater numbers of individuals were observed in Zone OA during 1980 (Mann-Whitney test, $P \leq 0.01$).

The solitary tunicate Chelyosoma productum accounted for 90% of the total number of organisms observed in Zone OA. This organism was present in particularly high densities at Station 2 during May (98.1 individuals/m^2; SCE 1981b). Sand cover at Station 2 decreased 72% between October 1979 and May 1980 (SCE 1980c, 1981b) leaving a considerable amount of uninhabited hard substrata. The presence of small individuals of Chelyosoma productum, Muricea californica, and Styela montereyensis indicated that recruitment to the exposed hard substrata occurred at Station 2 between October 1979 and May 1980. This recruitment pattern was not observed at the cobble stations in Zone 6 (Table 5B-3).

The ornate polychate, Diopatra ornata, and the sea fan, Muricea californica, were the only taxa ranked among the five most abundant enumerated organisms during all surveys in both zones. The distribution of Diopatra between zones was consistent with observations during 1979 (SCE 1980e).

Percent cover taxa abundant at inshore cobble stations in Zones OA and 6 during 1980 included ten algae or algal assemblages and six invertebrates (Table 5B-4). These taxa accounted for an average of 68% of the total biological cover in both zones. No percent cover taxa were abundant in both zones during every survey. Corallina/Haliptylon and erect ectoprocts were most abundant in Zone 6. Encrusting ectoprocts revealed an opposite trend with higher abundances recorded in Zone OA. Maximum biological cover was observed during October in both zones. The total cover contributed by abundant organisms has not changed appreciably in the last two years (SCE 1980e).

The five most abundant enumerated and percent cover taxa and/or taxa assemblages observed at the kelp stations during 1980 are presented in Tables 5B-5 and 5B-6, respectively. These taxa are considered to represent the dominant and functionally important organisms associated with the kelp forest habitat.

Abundant enumerated taxa included 1 alga and 19 invertebrate taxa (Table 5B-5). These taxa accounted for 76% of the total number of enumerated individuals observed at all kelp stations during 1980. The greatest number of individuals were consistently recorded at San Mateo Kelp (Station 9) with the exception of Station 23 during May. The majority of individuals (85%) sampled at Station 23 was contributed by the solitary tunicate Chelyosoma productum. This species was also the most abundant organism sampled at San Mateo Kelp, Barn Kelp, and Station 22 during all surveys, and at San Onofre Kelp (Station 10) during July and October. This preponderance of C. productum was also present in cobble areas without kelp (Station 2) suggesting successful area-wide recruitment during 1979-1980. Recruitment of C. productum also corresponded with increased estimates of hard substrata during May at San Onofre Kelp and Barn Kelp (Station 11). Another solitary tunicate, Styela montereyensis, also occurred in high densities at Stations 22, 23, and Barn Kelp. The presence of juvenile Styela spp. was noted at several inshore cobble stations and kelp stations during 1980 (SCE 1981b). Similar to previous results (SCE 1980e), the lower story kelp Pterygophora californica was abundant only at Stations 22 and 23.

Abundant percent cover organisms observed at the offshore kelp stations during 1980 included 9 algae and 6 invertebrate taxa (Table 5B-6) which accounted for 76% of the total biological cover. Total biological cover was greatest at San Onofre Kelp averaging 108% during 1980. Biological cover was similar among Barn Kelp, Station 22, and Station 23 averaging 50.5%, 59.0%, and 53.0%, respectively.

Table 5B-5. Density (number/m^2) and rank order of abundance (value in parentheses) of the five most abundant taxa enumerated at each kelp station during each 1980 survey.

Abundant Taxa	Station 9 Jan	Station 9 May	Station 9 Jul	Station 9 Oct	Station 10 May	Station 10 Jul	Station 10 Oct
Anthopleura artemisia	0.0	0.0	0.3	0.1	0.5	0.0	0.2
Anemone, unident.	0.4	0.0	0.0	0.0	0.2	0.1	0.0
Chelyosoma productum	15.5(1)	25.6(1)	119.3(1)	27.9(1)	0.3	9.4(1)	1.3(4)
Diopatra ornata	2.5	2.2	1.9(5)	2.6	1.0(4)	0.2	0.9(5)
Kelletia kelletii	1.0	1.5	0.8	0.9	0.9(5)	1.9(2)	0.4
Lytechinus spp.	2.6(5)	0.3	0.0	0.3	3.3(1)	0.5	0.3
Molgula spp.	7.1(3)	0.0	0.0	0.0	0.0	0.0	0.0
Mitrella carinata	14.9(2)	3.1(3)	1.8	14.1(2)	0.1	0.0	0.0
Muricea californica	3.9(4)	3.0(4)	2.5(3)	5.5(3)	0.0	0.0	0.0
Onuphid, unident.	0.0	0.0	0.0	0.5	0.0	1.2(4.5)	0.8
Pagurus spp.	0.0	0.0	0.0	0.0	0.0	1.1(6)	0.0
Pagurids, unident.	0.1	0.5	1.1	4.1(5)	0.0	0.0	0.2
Paguristes spp.	0.1	0.5	0.0	1.1	0.0	0.0	0.2
Patiria miniata	0.0	0.0	0.0	0.0	1.1(3)	1.4(3)	1.5(3)
Pyura haustor	0.2	4.2(2)	2.8(2)	3.0	0.1	0.0	0.0
Sabellarid, unident.	0.0	0.2	0.2	4.6(4)	0.0	0.0	2.0(2)
Spiochaetopterus costarum	0.4	0.5	0.1	1.9	2.2(2)	1.2(4.5)	3.9(1)
Strongylocentrotus franciscanus	2.2	2.3(5)	2.0(4)	2.3	0.0	0.2	0.5
Styela montereyensis	1.3	1.6	1.7	1.2	0.0	0.3	0.1
Zaolutus actius	0.0	0.0	0.1	0.0	0.1	0.1	0.1
Total number of individuals†	62.0	49.0	139.0	86.0	12.0	20.0	15.0
Total individuals, top five taxa††	44.0	38.0	129.0	56.0	9.0	16.0	10.0
Percent (%)§	71.0	77.6	92.8	65.1	75.0	80.0	66.7

Abundant Taxa	Station 11 Jan	Station 11 May	Station 11 Jul	Station 11 Oct	Station 22 May	Station 23 May
Anthopleura artemisia	0.0	2.1(5)	0.3	0.8	0.0	0.0
Anemone, unident.	3.1(3)	0.0	4.8(2)	0.0	0.0	0.0
Chelyosoma productum	1.1(5)	1.6	0.6	0.8	21.6(1)	296.5(1)
Diopatra ornata	5.0(2)	6.0(1)	7.2(1)	5.9(1)	1.4(4.5)	5.9(4)
Kelletia kelletii	0.0	0.7	0.1	0.1	1.4(4.5)	1.4
Lytechinus spp.	0.0	0.0	0.0	0.0	0.0	0.0
Molgula spp.	0.6	0.0	0.0	0.0	0.0	0.0
Mitrella carinata	0.0	0.0	0.0	0.0	0.0	4.4(5)
Muricea californica	2.8(4)	2.9(4)	3.7(4)	3.4(4)	0.0	0.0
Onuphid, unident.	0.0	0.0	0.1	0.2	0.0	0.0
Pagurids, unident.	0.0	1.0	0.0	0.0	0.0	0.0
Paguristes spp.	0.0	0.0	1.7	2.3(5)	0.0	0.0
Patiria miniata	0.0	0.0	0.0	0.0	1.2(6.5)	0.5
Pterygophora californica	0.0	0.0	0.0	0.0	3.7(2)	11.3(3)
Pyura haustor	0.3	0.4	0.6	0.5	0.0	0.0
Sabellarid, unident.	0.0	0.0	0.0	0.1	0.0	0.0
Spiochaetopterus costarum	0.0	1.9	1.0	1.7	0.1	1.9
Strongylocentrotus franciscanus	0.6	0.0	0.3	0.2	1.2(6.5)	0.1
Styela montereyensis	5.1(1)	5.0(2)	4.4(3)	3.6(3)	1.5(3)	16.7(2)
Zaolutus actius	0.0	4.2(3)	2.7(5)	5.4(2)	0.0	0.0
Total number of individuals†	22.0	29.0	33.0	32.0	38.0	348.0
Total individuals, top five taxa††	17.0	20.0	23.0	21.0	32.0	335.0
Percent (%)§	77.3	69.0	69.7	65.6	84.2	96.3

† Estimates based on 10 m^2 of sampling area.
†† Total number of individuals accounted for by the five most abundant taxa.
§ Percent represented by the five most abundant taxa.

Table 5B-6. 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 each 1980 survey.

Abundant Taxa	Station 9				Station 10		
	Jan	May	Jul	Oct	May	Jul	Oct
Astrangia spp.	1.9	1.2	2.4	2.3	1.9(5)	2.2(6)	4.1(5)
Balanus spp.	0.0	0.7	1.4	1.4	1.2	2.6(4.5)	0.7
Bossiella spp.	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Corallina/Haliptylon	1.8	2.0	3.5(5.5)	3.3	1.0	0.0	0.1
Crustose corallines, unident.	14.3(2)	9.7(2)	8.7(2)	8.1(5)	54.5(1)	52.5(1)	63.0(1)
Ectoproct, unident. (encrusting)	3.7	9.2(3)	3.3	14.3(2)	1.0	17.0(3)	4.4(4)
Ectoproct, unident. (erect)	15.0(1)	12.3(1)	40.5(1)	22.0(1)	0.0	0.0	0.1
Hildenbrandia prototypus	1.1	0.9	0.6	0.0	9.3(3)	2.6(4.5)	6.5(3)
Hydroids, unident.	9.9(3)	0.7	1.4	8.9(4)	11.3(2)	1.1	2.0
Macrocystis spp. (holdfast)	0.0	1.0	3.5(5.5)	1.5	0.0	0.0	0.0
Parvosilvosa	7.2(5)	3.1	0.5	12.6(3)	8.8(4)	40.5(2)	19.0(2)
Poriferans, unident.	1.9	1.2	1.5	1.3	1.6	0.3	1.5
Prionitis spp.	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Pterocladia/Gelidium	7.6(4)	7.7(4)	7.3(3)	6.7	0.0	0.0	0.0
Rhodymenia spp.	6.5	7.6(5)	6.5(4)	7.5	0.5	0.4	0.6
Total biological cover†	85.0	67.0	89.0	107.0	94.0	124.0	106.0
Cover, abundant taxa††	54.0	47.0	70.0	66.0	86.0	117.0	97.0
Percent (%)§	63.5	70.1	78.7	61.7	91.5	94.4	91.5

Abundant Taxa	Station 11				Station 22	Station 23
	Jan	May	Jul	Oct	May	May
Astrangia spp.	0.8	0.7	0.8	0.7	0.0	0.0
Balanus spp.	0.0	0.4	0.4	0.2	0.0	0.0
Bossiella spp.	1.5	2.7(3)	1.3	0.2	0.0	0.0
Corallina/Haliptylon	1.6	0.9	2.2(4)	2.5	4.0(4)	0.7
Crustose corallines, unident.	0.1	0.6	0.6	1.3	12.5(2)	5.4
Ectoproct, unident. (encrusting)	0.0	1.1	3.1(3)	13.8(2)	1.1	6.1(5)
Ectoproct, unident. (erect)	2.4(4)	6.0(2)	13.6(2)	18.4(1)	0.1	6.3(3)
Hildenbrandia prototypus	0.1	0.3	0.0	0.2	0.0	0.0
Hydroids, unident.	6.3(2)	1.0	0.8	3.2	0.9	6.2(4)
Macrocystis spp.	0.0	0.3	0.2	0.0	0.0	0.0
Parvosilvosa	0.7	1.5(5.5)	0.1	13.2(3)	14.7(1)	0.7
Poriferans, unident.	2.6(3)	0.9	2.0(5)	1.1	0.0	0.0
Prionitis spp.	2.2(5)	2.3(4)	1.6	3.5(5)	0.0	0.0
Pterocladia/Gelidium	1.4	1.5(5.5)	0.7	1.6	3.4(5)	7.1(2)
Rhodymenia spp.	11.1(1)	13.3(1)	14.2(1)	11.2(4)	9.8(3)	12.9(1)
Total biological cover†	40.0	39.0	46.0	77.0	59.0	53.0
Cover, abundant taxa††	25.0	27.0	35.0	60.0	44.0	38.0
Percent (%)§	62.5	69.2	76.1	77.9	74.6	71.7

† 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.

No one abundant percent cover organism occurred at every station during all surveys. Unidentified crustose coralline algae were considered abundant at all stations except Station 23 and Barn Kelp. The highest mean cover of unidentified crustose coralline algae (in excess of 50%) occurred at Station 10 in San Onofre Kelp during each survey.

Unidentified erect ectoprocts were abundant at Barn Kelp and San Mateo Kelp. At San Onofre Kelp this taxa was observed only during October (Table 5B-6). The red alga Rhodymenia spp., the most abundant percent cover organism identified at Barn Kelp and Station 23, averaged 12.5% and 12.9%, respectively (Table 5B-6). This abundance pattern was similar to that observed in 1979 (SCE 1980e).

OFFSHORE COBBLE STATIONS

As described in the Methods, abundance is estimated in two ways at the offshore cobble stations. Because of the close agreement between the two sampling techniques demonstrated for all previous PMP data (SCE 1980e) and the fact that all offshore cobble stations were sampled only during May, analysis of the 0.125-m^2 data set is not included in this report. These data have been presented previously (SCE 1981a,b) and are still a component of the preoperational benthic baseline data set.

Wide Area Substrata Reconnaissance

A definite distinction existed between groups of station-pairs with regard to substrata composition. Station-pairs 12-13, 14-15, 16-17, and 18-19 were surrounded principally by cobbles and boulders. Although the relative amount of cobble and boulder at each station-pair was variable, the total amount of hard substrata was relatively stable at these sites during 1980. The distribution of small (< 1 m dia.) patches of sand surrounding Station-pairs 12-13, 14-15, and 18-19, was similar and relatively homogeneous. In contrast, there were two distinct, relatively stable, and comparatively large (15-20 m wide) sand lenses located offshore (210°M) and upcoast (300°M) of Station-pair 16-17. As noted previously (SCE 1980e), Station-pair 20-21 was initially located on a comparatively small rock outcropping on an extensive plain of sand. Between October 1978 and January 1980, mean percent hard substrata near this station-pair was 15.2%. After the winter 1980 storms, it decreased to 5.3% at Station-pair 20-21 (SCE 1981b).

Total Number of Taxa, Percent Hard Substrata, and Percent Biological Cover

Observations on the total number of taxa, percent hard substrata, and percent biological cover recorded at each offshore cobble station during January and May 1980 are summarized in Table 5B-7. Comparison of data collected at Station-pair 12-13 during 1980 reveals that fewer numbers of taxa and reduced biological cover were observed during the May survey (Table 5B-7). These differences appear to be associated with the early 1980 storm activity.

Comparison of data collected during October 1979 (SCE 1979d) and May 1980 (SCE 1981b) reveals that biological cover decreased an average of 31.7% at all offshore cobble stations. The minimum mean reduction in biological cover was 7% at Station 13 and Station-pair 18-19. Maximum reduction in biological cover averaged 66.5% for Station-pair 20-21. The reduction in biological cover between October 1979 and May 1980 at Station-pair 20-21 is a direct result of significant sand accretion which was apparently the result of winter storms. During this period, percent sand cover at Station 20 increased from 38% during October 1979 to 96% in May 1980 (Table 5B-7; SCE 1980e). Percent sand cover at Station 21 increased from 34.7% to 59.3% during the same period. Associated with sand accretion at Station-pair 20-21 was a considerable amount of terrestrial debris (small tree branches, terrestrial seeds) observed by divers sampling these stations.

Table 5B-7. 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 during the January and May 1980 surveys.

		STATION									
		12	13	14	15	16	17	18	19	20	21
Jan	T	19	27	†	†	†	†	†	†	†	†
	S	94.0	94.3	†	†	†	†	†	†	†	†
	B	131.3	164.3	†	†	†	†	†	†	†	†
May	T	16	21	26	26	23	19	19	25	10	18
	S	95.0	96.7	84.0	91.0	65.7	60.3	91.7	94.3	4.0	40.7
	B	119.0	154.7	132.0	139.0	93.7	155.0	132.7	110.3	14.3	48.7

† Stations not sampled due to adverse weather conditions.

Community Composition and Three Dimensional Organism Layering

Primary producer and sessile invertebrate populations, similar to previous results (SCE 1980e), exhibited distinct similarities and differences among the offshore cobble stations. During 1980, sessile invertebrate populations were dominant at Station-pairs 12-13 and 20-21 accounting for means of 71% and 88% of the total biological cover, respectively (Tables 5B-7 and 5B-8). The reverse relationship is apparent at Station-pairs 14-15, 16-17, and 18-19 where primary producers accounted for a mean of 78% of the total biological cover during 1980 (Tables 5B-7 and 5B-8).

Table 5B-8. Biological cover (%/6 m^2) of primary producers (PP) and sessile invertebrates (SI) observed at offshore cobble stations during the January and May 1980 surveys.

		STATION									
		12	13	14	15	16	17	18	19	20	21
Jan	PP	30	31	†	†	†	†	†	†	†	†
	SI	96	119	†	†	†	†	†	†	†	†
May	PP	34	32	90	92	78	128	113	91	1	5
	SI	82	112	33	45	15	24	19	17	13	41

† Stations not sampled due to adverse weather conditions.

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-9.

Table 5B-9. Biological cover (%/6 m^2) recorded at Organism Levels 1 (OL1), 2 (OL2), and 3 (OL3) during each 1980 survey.

		STATION									
		12	13	14	15	16	17	18	19	20	21
Jan	OL3	5	9	†	†	†	†	†	†	†	†
	OL2	35	60	†	†	†	†	†	†	†	†
	OL1	93	97	†	†	†	†	†	†	†	†
May	OL3	2	6	3	7	2	12	4	1	1	1
	OL2	26	52	39	41	22	54	39	23	2	8
	OL1	92	97	90	91	70	90	89	86	12	41

† Stations not sampled due to adverse weather conditions.

Organism Level 1, the basement story, always included the major portion of the total biological cover reported for each station. Comparatively high levels of organism cover were recorded with all stations averaging nearly 90% except at Station-pair 20-21 where mean percent cover was 27%. The second organism level, OL2, exhibited considerable variability with highest mean cover at Stations 13 and 17, and lowest at Stations 20 and 21 (Table 5B-9). The lowest proportion of biological cover always occurred in the overstory, OL3, ranging from 12% at Station 17 to 1% at Stations 19, 20, and 21 (Table 5B-9). Comparison of data collected during October 1979 (SCE 1980e) with data collected in May 1980 reveals that a general reduction in organism cover occurred at all levels at all stations between these sampling periods.

Descriptive Taxa

For the purpose of this presentation, descriptive organisms are defined as 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). Descriptive organisms, in addition to elucidating temporal and spatial patterns of variation, may provide insight to localized environmental influences.

The percent biological cover estimates for descriptive organims sampled at Station-pair 12-13 during the 1980 sampling period appear in Table 5B-10. Sessile invertebrates, principally unidentified hydroids and ectoprocts, accounted for the majority of the biological cover recorded at these stations. Dominant algal components included the foliose red alga Rhodymenia spp. and unidentified crustose corallines. Unidentified hydroids were recorded in lower abundances during the May survey at both stations.

The biological cover of descriptive organisms sampled at Station-pair 14-15 is presented in Table 5B-11. Parvosilvosa, Pterygophora californica, and unidentified crustose corallines were the dominant organisms accounting for the majority of the biological cover at both stations. Comparison of biological cover between October 1979 (SCE 1980e) and May 1980 revealed that all organisms, with the exception of unidentified ectoprocts, exhibited lower abundances during 1980.

Table 5B-10. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at offshore cobble Station-pair 12/13 during the January and May 1980 surveys.

Descriptive Taxa	Station 12 Jan	Station 12 May	Station 13 Jan	Station 13 May
Crustose corallines, unident.	8 (6)	9 (6)	9 (6)	8 (6)
Rhodymenia spp.	15 (5)	12 (5)	14 (5)	14 (5)
Parvosilvosa	1 (7)	6 (7)	2 (7)	4 (7)
Macrocystis spp.	0 (8)	0 (8)	0 (8)	1 (8)
Hydroids, unident.	31 (1)	16 (3)	23 (3)	15 (4)
Muricea californica	16 (4)	14 (4)	35 (1)	37 (1)
Ectoprocts, unident. (encrusting)	27 (2)	32 (1)	16 (4)	23 (3)
Ectoprocts, unident. (erect)	19 (3)	18 (2)	33 (2)	29 (2)
Total biological cover (%)	131.3	119.0	164.3	154.7
Cover, descriptive taxa (%)†	117.0	107.0	132.0	131.0
Percent (%)††	89.1	89.9	80.3	84.6

† Total percent cover contributed by the descriptive taxa.
†† Percent of the total biological cover accounted for by the descriptive taxa.

Table 5B-11. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at offshore cobble Station-pair 14/15 during the May 1980 survey.

Descriptive Taxa	Station 14	Station 15
Crustose corallines, unident.	17 (3)	20 (3)
Crytonemia/Halymenia/Schizymenia	1 (7)	0 (8.5)
Rhodymenia spp.	6 (4.5)	7 (4.5)
Parvosilvosa	30 (2)	33 (1)
Desmarestia spp.	0 (9)	0 (8.5)
Laminaria spp.	0 (9)	0 (8.5)
Macrocystis spp.	0 (9)	0 (8.5)
Pterygophora californica	32 (1)	26 (2)
Ectoprocts, unident. (encrusting)	6 (4.5)	7 (4.5)
Ectoprocts, unident. (erect)	4 (6)	1 (6)
Total biological cover (%)	132.0	139.0
Cover, descriptive taxa (%)†	96.0	94.0
Percent (%)††	72.0	67.6

† Total percent cover contributed by the descriptive taxa.
†† Percent of the total biological cover accounted for by the descriptive taxa.

Abundance estimates of descriptive organisms sampled at Station-pair 16-17 appear in Table 5B-12. Similar to the data collected at Station-pair 14-15, algae accounted for the majority of the biological cover during 1980 and showed decreases in abundance when compared to data collected during October 1979 (SCE 1980e). Unidentified hydroids and ectoprocts exhibited slightly higher percent cover increases between October 1979 and May 1980. Pterygophora californica continued to be the dominant organism sampled at Station 17 as noted during all previous surveys (SCE 1980e).

Table 5B-12. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at offshore cobble Station pair 16/17 during the May 1980 survey.

Descriptive Taxa	Station 16	Station 17
Crustose corallines, unident.	22 (1.5)	24 (2)
Hildenbrandia prototypus	3 (6)	3 (7)
Pterocladia/Gelidium	2 (7)	6 (5)
Rhodymenia spp.	10 (4)	7 (3.5)
Parvosilvosa	22 (1.5)	7 (3.5)
Pterygophora california	13 (3)	78 (1)
Hydroids, unident.	4 (5)	3 (7)
Ectoprocts, unident. (encrusting)	1 (8.5)	3 (7)
Ectoprocts, unident. (erect)	1 (8.5)	1 (9)
Total biological cover (%)	93.7	155.0
Cover, descriptive taxa (%)†	78.0	132.0
Percent (%)††	83.2	85.2

† Total percent cover contributed by the descriptive taxa.
†† Percent of the total biological cover accounted for by the descriptive taxa.

Descriptive organisms exhibited remarkably similar mean percent cover estimates between Stations 18 and 19 during 1979 (SCE 1980e) and 1980 (Table 5B-13). Algae continued to constitute the majority of the biological cover in 1980, although reductions of Parvosilvosa estimates between October 1979 (SCE 1980e) and May 1980 averaged 58%. In contrast, abundance estimates of Rhodymenia were greater in May 1980 than in any previous survey (SCE 1980e). Similar to data collected at Station-pairs 14-15 and 16-17, unidentified hydroids and ectoprocts exhibited slightly higher percent cover estimates during the 1980 survey than during the last survey in 1979.

Abundance estimates of the descriptive organisms sampled at Station-pair 20-21 during May are presented in Table 5B-14. The significant effect of sand burial on biological cover at these stations has been noted previously. Sessile invertebrates continued to account for the majority of the biological cover sampled at this station-pair.

Designated Solitary Organisms

Density estimates of the designated solitary organisms enumerated at each offshore cobble benthic station are presented in SCE 1981b. Density estimates of most organisms generally remained similar or decreased slightly with respect to the October 1979 survey with two notable exceptions. Density estimates of the

Table 5B-13. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at offshore cobble Station-pair 18/19 during the May 1980 survey.

Descriptive Taxa	Station 18	Station 19
Crustose corallines, unident.	38 (2)	40 (1)
Coeloseira/Champia	1 (8)	1 (8)
Rhodymenia spp.	14 (3)	6 (3)
Parvosilvosa	41 (1)	38 (2)
Astrangia spp.	4 (5.5)	4 (5)
Hydroids, unident.	5 (4)	5 (4)
Muricea californica	3 (7)	3 (6.5)
Ectoprocts, unident. (encrusting)	4 (5.5)	3 (6.5)
Ectoprocts, unident. (erect)	0 (9)	0 (9)
Total biological cover (%)	132.7	110.3
Cover, descriptive taxa (%)†	110.0	100.0
Percent (%)††	82.8	90.6

† Total percent cover contributed by the descriptive taxa.
†† Percent of the total biological cover accounted for by the descriptive taxa.

white urchin, Lytechinus spp., were substantially higher in the San Onofre Kelp forest at Station-pairs 16-17 and 18-19 in comparison to the October 1979 sampling period. Densities of Diopatra ornata also increased considerably at all stations except at Station 20 where only fourteen individuals were recorded. This represents a decrease in nine individuals at Station 20 from the previous 1979 October survey (SCE 1980e).

Table 5B-14. Biological cover (%/6 m^2) and rank order of abundance (value in parentheses) of the descriptive taxa sampled at offshore cobble Station-pair 20/21 during the May 1980 survey.

Descriptive Taxa	Station 20	Station 21
Crustose corallines, unident.	0 (7.5)	2 (5)
Rhodymenia spp.	0 (7.5)	1 (7.5)
Parvosilvosa	1 (4.5)	1 (7.5)
Hydroids, unident.	1 (4.5)	9 (2.5)
Muricea californica	4 (1)	15 (1)
Balanus spp.	1 (4.5)	1 (7.5)
Ectoprocts, unident. (encrusting)	2 (2)	9 (2.5)
Ectoprocts, unident. (erect)	1 (4.5)	6 (4)
Total biological cover (%)	14.3	48.7
Cover, descriptive taxa (%)†	10.0	44.0
Percent (%)††	69.9	90.3

† Total percent cover contributed by the descriptive taxa.
†† Percent of the total biological cover accounted for by the descriptive taxa.

SAN ONOFRE KELP FOREST

Substrata and Select Organisms

The mean percent substrata (%/10 m^2) and organism density estimates (no./10 m^2) sampled at each station are presented in Table 5B-15. Similar high estimates of sand were recorded at Stations 16-17 and Station 22. Highest mean estimates of hard substrata were recorded at Stations 14-15. Mean cover estimates averaging 21.4% and 78.8% of sand and hard substrata, respectively, were recorded at the remaining stations (Stations 10, 18-19, 23).

Pterygophora californica, Strongylocentrotus spp., and adult (height > 2 m) Macrocystis pyrifera plants were the most numerous organisms sampled. Strongylocentrotus was sampled at all stations. Densities were comparatively high surrounding PMP Station 18-19 (mean of 13.6 individuals/10 m^2). Highest mean density estimates of Pterygophora were recorded at Stations 14-15 and Station 23 where greatest densities of unidentified laminoids were also sampled. Macrocystis plants > 2 m tall were observed at all stations except Stations 10 and 16, 17. Highest densities were sampled in the area surrounding Stations 14, 15, and 23. Low densities of Macrocystis plants were sampled at Stations 18-19 and Station 22. All Macrocystis plants within the general sampling area of each station appeared to be in good condition showing no signs of discoloration or senescence (fouled and/or tattered blades).

Table 5B-15. Mean and standard error (SE) of substrata percent cover estimates (%/10 m^2) and density estimates of select organisms (no./10 m^2) at the San Onofre Kelp forest monitoring stations during December 1980. A total of twelve randomly located 10-m^2 circles (120 m^2) were sampled within 33 m of each station.

	Station					
	10	14-15	16-17	18-19	22	23
Parameter	Mean/SE	Mean/SE	Mean/SE	Mean/SE	Mean/SE	Mean/SE
Substrata						
Cobble (%)	41.8/7.0	63.3/3.9	9.3/3.1	55.1/5.8	9.9/23	60.5/7.1
Boulder (%)	36.3/6.0	25.8/3.9	24.1/6.0	29.1/5.1	19.3/3.9	13.8/2.3
Sand (%)	21.9/6.9	11.0/1.0	66.7/8.4	16.7/2.2	70.8/5.6	25.8/6.4
Organism						
Laminaria spp.	-	-	0.1/0.1	-	-	0.3/0.2
Pterygophora californica	-	28.5/4.6	6.0/2.2	3.5/2.4	13.3/4.3	44.3/5.7
Strongylocentrotus spp.	1.3/1.0	4.3/1.7	0.9/0.1	13.6/2.8	1.8/0.8	0.1/0.1
Macrocystis (15-40cm)	-	-	-	-	-	-
Macrocystis (40cm-2m)	-	0.1/0.1	-	-	-	-
Macrocystis (> 2m)	-	1.0/0.3 6.6†	-	0.2/0.2 27.0†	0.1/0.1 20.0†	0.9/0.4 19.8†
Laminoid, unident.	0.1/0.1	18.8/13.2	-	0.4/0.4	-	3.3/1.4

† Mean number of stipes per individual plant.

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CHAPTER 6

FISH

INTRODUCTION

Temporal and spatial variability in the adult fish populations offshore San Onofre are a function of seasonal reproductive and movement patterns mediated by oceanic disturbances in the form of storms or localized upwelling. In addition to the natural mortality occurring within the populations offshore, the operation of San Onofre Unit 1 cooling water system represents an additional source of mortality to larval, juvenile, and adult fish. The dynamics of offshore populations and the effects of plant operations on these populations are presented in the following separate but interrelated chapters. Analysis of fisheries statistics compiled by California Department of Fish and Game for fish blocks off San Onofre in 1979 was not performed as 1979 data was unavailable at the time this report was written.

CHAPTER 6A

ADULT FISH FIELD STUDY

INTRODUCTION

The adult fish studies reported in this chapter were conducted during 1980 primarily to continue preoperational data collection. This study was designed to provide a baseline to determine the possible effects of San Onofre Units 2 and 3 on the species composition, distribution, and abundance of fish inhabiting the receiving waters offshore of the generating station. Secondary objectives included the continuation of the Unit 1 operational effects study. The studies conducted in 1980 met all regulatory objectives and requirements of the Environmental Technical Specifications (ETS), Preoperational Monitoring Program (PMP), and National Pollution Discharge Elimination System (NPDES).

The purpose of this chapter is to 1) present a summary of the data collected during 1980 pertinent to the baseline evaluation for the PMP and the Unit 1 ETS and NPDES requirements; 2) analyze this data to meet the objectives of the PMP, ETS, and NPDES requirements; 3) describe the species composition, distribution, and abundance of fish inhabiting the receiving waters offshore of the generating station; and 4) develop a perspective of the fish communities and populations offshore of San Onofre relative to those found in other areas of the Southern California Bight.

The Southern California Edison Company (SCE) 1980 biological and physical data analyzed in this report have been presented in Volumes I and II of the 19[illegible] Annual Operating Report, San Onofre Nuclear Generating Station (SCE 1981a,b). Volume I, which includes a brief summary of data required by regulatory agencies, was submitted to those agencies on 31 March 1981 (SCE 1981a). Volume II contains the regulatory and supplemental raw data collected for the SCE programs to meet the 1980 objectives (SCE 1981b).

BACKGROUND

HISTORICAL REVIEW (1963-1979)

Fish sampling offshore San Onofre has developed from early semiquantitative visual observations by divers to quantitative multi-gear sampling techniques (Table 6A-1). Quantitative data on fish populations prior to San Onofre Unit 1 operation are limited. Visual observations by divers from 1963 to 1968 produced a species list consisting primarily of demersal species for the Marine Environmental Monitoring (MEM), preoperational, and transitional monitoring studies (Hickman 1973). Similar observations were made during the initial operation of Unit 1, although they were often limited due to turbid water (MEM operational study).

Short term studies using gill nets and otter trawls over a three day period during late 1972 and early 1973 (Hickman 1973) constituted the first quantitative assessment of the San Onofre fish populations. Gill nets of 3 inch mesh set near the generating station produced minimal information due to the short (1-h)

Table 6A-1. Synopsis of SCE fisl: studies conducted offshore of San Onofre from 1963 through 1980.

	Total No. of Surveys	No. of Surveys per Year	No. of Stations	Sampling Gear	Duration	Depth (m)	Replicates /Station	Locality	Type of Data Collected
Adult Fish Studies									
MARINE ENVIRONMENTAL MONITORING (MEM) PROGRAM									
Unit 1 Preoperational 1963-1966	5	1-2	10	Diver Observation	-	Intertidal & 5.5-12.8	1	BK, SO	A
Unit 1 Transitional 1966-1967	2	1	10	Diver Observaticn	-	Intertidal & 5.5-12.8	1	BK, SO	A
Unit 1 Operational 1968-1972	12	2	10	Diver Observation	-	Intertidal & 5.5-12.8	1	BK, SO	A
Unit 1 Operational Special Program 1972-1973	2	2	15	Gill net-7.6cn mesh)	1 hr	3.7-13.7	1	SO, SMP, DL	B,E
	1	1	8	Otter trawl-7.6m	10 min	3.7-11.6	1	SO, SMP, DL	A,E
ENVIRONMENTAL TECHNICAL SPECIFICATIONS (ETS)									
Unit 1 1975-1976	5	4	6	Surface & bottom gill nets	24 hr	9.1	2	SO, DL	B,C
Unit 1 1976-1977	7	4	6	Bottom gill nets	24 hr.	9.1	2	SO, DL	B,C
1978 to mid-1980	12	6	8	Bottom gill nets	24 hrs	9.1	2	SO, DL, SMP	B,C,D
mid-1980	2	4	6	Bottom gill nets	24 hrs	9.1	2	SO, DL	B,C
MARINE REVIEW COMMITTEE (MRC)									
Unit 1 Operational 1976-1977	5	2-3	4	Beach seine-50m	-	0-5	6	Me to Osd	B,C,F
	4	4	5-27	Lampara net-75m	-	5-11, 11-14, 14-20	1	Me to Osd	B,C,F,G
Units 2 & 3 Baseline Study 1978-1980	36	12	12	Lampara net-75m	-	5-11, 12-16, 18-27	1-3	SMP to Osd	B,C,F,G
1980	12	12	4	Otter trawl-7.6m	5 min	18 and 30	4	SO, StM	B,C
NPDES PRELIMINARY TRAWLS March 1978	1	1	3	Otter trawl-7.6m	5 min	6.1, 11.2, 18.3	2	SO, SMP, DL	B,C
PRELIMINARY PMP STUDY March 1978	1	1	4	Gill nets-multimesh	4 hrs	9.1, 13.7	2	SO	B,C
	1	1	3	Gill nets-multimesh	24 hrs	9.1, 13.7	2-3	SO, SMP, DL	B,C
	1	1	3	Otter trawl-7.6m	5 min	6.1, 12.2, 18.3	6-8	SO	B,C
PREOPERATIONAL MONITORING PROGRAM (PMP) Units 2 and 3 1978 to mid-1980	12	6	6	Bottom gill nets	24 hrs	13.7	2	SO, DL, SMP	B,C,D
	12	6	9	Otter trawl-7.6m	5 min	6.1, 12.2, 18.3	4†	SO, DL, SMP	B,C,D
INTERIM TRAWL PROGRAM mid-1980	3	6	9	Otter trawl-7.6m	5 min	6.1, 12.2, 18.3	4†	SO, DL, SMP	B,C,D
Ichthyoplankton Studies									
In-Plant Study (MRC) 1976	25	25	1	Centrifugal pump	$50\ m^3$	4.5 in INT	3	INT	H
In-Plcnt and offshore Preoperational Survey (MRC) 1977-1980	48	24	5-10	Manta, bongo, auriga nets (333 µm)	$400 m^3$	6-75	2-4	INT	H,I,J
In-Plant and Offshore Special Study (MBC) 1977-1979	27	12	3-4	Manta, bongo, auriga nets (333 µm)	762m	8-15	1-5	SO, SMP	H,I
	27	12	1	Pump (333 µm)	30 min	4.5 in INT	4-8	INT	H,I
In-Plant 316(b) Study mid-1979 to mid-1980	12	12	1	Pump (333 µm)	2 hrs	4.5 in INT	12	INT	H,I
	2	2	1	Pump (333 µm)	2 hrs	5 in DIS	12	DIS	H,I

† Two on each of two days
BK - Barn Kelp, SO - San Onofre, DL - Don Light, SMP - San Mateo Point, StM - Stuart Mesa, INT - San Onofre Unit 1 intake,
DIS - San Onofre Unit 1 Discharge, Me - 1-3 km upcoast of the Unit 1 discharge, Osd - Oceanside (16-19.5 km downcoast of Unit 1)
A - Number of species and frequency of occurrence
B - Number of individuals/species, standard length
C - Sex
D - Gonosomatic indices
E - Reproductive condition
F - Fish tagging
G - Biomass
H - Number of species and individuals; identification to species
I - Body length
J - Larval gut content studies

fishing period. Randomly placed 10-min otter trawls conducted in 1972 demonstrated the high variability of catches from fish populations in the San Onofre area (Hickman 1973) and provided the necessary abundance and length frequency data for a more complete description of fish populεtions.

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 San Onofre Unit 1 discharge (Zone 0A) and a reference area near Don Light, approximately 7 km downcoast of the generating station (Zone 6; Figure 6A-1). Gill net sampling during the first five surveys indicated that nets set near the bottom over cobble substrata yielded substantially more fish than those set over sand or near the surface. Consequently, all ETS gill net stations were established on primarily cobble substrata and nets were set near the bottom.

Two extensive 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 additional reference area upcoast. These findings and additional offshore (13.7-m, 45-ft) gill net stations were subsequently incorporated into the Preoperational Monitoring Program (PMP) which began in April 1978. The combined ETS/PMP/NPDES gill net and otter trawl sampling program continued bimonthly at 23 stations (Figure 6A-1) with replicates at each station. During each survey four replicate otter trawls were conducted over a two-day period at three stations located in each of three areas on the 6.1-, 12.2-, and 18.3-m (20-, 40-, and 60-ft) isobaths. Two replicate gill nets were set for 24 h at each of the 14 gill net stations, 8 along the 9.1-m (30-ft) isobath and 6 along the 13.7-m isobath.

An ichthyoplankton study was conducted from August 1977 to July 1979 as a special activity for the PMP at stations in the vicinity of San Onofre Units 2 and 3 discharge lines, in a reference area near San Mateo Kelp, and in the Unit 1 intake riser. Day and night samples were collected monthly at three water-column levels (surface, midwater, and near bottom) at offshore stations and at the Unit 1 intake (SCE 1980b). 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. Additionally, Unit 1 monthly intake sampling for larvae was continued from mid-1979 through mid-1980 as part of the 316(b) demonstration program. The results from this study will be reported in late 1981 to the California Water Quality Control Board, San Diego Region.

1980 STUDIES

The combined PMP and ETS gill net sampling was continued at the same stations (Figure 6A-1) on a bimonthly sampling basis during February, April, and June 1980; at this time the formal NRC two-year PMP ended. The ETS gill net portion of this sampling program was continued on a quarterly basis for the remainder of 1980. This resulted in three PMP and five ETS gill net sampling periods. Otter trawling in conjunction with gill netting was conducted bimonthly during all of 1980 for the formal PMP and then as a portion of SCE's continuing interim study when the PMP terminated in June. During the combined ETS and PMP study, temperature-transmissivity measurements were collected during each survey day at each gill net station cluster on the 9.1- and 13.7-m isobaths. Temperature-transmissivity measurements were collected during the remainder of 1980 at ETS gill net stations and at each trawling station during each survey day. Lampara seine sampling off San Onofre has been conducted since 1977 (Table 6A-1) for the Marine Review Committee (MRC). In 1980, the sampling incorporated day-night otter trawling at 18- and 30-m (59- and 98-ft) depths at two sites complimentary to the LES-SCE combined program otter trawls and the MRC lampara seining.

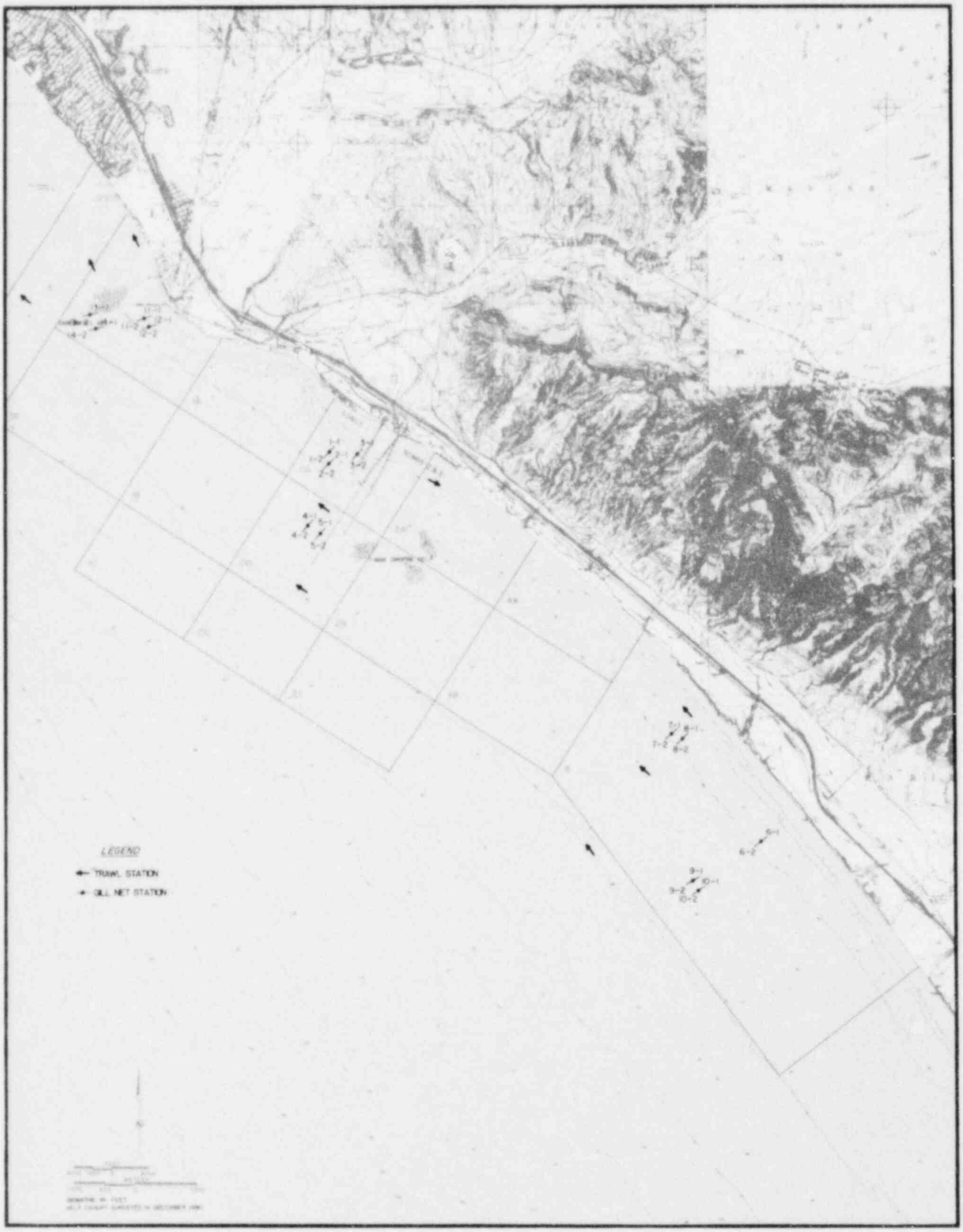

Figure 6A-1. ETS and PMP fish receiving water station locations at San Onofre Nuclear Generating Station.

DISCUSSION

Specific topics are addressed in this section that pertain to the establishment of preoperational baseline data for Units 2 and 3, and the assessment of operational effects of San Onofre Unit 1 on the fish resources in the vicinity of the generating station. In the following subsections the fish community and populations are discussed in terms of spatial and temporal patterns of occurrence and abundance observed in the study area and within the Southern California Bight. The findings of the 1980 and earlier San Onofre studies are discussed in terms of identifible patterns and possible explanations for the existence of these patterns. An overview of the fishes present in the Bight and major Bight-wide environmental changes is also presented to provide insight as to how the San Onofre community and populations relate to those in the Bight.

The major fish assemblages that are common to San Onofre and the rest of the Southern California Bight are, for the most part, of little sport or commercial fishery importance. Because of their limited usefulness to man directly they have been studied little until recently. Fish collection in the nearshore environment, avoided in the past because of the difficulty in sampling, has only recently been intensely studied. This has occurred primarily in areas where man may potentially alter the environment. These studies, mainly sponsered by utilities and municipal dischargers, range widely in methodologies. Otter trawling has been one common element to the multi-faceted sampling schemes used in the Southern California Bight. Trawling information has been systematically gathered at San Onofre since 1978 (SCE 1979d, 1980e). Additionally, several municipalities have employed the Southern California Coastal Water Research Project (SCCWRP) to ascertain the status of fish populations near sewage discharges from Los Angeles and Orange County (Johnson and Kulik 1980). The major source of nearshore trawling information comes from the National Pollution Discharge Elimination System (NPDES) receiving water monitoring reports (MBC 1978, 1979a,b,c,d; LCMR-IRC 1979; IRC 1981). The 316(b) demonstration program has also generated a large body of information pertaining to the nearshore distribution of fishes (LES 1981). Additionally, independent research also presents useful nearshore fish community and population information (Werner 1971; VANTUNA Trawling Program; J. Stephens, Occidental College, pers. comm.).

SOUTHERN CALIFORNIA BIGHT OVERVIEW

Situated at a boundary between cool temperate and subtropical water masses, the Southern California Bight harbors a rich and dynamic fish assemblage (Horn and Allen 1978) characterized by a mixture of cool and warm-water species. There is increasing evidence that the Bight, when examined habitat by habitat, forms a fairly homogeneous environment for many marine species. This may be due, at least in part, to larval entrainment by prevailing currents. Ocean currents off southern California during late winter and spring (peak spawning periods for many fishes) are characterized (Reid et al. 1958; Wyllie 1966) by the southerly flowing California Current along the coast of central California and offshore of southern California, and the development of a counter-clockwise eddy off the coast of southern California. In April, however, the eddy is sometimes absent and the California Current is close to shore even in southern California (Schwartzlose 1963). The southern California eddy originates as an easterly flowing branch of the California Current at about the latitude of the Mexican border. Smaller-scale eddies exist in the western part of the Santa Barbara Channel (Reid 1965; Kolpack 1971). Schwartzlose (1963) suggested that other small-scale eddies may exist off southern California, but these have not been extensively documented.

Based on an examination of these currents, Love and Larson (1978) estimated that kelp rockfish, Sebastes atrovirens, larvae would be entrained in the southern California eddy, their transport north around Pt. Conception blocked by the southern flowing California Current. Johnson (1960) suggested this mechanism also limited California spiny lobster, Panulirus interruptus, larvae dispersal. Brinton (1976) regarded southern California populations of the pelagic Euphausia pacifica as autonomous, due to the sluggish circulation of the southern California eddy.

However, there is likely no such hindrances to larval dispersal within the Bight. Though discrete circulation cells do exist within the Bight. there are no known autonomous units (Reid et al. 1958; Schwartzlose 1963). Some differences have been noted in fish populations, particularly in the northernmost and westernmost reaches of the Bight. Bathed by the California Current, the westernmost islands (San Miguel, Santa Rosa and to a certain extent Santa Cruz) exhibit water temperatures more closely resembling central and northern California, and their fish faunas reflect these conditions (Hubbs 1967; Schwartzlose 1963; Hendricks 1977). A number of species rare or absent from more southernly parts of the Bight are common constituents of the islands' fauna (these include Chirolophis nugator, mosshead warbonnet; Nautichthys oculofasciatus, sailfin sculpin; Synchirus gilli, manacled sculpin; Sebastes nebulosus, china rockfish; S. flavidus, yellowtail rockfish; and Embiotoca lateralis, striped surfperch).

Some faunal differences also exist along the mainland. In the westernmost section, black rockfish, Sebastes melanops, and striped surfperch are found in some abundance from Santa Barbara north and west, but are missing in the rest of the Bight (E. lateralis reappearing in the cold upwelled waters off Punta Banda, Baja California). By the same token, a number of subtropical forms, such as Hermosilla azurea, zebraperch; Anisotremus davidsonii, sargo; and Paralabrax maculatofasciatus, spotted sand bass, although relatively abundant in the southern Bight are uncommon north of perhaps Santa Monica Bay. Patton and Smith (unpubl. data) divided the inshore reef fishes within the Bight into northern and southern bightwide elements, using cluster analysis. The division of the Bight occurred at approximately the southern end of Santa Monica Bay.

Studies on several species (Engraulis mordax, northern anchovy; Phanerodon furcatus, white surfperch; Paralabrax clathratus, kelp bass; and Genyonemus lineatus, white croaker) have failed to show the existence of distinct Bight populations (Haugen et al. 1969; R. Beckwitt pers. comm.) although Swank (1979) presents evidence for several populations of Clinocottus analis off southern California. Given a fairly long-lived pelagic egg and larval phase and/or a migratory adult stage, it is likely that most fishes form a more or less homogeneous assemblage throughout much or all of the Bight. It is noteworthy that Haldorson (1978), studying viviparous, somewhat sedentary surfperches, was unable to show significant differences during electrophoretic analysis of fish muscle proteins between two areas (Puget Sound, Washington and Punta Banda, Baja California) for Damalichthys vacca and E. lateralis).

There is growing evidence that many fish species move about extensively within the Bight. Moreover, it appears that, at any given habitat, some fish populations are unstable both spatially and temporally.

Among certain pelagic species (Pacific sardine, Sardinops sagax caeruleus; northern anchovy; Pacific hake, Merluccius productus; Pacific saury, Cololabis saira; and Pacific mackerel, Scomber japonicus), it is estimated that considerable variation in abundances has occurred over the past 200 years. Based on the record of scale deposition in the anaerobic sediments of the Santa Barbara

Basin (Souter and Isaacs 1974), sardine, saury and mackerel undergo large population fluctuations. Indeed, at times these species seem to have been essentially absent from the region, only to reappear, sometimes in great strength, at a later date. Although northern anchovy and Pacific hake populations seem more stable, even these are subject to considerable variability.

Looking even further into the past, Souter and Isaacs (1969) found similar trends over the past 2,000 years, with sardines showing great abundance changes and anchovies and hake somewhat more constant and abundant. Interestingly, there are apparently long-term trends of abundance. For instance, despite the present general dominance of anchovies, there is a 1,000 year decrease in absolute anchovy abundances.

Nor is this a solely historical phenomenon. Studies on reef fishes in southern California (Stephens and Zerba 1981) indicate that fluctuating populations are more the norm than the exception. Using counts from five years of diver transects in King Harbor, Redondo Beach, Stephens and Zerba found that a number of species varied widely in abundance from year to year. Populations of some species (such as garibaldi, Hypsypops rubicundus; barred sand bass, Paralabrax nebulifer; and shiner surfperch, Cymatogaster aggregata) fluctuated in a directed manner (increasing or decreasing) over the five year span, while others (jack mackerel, Trachurus symmetricus; sargo; and blacksmith, Chromis punctipinnis) exhibited large nondirectional variations in abundance. Habitat preference did not seem to influence the amount of variability found in King Harbor species, as fishes as diverse as the pelagic jack mackerel and the benthic barred sand bass all showed population fluctuations.

Somewhat similar results were reported by Ebeling et al. (1980) from fish populations in canopy and bottom habitats in kelp beds off Santa Barbara and Santa Cruz Island. Based on a four year study, some variability was noted between years, particularly for midwater planktivores (such as blacksmith and senorita, Oxyjulis californicus). Variability was less intense in fishes occupying reef bottom. However, Larson (1977) noted that counts of black-and-yellow rockfish, S. chrysomelas, and gopher rockfish, S. carnatus, decreased significantly from 1973-1976 at several stations off Santa Cruz Island. In addition, fish populations at King Harbor generally exhibited greater fluctuations than did those at reefs further to the north.

Annual changes in abundance are also found in fishes inhabiting the soft bottom, benthic communities in the Bight. Studies conducted with otter trawls in Santa Monica Bay (Carlisle 1969), off Palos Verdes and Santa Catalina Island (Sherwood 1980), and off Orange County (Mearns 1977) all show annual changes in catch rates for a number of species (including speckled sanddab, Citharichthys stigmaeus; yellowchin sculpin, Icelinus quadriseriatus; California tonguefish, Symphurus atricauda; plainfin midshipman, Porichthys notatus; and slender sole, Lyopsetta exilis). Moreover, the total catch of all species, was highly variable.

A principal cause of the observed variations in fish populations seems to be the relative strengths of recruitment of postlarval juveniles settling out of the water column. A strong recruitment will influence a community population structure for years. Examining fluctuations in trawl catches in the Southern California Bight, Sherwood (1980) noted that some demersal species (notably Pacific sanddab, Citharichthys sordidus; speckled sanddab; stripetail rockfish, Sebastes saxicola; and splitnose rockfish, S. diploproa) recruit every year, though the specific month and the size of recruitment might vary. However, a number of species seem to exhibit a "boom or bust" cycle, with heavy recruitment

in one year followed by little or none in subsequent years. Calico rockfish , *S. dallii*, exhibited this phenomena in summer 1975 (Mearns et al. 1980) recruiting heavily off Palos Verdes, King Harbor, and Newport for the first time since the early mid-1960's. Both the California lizardfish, *Synodus lucioceps*, and tonguefish settled out in very large numbers in 1973 and 1977. In King Harbor, after 1975, calico rockfish populations declined, increased again in 1979 with heavy juvenile recruitment, then declined.

Annual differences in oceanographic conditions (i.e., current patterns, temperature, and food availability) likely lead to increased or decreased fish reproductive success, and subsequent recruitment and survival of juveniles. In particular, temperature may play a leading role in larval (and hence year class) survival. Waters of the Southern California Bight are subject to conspicuous annual temperature fluctuations (Reid et al. 1958; Radovich 1961; Mearns 1977), linked to the relationships between coastal upwelling and the intensity of the California Current and nearshore counter current.

Larval survival of some species (i.e., Pacific sardine) is known to be inversely correlated to water temperatures during their larval cycles (Murphy 1961). It is known that larval survival is usually quite low (0.1% for sardine; Ahlstrom 1954) and that mortality is due primarily to predation. Colder temperatures may prolong the larval phase (Ahlstrom 1954). Therefore, mortality may be, at least partially, a function of the length of time an individual remains a larva and is most susceptible to predation. Lower temperture may also adversely affect larvae by lowering their maximum swimming speeds (Brett et al. 1958), thereby placing them at a competitive disadvantage with more cold tolerant species and making them more susceptible to predation. Murphy (1961) estimated that a three degree range of temperature, approximating the difference between warm and cold years in the California Current during the spring reproductive season, might result in a 10-fold variation in survival for a cold intolerant species, such as the Pacific sardine. The heavy influx of juvenile lizardfish and tonguefish in 1973 and 1977 (Sherwood 1980) corresponds with warmer water years. Both species are characteristic of warm temperate or subtropic communities, and it would be expected that elevated temperatures would favor their survival.

Temperature may also affect reproductive success by lengthening or shortening spawning periods or spawning area boundaries. This may jeopardize or enhance spawning success by placing eggs and larvae in a greater or smaller range of environmental conditions (Miller 1956).

Colder water may also lead to increased larval survival for other species. Mearns (1977) noted that increased trawl catches of a number of juvenile fish species was correlated with periods of colder, more turbid waters. It is possible that differences in catch rates were due to fish avoiding nets in clearer, warm water periods. However, Reid et al. (1958) showed that, in the California Current region, a decrease in temperature was accompanied by an increase in plankton standing crop. Therefore, food availability in colder water years may be in part responsible for a particularly successful year class in some species.

Zentara and Kamykowski (1977) and Eppley (1978) described an inverse relationship between temperature and available nutrients which may limit phytoplankton production in warmer years. Bernal (1979) analyzed annual differences in productivity of the California Current and associated areas by comparing the plankton volumes from CalCOFI cruises in 1949-1969. He recognized five major biological events, four with surges of increased productivity. The fifth (May 1957-February 1960) was a period of low productivity corresponding to clearer (tropical) water incursion.

There is general agreement that the strength of a year class is in part determined by the availability of planktonic food shortly after the larval yolk supply has been exhausted. Because it has been concluded that the mean density of larval food organisms in the ocean is generally too low to support larval survival (Beers and Stewart 1967, 1969; May 1974), food availability, both in numbers and kind, appears to be another crucial aspect of recruitment success or failure. Lasker (1975) found that food requirements for larval anchovies off southern California were quite specific and restricted. Deviations from these standards probably led to starvations. It was noted that phytoplankton had to be present at certain minimum concentrations, within 2 1/2 days after the larvae were ready to feed. Moreover, only some phytoplanktors stimulated feeding and subsequent anchovy growth. There was also evidence that proper feeding conditions were quite transient, as plankton aggregations were dispersed after a few days by heavy winds. Thus food availability, influenced by water temperature, current patterns, upwelling etc., probably plays a major role in year class strength.

Density-dependent factors (Hunter 1976) independent of food supply may also influence larval success. Increased intraspecific competition during years of heavy spawning, along with interspecific larval competition, and increased predation may all play a role.

Natural fluctuations of adult fish populations due to migration within the Bight are also well documented. Some species spend only a part of the year within the Bight. Pacific hake spawn offshore of southern California during the summer and migrate north to winter off northern California, Oregon, and Washington (Alverson and Larkins 1969). Jack mackerel, found during fall and winter offshore of southern California, migrate to the Gulf of Alaska during summer (Blunt 1969). As part of their amphi-Pacific migrations, albacore, Thunnus alalunga, pass through the Bight during summer and fall (Clemens 1961).

Seasonal movements are also frequent. White surfperch, Phanerodon furcatus, move inshore to give birth in late spring, returning offshore in fall. Similar spawning migrations are known for the shiner surfperch and the rainbow surfperch, Hypsurus caryi (A.W. Ebeling, UCSB, pers. comm.). Spotted scorpionfish, Scorpaena guttata, seem to move in the opposite direction to reproduce, spawning offshore during spring and summer, returning to inshore reefs in winter. Sculpin also make extensive along shore movements; two individuals tagged off Redondo Beach were recovered off the Coronado Islands.

Water temperature is a major influence of fish movements. A number of fishes seem to follow cold upwelled waters into shallow zones. These include the black rockfish and juvenile vermilion rockfish, S. miniatus, both of which appear in spring off Naples Reef, Santa Barbara, and the kelp greenling, Hexagrammos decagrammus, and lingcod, Ophiodon elongatus, which come up Redondo Canyon into King Harbor during upwelling periods.

A number of species occur with greater frequency within the Bight as water temperatures rise. During warm water years, characterized by a weakening California Current and a concomitant influx of subtropical southern water, a host of tropical and subtropical fishes visit local waters.

In particular, the population size, off southern California, of California yellowtail, Seriola dorsalis, and California barracuda, Sphyraena argentea, are closely tied to water temperatures (Radovich 1961), as are those of yellowfin tuna, Thunnus albacares, and skipjack, Euthynnus pelamis. Interestingly, albacore populations off southern California seem to be inversely correlated with water temperature. Warmer water seems to hold the fish offshore and in very warm years most albacore bypass the Bight altogether (Radovich 1961).

Schooling pelagic fishes move throughout the Bight. Tagging data from the northern anchovy, Pacific mackerel, Pacific bonito, Sarda chiliensis, and Pacific sardine indicate that schools move about extensively and more or less continuously, both along shore and on- and offshore (Frey 1971). Less is known about schooling inshore species, such as white croaker, Genyonemus lineatus, and queenfish, Seriphus politus, however, there is some evidence (M.S. Love, Occidental College, unpubl. data) that white croaker make inshore-offshore seasonal migrations.

SAN ONOFRE COMMUNITY ANALYSIS

A total of 87 species and 39,266 individuals were caught in 1980 using gill nets and otter trawls (Table 6A-2). Gill nets caught 10.4% (4,102 individuals) of the total catch while otter trawls caught the remaining 89.6% (35,164 individuals). Compared to 1979, gill nets caught 2,731 fewer fish in 1980 while the otter trawl catch declined by 7,757 individuals.

Table 6A-2. Total number of fish species (S) and individuals (I) sampled in the ETS program from 1975 to 1977, and for the combined ETS-PMP programs in 1978, 1979, and 1980.

Category		1975†	1976†	1977†	1978††	1979††	1980§
Shallow Sand Habitat							
6.1-m and 12.2-m Otter Trawls	S	-	-	-	60	57	59
	I	-	-	-	34,934	41,036	32,443
Deep Sand Habitat							
18.3-m Otter Trawl	S	-	-	-	38	32	36
	I	-	-	-	7,880	1,885	2,721
Cobble Habitat Without Kelp							
9.1-m Bottom Gill Nets	S	44	44	41	61	54	[illegible]8
	I	2,874	3,383	3,216	4,947	5,078	3,469
9.1-m Surface Gill Nets	S	15	5	-	-	-	-
	I	334	31	-	-	-	-
Cobble Habitat With Kelp	S	-	-	-	49	52	33
13.7-m Bottom Gill Nets	I	-	-	-	2,143	1,[illegible]53	633
TOTALS	S	49	46	41	106	8[illegible]	87
	I	3,206	3,414	3,216	49,895	49,752	39,266

\- No sampling conducted
† 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.
§ The 1980 survey data are based upon bimonthly gill net and otter trawl samples for February, April, and May; quarterly gill net surveys in August and December; and bimonthly otter trawl surveys in August, October, and December.

A classification (cluster analysis) of the fish community represented by gill net catch offshore San Onofre in 1979 and 1980 indicated that the composition of the fish community, as measured by groups of associated sampling sites or of species, was stratified primarily on the basis of depth. In both years the consistent co-occurrence of the San Onofre Unit 1 discharge station (SONGS 3 in site classification) with shallow (9.1-m, 30-ft) stations at Don Light formed a distinctive cluster while all deeper stations (13.7-m, 45-ft) and shallow San Mateo Point-SONGS (1 and 2) stations tended to cluster. The factors responsible for this consistent pattern are, perhaps, related to type and stability of substratum. Evaluation of species groups in 1979 indicated that a group of fishes feeding primarily from the water column distinguished the shallow Don Light and San Onofre Unit 1 discharge stations from all others. In contrast, species clusters distinguishing deeper stations from the shallow Don Light-Unit 1

discharge cluster, contained fish assemblages displaying primarily bottom oriented feeding habits. The temporal predictability of these groups indicates that shallow Don Light-Unit 1 discharge stations are located over predominantly sand substratum which is characteristically unstable (Chapter 5B; SCE 1980e) and unlikely to support an infaunal community upon which bottom oriented fishes may feed. Composition of species clusters at deeper stations reflects the presence of cobble substrata, which although occasionally disturbed by storms, is sufficiently stable to support a temporally predictable assemblage of primarily bottom oriented fishes.

The site and species classifications based on otter trawl catches resolved well-defined spatial groups within the demersal fish community sampled on soft substrata. The well-defined division between the fish community sampled at 6.1 m (20 ft) and 12.2 m (40 ft), and that sampled at 18.3 m (60 ft) results from a habitat discontinuity reflected by a dramatic change from a group of fishes feeding primarily from the water column at 6.1 m and 12.2 m to those feeding primarily from the bottom at 18.3 m. This pattern has been observed since the inception of the otter trawl program in 1978 (SCE 1980e).

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 San Onofre Unit 1, therefore, had no apparent effect on fish community structure as evaluated by classification analysis.

The fish community offshore San Onofre, as sampled by a combination of gill net and otter trawl catches over the past several years, is composed of a diverse assemblage of demersal and water column fishes displaying a wide variety of feeding habits. Distributional variability in space (depth) appears related to the type and stability of substrata. Habitats composed of unstable substrata (Don Light and San Onofre Unit 1 discharge stations) that are subjected to erosion and accretion cycles mediated by oceanic disturbances (storms), tend to support ephemeral assemblages of fish relying on prey items in the water column.

Habitats composed of hard substratum (cobble), although extremely dynamic (see Chapter 5B; SCE 1980e), are sufficiently stable to support a temporally predictable assemblage of fishes which display bottom feeding habits. Presumably, the primary prey items of these species are the invertebrate taxa associated with cobble substratum.

SAN ONOFRE POPULATION ANALYSIS

The San Onofre fish community has been studied intensely for the past five years. Based on these studies and extensive research in other areas within the Southern California Bight, several generalized patterns have emerged. The patterns relate the major fish populations and the environments they inhabit. The fish populations under study have been categorized according to their feeding roles in the San Onofre region and other temperate waters (SCE 1980e), and their habitats. Each population was examined in detail when it was represented in sufficient abbundance in a particular habitat. Four major habitat types have been identified during past nekton and benthic investigations offshore San Onofre. These four habitats and the fish populations that are commonly associated therein are presented in Table 6A-3. Several of these populations, as indicated, were underrepresented because of gear biases in the sampling methodologies employed.

The following section describes the dynamics of several select species populations which have, historically, been the most numerous fish taxa caught offshore and/or in-plant. Each species is discussed within the context of the cobble and sand habitats found off of San Onofre.

Table 6A-3. Feeding guilds of fish and representative fish species that are typical of the four major habitat types in the San Onofre area.

LEVEL BOTTOM - SAND HABITAT	Shallow	Deep
FISH THAT FEED FROM THE WATER COLUMN		
Strictly Water Column Feeders		
Filter Feeders	*Engraulis mordax*†	*Engraulis mordax*†
Midwater Planktivore	juvenile *Seriphus politus*†, juvenile *Genyonemus lineatus*†	juvenile *Seriphus politus*†, Juvenile *Genyonemus lineatus*†
Miscellaneous Large Predators	*Mustelus* spp., *Squalus acanthias*, *Cynoscion nobilis*	*Mustelus* spp., *Torpedo californica*
Water Column and Substrata Feeders		
Switch Feeding Carnivore	adult *Seriphus politus*†	adult *Seriphus politus*†
Plant Cropping Omnivores	none	none
Microcarnivorous Pickers	*Phanerodon furcatus*†	*Phanerodon furcatus*†
Bottom Oriented Feeders		
Demersal Microcarnivore	*Amphistichus argenteus*	none
Demersal Mesocarnivore	*Scorpaena guttata*	none
Bottom Feeding Micro-Mesocarnivore	*Genyonemus lineatus*†	*Genyonemus lineatus*†
FISH THAT FEED FROM THE BOTTOM, MAINLY SOFT BOTTOMS		
Fish that feed above the bottom	*Paralichthys californicus*†, *Citharichthys stigmaeus*†	*Citharichthys stigmaeus*†, *Paralichthys californicus*†
Fish that feed on and above bottom	*Synodus lucioceps*	*Otophidium scrippsi*
Fish that feed on the bottom only	*Menticirrhus undulatus*	*Pleuronichthys verticalis*

COBBLE BOTTOM HABITAT	Without Kelp	With Kelp
FISH THAT FEED FROM THE WATER COLUMN		
Strictly Water Column Feeders		
Filter Feeders	*Engraulis mordax*	*Engraulis mordax*†
Midwater Planktivore	*Hyperprosopon argenteum*†, *Atherinopsis californiensis*	*Chromis punct[illegible]is*, *Oxyjulis californica*, *Hyperprosopon argenteum*†
Miscellaneous Large Predators	*Squalus acanthias*	*Cynoscion nobilis*, *Sphyraena argentea*
Water Column and Substrata Feeders		
Switch Feeding Carnivore	*Paralabrax nebulifer*, *Seriphus politus*†	*Paralabrax clathratus*, *Seriphus politus*†
Plant Cropping Omnivores	*Girella nigricans*	*Medialuna californiensis*
Microcarnivorous Pickers	*Phanerodon furcatus*†	*Brachyistius frenatus*, *Phanerodon furcatus*†
Bottom Oriented Feeders		
Demersal Microcarnivore	*Halichoeres semicinctus*, *Embiotoca jacksoni*	*Damalichthys vacca*, *Embiotoca jacksoni*, *Rhacochilus toxotes*
Demersal Mesocarnivore	*Pimelometopon pulchrum*, *Sebastes* spp.	*Pimelometopon pulchrum*, *Scorpaenichthys marmoratus*
Bottom Feeding Micro-Mesocarnivore	*Genyonemus lineatus*†, *Roncador stearnsii*, *Menticirrhus undulatus*, *Cheilotrema saturnum*	*Cheilotrema saturnum*, *Genyonemus lineatus*†
FISH THAT FEED FROM THE BOTTOM, MAINLY SOFT BOTTOMS	None	None

† Captured in sufficient abundance to warrant detailed population analyses.

Seriphus politus (Queenfish)

Off San Onofre the queenfish, Seriphus politus, appears to be a habitat-generalist as it is commonly found over sandy and cobble substrata. Its distribution and abundance are largely governed by a combination of diel feeding behavioral patterns and reproductive activity which are influenced to some extent by events such as storms or upwelling.

This species has two foraging roles during its lifecycle. As juveniles, queenfish feed on zooplankton and as adults they prey on a variety of vertebrate and invertebrate species (Hobson and Chess 1976). Juveniles are generally present throughout the year in the shallow sand habitat, coincident with their occurrence as larvae in the plankton from February to December (SCE 1980e). Peak abundances of juveniles have been found to follow the time of maximum larval concentration in July and August (SCE 1980e), although in 1980, juvenile queenfish appeared somewhat later relative to previous years.

Queenfish diel distribution, in the nearshore environment, results from their feeding habits. Hobson and Chess (1976) observed that at dusk S. politus adults disperse from inshore, daytime resting schools to offshore areas near kelp beds to feed during the night, mainly on mysids that rise from the bottom. At dawn, the adults return to the inshore sandy areas, as the mysids migrate to the bottom or kelp beds for daytime shelter. Juvenile queenfish apparently do not make the nighttime offshore migration, but remain in the sandy shallows to feed at night. As a queenfish grows its feeding habits change from a diet of copepods to one of mysids and other plankters that appear in the water-column after dark (Hobson and Chess 1976). An additional food source are anchovies which have often been found in the guts of queenfish caught offshore of San Onofre.

Movements of S. politus out of the nearshore sand bottom habitat occur during winter (December-February of 1978, 1979, 1980) and spring (April 1978, 1979, 1980). Adults apparently move offshore (> 30 m, 98.4 ft) in early winter, while juveniles continue to inhabit the nearshore zone (DeMartini 1981). Low winter abundance of queenfish coincides with the breakdown of water-column stability, represented throughout much of the summer and fall by a thermocline. Changes in water column stability have been found to influence the distribution and activities of many organisms (Sverdrup et al. 1942). The offshore movement of mysids, one of the main prey items for queenfish, coincides with the breakdown of the summer thermocline (DeMartini 1981). Perhaps, the movement of one of its primary food sources induces queenfish to move offshore as well.

The offshore (deep) sand habitat off San Onofre has been infrequently utilized by either S. politus juveniles or adults (SCE 1980e). This area seems to be inhabited only during times of transition when adult queenfish move to (October) and from (February and April) their deeper (> 30 m) overwintering habitat (DeMartini 1981).

Like the sand habitat, queenfish also occur frequently over cobble substrata in the absence of kelp. Queenfish abundance within this habitat during 1980 was lower than previous years, but consistent with an overall three-year trend.

Queenfish return to the nearshore sand environment in late winter, apparently influenced by the occurrence of spring upwelling. Inshore movement patterns may also 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 nearshore.

Queenfish apparently avoid the cold upwelled water in the shallow areas in April, by moving above it where temperatures are relatively warmer. This was evident when shallow zone trawl data and lampara net data (DeMartini 1981) from a similar time period and in similar San Onofre areas were compared. The results show that queenfish are present in April, but only above the bottom. A similar phenomenon was observed in June, however, bottom temperatures were not as cold as in April and a few queenfish were caught near the bottom by trawls. Later in the year, as the thermocline stabilized, queenfish were abundant near the bottom.

In February, as queenfish commenced their onshore migration they appeared to congregate around the Unit 1 discharge structure. Queenfish may be attracted to this area because of the discharge reef itself or increased food from entrained zooplankton (Clutter 1978).

The period of severe upwelling, recorded during the entire month of April, may have temporarily inhibited ovarian maturation in 1980. Based on gonosomatic index values (GSI), female queenfish in all habitats reached a reproductive peak in August, while in 1979 this peak occurred in June. In 1979 upwelling was recorded in short period bursts, each lasting about a week in April through June (SCE 1980a). These longer periods of cold temperatures in 1980 may have slowed metabolism and reproductive maturation. Seriphus politus has a fairly well-defined spawning season. Since spawning peridoicity in many species is correlated largely with temperature, changes in that periodicity may result from rising or falling temperature. It is particularly important that spawning period and proper season (temperature) be synchronized as tolerance limits for temperature are generally narrowest for reproductive processes and survival of eggs and young (Brett 1970).

Queenfish caught in all offshore areas and inshore at Don Light had significantly larger mean gonad weights than those fish caught in other cobble habitat locations. This is consistent with the offshore spawning behavior found in this species (Skogsberg 1939; Watson, Barnett, and Sertic 1979).

Seasonal onshore movement of queenfish in late winter is also part of their reproductive behavior. Based on ichthyoplankton collections at San Onofre, surface orienting yolk-sac and first feeding larvae were captured offshore in March, but not inshore until April (SCE 1980e). Spawning in queenfish is not restricted to offshore areas, as indicated by GSI values from 1979-1980 which show that females captured in the nearshore zone were not reproductively different from females in the deep zone. Based on these results, it is suggested that older individuals probably mature sooner and have spawned at least once before they reach the inshore sand habitat (≤ 12 m, 40 ft).

The queenfish population, observed in the deep sand habitat (18.3 m, 60 ft), was composed of older individuals than at the shallower depths. The rare appearance of young-of-the-year, accounts for the spatial disparity in length frequency. Relatively fewer females were present in the deep habitat and appear to congregate at shallower depths. In addition, females caught inshore (6.1 and 12.2 m, 20 and 40 ft) had heavier gonads. Females that are older and larger, however, probably mature sooner than those inshore and may have already spawned prior to capture. Large females and males, based on the catch comparison of older individuals in trawls and gill nets, can apparently avoid capture by trawls to a great extent. Gear avoidance in both the deep and shallow sand habitats may artificially, although systematically, bias the interpretation of adult queenfish movement associated with reproductive activity.

The size distribution of queenfish collected by gill nets was restricted to adults (> 120 mm, 4.7 in. SL) because of mesh size. The size distributions obtained in 1980 were similar to previous years. With five years of gill net data available, it appears that age 3+ (150-160 mm, 5.9-6.3 in. SL) individuals have been under-represented each year. Apparently queenfish from 150 to 160 mm SL (age 3+; LES 1981) are captured by mesh sizes used in this study but with reduced efficiency compared to other sizes. Therefore, this gear artificially depresses the catch of age 3+ S. politus. A bimodal distribution with 1+ and 2+ year olds (125-139 mm, 4.9-5.5 in. and 140-149 mm, 5.5-5.9 in. SL) representing one mode and 4+ year olds (160-240 mm, 6.3-9.4 in. SL) another, may have been due to the absence of panels between 4.4-and 6.3-cm (1.8 and 2.5 in.) bar mesh in the gill nets.

Differences in distribution of larger adults, observed between kelp and non-kelp cobble habitats may be linked with reproductive activity. In both cobble habitats large adults were under-represented in February compared to the rest of the year. Following February, these older individuals were under-represented in the cobble with kelp areas through June. The pattern of reduced abundance during the mid- to latter part of the year may result from breeding migration combined with a behavioral change in feeding habits. Breeding, as discussed for the shallow sand habitat, occurs first in older individuals in offshore waters (Watson, Barnett, and Sertic 1979; DeMartini 1981). Older individuals probably mature earlier and remain offshore to spawn, thus their low catches over shallow cobble (≤ 14 m, 45 ft) in February. Later in the year (April-June), the older adults move inshore, and are still reproductively active in breeding condition. These fish may have depressed appetites (Love 1970; Smigielski 1975), in which case they probably would not move offshore to the kelp at night to feed.

Inhibited feeding may also affect the sex ratios of catches, as females may be more physiologically affected during the spawning season. Since GSI values do not vary with animal size, younger, slowly maturing females would have similar ratios of gonad weight to body weight as older individuals. These younger fish may continue to feed; hence be captured, until reproductive condition peaks.

Genyonemus lineatus (White croaker)

Like queenfish, the white croaker, also exhibits a habitat generalist life style off San Onofre. Also, like queenfish, juvenile white croaker feed on zooplankton (DeMartini 1981), but adults select demersal food items (Skogsberg 1939, DeMartini 1981). Juveniles tend to occur in the shallow zone year-round.

Short-term movement out of the study area during the winter coincides with the pattern found for queenfish, except the latter species seems to return at a slower rate. These results are consistent with DeMartini's (1981) findings in the San Onofre region. Both species occur in mixed schools, so their migratory behavior may be triggered by similar stimuli. Oceanographic conditions during the winter consist of reduced water temperature (from a summer peak of 20.0°C, 68°F, to a winter low of 15.0°C, 59°F) and mixing of the water column (breakdown of thermocline). In addition, storm activity creates considerable mechanical mixing of the nearshore water mass. As discussed for S. politus, the evacuation of the nearshore area by these two sciaenids may be elicited by water mass instability.

Environmental factors appear to influence white croaker population abundances as they do with queenfish. Upwelling apparently causes movement of G. lineatus up into the water column as it does for S. politus. However, since white croaker spawn in winter their reproductive activity was not interrupted by intense upwelling in April 1980.

The causes of offshore movement in the fall are not as clearly defined. One explanation put forth in the past, relates reduced inshore abundances to the instability of the water column as the thermocline breaks down. Another hypothesis links the offshore movement of mysids, an adult queenfish prey, and offshore movements of adult queenfish (DeMartini 1981). Movement of or changes in prey item density alsc may induce offshore movement of white croaker.

White croaker use of the deep sand habitat in 1980 follows the pattern described above for queenfish. The winter retreat from the nearshore zone into depths beyond the deep sand habitat (18.3 m, 60 ft) concur with DeMartini's (1981) observations.

Considerable spatial variability in catch of white croaker over cobble substrata exists among years during the period from April to October. White croaker in the Don Light area during 1980 were consistently more adundant than elsewhere, except in December. In previous years white croaker were more abundant at Don Light during the peak part of the year on the 9.1-m (30-ft) isobath and throughout the year on the 13.7-m (45-ft) isobath. Their prevalence in the downcoast control area is perhaps, related to feeding habits. Adult white croaker feed primarily on small fish and infaunal invertebrates (Joseph 1962). The cobble habitat sampled at Don Light is a small island in a predominantly sand habitat. In contrast, the cobble habitat upcoast (San Onofre to San Mateo Point) is more widespread and supports kelp in the offshore areas. Therefore, infaunal organisms are probably more abundant in the downcoast control area. The spatial variability observed for white croaker may simply represent an annular nondirected change in abundance. Several investigators examining reef habitats (Ebeling et al. 1980; Stephens and Zerba 1981) and soft-bottom communities (Carlisle 1969; Sherwood 1980; Mearns 1977) all show substantial annular changes in fish species composition and catch per individual species. These variations are perhaps a function of recruitment success or failure of young-of-the-year to the habitat (Sherwood 1980; Mearns et al. 1980).

In fall and early winter, white croaker move out of the area (DeMartini 1981). A small, remnant population of adult white croaker appear to over-winter in the nearshore area adjacent to the Unit 1 discharge as catches for this area are highest in December and February. This is similar to the queenfish which overwinter near the Unit 1 discharge, apparently because of the reef-like qualities of the area and abundant food in the form of discharged zooplankton (Clutter 1978).

Abundances of G. lineatus in cobble areas with kelp are generally lower during the year than areas without kelp. The catches in kelp bed areas probably occur due to movements to and from sandy areas which are near to kelp beds rather than movment directed at kelp beds like S. politus (Chapter 5B).

Comparison of 1978-1980 results, indicate that the late winter peak is followed generally by a mid-year abundance. After this peak, lower catches reflect movement offshore to overwintering habitats (DeMartini 1981). Mid-year peak catches in past years reflect the culmination of recruitment success from the previous year (age 1+; SCE 1980e). These individuals may be aggregating at this offshore area in August prior to moving further offshore to overwinter (DeMartini 1981).

Like queenfish, male white croaker were caught more often than females in the deep habitat. The capture of more males may reflect a gear avoidance bias as larger fish, of which more are females (LES 1981), can probably out swim or

maneuver a slow (120 cm/sec, 2.7 mph) moving trawl. Dorn, Johnson, and Darby (1979) found that G. lineatus (173-213 mm, 6.8-8.4 in. SL) could burst-swim at speeds of 5.9 ± 1.4 body lengths per second (137 ± 0.1 cm/sec, 3.06 ± 0.002 mph) which would allow larger individuals to escape the trawl.

Significantly ($P < 0.05$) more female white croaker were caught by gill nets in 1980 on the 9.1-m isobath in all areas except in the vicinity of the Unit 1 discharge. The pattern of female numerical dominance in the entire San Onofre area has been observed in previous years suggesting that the deviation from a 1:1 ratio is real. Increased female abundance appears to be correlated with the reproductive cycle. During 1978, 1979, and 1980 significantly more females were caught in February and April when white croaker are reproductively active. Reasons for this female predominance are not clear.

White croaker become gravid in October and spawn intermittently into April indicated by 1979-1980 GSI values at San Onofre and other southern california areas (Skogsberg 1939; Goldberg 1976; LES 1981). The larger, primarily female, age classes are captured less frequently than smaller age classes by trawls. Year class strength of age 0+ and 1+, however, has been high year after year. Therefore, it is unlikely that the more fecund individuals are really low in abundance, but that they probably avoid the gear. Larger females move quicker and mature earlier than the smaller, younger white croaker (Dorn et al. 1979; LES 1981). Earlier maturation, of larger adults moving offshore in winter, would correspond with the first presence of white croaker ichthyolarvae in deeper areas (SCE 1980e). Subsequent to offshore spawning, females move inshore and continue spawning in all habitats as indicated by mean GSI's and other studies (Goldberg 1976).

The length structure of white croaker caught by gill nets in the San Onofre area was bimodal. Almost no juvenile (age 0+) white croaker were collected by gill nets. Adults were composed of age 1+ (105-134 mm, 4.1-5.3 in. SL) and age 3+ to 4+ (155-169 mm, 6.1-6.7 in. and 170-179 mm, 6.7-7.1 in. SL). Age 2+ white croaker were under-represented in gill net catches when compared to otter trawls. This situation is similar to that observed for queenfish, except that the missing queenfish size class was larger. The reason for the size class discrepancy may be based upon morphological differences. Gill net catch efficiency is based not on fish length but on the cross section of the fish at the operculum. Queenfish are less robust than white croaker, therefore, an age 2+ white croaker may correspond to an age 3+ queenfish relative to the gill net mesh size.

Hyperprosopon argenteum (Walleye surfperch)

Walleye surfperch are viviparous (live-bearing), thus, juveniles are miniature replicas of the adults which probably feed on many of the same food items that adults utilize (DeMartini 1969). Therefore, young and old are considered components of a single feeding guild. Walleye surfperch normally frequent a variety of habitats but most of the population is found in the sandy shallows and around piers (Frey 1971; DeMartini 1969). During the day, schools of H. argenteum are inactive and remain inshore (Limbaugh 1955; Feder et al. 1974); at sunset, the schools disperse and move offshore to feed on plankton in the water column at night (Ebeling and Bray 1976; Hobson and Chess 1976).

The summer peak abundance of H. argenteum in the San Onofre nearshore shallow habitat can be attributed to the recruitment of recently born young. In 1978-1979, peaks in abundance due to recruitment, occurred later (August) than in 1980 (June). Although, juveniles usually remain in the nearshore (6.1- to 12.2-m,

20 to 40-ft) zone only for a short time, abundances in October 1980 were almost as high as in June. By December the nearshore abundance was low indicating that movement from this area had occurred.

Movement to offshore depths was not indicated in 1980 as walleye surfperch seem to have changed their utilization of the deep sand habitat over the past few years. In 1978, they were regularly found in the deep zone, especially in fall. Since then, H. argenteum has been found almost exclusively in the shallow habitat. It is unlikely that they would move further offshore in winter as their depth distribution has been reported to be limited to 18.3 m (60 ft) (Miller and Lea 1972), and they are more often found inshore near the surfzone (Carlisle et al. 1960). Changes in distribution after 1978 probably reflect responses to alterations in the environment off San Onofre within their normal distributional limits.

In most areas of cobble bottom without kelp, walleye surfperch have been caught consistently in low abundances during the past three years. These abundances may be a reflection of their diel movement pattern as discussed above. Remaining in shallow sand habitats by day and moving to kelp areas at night would reduce susceptibility to capture by gill nets in cobble habitat without kelp. In the past, walleye surfperch have been more abundant in catches from kelp habitats during summer and fall (SCE 1980e). An exception to this general pattern occurred in the area near the Unit 1 discharge where many individuals were caught from December through March in two of the last three years. The discharge area may serve as an attractant for this species as thermal enrichment and entrained zooplankton offer stable environment rich in food, during a time of changing environmental conditions outside the influence of the discharge.

The recent pattern of low abundance in the other cobble habitats without kelp is substantially different from the 1975-1977 pattern when mean abundances of walleye surfperch were high. This indicates that overall replacement (births and immigration) rates are not maintaining the population level despite favorable conditions in winter and spring near the Unit 1 discharge.

Length structure of H. argenteum reveals that young-of-the-year (< 90 mm, 3.5 in. SL) were more prevalent in all areas during summer and winter (August-February). Juveniles were not caught by gill nets during the summer when the young are born, which is reasonable given their size at birth (40 mm, 1.6 in. SL; Rechnitzer and Limbaugh 1952). This temporal pattern of recruitment corresponds with estimates from other studies (Rechnitzer and Limbaugh 1952; Frey 1971; LES 1981).

No juvenile walleye surfperch were captured in the cobble bottom with kelp habitats during 1980. This may be due to gear selectivity or to the depth of the kelp beds which are concentrated along the 12.2-m (40-ft) isobath. Females apparently move inshore of these areas to bear young. This is supported by the presence of juveniles in the otter trawls over the shallow sand habitat.

Phanerodon furcatus (White surfperch)

White surfperch, also a viviparous (live-bearing) embiotocid, uses the shallow sand habitat seasonally. Like the populations discussed above, white surfperch are more frequently caught in summer and fall. Abundances, throughout 1980, corresponded closely to past results. Unlike H. argenteum, P. furcatus young were found in the deeper (12.2-m) isobath of the shallow sand habitat. Recruitment in June 1980 corresponded closer to published data (Goldberg 1978)

than the later recruitment in August 1979. Fall offshore movements of young-of-the-year and adults may correspond to breeding season (Goldberg 1978) and/or changes in the nearshore physical environment (decline of water-column stability). However, only adults were found in the deep sand habitat and in low numbers. Apparently the adults use this area only temporarily, while moving further offshore. Temporal sampling gaps may obscure offshore movements that occur in a relatively short time period. In 1978, higher abundances during fall surveys seemed to occur during their movements into deeper water. White surfperch appear to return to the shallow sand habitat when embryos are full-term and the water-column becomes more stable.

White surfperch were more frequently caught in the deep sand habitat in 1978, as observed for H. argenteum. Perhaps changes between 1978 and 1979, such as substrata and infaunal composition have modified food resource availability so that the nearshore sand habitat was favored during 1979 and 1980. Sand movement, documented in the Subtidal Cobble Chapter (Chapter 5B), has noticeably increased since the major storm activity beginning in 1978. In 1979 sediment infaunal community composition changes in sandy areas were found along the 15-m (49-ft) isobath at San Onofre (SCE 1980e; Chapter 5A). These changes followed modifications of the sediment substrata in which high proportions of very coarse, coarse, and medium sands were exposed and mixed with finer sediment (SCE 1980e). Since P. furcatus has been found to be primarily a substrate (kelp, other algae, soft substrata) oriented feeder (Bray and Ebeling 1975), the changes in prey composition in the deep sand habitat may have caused white surfperch to move to inshore sand areas during most of the year.

Although catches of P. furcatus tended to be low in areas of cobble bottom without kelp, higher catches occurred during December in all but one of the past five years in this habitat (SCE 1979b, 1980e). This pattern can apparently be explained by the movement of these fish into or through the shallow cobble areas during the breeding season which occurs from November to December (Goldberg 1978). More white surfperch were captured in kelp habitats than areas without kelp throughout 1980. The preference for encrusting ectoprocts found on Macrocystis and benthic algae as a food source may explain its elevated abundance nea kelp (Bray and Ebeling 1975).

The size structure of P. furcatus was similar to past years and dominated by new recruits. Young-of-the-year, because of their large size at birth (53 mm, 2.1 in. SL), were also captured by gill nets in December (Goldberg 1978).

Study of the length structure of the white surfperch caught in the kelp bed habitat indicates that emigration and immigration of different size/age classes occurred during all year. The smaller younger age classes (age 0+ and 1+) were numerically dominant during February and April but by June older age classes (age 2+ or older) predominated and the young were rare. Growth rates indicate that a 1+ individual would not grow fast enough to be included in these older age classes by June (Eckmayer 1979). This indicates that the increased abundance of fish in excess of 140 mm (5.5 in.) SL was due to movement of older individuals into the kelp habitat and not the growth of one age class. Since a majority of the catch were females, this movement may be linked to the reproductive cycle of this species.

Paralichthys californicus (California halibut)

The California halibut is one of the most popular food fish in the San Onofre region (Frey 1971). Its feeding habits, in open coast waters, are almost entirely piscivorous (Clark 1930; Haaker 1975). California halibut are more uniformly

distributed and show lower abundance levels in the shallow sand habitat than croakers, surfperch, and anchovies. This uniform distribution is indicated by the narrow confidence limits about each survey's mean abundance. Like many of the dominant San Onofre fish, abundance levels of California halibut in the shallow sand habitat increase during the months of water-column stability (June through October). During this period, forage fishes (anchovies, queenfish, etc.) are plentiful in the shallow sand habitat (Ford 1965; Haaker 1975).

Off San Onofre, the California halibut population appears to be reproductively active year-round based on male reproductive condition. Males were used as indicators of reproductive condition, because they can be easily milked. The year-round reproductive activity of adults agrees with the year-round presence of larvae in the San Onofre ichthyoplankton (SCE 1980e). Females, however, are more critical in timing ovarian maturity. No running-ripe females were ever caught off San Onofre during this study. The ovaries of a few large females had well developed but not hydrated ova. Hydration of ova occurs shortly before spawning (Norman 1963). Without egg hydration occurring first, non-destructive sex examinations (egg stripping) cannot be performed.

Juvenile P. californicus (< 60 mm, 2.4 in. SL) have rarely been captured at San Onofre and other southern California inshore areas (SCE 1979b, 1980e, 1981b; Innis 1980). Two juveniles were captured for the first time at San Onofre during October 1980. This pattern supports their observed abundance in lagoons and bays which are used as nursery grounds for the early growth and development (Haaker 1975; Innis 1980). Occurrence of juveniles in October in open coastal waters may be indicative of their emigration from nursery grounds (Haaker 1975).

The low abundances of P. californicus in the deep sand zone indicates that although present offshore up to 133-m (436-ft) depth (Carlisle 1969), the main population is located inshore (Ford 1965; Allen 1974; Fay, Vallee, and Brophy 1978). Higher abundances inshore are probably related to the inshore abundance of forage fish species such as anchovies and queenfish.

Engraulis mordax (Northern anchovy)

Adult E. mordax and larval engraulids are known to have highly contagious (patchy) distributions in other areas (Ahlstrom 1967; Huppert et al. 1980). This is apparent at San Onofre as the confidence limits about the mean catches were wide. Like many of the San Onofre fish, anchovies were caught in greater numbers in the summer and fall. The larval stages were also abundant earlier, as large catches occurred in late winter and early spring. This coincides with the peak January to May spawning period described by many investigators (Baxter 1967; Lasker and Smith 1977) and with upwelling in the shallow sand habitat (Lasker and Smith 1977). A natural consequence of upwelling is increased plankton productivity which would favor larval survival. Adults, however, seem to avoid the nearshore habitat until the water column becomes more stable (Lasker and Zweifel 1978). The late fall and early winter breakdown of the water column coincides with movement of both adults and larvae away from the nearshore area. Ichthyoplankton data show that the larger larval stages to be epibenthic (SCE 1980e).

Adult northern anchovies have been encountered infrequently in the deep sand habitat. Larval engraulids, however, were captured here and the pattern of their high abundances match those of offshore epibenthic ichthyoplankton collections (SCE 1980e). Greater water-column depth may allow subadult and adult E. mordax more "room" to school above the bottom in this habitat, thus reducing near bottom trawl catches. Lending credence to this hypothesis is the fact that E. mordax has been captured "abundantly" in lampara (whole water-column) nets in this habitat off San Onofre (DeMartini 1981).

Citharichthys stigmaeus (Speckled sanddab)

The speckled sanddab, a species that demonstrates a cool-water (11-14°C, 51.8-57.2°F) preference (Ehrlich et al. 1979), has exhibited an abundance pattern indicating that this fish follows the movement of cool water into the nearshore environment. Speckled sanddab were generally most abundant in the shallow sand habitat after periods of upwelling (spring and early summer) when the water-column was thermally stratified and bottom temperatures were low.

Catches of the speckled sanddab off San Onofre have been generally larger in the deep sand habitat than inshore. These results coincide with observations made by Ford (1965) that indicated that the sandy offshore area between 15 to 25 m (49 to 82 ft) is their preferred habitat. Their distribution may also be related to predation pressures. California halibut, a predator of C. stigmaeus (Ford 1965), are mainly distributed in the San Onofre shallow sand habitat. Thus, by remaining offshore, C. stigmaeus may avoid one of their major predators.

Behavioral responses to water temperature may also serve as a predation reducing response since C. stigmaeus prefers cooler temperatures (Ehrlich et al. 1979) while P. californicus generally selects warmer conditions (Innis 1980). As cool water masses move inshore or offshore, C. stigmaeus probably follows this change and expands its distribution without increased predation as P. californicus probably moves to stay within the warmer water.

During June 1980 many small juveniles (< 30 mm, 1.2 in. SL) were captured along the 12.2-m (40-ft) isobath of the shallow sand habitat. Their presence corresponds with the April through August period of greatest oocyte maturation observed by Ford (1965) at the La Jolla Canyon shelf. Ichthyoplankton collections at San Onofre found Citharichthys spp. larvae (probably C. stigmaeus) nearly all year, but the greatest densities appeared from November through February (SCE 1980b). It appears that C. stigmaeus spawns year-round but the micro-environment in each area may differentially affect reproduction.

INTERRELATIONSHIPS WITHIN THE SOUTHERN CALIFORNIA BIGHT

A comparison was made between San Onofre 1978-1980 shallow sand habitat trawl data and trawl data from other sites at similar depths within the Southern California Bight. The following sites were separately compared with San Onofre 1978, 1979, and 1980: Huntington Beach (MBC 1978), Huntington Beach-VANTUNA (J. Stephens, Occidental College, pers. comm.), Haynes-Alamitos Bay (MBC 1979a), Los Angeles Harbor-VANTUNA (J. Stephens, pers. comm.), Redondo Beach (MBC 1979b), Scattergood-El Segundo 1978 (IRC and LCMR 1979), Scattergood-El Segundo 1980 (LES 1981), Ormond Beach-Port Hueneme (MBC 1979c), Mandalay-Ventura (MBC 1979d), and Santa Barbara (Werner 1971). At each station, the 20 most abundant species were ranked and the ranked species arrays measured by Kendall's tau. Results of these comparisons are listed in Table 6A-4.

It is immediately apparent that throughout the Southern California Bight (at least from San Onofre to Ventura) there are soft bottom, inshore habitats with similar fish communities. Significant correlations were found between San Onofre data for all three years and Huntington Beach, El Segundo, Ormond Beach, and Mandalay. In all cases northern anchovy, white croaker, walleye surfperch, white surfperch, speckled sanddab, and queenfish were major constituents of their communities. Of somewhat lesser importance, but nonetheless shared by all six sites were California halibut; barred surfperch, Amphistichus argenteus; and shiner surfperch.

Table 6A-4. A comparison between trawl catch off San Onofre from 1978-1980 and other sites within the Southern California Bight, using rank correlation (Kendall's tau) between ranked species arrays.

	San Onofre					
	1978		1979		1980	
	tau	P	tau	P	tau	P
San Onofre 1978	--	--	0.68	<0.001*	0.65	<0.001*
San Onofre 1979	0.68	<0.001*	--	--	0.60	<0.001*
San Onofre 1980	0.65	<0.001*	0.60	<0.001*	--	--
Huntington Beach	0.33	<0.05*	0.38	<0.01*	0.31	<0.03*
Huntington Beach-VANTUNA	0.28	<0.05*	0.30	<0.05*	0.26	<0.05*
Haynes	0.25	0.07	0.23	0.11	0.19	0.17
Los Angeles Harbor-VANTUNA	0.07	0.58	0.07	0.61	0.01	0.94
Redondo	0.17	0.24	0.14	0.29	0.14	0.32
Scattergood 1980	0.16	0.25	0.18	0.21	0.23	0.09
Scattergood 1978	0.43	<0.01*	0.40	<0.01*	0.40	<0.01*
Ormond Beach	0.26	0.05*	0.30	<0.05*	0.28	0.04*
Mandalay	0.30	<0.05*	0.28	0.04*	0.38	<0.01*
Santa Barbara	0.12	0.36	0.10	0.46	0.14	0.28

* $P < 0.05$
P Probability Level

Significant differences in species rank abundance were found between San Onofre and Haynes, Los Angeles Harbor, Redondo, Scattergood-1980, and Santa Barbara. Fish populations off Haynes, located within Alamitos Bay and near the mouth of the San Gabriel River might be expected to differ from open coastal sites such as San Onofre. Species captured off San Onofre, such as the spotted scorpionfish and yellowfin croaker, Umbrina roncador, are absent off Haynes. Tonguefish and the freshwater fish the Mozambique mouthbrooder, Tilapia mossambica, are abundant off Haynes. Tonguefish are found only in deep water while the Mozambique mouthbrooder is absent off San Onofre.

Dissimilarities in trawl catches between Los Angeles Harbor, Santa Barbara, and San Onofre are again likely due to differences in sampling habitats. Many of the trawls within Los Angeles Harbor and all those off Santa Barbara occurred over hard or somewhat rocky bottoms. Trawling along the Los Angeles Breakwater yielded many reef forms (such as black surfperch, Embiotoca jacksoni; vermilion rockfish; and calico rockfish) that were rare or absent in San Onofre trawls. Similarly, Santa Barbara captures, rich in black and rainbow surfperch, reflected trawling effort along the outer margin of kelpbeds.

Based on data now available, fish populations in the San Onofre vicinity appear comparable to those in some other parts of the Southern California Bight. Trawl data in particular indicate that the fish species composition over soft bottom is similar to soft bottom habitats many kilometers to the north. Given the more or less continuous habitat, the planktonic larvae and wandering nature of many soft bottom fishes, it is not surprising that few differences would be seen. What differences do appear may, in fact, be due to the geographical location of San Onofre in the more southerly part of the Bight. The relative abundance of a warm water genus, Anchoa, especially A. delicatissima (slough anchovy), for

instance, may be linked to the somewhat higher water temperatures found off San Onofre compared to sites in the northern part of the Bight. It is curious that this species was most abundant in the coolest year of the study (1979) and could reflect attraction to the warm effluent. Another difference in the trawling samples is the relatively large number of shovelnose guitarfish, Rhinobatos productus; and round stingray, Urolophus halleri, as compared to other trawling studies. Perhaps the presence of these two shallow water elasmobranchs reflects the very shallow depth (6.1 m, 20 ft) of some San Onofre trawls, but it may also be related to their southern affinities and the fact that San Onofre is the southernmost of the trawl study sites.

The lack of uniqueness of the San Onofre area is also emphasized by Ebeling's preliminary report to Lockheed (6 August 1980) for the kelp bed habitat. Ebeling lists 17 species recorded from cinetransects of 20 June 1980. Of these, six are listed by Patton (Occidental College, pers. comm.) as bightwide species; six are classified as southern turf associated species (common inhabitants of kelp beds south of Santa Monica Bay); three are hern low relief species; and one is a southern turf indifferent. The fina. species, black croaker (Cheilotrema saturnum), did not cluster strongly with any group. Therefore 76% of the fish were southern or bightwide common species, and 18% were wide ranging "northern" low relief inhabiting forms.

During December 1979, divers from Occidental College surveyed kelp beds off San Onofre and Dana Point with visual transects. Sixteen species were observed in each kelp bed, all species common to Occidental's seven-year study of the Palos Verdes kelp (J. Stephens, pers. comm.). One difference noted in Occidental's study of San Onofre kelp was the dominance of white surfperch in the canopy. These are rarely seen in the canopy at Palos Verdes, where they are usually well below the thermocline associated with cover. The absence of a distinct thermocline during their study could have resulted in this distribution.

Ebeling's transects suggest that groups A and C of the cluster analysis (1979, 1980) represent the basic kelp bed community. Remaining clusters are largely wandering species or sand inhabitants occasionally entering the kelp environment. Again, the gill net samples are quite typical of any survey in the southern Bight. In fact, all species represented in the gill net studies are the same as those taken by Marine Biological Consultants (1977) within Long Beach Harbor.

Patton (Occidental College, pers. comm.) in his analysis of shallow water fish associations from Point Conception to San Diego developed clusters based upon substrata, relief, temperature, latitude, and degree of sand scouring (recent burial). None of the clusters from the gill net or trawl sites fit into Patton's habitat groups. Most are heterogeneous including Bight-wide species (not habitat specific), low relief and/or sand related species, and some migrating or pelagic forms. These data do not indicate that the San Onofre samples are in any way distinctive from those collected elsewhere in the southern half of the bight.

SAN ONOFRE UNIT 1 EFFECTS

During much of 1980, Unit 1 was not operational due to steam generating problems. This afforded an opportunity to consider the ETS objectives in terms of nearly six consecutive years of monitoring studies, ending with four consecutive fish surveys during which the unit was not operational. Comparison of data collected during the period while the unit was not operational showed minor differences in composition, distribution, or abundance of fish population characteristics between years, but no consistent pattern indicating that 1980 was not different from previous years when the unit was operational most of the year.

Based on the analysis of the 1978-1980 data, all indications are that the variability inherent within the fish community and the governing physical factors may exceed any differences attributable to the thermal discharge of Unit 1.

UNITS 2 AND 3 PREOPERATIONAL BASELINE OBJECTIVES

Successful completion of the Preoperational Monitoring Program in June 1980 and the continuing Interim Otter Trawl Program provided data on the nature and extent of fish resources in the vicinity of San Onofre. All populations were found to exhibit spatial and temporal variation within the range expected in the Southern California Bight. The most distinct and persistent patterns were differences in community and population composition based on water depth. Spatial variation was consistent due to habitat (substratum) differences in the study and control areas. Temporal variation showed recurrent patterns on a seasonal basis. The most persistent of these was movement away from the nearshore zone to deeper areas in early winter followed by return to the nearshore areas in late winter and spring. A major seasonal influx of young-of-the-year, mainly sciaenids and embiotocids, during spring, summer, and fall attributed to much of the temporal variability.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

APPROACH

The following analysis of fish data is used to develop a qualitative model describing the fish community offshore San Onofre, select species populations within that community, and evaluate the interaction of these populations with certain physical variables. Description of the San Onofre fish community involves the definition of habitat preferences of species based upon their abundance, significant differences in relative abundance based upon habitat, and the apportionment of individuals among the species relative to habitat. Select species, chosen because of their trophic (functional) significance in the San Onofre area, are analyzed for differences in numerical abundance, size (age) structure, sex composition, and ovarian development. Temporal and spatial variation in community and population parameters are examined within the potential area of influence and reference areas. Using the results derived from analysis of the San Onofre fish community and select species populations, similar analyses are performed for similar habitats throughout the Southern California Bight which are outside any potential influence of San Onofre Units 1, 2, and 3.

METHODS

A detailed description of station locations and field methodology is given in ETS Fish Survey Procedures (LES procedures EMP 25-5-35) and PMP Fish Survey procedures (LES 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 6A-1). Each gill net station consisted of a pair of identical Marinovich experimental monofilament gill nets for replicate sampling. Each net measured 45.7 m (150 ft) long, 1.8 m (6 ft) deep, and contained six 7.6-m (25-ft) panels with the following sizes of bar mesh: 19, 25, 32, 38, 44, and 64 mm (0.75, 1.0, 1.25, 1.5, 1.75, and 2.5 in.). All nets were set perpendicular to the shoreline over mostly cobble substrata and were retrieved after 24 h. The fishing period encompassed 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) were located on the 9.1-m (30-ft) isobath. The remaining six stations (Stations 4, 5, 9, 10, 13, and 14) were located on the 13.7-m (45-ft) isobath (Figure 6A-1). Station 3 was located within 50 m (164 ft) of the Unit 1 discharge and Station 6 was located approximately 2 km (1.24 mi) downcoast of Stations 7 and 8 (Figure 6A-1).

Otter trawls were 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 6A-1). A 7.6-m semi-balloon otter trawl was 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 were considered to be replicates. Trawl samples were collected during the same period that gill nets were fished. Trawl stations were located at sites over sandy bottom in the same general areas as gill nets. Station sites were established to provide baseline data for assessing possible future operational effects of Units 2 and 3, as well as to provide data for assessing the present effects of the San Onofre Unit 1 discharge.

Temperature and light transmissivity were measured daily at each cluster of 9.1-m and 13.7-m gill net stations during the two days of the survey. Data were taken at 1-m (3.3-ft) depth intervals from the surface to the bottom.

ETS and PMP gill net sampling was conducted bimonthly on 26-17 February, 23-24 April, and 25-26 June 1980. In June the two-year PMP ended and the ETS continued during the remainder of 1980. The remaining 1980 ETS sampling was conducted quarterly and took place on 21-22 August and 10-11 December 1980. Otter trawling for the interim program was conducted on the same days as the ETS survey plus one additional survey on 20, 21, and 23 October 1980.

LABORATORY

All fishes collected in gill net and otter trawl samples were 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 San Onofre 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 were 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 were measured. A random subset of no more than 50 individuals per species were sexed (male, female, juvenile, indeterminate) by examining their gonads or by noting obvious secondary sexual characteristics. Indeterminate individuals were defined as fish having recently spawned or been damaged such that sex cannot be determined. A maximum of 10 female Seriphus politus and 10 female Genyonemus lineatus per net were subsampled for gonosomatic index analysis. Gonad and total body wet weights were determined for each subsampled female with gonad weight divided by total body weight then multiplied by 100 to calculate the index on a survey, area, and depth, basis.

In addition to the preceding methods which were utilized for the combined Units 1, 2, and 3 program, certain additional length and sex data were taken to maintain compliance with the Unit 1 ETS at some stations. These data included measurements of all fish from the six nets near the Unit 1 discharge (Zone 0A) and the six nets at the downcoast inshore reference area (Zone 6) and sexual determination of a maximum of 10 individuals of each resident species.

DATA ANALYSIS

Gill net and otter trawl samples of fish from receiving waters were analyzed at community and population levels. Community level analysis evaluated species composition and relative abundances; population analysis evaluated abundance, size (age) structure, sex composition, and reproductive condition of select species populations.

Community level analysis utilized species composition and relative abundance data to define areas in which fish species live based upon their presence and abundance (classification of the fish community; Clifford and Stephenson 1975).

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 with ± 90% confidence limits for gill net and otter trawl catches. Original values (x), whose distributions are skewed, are transformed to log (x + 1) to compute means and confidence limits, which are converted back to antilogs (geometric mean) for graphical presentation. The log (x + 1) transformation minimizes extreme values so variances are no longer correlated with means and tend to be homogeneous among samples. Valid use of parametric statistics, such as comparing means by confidence intervals, assumes that distributions of the variates approach normality; i.e., that variances are nearly independent of means and are nearly homogeneous. This assumption allows visual evaluation of significance by comparing mean abundances by overlap or non-overlap of their confidence interval within study areas, between depths, and through time.

Length frequency distributions presented as histograms are used to estimate the size (age) structure of the 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 within areas. The Chi-square goodness of fit for replicated tests (Sokal and Rohlf 1969) is used to test for significant departures from a 1:1 ratio of males to females among depths and within areas combining surveys in 1980.

Reproductive condition of Seriphus politus and Genyonemus lineatus is 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, and through time using analysis of covariance (ANCOVA; Snedecor and Cochran 1967). Significant results are identified by Duncan's multiple range test (Duncan 1965).

RESULTS

COMMUNITY ANALYSIS

Analysis of the fish community represented by gill net and otter trawl samples consists of classification analysis based upon data collected in 1979 and 1980. Additionally, the fish community observed off San Onofre from 1975-1980 will be placed in perspective relative to nearshore fish distribution and abundance patterns observed from Santa Barbara to San Onofre.

Yearly patterns of species composition and abundance for fish assemblages sampled by gill nets and otter trawls were evaluated by cluster analysis (Clifford and Stephenson 1975). Comparisons between 1979 and 1980 were made using gill net and otter trawl data collected during all surveys, at all depths and areas with one exception. Two analyses were required for 1980 gill nets since the PMP gill net program ended in June 1980. The first analysis classifies sites and species at the 9.1- and 13.7-m (30- and 45-ft) isobaths for surveys conducted in February, April, and June; the second analysis utilizes data from June through December for gill net stations located on the 9.1-m isobath, exclusively.

Gill Nets

"Sites" are defined as the gill net stations in each of the sampling areas (Figure 6A-2). Clusters of sites with similar species composition (site groups) were numbered for easier identification.

Three site groups were formed in 1979 and four in 1980 (Figure 6A-2), site groups in both years were based primarily on site depth. Site affinities within each site group in 1979 were discordant relative to the test site (SONGS area) and control sites (Don Light and San Mateo Point areas). The 1980 site groups displayed a higher degree of within area concordance (Figure 6A-2) than that observed in 1979. It is interesting to note that in 1979 site group 1 was distinctly dissimilar from groups 2 and 3, while in 1980 this disparity was much reduced. Comparison of affinities within site groups between years suggests that little change occurred in community structure between 1979 and 1980. Of the 14 possible sites, 50% of them co-occurred together in 1979 and 1980. These include the shallow Don Light sites and Unit 1 discharge (SONGS 3) site (site group 1 in 1979 and 1980, Figure 6A-2), and the deep Don Light sites and San Mateo Station 13 (site group 2 in 1979 and 1980, Figure 6A-2).

Two site groups resulted from the classification of gill net catches on the 9.1-m isobath during the remainder of 1980. The affinity of the Unit 1 discharge site (SONGS 3) for shallow Don Light sites observed during 1979 and the first half of 1980 was not maintained during the second half of 1980 (Figure 6A-2).

The classification of fish species by sites where they are most abundantly caught resulted in four groups in 1979 and five in 1980 (Figures 6A-3, 6A-4, and 6A-5). Species groups generally contained diverse and variable assemblages of

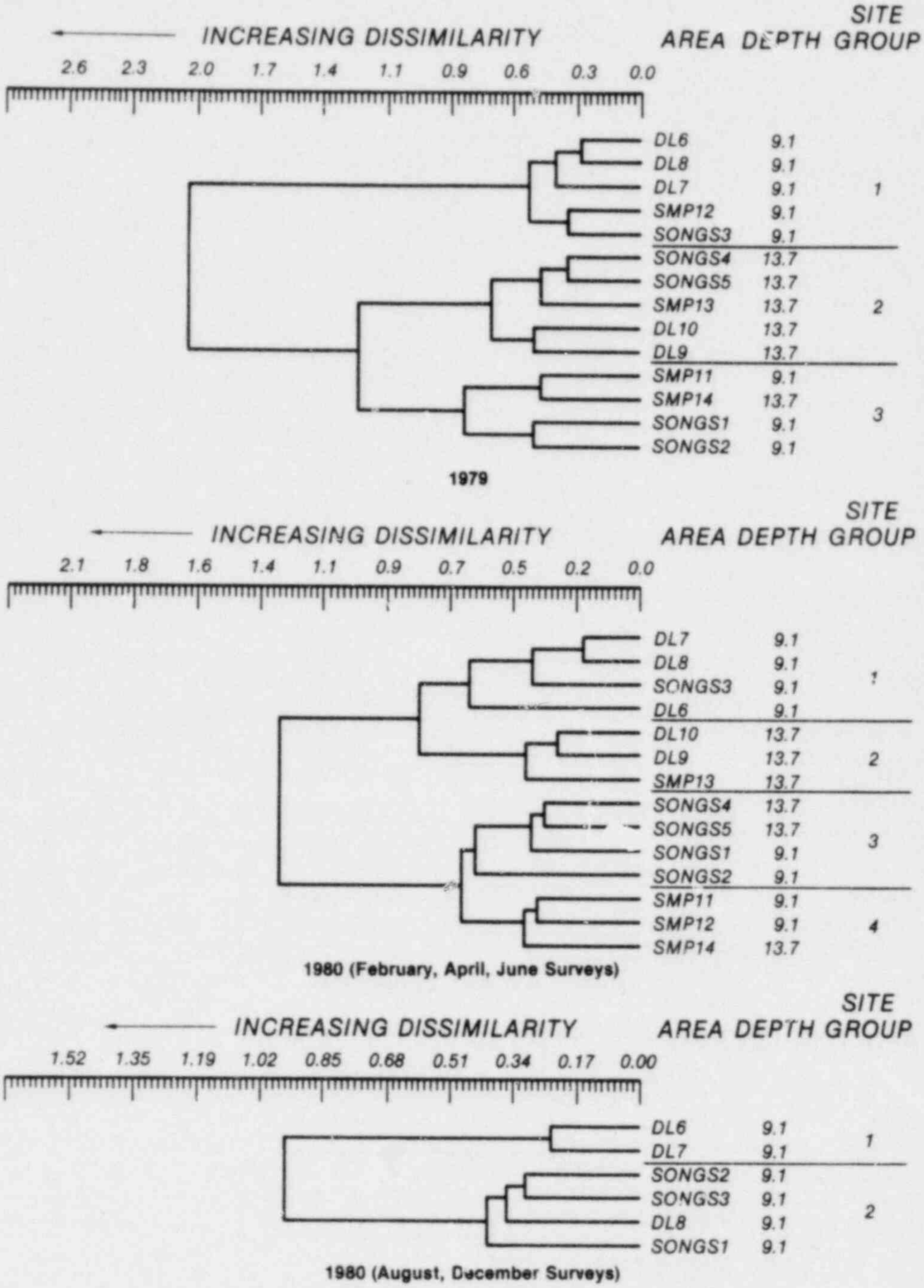

Figure 6A-2. Site classification of 1979 and 1980 gill net catch.

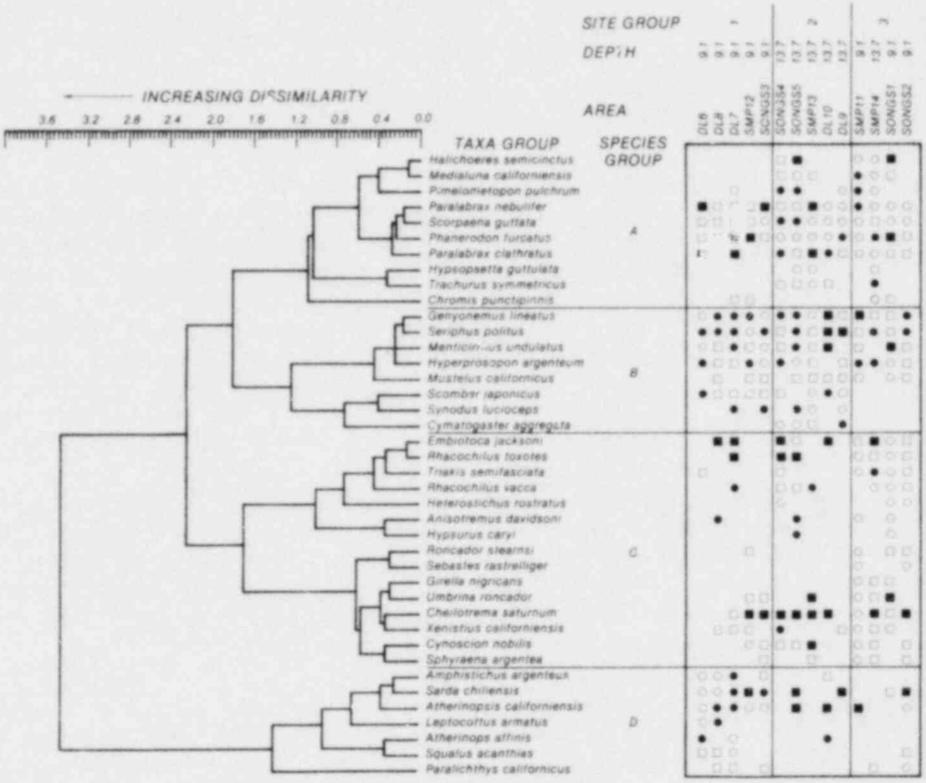

Figure 6A-3. Species classification and site group classification with resultant two-way table for 1979 gill net catch.

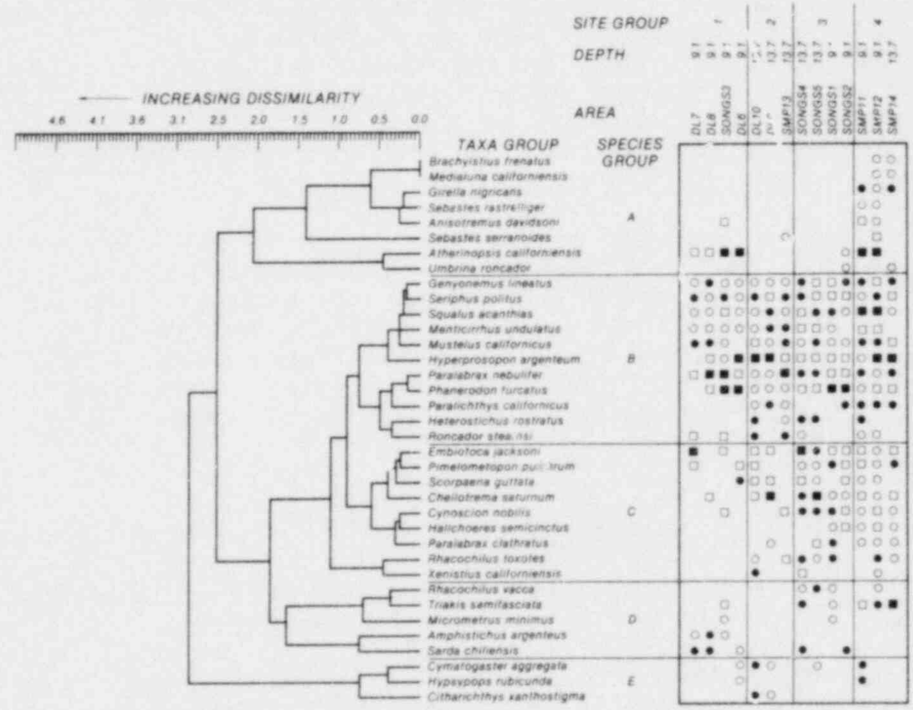

Figure 6A-4. Species classification and site group classification with resultant two-way table for 1980 gill net catch (February, April, June).

fish taxa. As in previous studies (SCE 1980e) this is the expected result considering the heterogeneous habitat (level bottom, kelp bed, water column) and demersal species sampled by gill nets. The recurring group of species (SCE 1980e) consisting of Seriphus politus, queenfish; Genyonemus lineatus, white croaker; Menticirrhus undulatus, California corbina; and Hyperprosopon argenteum, walleye surfperch, was again resolved during the first half of 1980 (Figure 6A-4).

Other species varied in co-occurrence between years, although a group of bottom oriented fishes (Rhacochilus vacca, Embiotoca jacksoni, Cheilotrema saturnum, Menticirrhus undulatus, Umbrina roncador) was consistently observed. Species group C in 1979 and 1980 contained considerably more members of this bottom oriented feeding guild relative to other guilds. Members of this group were most abundant at site group 3 (1979) and site groups 3 and 4 (1980) (Figuse 6A-3 and 6A-4), primarily at San Mateo Point and San Onofre shallow stations, respectively.

Otter Trawls

"Sites" are now defined as the otter trawl stations in each of the sampling areas. Thus, the yearly analyses are classified on the basis of nine otter trawl sites. In both 1979 and 1980, site classification resolved two site groups both based upon depth strata (Figure 6A-6), as the species assemblages caught with otter trawls at the 18.3-m (60-ft) isobath were easily distinguished from those caught on the 6.1- and 12.2-m (20- and 40-ft) isobaths.

Four groups resulted from the classification of co-occurring species for 1979 and 1980 otter trawl catches (Figures 6A-7 and 6A-8). In 1979 a group of fishes that feed primarily from the bottom (species group C; Citharichthys stigmaeus, Paralichthys californicus, Urolophus halleri, Pleuronichthys ritteri, P. verticalis) were found at all isobaths (Figure 6A-7). The distinct separation of site groups based upon depth reflects the virtual absence of species groups B and D from the deep (18.3-m) and shallow (6.1- and 12.2-m) stations, respectively (Figure 6A-7). Species group B is composed of a wide variety of fish taxa, but a group of fish that feed strictly from the water column (Atherinopsis californiensis, Hyperprosopon argenteum, Anchoa compressa, Anchoa delicatissima, and Engraulis mordax) predominated in this species group. Species group D was comprised of a group of fish feeding from the bottom (Citharichthys xanthostigma, Hippoglossina stomata, Raja binoculata, Raja inornata).

The separation of deep and shallow habitats in the 1980 inverse classification resulted from the virtual absence of all but one species group (group C) at deep (18-m) stations (Figure 6A-8). Species composition of group C, as noted above, was dominated by fishes feeding on or near the bottom. With the exception of group A, remaining species groups (B, D) contained a diverse assemblage of fishes encompassing a wide range of feeding guilds. Like 1979, a suite of strictly water column feeding fish predominated species group A in 1980.

POPULATION ANALYSIS

Shallow Sand Habitat - Seriphus politus (Queenfish)

During 1980, the seasonal pattern of abundance of juvenile and adult queenfish observed in the San Onofre shallow sand habitat (Figure 6A-9), resembled that of the previous two years: a period of large catches from June to October followed an abrupt decline during December. Juveniles were always more abundant than adults, and were generally caught throughout the year. Peak abundance of

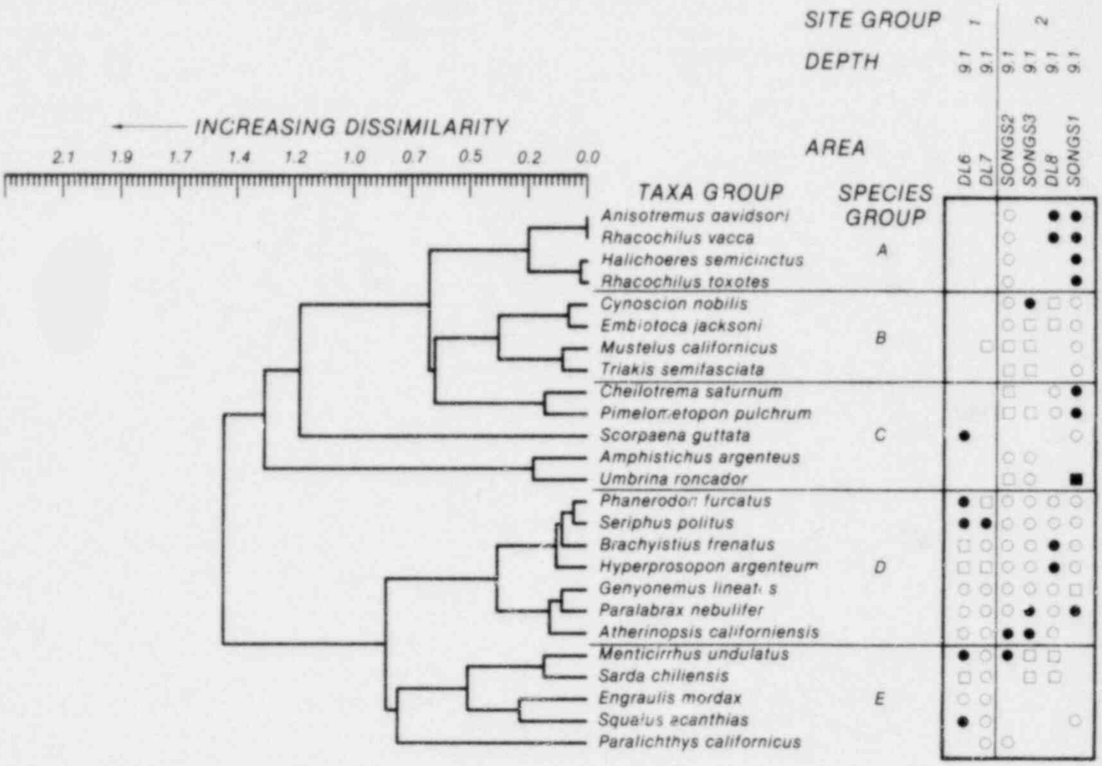

Figure 6A-5. Species classification and site group classification with resultant two-way table for 1980 gill net catch (August, October, December).

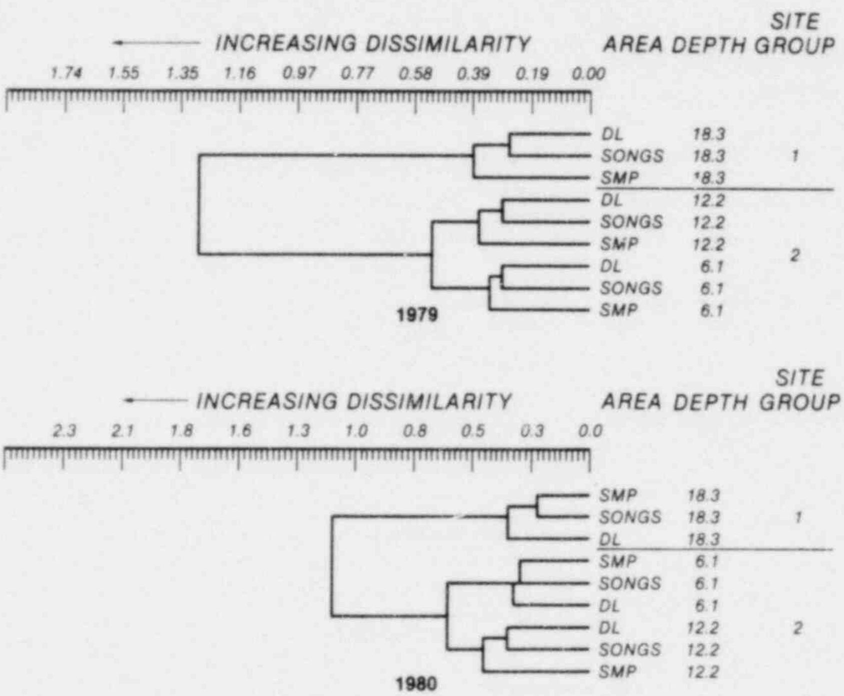

Figure 6A-6. Site classification of 1979 and 1980 otter trawl catch.

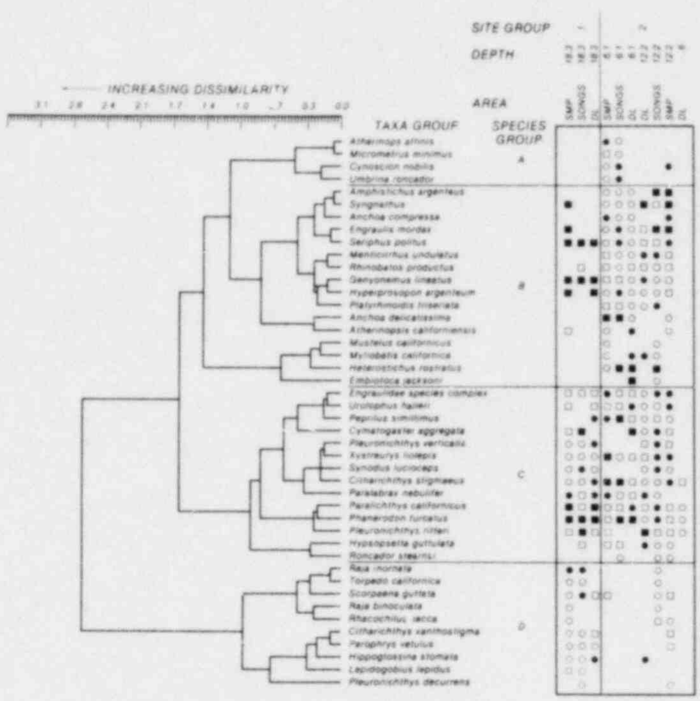

Figure 6A-7. Species classification and site group classification with resultant two-way table for 1979 otter trawl catch.

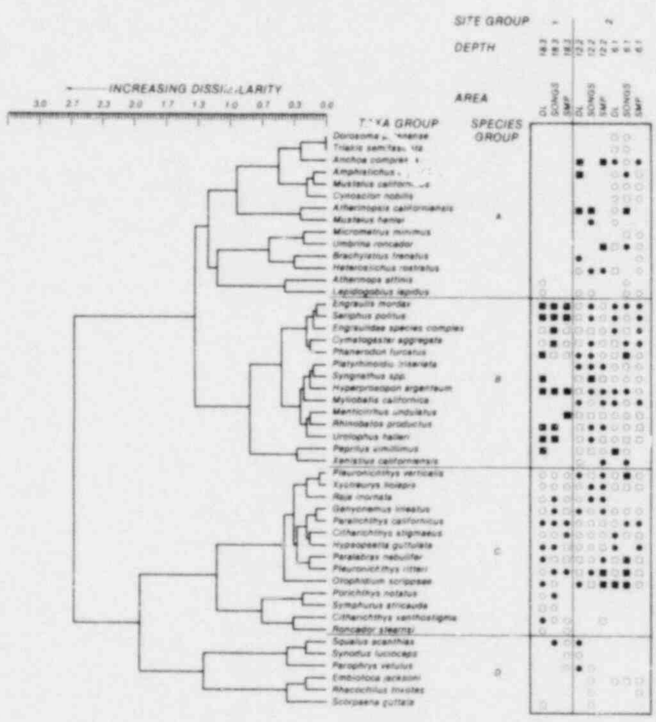

Figure 6A-8. Species classification and site group classification with resultant two-way table for 1980 otter trawl catch.

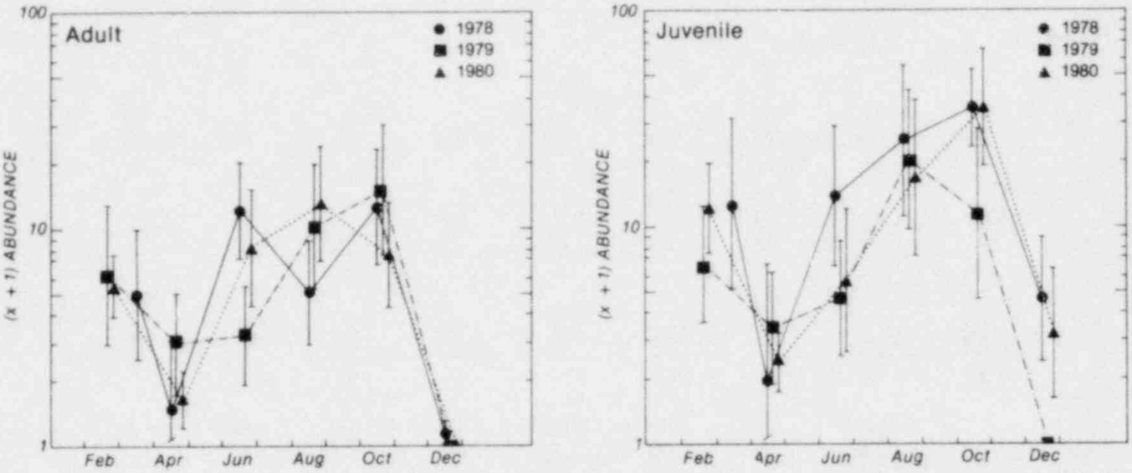

Figure 6A-9. Geometric mean abundance and 90% confidence limits for adult and juvenile *Seriphus politus* collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1978, 1979, and 1980.

queenfish (adults and juveniles) occurred during either the August or October survey of the past three years. In December, all adults and many juveniles disappeared from the shallow sand habitat only to reappear during February before another substantial decline in April.

Juveniles were more abundant than adults and were caught throughout the year. Yet all adults and many juveniles disappeared in December only to reappear during February before another substantial decline in April.

Length frequency histograms revealed three major size classes of queenfish between 15 and 210 mm (0.6-8.3 in.) SL (SCE 1981b). Two modes, 20-29 mm (0.8-1.1 in.) SL and 45-65 mm (1.8-2.6 in.) SL, represented the young-of-the-year, age class 0+, apparently recruited from two periods of peak reproductive activity, while a mode at 100-125 mm (3.9-4.9 in.) SL, represented subadults, age class 1+. Length frequency also showed three modes in past years, although larger (180-200 mm, 7.1-7.9 in. SL) adults were more abundant in 1979 than in 1978 or 1980. Although new recruits resembled those of past years in size, they were collected later (August; SCE 1981b) than usual (June; SCE 1980e). As usual, females numerically dominated the larger size classes (160-210 mm, 6.3-8.3 in. SL).

Annually, female queenfish were more abundant than males in trawl catches from all areas in the shallow sand habitat during 1980 (Figure 6A-10) and 1979 (SCE 1980e). Only during June and August were significantly more males were captured (SCE 1981b).

Based on gonosomatic indices (GSI), the fish's seasonal reproductive cycle (Figure 6A-11) resembled last year's (SCE 1980e). Mean GSI rose between December 1979 and April-June 1980, indicating the onset of reproductive activity. The fish spawned during the summer. Low GSI during the fall, August to December, indicated that fish were reproductively inactive then. Gonad weights were significantly greatest during April and June. Fish from the shallow sand habitat at San Mateo Point had significantly ($P \leq 0.05$) smaller mean gonad weights than other areas. During 1979, however, weights differed significantly among all areas compared. During the summer, spawning fish were caught more frequently in the shallow than in the deep sand habitat at San Onofre and Don Light.

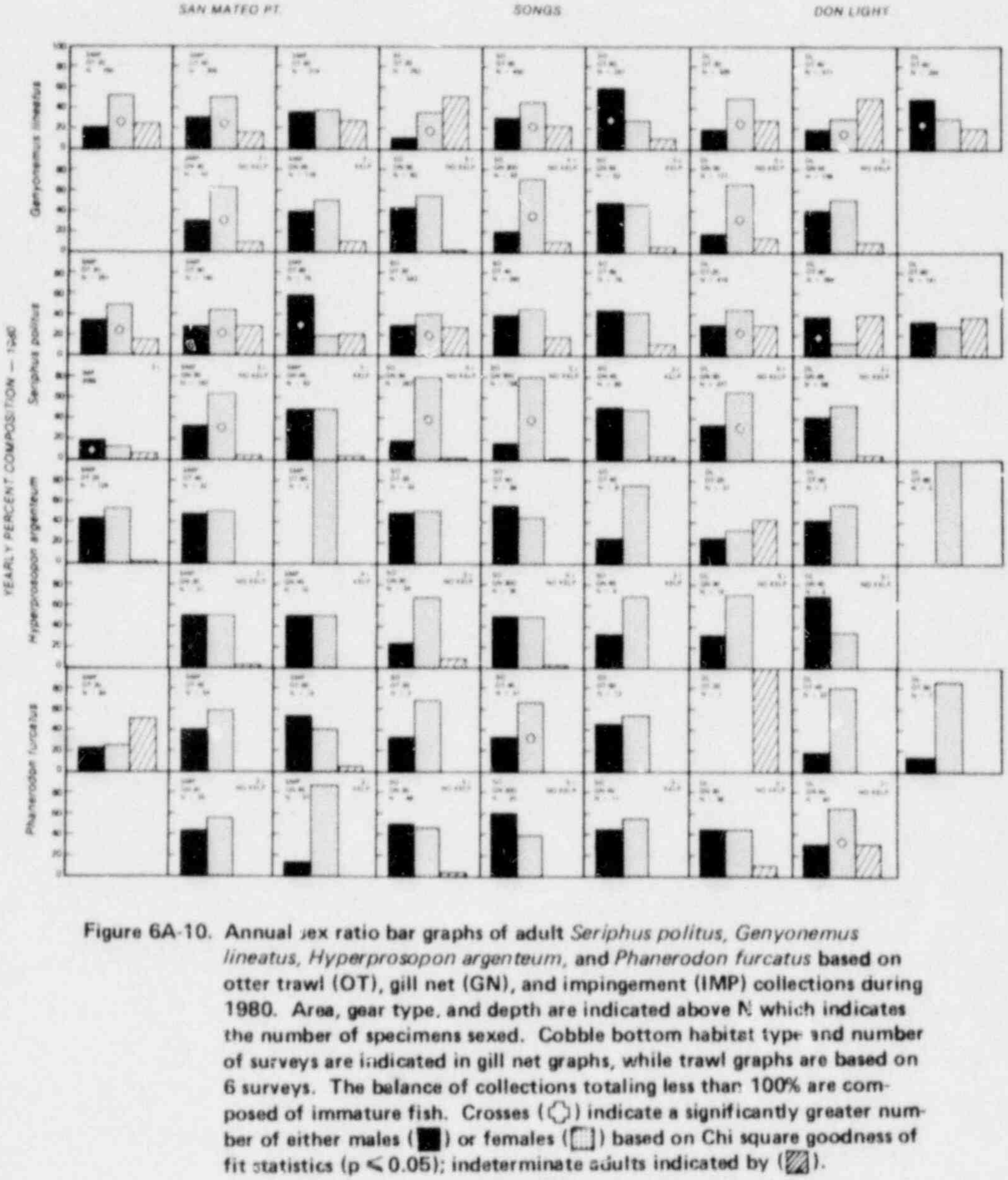

Figure 6A-10. Annual sex ratio bar graphs of adult *Seriphus politus, Genyonemus lineatus, Hyperprosopon argenteum,* and *Phanerodon furcatus* based on otter trawl (OT), gill net (GN), and impingement (IMP) collections during 1980. Area, gear type, and depth are indicated above N which indicates the number of specimens sexed. Cobble bottom habitat type and number of surveys are indicated in gill net graphs, while trawl graphs are based on 6 surveys. The balance of collections totaling less than 100% are composed of immature fish. Crosses (○) indicate a significantly greater number of either males (■) or females (□) based on Chi square goodness of fit statistics ($p \leq 0.05$); indeterminate adults indicated by (▨).

Shallow Sand Habitat - Genyonemus lineatus (White croaker)

White croaker had a pattern of seasonal abundance similar to queenfish (Figure 6A-12): white croaker were abundant during all months but April and December, and juveniles peaked in spring. This pattern more closely resembled that of 1978 than that of 1979.

Age-class frequencies were also typical. Over 50% were age 0+ (<100 mm, 3.9 in. SL). Age 1+ (100-135 mm, 3.9-5.3 in. SL) and age 2+ (135-155 mm, 3.9-6.1 in. SL) fish constituted the majority (35%) of adults in the total catch, while only 10% were age 3+ or older (155-229 mm, 6.1-9.0 in. SL; SCE 1981b; LES 1981). As in 1978, the major period of juvenile (<40 mm, 1.6 in. SL) recruitment was February to August, and did not include a decline from April to June as observed in 1979

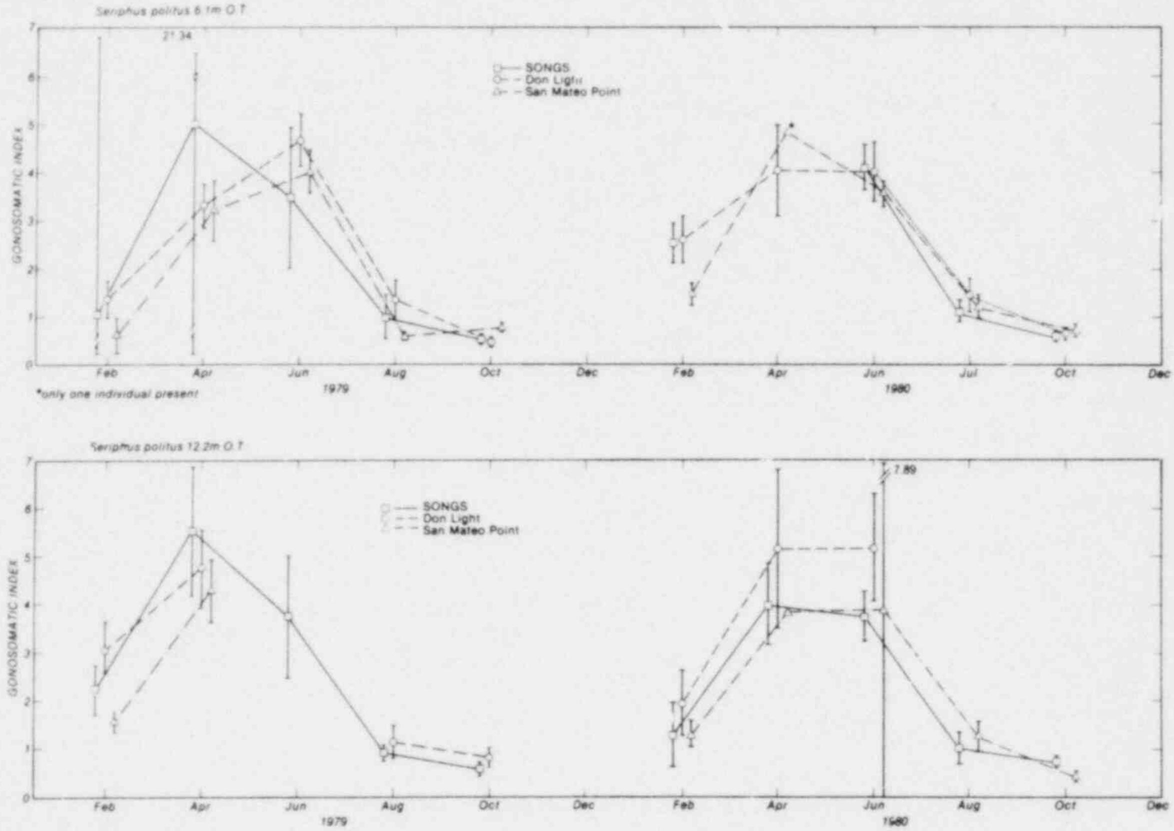

Figure 6A-11. Gonosomatic indices (gonad wet weight x 100/total body wet weight) of female *Seriphus politus* collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1979 and 1980.

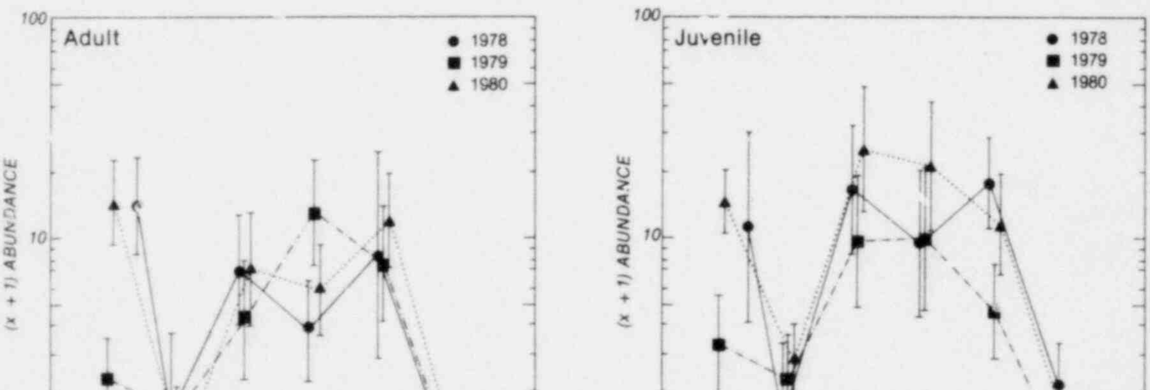

Figure 6A-12. Geometric mean abundance and 90% confidence limits for adult and juvenile *Genyonemus lineatus* collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1978, 1979, and 1980.

(SCE 1980e). Like queenfish, larger individuals were usually females, which generally numerically dominated catches in 1980 (Figure 6A-10), as well as in 1978 and 1979 (SCE 1979d, 1980e).

The seasonal pattern of reproductive activity, resembled that for 1979 (Figure 6A-13). Fish spawned from February to June during both years. During 1980, GSI values were more variable, possibly due to a mixed catch of ripe and spent individuals. Consistently low mean GSI values from June to August indicated that fish were refractory then. Increasing GSI from late August or early October through February indicated the beginning of reproductive activity during both 1979 and 1980.

White croaker caught in the inshore (6.1 m) shallow sand habitat had significantly ($P \leq 0.05$) larger gonads than white croaker caught in deeper (12.2- and 18.3-m) trawls. Fish caught during the spawning period (February, April, and October) differed significantly ($P \leq 0.05$) in gonad weights among surveys.

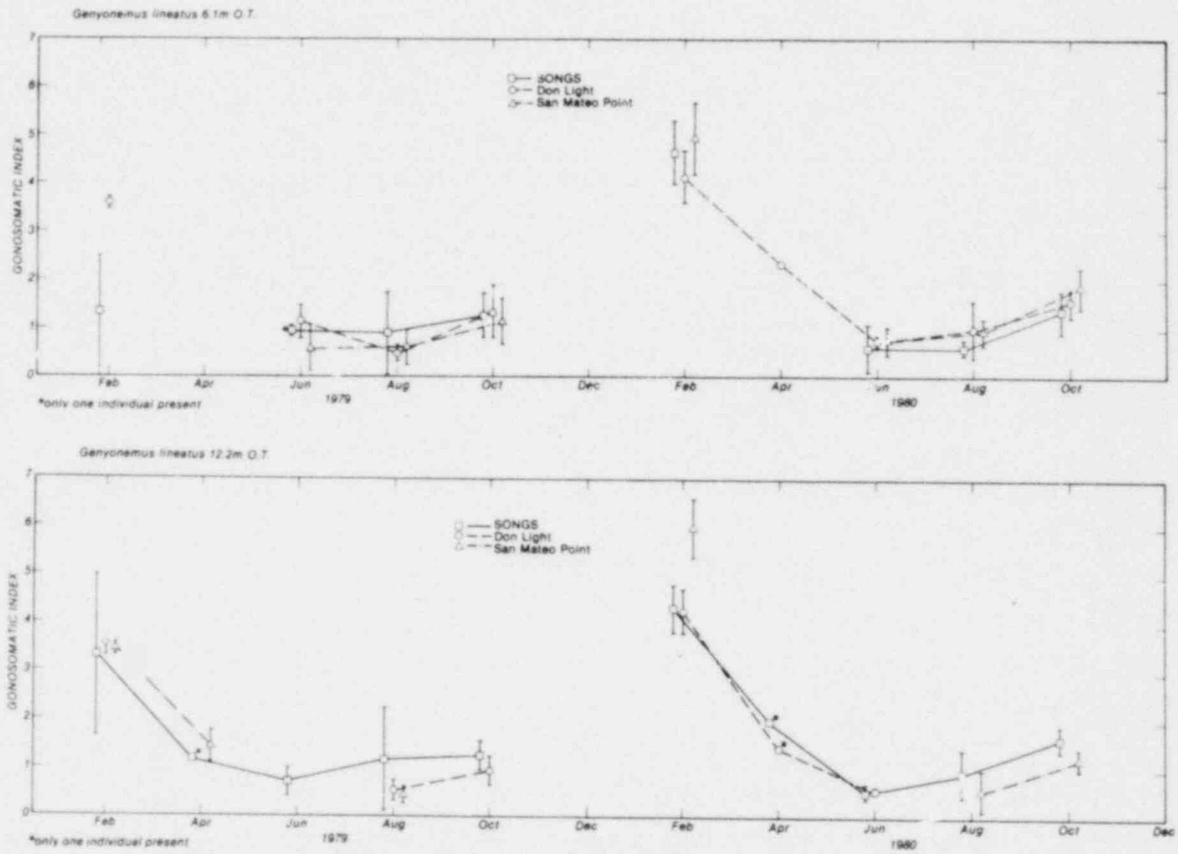

Figure 6A-13. Gonosomatic indices (gonad weight x 100/total body wet weight) of female *Genyonemus lineatus* collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1979 and 1980.

Shallow Sand Habitat - Hyperprosopon argenteum (Walleye surfperch)

Walleye surfperch were most abundant from June to October 1980 (Figure 6A-14) and were collected in much lower abundances than queenfish and white croaker in this habitat. As in 1978 and 1979, young-of-the-year (age 0+, 40-50 mm, 1.6-2.0 in. SL) were collected in the shallow sand habitat beginning in April, collected in larger numbers during June, and were continually present during the rest of 1980. Age 1+ adult walleye surfperch were caught in February (mode 85-90 mm, 3.4-3.5 in. SL), June (mode 100-110 mm, 3.9-4.3 in. SL), and August (mode (105-120 mm, 4.1-4.7 in. SL). Large adults, age 2+ class (120-140 mm, 4.7-5.5 in. SL), were caught in quantity only during June.

Consistent with the patterns observed in 1978 and 1979 (SCE 1979d, 1980e), sex composition based on annual totals (Figure 6A-10) was 1:1.

Shallow Sand Habitat - Phanerodon furcatus (White surfperch)

White surfperch showed seasonal changes in mean abundance in the shallow sand habitat (Figure 6A-15). White surfperch were most abundant June to October, especially along the 12.2-m isobath. Young-of-the-year were caught during June and August. Juveniles appeared in August 1979 (SCE 1980e) and June 1978 (SCE 1979d). Adults comprised the majority of the 1980 catch only in October (SCE 1981b).

Juvenile white surfperch captured during June 1980 had a modal length-frequency distribution of 55-65 mm, 2.2-2.6 in. SL. This age 0+ class was captured throughout the rest of 1980 and demonstrated growth as the modal class sizes increased to 90-100 mm (3.5-3.9 in.) SL in December. Similarly, the adult age class, 1+, had a 100 to 115-mm (3.9-4.6 in.) SL mode in June which increased to the 125 to 140-mm (4.9-5.5 in.) SL mode in October (SCE 1981b).

More white surfperch females than males were taken during 1980 (Figure 6A-10). More females were also taken in 1979, though males predominated in 1978.

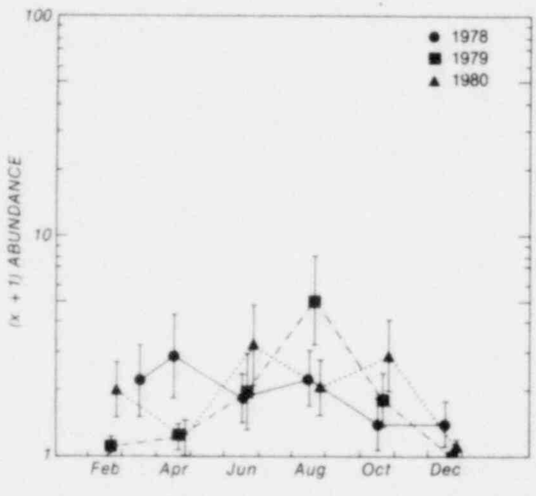

Figure 6A-14. Geometric mean abundance and 90% confidence limits for *Hyperprosopon argenteum* collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1978, 1979, and 1980.

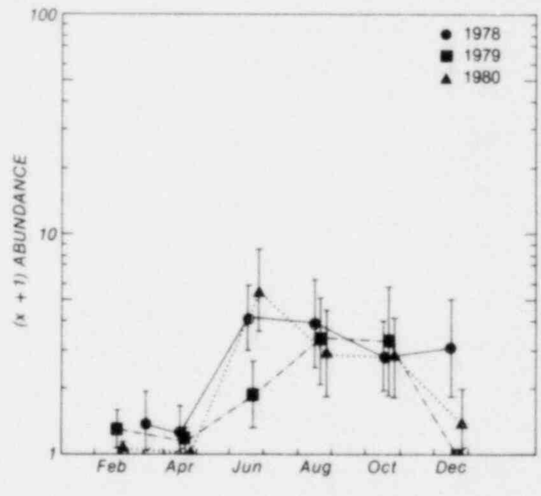

Figure 6A-15. Geometric mean abundance and 90% confidence limits for *Phanerodon furcatus* collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1978, 1979, and 1980.

Shallow Sand Habitat - Paralichthys californicus (California halibut)

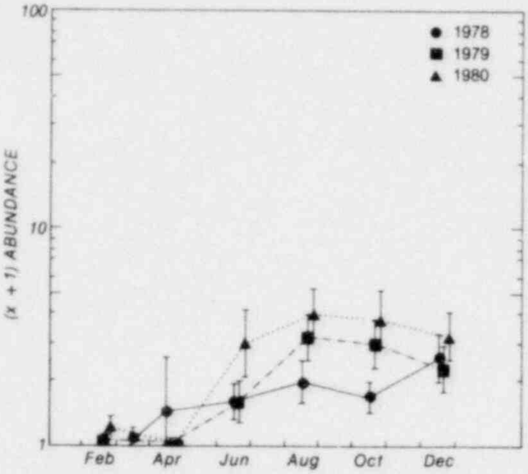

Figure 6A-16. Geometric mean abundance and 90% confidence limits for *Paralichthys californicus* collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1978, 1979, and 1980.

Except during March and April (Figure 6A-16), more California halibut were caught offshore of San Onofre in 1980 than in the past two years. During 1979 and 1980, and to a lesser extent in 1978, P. californicus were absent from the shallow sand habitat during February through April, returning in May or June. Catch during this period peaked during August and October.

Age 1+ (125-250 mm, 4.9-9.8 in. TL) and age 2+ (250-375 mm, 9.8-14.8 in. TL) individuals were taken in nearly equal abundance during 1980 (Hulbrock 1974; SCE 1981b). Older individuals (age 3+; 375-600 mm, 14.8-23.6 in. TL), usually taken in low abundance were captured more frequently during October and December. A few age 0+ individuals (< 125 mm, 4.9 in. TL) were captured during October and December.

Shallow Sand Habitat - Engraulis mordax (Northern anchovy)

The northern anchovy is the most abundant species of a group of anchovies which are the primary filter feeding fishes in the San Onofre region. Though adults are easily identified, larval E. mordax are readily separated from larvae of other anchovies. Hence, anchovy larvae were identified as Engraulid Species Complex during 1979 and 1980. Due to the large abundance of E. mordax adults observed relative to other anchovies, most Engraulid Species Complex larvae were probably larvae of this species.

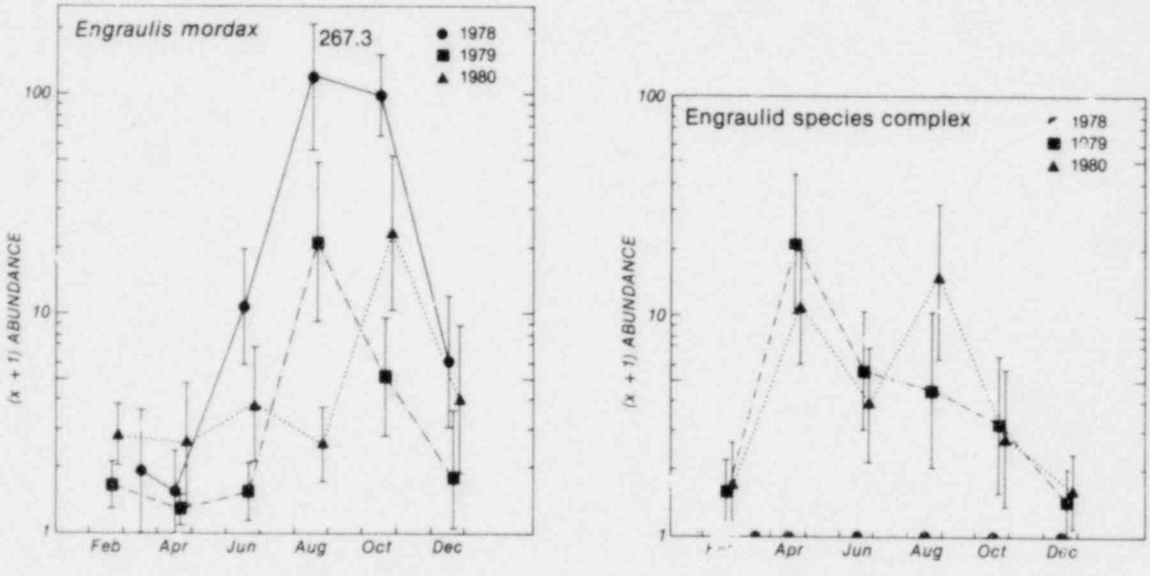

Figure 6A-17. Geometric mean abundance and 90% confidence limits for adult *Engraulis mordax* and Engraulid Species Complex larvae collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1978, 1979, and 1980.

Adult northern anchovy have been abundant during late summer (August) and/or fall (October) during the last three years with catches of larvae peaking in April (1979 and 1980) and August (1980; Figure 6A-17). In 1978, engraulid larvae were included with adults as E. mordax. This may have contributed to the exceptionally high summer catches of northern anchovy in 1978. The northern anchovy was rarely captured during winter and spring (December-April).

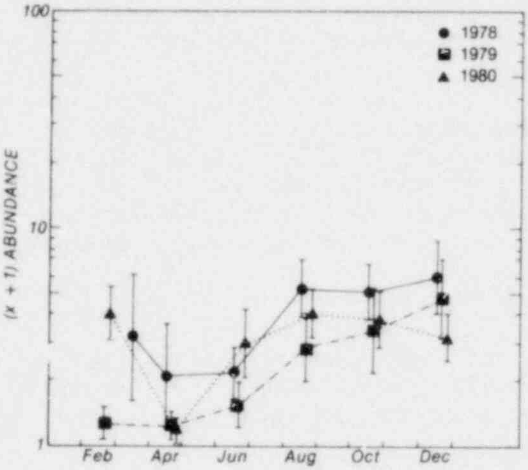

Figure 6A-18. Geometric mean abundance and 90% confidence limits for *Citharichthys stigmaeus* collected by otter trawls in the shallow sand habitat (6.1 and 12.2 m) during 1978, 1979, and 1980.

Shallow Sand Habitat - Citharichthys stigmaeus (Speckled sanddab)

Speckled sanddab were generally most abundant after periods of upwelling when the water column was thermally stratified and bottom temperatures were low (Figure 6A-18). Bottom water temperatures have been traditionally the warmest during late winter and early spring when the water column is unstable (SCE 1980e). Consequently, abundances were lowest in April and increased before June and August.

Deep Sand Habitat - Seriphus politus (Queenfish)

Fewer queenfish juveniles and adults were caught by trawling in the deep sand habitat compared to the shallow sand habitat (Figures 6A-9 and 6A-19). Though seasonal abundance patterns have been observed in past years, catches fluctuated in 1980. Catches were greatest during February for juveniles, and during February and April for adults.

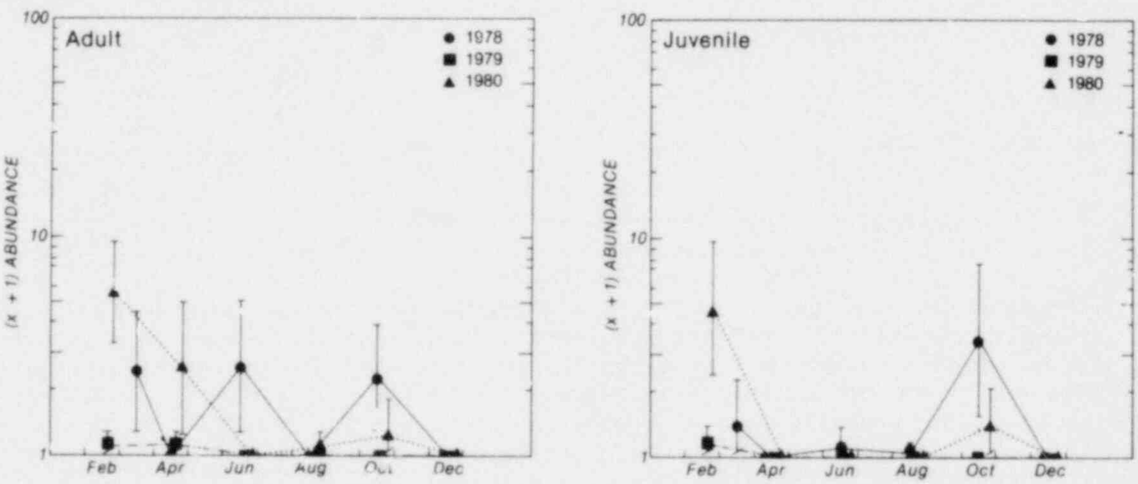

Figure 6A-19. Geometric mean abundance and 90% confidence limits for adult and juvenile *Seriphus politus* collected by otter trawls in the deep sand habitat (18.3 m) during 1978, 1979, and 1980.

Queenfish inhabiting the deep sand habitat had size class modes that were larger than those in the shallow habitat. Older individuals, age 1+ and 2+ or older, comprised 12% and 17% of the annual catch in the deep zone, but only 5% and 6% in the shallow habitat. The dominant size classes were the young-of-the-year (65-85 mm, 2.6-3.4 in. SL) and age 1+ queenfish (120-135 mm, 4.7-5.3 in. SL). The length frequency distribution of S. politus in the deep habitat during

198O was similar to that observed in 1978. Few queenfish were captured in the deep habitat during 1979.

Most queenfish were caught in February and April only. The lack of size class data from the rest of 1980 may explain the differences in size distribution between habitats. A few 20-25 mm (0.8-1.0 in.) SL juveniles were caught in October. Sexual size dimorphism was observed only during February when females were larger than males (SCE 1981b). Similar to 1979 (SCE 1980e), more males were observed than females in the deep sand habitat during 1980 (Figure 6A-10).

Otter trawls conducted during 1980 in the deep sand habitat caught insufficient numbers of queenfish for statistical analysis of GSIs. A trend of reproductive activity, based on discontinuous data points, was similar to that observed for queenfish in the shallow sand habitat (Figure 6A-11), although mean gonad weights were comparatively smaller than those in the shallow sand habitat.

Deep Sand Habitat - Genyonemus lineatus (White croaker)

White cro[illegible] adults and juveniles have not displayed seasonal patterns of abundance in [illegible] deep sand habitat in past years (Figure 6A-20). In 1980 large numbers of fi[illegible] were taken in February, after which catches were low.

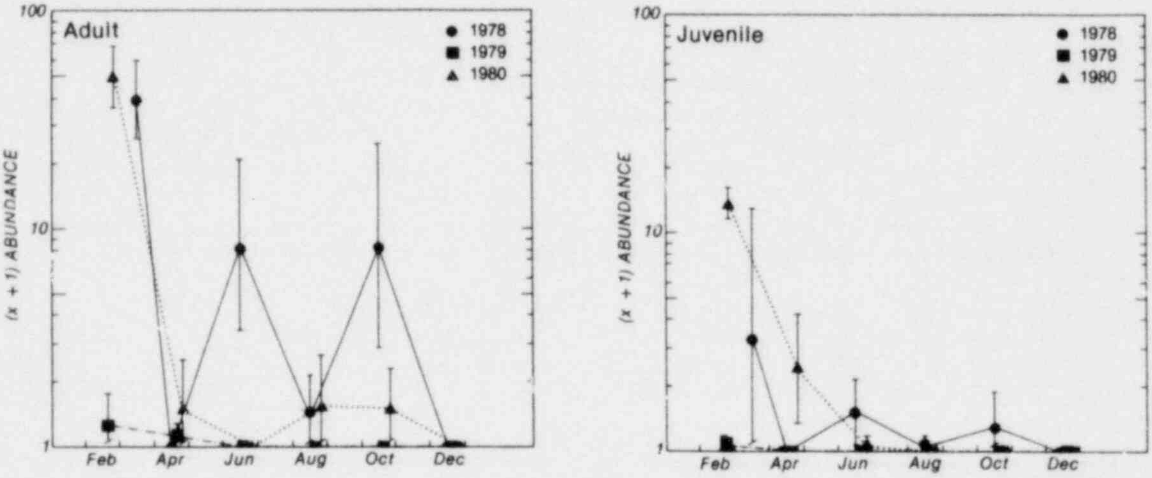

Figure 6A-20. Geometric mean abundance and 90% confidence limits for adult and juvenile *Genyonemus lineatus* collected by otter trawls in the deep sand habitat (18.3 m) during 1978, 1979, and 1980.

Thirty percent of the white croaker captured were age 3+ or older (170-179 mm, 6.7-7.0 in. SL). This pattern was consistent with 1978 results, when an even higher percentage of adults was captured. Most of the largest individuals were females, while in the smaller size classes (100-170 mm, 3.9-6.7 in. SL), males and females overlapped in size. A few juveniles (10-20 mm, 0.4-0.8 in. SL) were caught in this area during April. Significantly more male than female white croaker were caught in the deep sand habitat (Figure 6A-10).

As in shallower water, white croaker reproduced in winter, though too few white croaker were captured to be statistically analyzed. Some comparative aspects of reproductive activity in the deep and shallow sand habitats are detailed in the shallow depth results.

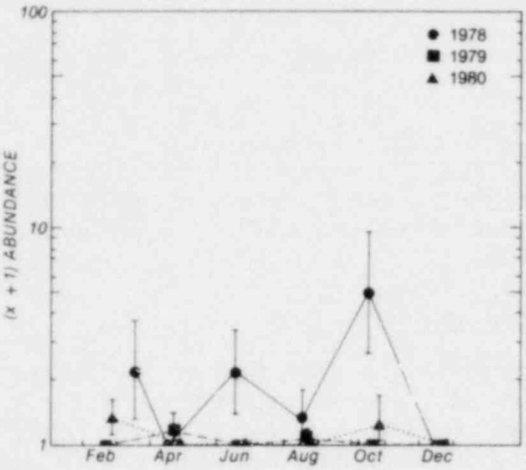

Figure 6A-21. Geometric mean abundance and 90% confidence limits for *Hyperprosopon argenteum* collected by otter trawls in the deep sand habitat (18.3 m) during 1978, 1979, and 1980.

Deep Sand Habitat - Hyperprosopon argenteum (Walleye surfperch)

As in 1979, walleye surfperch were collected infrequently in the deep sand habitat (Figure 6A-21). Hyperprosopon argenteum were commonly taken in 1978.

Similar to 1978 (SCE 1979d), two modal size classes, young-of-the-year (80-100 mm, 3.2-3.9 in. SL) and combined age 1+ and 2+ (110-135 mm, 4.3-5.3 in. SL), were present during 1980. Consistent with observations in 1978 and 1979 (SCE 1979d, 1980e), sex composition did not differ from a 1:1 ratio (Figure 6A-10).

Deep Sand Habitat - Phanerodon furcatus (White surfperch)

During the past three years white surfperch in the deep sand habitat have been taken in low numbers with no distinct seasonal pattern (Figure 6A-22). During October 1980, coincident with high catches of adult P. furcatus in the shallower zone, there was a slight increase in catch. The majority of white surfperch collected were adults though a few young-of-the-year, 90-95 mm (3.5-3.7 in. SL), were also caught. Juvenile white surfperch have not been caught during this study in this habitat prior to 1980 (SCE 1979d, 1980e).

Similar to 1978 (SCE 1979d), sex composition was nearly a 1:1 ratio during the 1980 surveys (Figure 6A-10). This trend differed from the slight female majority in 1979 catches (SCE 1980e).

Deep Sand Habitat - Paralichthys californicus (California halibut)

Fewer California halibut were caught in the deep sand than in the shallow sand habitat. Over the past two years of study the San Onofre catches of California halibut have lacked distinct seasonality (Figure 6A-23). In 1980,

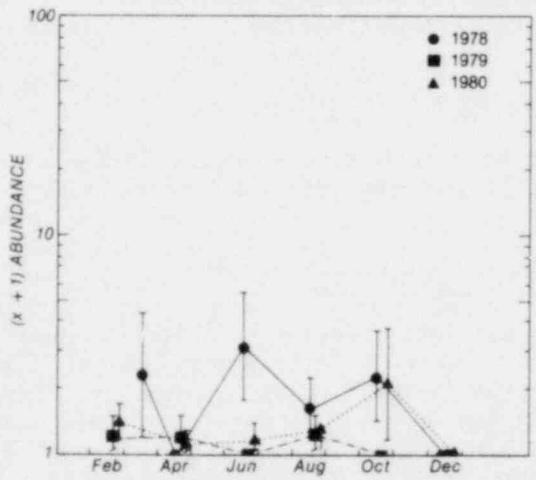

Figure 6A-22. Geometric mean abundance and 90% confidence limits for *Phanerodon furcatus* collected by otter trawls in the deep sand habitat (18.3 m) during 1978, 1979, and 1980.

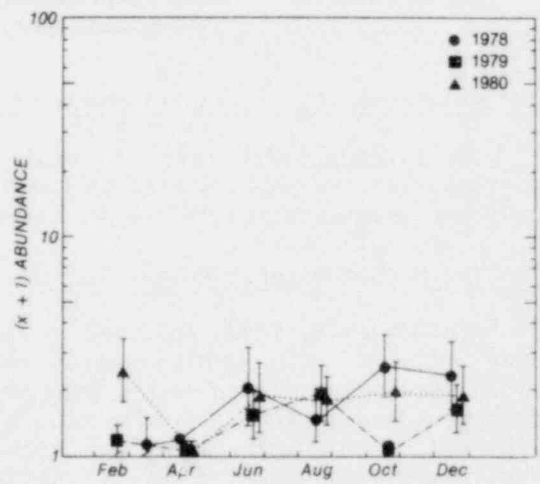

Figure 6A-23. Geometric mean abundance and 90% confidence limits for *Paralichthys californicus* collected by otter trawls in the deep sand habitat (18.3 m) during 1978, 1979, and 1980.

however, the observed abundance level in April was lower than during any other survey.

Consistent with 1978 and 1979 catches (SCE 1979d, 1980e), larger and older individuals dominated the catch. Age 2+ individuals were most abundant, with age 1+ fish taken in low numbers (primarily in February) and a few age 3+ individuals captured every month except April. Running-ripe males were captured in high percentages (33-50%) throughout 1980 except April.

Deep Sand Habitat - Engraulis mordax (Northern anchovy)

Adult northern anchovy were rarely captured in the deep sand bottom habitat during 1979 and 1980 (Figure 6A-24). Even when adults were captured frequently in 1978, the level of capture was less than in the shallow habitat. Larval engraulids were caught in similar abundances in both habitats during 1979 and 1980 (Figures 6A-17 and 6A-24). As observed in the shallow habitat, larval anchovies are seasonally abundant during spring and late summer or fall.

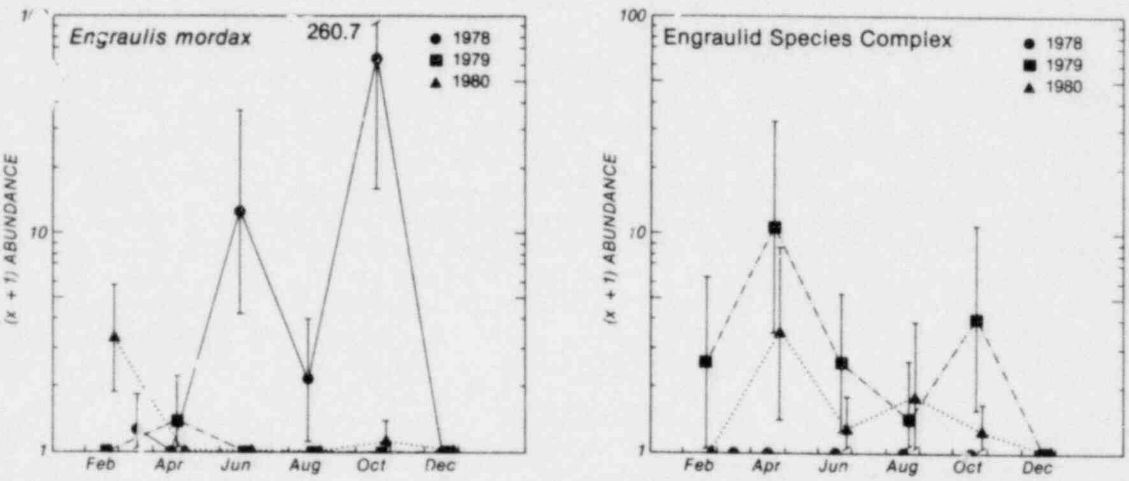

Figure 6A-24. Geometric mean abundance and 90% confidence limits for adult *Engraulis mordax* and Engraulid Species Complex larvae collected by otter trawls in the deep sand habitat (18.3 m) during 1978, 1979, and 1980.

Deep Sand Habitat - Citharichthys stigmaeus (Speckled sanddab)

Speckled sanddab have, in past years, been much more abundant in the deep rather than the shallow sand bottom habitat, though the 1980 catch (Figure 6A-25) was uncharacteristically low in the deep zone.

Cobble Bottom Without Kelp - Seriphus politus (Queenfish)

During 1978, 1979, and 1980, S. politus was less abundant in winter (February and December) than during spring and summer (April-August; Figure 6A-26). The 1980 mean catch during each survey was less than in past years, especially during February and April. During February when catches were low elsewhere, catches near the Unit 1 discharge were much higher. In April, more queenfish were caught at San Mateo Point (9.1 m, 30 ft) and Don Light (13.7 m, 45 ft) than other cobble bottom areas without kelp. During the remainder of the year, all catches from cobble bottom areas without kelp forests were similar.

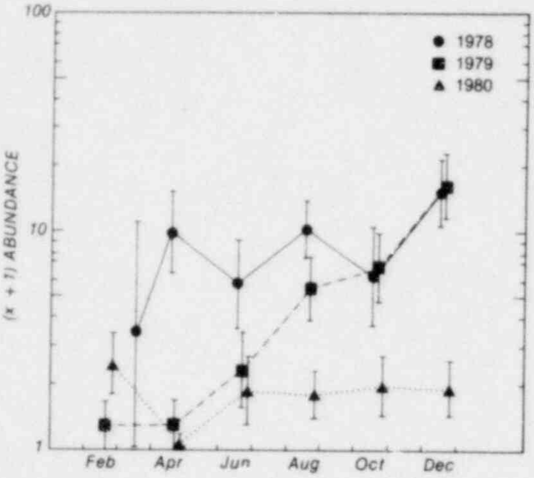

Figure 6A-25. Geometric mean abundance and 90% confidence limits for *Citharichthys stigmaeus* collected by otter trawls in the deep sand habitat (18.3 m) during 1978, 1979, and 1980.

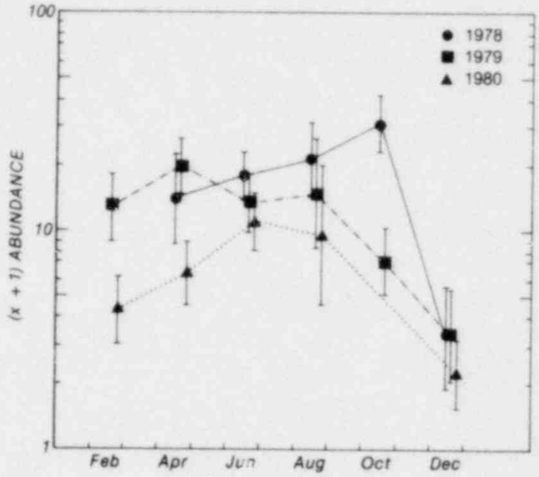

Figure 6A-26. Geometric mean abundance and 90% confidence limits for *Seriphus politus* captured in gill nets set in the cobble habitat without kelp (9.1 and 13.7 m) during 1978, 1979, and 1980.

A bimodal size distribution of queenfish was captured throughout the year. Ages 1+ and 2+ (125-139 mm, 4.9-5.5 in. SL and 140-149 mm, 5.5-5.9 in. SL) comprised the first mode and 34 percent of the queenfish catch. The other mode was composed of individuals 4+ or older (160-240 mm, 6.3-9.4 in. SL) and represented 62 percent of the annual catch.

Significantly ($P < 0.05$) more females than males were captured along the 9.1-m isobath (Figure 6A-10). This pattern was evident during all surveys of 1979 and 1980 (SCE 1980e, 1981b). The majority of the 1980 catch along 9.1-m isobath and on the 13.7-m isobath at Don Light (SCE 1981b) was made in August.

Seriphus politus reproductive cycle (Figure 6A-27) was similar to that observed in the shallow sand habitat in 1980 and in 1979. Queenfish in the Don Light areas (9.1 and 13.7 m) had significantly ($P < 0.05$) larger mean gonad weights than queenfish at other locations with this habitat type. Females at Don Light were not significantly larger than in other areas.

Cobble Bottom without Kelp - Genyonemus lineatus (White croaker)

G. lineatus decreased in mean abundance as the year progressed (Figure 6A-28). Variations in this pattern did occur within past years of the study. For example, though low catch of white croaker occurred in April 1980, the 1978 peak catches occurred in April (Figure 6A-28). In general, gill net catches were the highest in the Don Light area at 9.1 and 13.7 m until December when gill nets set within 50 m (164 ft) of the Unit 1 discharge collected more (SCE 1981b).

The 1980 size composition was bimodal. The first mode was comprised mainly of age 1+ (105-140 mm, 4.3-5.5 in. SL), while the second mode was composed of nearly equal numbers of ages 3+ and 4+ (155-169 mm, 6.1-6.6 in. SL and 170-179 mm, 6.7-7.0 in. SL) (LES 1981; SCE 1981b). Age 2+ (135-154 mm, 5.3-6.1 in. SL) individuals occurred less frequently (13%) than age 3+ (17%) individuals. Large adults (170-244 mm, 6.7-9.6 in. SL) were primarily captured in February, while the majority of the youngest white croaker (age 1+) were caught in August. No age 0+ individuals were collected.

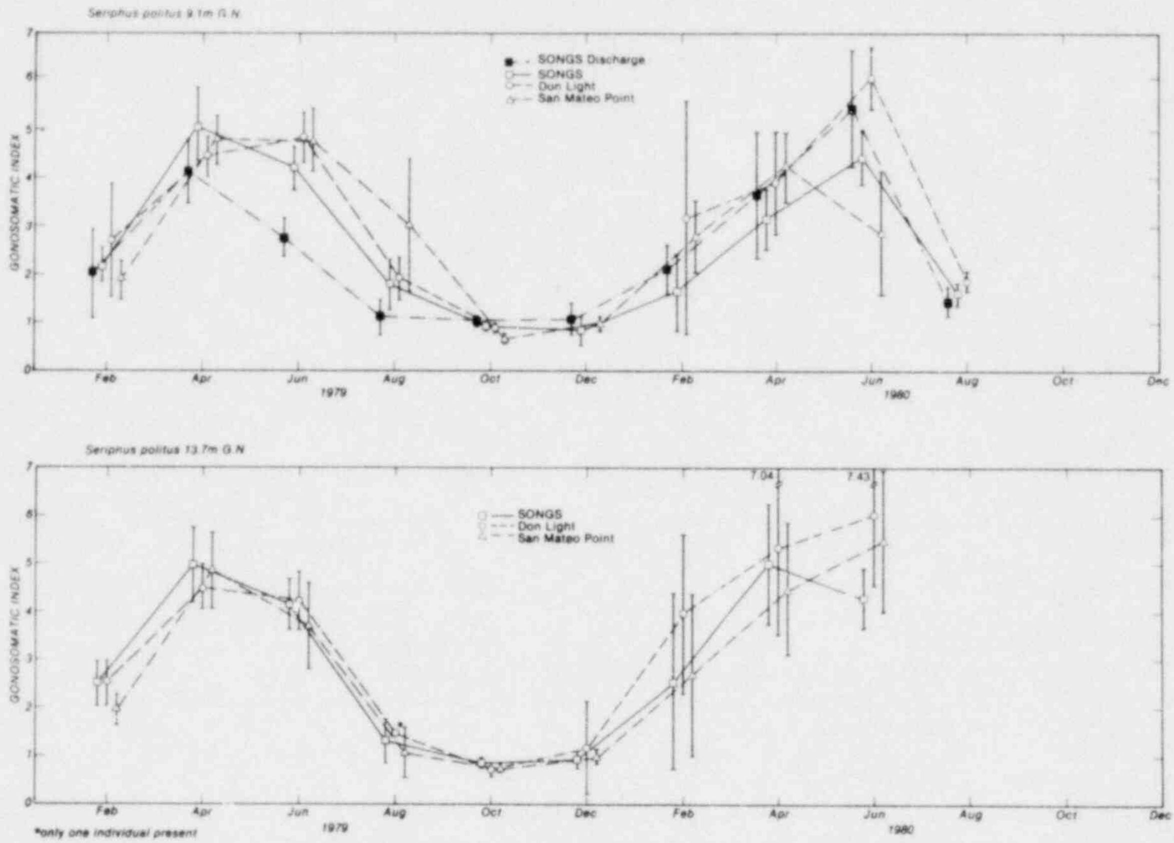

Figure 6A-27. Gonosomatic indices (gonad wet weight x 100/total body wet weight) of *Seriphus politus* captured in gill nets set in the cobble habitat without kelp (9.1 and 13.7 m) and cobble habitat with kelp (13.7 m) during 1979 and 1980.

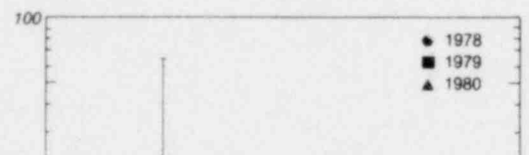

Figure 6A-28. Geometric mean abundance and 90% confidence limits for *Genyonemus lineatus* captured in gill nets set in the cobble habitat without kelp (9.1 and 13.7 m) during 1978, 1979, and 1980.

Significantly ($P \leq 0.05$) more females than males were captured, (Figure 6A-10) except at a station 500 m (0.31 mi) upcoast of the Unit 1 discharge (Stations 1 and 2).

Genyonemus lineatus reproduced during the winter. This was similar to 1979 findings (Figures 6A-13 and 6A-29). Analysis of mean gonad weights detected no differences between cobble areas without kelp on the 9.1-m isobath or between depths within an area of cobble without kelp (i.e., Don Light 9.1 and 13.7 m).

Cobble Bottom Without Kelp - *Hyperprosopon argenteum* (Walleye surfperch)

Similar to previous years, *H. argenteum* were taken in approximately equal numbers throughout 1980 (Figure 6A-30). Within this habitat, walleye surfperch was captured less frequently in the area

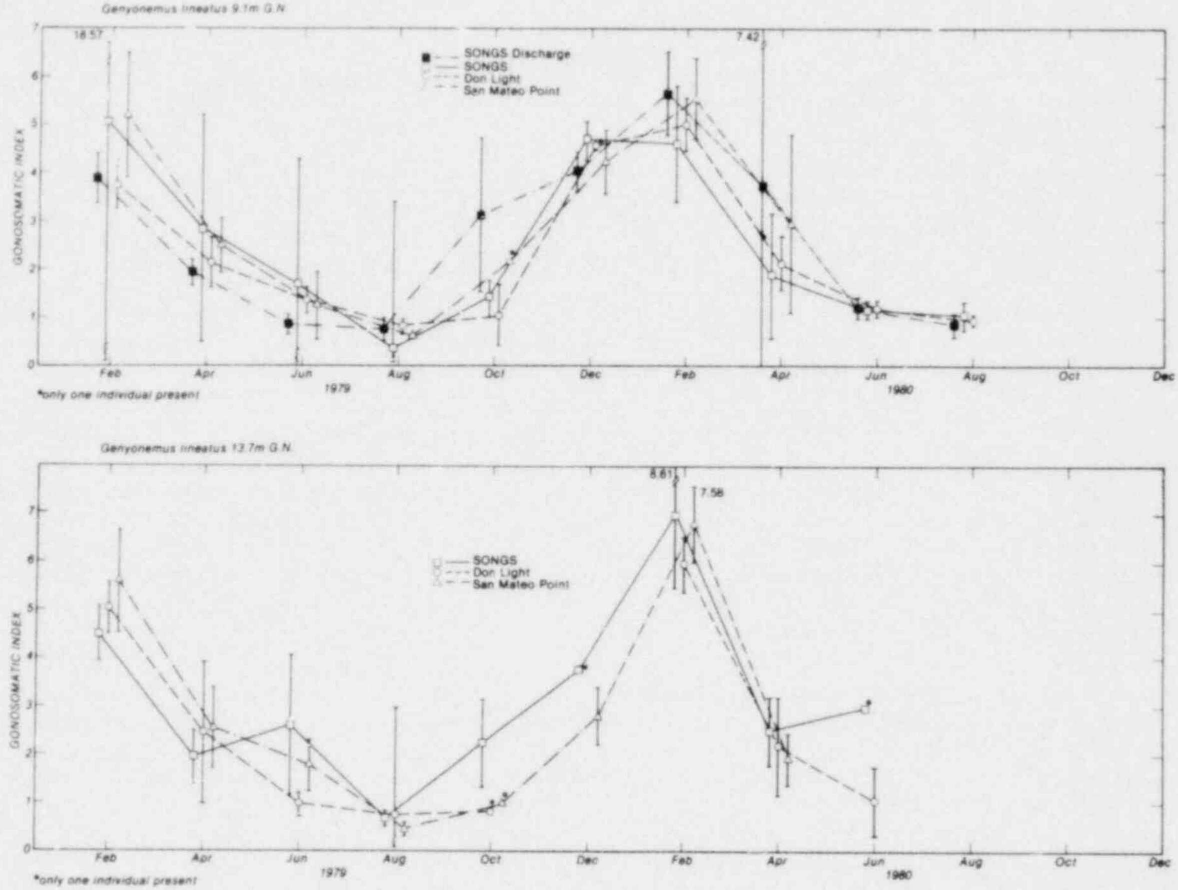

Figure 6A-29. Gonosomatic indices (gonad wet weight x 100/total body wet weight) of *Genyonemus lineatus* captured in gill nets set in the cobble habitat without kelp (9.1 and 13.7 m) and cobble habitat with kelp (13.7 m) during 1979 and 1980.

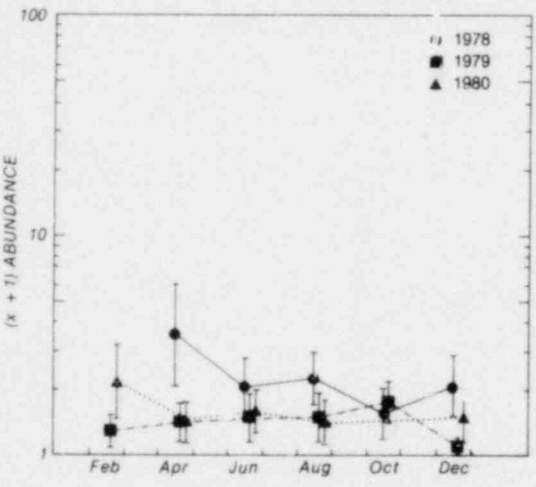

Figure 6A-30. Geometric mean abundance and 90% confidence limits for *Hyperprosopon argenteum* captured in gill nets set in the cobble habitat without kelp (9.1 and 13.7 m) during 1978, 1979, and 1980.

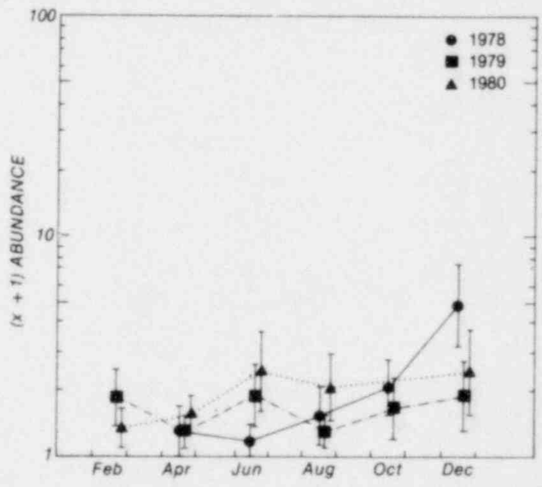

Figure 6A-31. Geometric mean abundance and 90% confidence limits for *Phanerodon furcatus* captured in gill nets set in the cobble habitat without kelp (9.1 and 13.7 m) during 1978, 1979, and 1980.

within 50 m of the Unit 1 discharge. The main age/size class caught in this habitat was age 1+ (90-125 mm, 3.5-4.9 in. SL) (Eckmayer 1979; LES 1981; SCE 1981b), though age 0+ (≤ 90 mm, 3.5 in. SL) H. argenteum were caught in February, August, and December. No major differences in length frequency distribution between 1979 and 1980 were observed (SCE 1980e, 1981b).

Consistent with the pattern observed in 1978 and 1979 (SCE 1979d,1980e), equal numbers of males and females were captured (Figure 6A-10).

Cobble Bottom Without Kelp - Phanerodon furcatus (White surfperch)

Over the past three years (Figure 6A-31), white surfperch have been captured in low numbers. In 1978 and 1980 a slight increase in catch has been noted in December (SCE 1980e, 1981b).

White surfperch captured were generally older than walleye surfperch during most of 1980. The modal size distribution of white surfperch was similar throughout 1980 (160-185 mm, 6.3-7.3 in. SL), except in December when mainly older and larger individuals were collected. These were primarily age 2+ (140-160 mm, 5.5-6.3 in. SL) through age 7+ (215 mm, 8.5 in. SL). Young-of-the-year (≤ 105 mm, 4.1 in. SL; Eckmayer 1979) were caught in high numbers only during December. Age 1+ (105-140 mm, 4.1-5.5 in. SL; Eckmayer 1979) were infrequently captured during 1980, except in June and August.

Male and female white surfperch were caught in similar numbers from this habitat. In the one deeper area (Don Light 13.7 m), female P. furcatus were more abundant, mainly during June (Figure 6A-10). Past trends of sexual composition for this habitat are similar to the 1980 results (SCE 1979d, 1980e).

Cobble Bottom With Kelp - Seriphus politus (Queenfish)

Fewer queenfish were captured during 1980 than in past years (Figure 6A-32). Though their abundance was not seasonal, queenfish catches did vary between years during some months (Figure 6A-32).

Age 1+ and 2+ queenfish predominated the catch during the first half of 1980. Age 3+ was poorly represented and fish age 4+ or older (> 160 mm, 6.3 in. SL) were also under-represented (30%) in kelp areas compared to catches from non-kelp areas (50%) during the first three 1980 surveys. Queenfish exhibited a nearly equal annual sex composition (Figure 6A-10). However, in April more males were taken (SCE 1980a,b). Queenfish reproduced at the same season as conspecifics taken in other habitats (Figure 6A-27). Female queenfish caught in this habitat had mean gonad weights that were significantly ($P \leq 0.05$) larger than those caught directly inshore in cobble areas devoid of kelp.

Cobble Bottom With Kelp - Genyonemus lineatus (White croaker)

White croaker catches demonstrated a major winter peak, mid-year (June) decline, an August recovery, and declining catches in fall and early winter (Figure 6A-33). Mean catches during 1980 surveys appeared to be lower than those of 1978 and 1979. However, only June was significantly lower (Figure 6A-33). In June there were low catches in areas with kelp (San Mateo Point and San Onofre) and high catches in areas without kelp (Don Light 13.7 m) (SCE 1981b).

White croaker caught near kelp had about the same bimodal length frequency distribution as areas without kelp. Most of the individuals were large, age 3+ or more (155-244 mm, 6.1-9.6 in. SL). Males and females were taken in equal numbers during the three 1980 surveys. In 1979 a majority of the fish were males (SCE 1980e), but in early 1978 (SCE 1979d), equal numbers were captured.

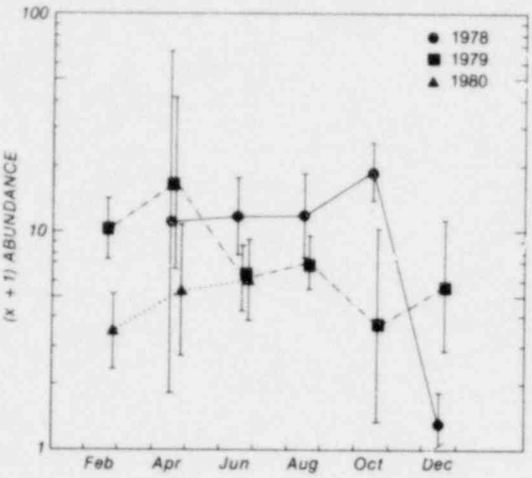

Figure 6A-32. Geometric mean abundance and 90% confidence limits for *Seriphus politus* collected by gill nets in the cobble habitat with kelp (13.7 m) during 1978, 1979, and 1980.

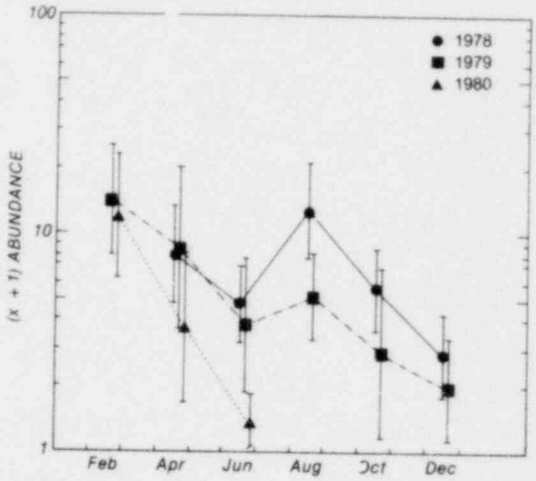

Figure 6A-33. Geometric mean abundance and 90% confidence limits for *Genyonemus lineatus* collected by gill nets in the cobble habitat with kelp (13.7 m) during 1978, 1979, and 1980.

White croaker collected in the cobble substratum habitat with kelp, like white croaker collected elsewhere, spawned in winter (Figure 6A-29). No differences in mean gonad weight were detected between areas with kelp or between kelp-forested and non-forested cobble bottom habitats.

Cobble Bottom With Kelp - Hyperprosopon argenteum (Walleye surfperch)

As in previous years walleye surfperch were captured in low abundance during the early half of 1980 (Figure 6A-34). During the two-year PMP study, the cobble habitats with kelp have had highest abundance levels in the summer and fall (August-October). No age 0+ (< 90 mm, 3.5 in. SL) walleye surfperch were caught during 1980 (SCE 1981b). Of the few fish taken, nearly all were age 1+ (90-125 mm, 3.5-4.9 in. SL).

Consistent with observations in 1978 and 1979 (SCE 1979d, 1980e), males and females were taken in equal numbers (Figure 6A-10).

Cobble Bottom With Kelp - Phanerodon furcatus (White surfperch)

More white surfperch were captured in areas with kelp than in the areas without kelp during 1980 (Figure 6A-35). Although, sampled only through June, the population abundance trend followed closely that observed in 1978-1980. August has been the time of peak catch with a substantial catch also in October and December 1978.

White surfperch captured during the first two 1980 surveys were mainly age 0+ and 1+, but older individuals (2+ through 5+, 140-200 mm, 5.51-7.87 in. SL) comprised the majority caught during June (SCE 1981b). This was similar to the length frequency distribution observed during the first three surveys of 1979 (SCE 1980e).

Consistent with the previous two years (SCE 1979d, 1980e), female white surfperch were more abundant than males during the 1980 surveys (Figure 6A-10).

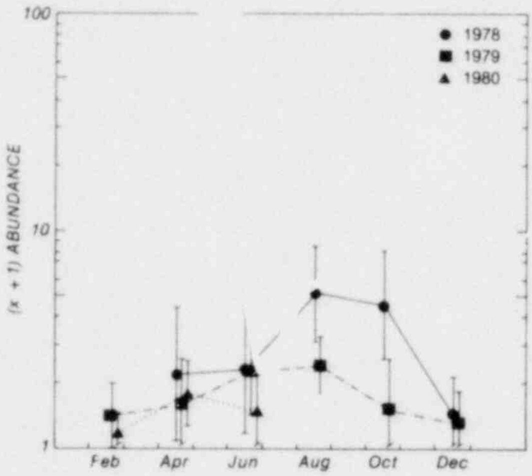

Figure 6A-34. Geometric mean abundance and 90% confidence limits for *Hyperprosopon argenteum* collected by gill nets in the cobble habitat with kelp (13.7 m) during 1978, 1979, and 1980.

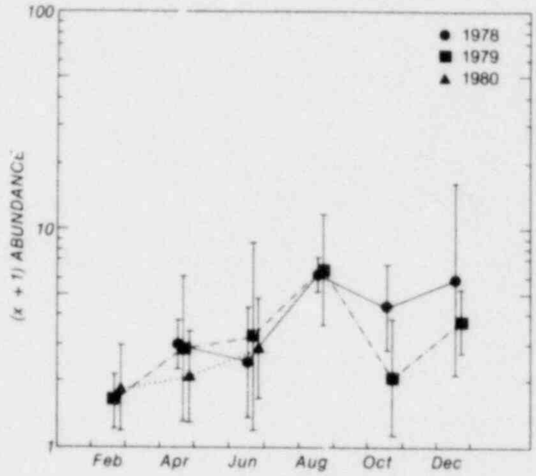

Figure 6A-35. Geometric mean abundance and 90% confidence limits for *Phanerodon furcatus* collected by gill nets in the cobble habitat with kelp (13.7 m) during 1978, 1979, and 1980.

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CHAPTER 6B

ADULT FISH IN-PLANT

INTRODUCTION

The ongoing marine monitoring studies reported in this chapter are being conducted to define the magnitude of impingement and to relate this information to offshore fish populations. These studies comply with Nuclear Regulatory Commission (NRC), and National Pollution Discharge Elimination System (NPDES).

All 1980 biological data analyzed in this chapter are presented in Volumes I and II of the Annual Operating Report, San Onofre Nuclear Generating Station-Biological Data 1980 (SCE 1981a,b).

This chapter presents a summary of data collected in 1980 and a review of past studies at San Onofre Unit 1. 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.

Estimates of the number and weight of the total impingement catch, the impingement catch of select species, and analysis of size (age) and sex structure of select impinged species are developed in this section. Size and sex structure of impinged fish is compared with offshore fish data to determine if San Onofre Unit 1 impingement is selective with respect to these factors.

BACKGROUND

HISTORICAL REVIEW (1963-1979)

In order to place the study objectives and results into perspective, a brief description of past impingement studies is presented.

From August 1968 to June 1971, thirty-three 8-h normal operational samples were taken on a monthly basis and 31 heat treatment samples were obtained. These surveys were conducted by generating station personnel who classified the impinged biomass with such general terms as "jellyfish, herring, croaker, etc.". Each report gives total pounds of "fish" impinged.

In 1972 biologists began surveying heat treatment losses. All fish were identified to species and an estimate was made of the number of fish of each species. Invertebrates and algae were also identified to species when possible and enumerated. The total weight of biomass was given and an estimate of the weight distribution between fish, algae, and invertebrates.

Beginning in 1974 heat treatments were expanded to include counts as well as weights of fish by species and up to 125 fish of each species were measured for standard length. In addition, normal operation sampling was completed for one 24-h period per week for 3 weeks following a heat treatment then twice per week thereafter. Since October 1978, normal operation sampling has been maintained at approximately twice per week during normal operational periods (all circulating

water pumps in operation) with additional abiotic observations including wind, weather, intake sea temperature, and turbidity measured in the screenwell using a nephalometric turbidimeter.

1980 STUDY

In-plant sampling of impinged fish species including lengths, weights, and sex of resident and select species during 2 heat treatments and 32, 24-h normal operation periods continued during 1980 through April. In-plant sampling was discontinued during May, due to periodic plant maintenance, but resumed in June and July. During this time, the generating station was not operational but the pumps were circulating water. Impingement sampling was not continued after July as the generating station remained non-operational from July through the end of 1980 due to plant maintenance.

DISCUSSION

The 1980 estimate of total fish impinged by San Onofre Unit 1, standardized to 152 operational days between January and July, indicates that more fish were impinged per day in 1980 than during the previous five years (Table 6B-1). Impingement of select species (queenfish, white croaker, walleye surfperch, and white surfperch) followed a similar trend. Evaluation of monthly impingement rates for select species over the past four years indicates that highest impingement catches occur from January through July (Table 6B-2). This distinct seasonality results from the synergistic effects of seasonal movement and reproductive patterns coupled with oceanic disturbances in the form of storms and localized upwelling.

Table 6B-1. Total yearly and daily mean† impingement by number and weight (lbs) for all species and *Seriphus politus*, queenfish; *Genyonemus lineatus*, white croaker; *Hyperprosopon argenteum*, walleye surfperch, and *Phanerodon furcatus*, white surfperch from 1975 to 1980.

	1975		1976		1977		1978		1979		1980	
	no.	lbs.	no.	lbs.	no.	lbs.	no.	lbs.	no.	lbs.	no.	lbs.
All Species												
Total yearly	296,319	30,832	198,266	24,631	235,555	20,625	601,.93	43,820	584,647	52,916	·59,573	48,069
Daily mean	935	97	734	91	832	73	1,991	145	1,602	145	3,024	316
Seriphus politus												
Total yearly	210,868	14,298	155,631	11,484	33,133	1,730	372,520	16,247	430,966	19,898	323,404	15,880
Daily mean	665	45	576	43	117	6	1,234	54	1,181	55	2,128	105
Genyonemus politus												
Total yearly	12,851	765	1,504	52	6,758	472	76,048	5,422	23,794	1,912	38,444	5,102
Daily mean	41	2	6	0.2	24	2	252	18	65	5	253	34
Hyperprosopon argentuem												
Total yearly	38,187	2,547	20,511	1,639	24,790	2,209	45,763	4,302	60,534	3,504	36,963	2,761
Daily mean	121	8	76	6	88	8	152	14	166	10	243	18
Phanerodon furcatus												
Total yearly	5,975	367	3,335	471	3,451	196	10,383	571	10,393	503	5,271	441
Daily mean	19	1	12	2	12	1	34	2	29	1	35	3
Days of operation	317		270		283		302		365		152	

† Yearly estimated impingement divided by the days of operation for the year.

High impingement catches of queenfish and white croaker from January through March are likely the result of recruitment of larval individuals to the epibenthic and midwater portions of the water column (SCE 1980e) coupled with storm activity during this portion of the year. Assuming that monthly rainfall totals are an index of storm activity, the combined rainfall totals for January, February, and March 1980 accounted for over 91 percent of the annual 1980 total. Perhaps the coincident occurrence of newly recruited larvae and frequent storms increases the susceptibility of young fish to impingement during this time of the

Table 6B-2. Mean monthly impingement catch by number per operational day for *Seriphus politus*, queenfish; *Genyonemus lineatus*, white croaker; *Hyperprosopon argenteum*, walleye surfperch; and *Phanerodon furcatus*, white surfperch from 1977 to 1980. The number of operational days/month equals the mean monthly flow (gallons/day) divided by the mean daily normal flow (4.8 x 10^8 gallons) multiplied by the number of days/month.

	J	F	M	A	M	J	J	A	S	O	N	D
Seriphus politus												
1977	†	†	†	74	17	6	33	5	18	19	10	10
1978	44	69	35	137	74	26	23	63	28	-	8	10
1979	37	229	79	128	109	306	208	175	141	125	71	70
1980	207	714	528	1,119	299	530	†	†	†	†	†	†
Genyonemus lineatus												
1977	†	†	†	4	1	<1	<1	<1	<1	<1	<1	4
1978	1	5	1	1	10	5	3	54	<1	-	<1	1
1979	2	6	1	2	1	19	21	35	6	6	1	1
1980	48	315	26	11	2	13	†	†	†	†	†	†
Hyperprosopon argenteum												
1977	†	†	†	12	2	1	1	1	7	1	7	3
1978	28	14	5	6	1	3	2	6	1	-	1	1
1979	11	75	2	3	2	25	40	15	11	4	38	4
1980	74	115	33	21	4	13	†	†	†	†	†	†
Phanerodon furcatus												
1977	†	†	†	1	<1	<1	1	<1	1	<1	<1	<1
1978	1	1	1	2	2	1	1	2	<1	-	<1	<1
1979	1	2	<1	1	3	25	12	4	1	<1	1	1
1980	1	22	3	22	8	17	†	†	†	†	†	†

† Plant offline for maintenance

year. As suggested previously (SCE 1980e), high impingement catch of walleye and white surfperch coincides with offshore movements of females which were inseminated in shallow water during fall and early winter. The offshore movement of burdened females at a time of severe weather disturbance may make them more vulnerable to impingement (SCE 1980e). Additionally, pregnant female surfperch tend to have reduced ability to avoid intake current velocities as measured by their swimming performance (Dorn et al. 1979).

By April, storm activity usually subsides, however, a second seasonal disturbance in the form of localized upwelling begins and continues sporadically through July off San Onofre (Barnett et al. 1980). Increased impingement catches of queenfish in April 1980 resemble those observed in April 1978 and to a lesser extent April 1979. The co-occurrence of upwelling and increased impingement catch of queenfish for the past three years suggests that newly recruited and reproductively active individuals are vertically migrating to avoid the intrusion of colder upwelled water (Chapter 6A). In doing so, these fish may become more susceptible to entrapment and subsequent impingement in the Unit 1 cooling water

system. The virtual absence of juvenile queenfish from otter trawl samples during April and June, and the presence of queenfish in lampara nets (DeMartini 1981) during this period appear to substantiate this scenario.

Comparison of the size structure of queenfish sampled in-plant and by otter trawl and gill nets between 1979 and 1980 revealed similar patterns for February, April, and June. The juveniles present in otter trawl and impingement samples during these months represent juveniles spawned late in 1978-1979 since young-of-the-year (age 0+) do not generally appear inshore until August (SCE 1980e). Thus, impingement data was not available during the period in 1980 when larval impingement and entrainment are historically the greatest.

The impingement catches relative to otter trawl and gill net catches from 1978 to 1980 appear to be sampling the same size classes available in the offshore population with the exception of juveniles 20-40 mm (0.8-1.6 in.) SL and larger (> 170 mm, 6.7 in. SL) females caught in gill nets. The absence of 20- to 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 pronounced shift in impingement from female to male queenfish during early 1980 is unexplainable at this time. Analysis of trawl and gill net data indicated that females were generally more numerous than males in all but two surveys (June, August; see Chapter 6A). Although males generally outnumbered females in February, April, and June impingement samples, numerical dominance by males was significant only for February and April samples. Male queenfish dominance in 1980 represents a reversal in pattern from the female dominance observed since 1978. Perhaps severe storm activity early in 1980 resulted in a change in the spatial distribution of males relative to females thereby increasing their susceptibility to impingement. This pattern, however, was not observed in early 1978 which was also extremely stormy (SCE 1979d).

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

METHODS

HEAT TREATMENT

Heat treatments practiced at San Onofre 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 on an as-required schedule based upon a conduit biofouling growth model (LCMR 1977b) and operational requirements of the plant.

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 possible.

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 h 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, and (3) estimating sex ratios of sel.ct species.

The annual impingement catch in weight and numbers of fish is estimated as the sum of monthly means weighted by the total number of 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 (mo:.th)

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 San Onofre Unit 1 impingement catch. Analysis of length frequency samples for other select species (see Chapter 6A) 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 (5, 26, 19 February and 4 March; 1, 4, 8 April; 17, 20, 24, 27 June) 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.

RESULTS

ANNUAL IMPINGEMENT ESTIMATE

The estimate of 1980 fish impingement is based upon 32 normal flow impingement samples and 2 heat treatment samples conducted during the first 7 months of

Table 6B-3. Rank order of abundance by numbers of individuals of each species impinged during 1980.

Rank	Species	Common Name	Number of Individuals	Percent of Total
1	Seriphus politus	Queenfish	323,404	69.47
2	Genyonemus lineatus	White croaker	38,444	8.26
3	Hyperprosopon argenteum	Walleye surfperch	36,963	7.94
4	Engraulis mordax	Northern anchovy	16,585	3.56
5	Atherinopsis californiensis	Jacksmelt	16,247	3.49
6	Phanerodon furcatus	White surfperch	5,271	1.13
7	Leuresthes tenuis	California grunion	4,458	0.96
8	Anchoa compressa	Deep body anchovy	2,988	0.64
9	Peprilus simillimus	Pacific butterfish	2,962	0.64
10	Citharichthys stigmaeus	Speckled sanddab	1,581	0.34
11	Menticirrhus undulatus	California corbina	1,420	0.31
12	Urolophus halleri	Round stingray	1,342	0.29
13	Roncador stearnsi	Spotfin croaker	1,184	0.25
14	Porichthys notatus	Plainfin midshipman	1,023	0.22
15	Atherinops affinis	Topsmelt	1,009	0.22
16	Cymatogaster aggregata	Shiner surfperch	939	0.20
17	Scorpaena guttata	Sculpin	784	0.17
18	Embiotoca jacksoni	Black surfperch	670	0.14
19	Otophidium scrippsi	Basketweave cusk eel	638	0.14
20	Paralichthys californicus	California halibut	532	0.11
21	Umbrina roncador	Yellowfin croaker	522	0.11
22	Amphistichus argenteus	Barred surfperch	511	0.11
23	Paralabrax nebulifer	Barred sandbass	501	0.11
24	Syngnathus spp.	Pipefish	476	0.10
25	Xenistius californiensis	Salema	372	0.08
26	Platyrhinoidis triseriata	Thornback	358	0.08
27	Squalus acanthias	Spiny dogfish	335	0.07
28	Heterostichus rostratus	Giant kelpfish	332	0.07
29	Anisotremus davidsoni	Sargo	330	0.07
30	Girella nigricans	Opaleye	317	0.07
31	Torpedo californica	Pacific electric ray	306	0.07
32	Micrometrus minimus	Dwarf surfperch	263	0.06
33	Rhinobatos productus	Shovelnose guitarfish	208	0.04
34	Myliobatis californica	Bat ray	208	0.04
35	Hypsopsetta guttulata	Diamond turbot	202	0.04
36	Brachyistius frenatus	Kelp surfperch	168	0.04
37	Sebastes serranoides	Olive rockfish	154	0.03
38	Cheilotrema saturnum	Black croaker	142	0.03
39	Rhacochilus toxotes	Rubberlip surfperch	129	0.03
40	Damalichthys vacca	Pile surfperch	127	0.03
41	Triakis semifasciata	Leopard shark	119	0.03
42	Pleuronichthys ritteri	Spotted turbot	112	0.02
43	Mustelus californicus	Gray smoothhound	108	0.02
44	Cynoscion nobilis	White seabass	91	0.02
45	Pleuronichthys coenosus	C-O turbot	91	0.02
46	Sebastes rastrelliger	Grass rockfish	82	0.02
47	Hypsoblennius jenkinsi	Mussel blenny	65	0.01
48	Otophidium taylori	Spotted cusk-eel	57	0.01
49	Gymnura marmorata	California butterfly ray	50	0.01
50	Pleuronichthys verticalis	Hornyhead turbot	49	0.01
51	Porichthys myriaster	Specklefin midshipman	33	0.01
52	Heterodontus francisci	Horn shark	31	0.01
53	Hypsypops rubicunda	Garibaldi	30	0.01
54	Sebastes auriculatus	Brown rockfish	26	0.01
55	Scorpaenichthys marmoratus	Cabezon	21	0.00
56	Paralabrax clathratus	Kelp bass	19	0.00
57	Halichoeres semicinctus	Rock wrasse	14	0.00
58	Chromis punctipinnis	Blacksmith	13	0.00
59	Leptocottus armatus	Staghorn sculpin	12	0.00
60	Pimelometopon pulchrum	California sheephead	11	0.00
61.5	Parophrys vetulus	English sole	10	0.00
61.5	Sebastes paucispinis	Bocaccio	10	0.00
63	Xystreurys liolepis	Fantail sole	9	0.00
64	Raja binoculata	Big skate	8	0.00
65.5	Gymnothorax mordax	California moray	7	0.00
65.5	Oxyjulis californica	Senorita	7	0.00
68	Alopias vulpinus	Pelagic thresher	5	0.00
68	Hermosilla azurea	Zebra perch	5	0.00
68	Merluccius productus	Pacific hake	5	0.00
70	Vomer declivifrons	Pacific moonfish	4	0.00

1980. 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 32 normal operation samples and two heat treatment samples is presented in Volume II of the Annual Operating Report (SCE 1981b). Table 6B-3 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 6B-4. Table 6B-5 presents estimates of the number and weight of total fish and selected species using weighted monthly averages of catch for seven months in 1980.

Table 6B-4. Number and weight of select fish species impinged by San Onofre Unit 1 during 1980.

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	8,760	904.0	13,847	420.0	253	14.5	37,989	1,014.8	65,164	4,537.8	7
Feb	21,446	1,047.4	7,845	265.6	1,515	79.8	48,553	1,001.4	97,418	5,659.1	4
Mar	6,353	299.0	8,108	315.4	754	30.2	130,616	3,277.8	165,161	6,128.3	8
Apr	430	19.2	1,820	51.0	850	29.5	43,650	823.2	49,400	2,471.8	3
Jun	38	1.2	90	4.1	173	16.2	6,465	94.5	7,673	802.9	4
Jul	1,395	40.4	1,354	24.4	1,715	29.2	54,994	955.6	74,757	2,199.9	6

Table 6B-5. Annual estimate of number and weight of total fish and select species impinged during normal operation and heat treatments by San Onofre Unit 1 during 1980 based upon 32 24-h samples. 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
Genyonemus lineatus	38,421 ± 10,140	23	2,311.26 ± 849.68	2.50
Hyperprosopon argenteum	33,063 ± 8,919	3,900	1,080.49 ± 285.56	170.66
Phanerodon furcatus	5,260 ± 860	11	199.37 ± 41.60	1.02
Seriphus politus	322,267 ± 35,880	1,137	7,167.38 ± 909.87	34.70
Total Individuals	459,573 ± 54,893	5,936	21,799.85 ± 3,372.56	400.89
Combined Total	465,509		22,201	

Six species accounted for approximately 94% of the total (normal and heat treatment) impingement catch in 1980 (Table 6B-3). Queenfish, Seriphus politus, numerically dominated the impingement catch followed by white croaker, Genyonemus lineatus; walleye surfperch, Hyperprosopon argenteum; northern anchovy, Engraulis mordax; jacksmelt, Atherinopsis californiensis; and white surfperch, Phanerodon furcatus.

Estimated monthly normal operation impingement ranged from a maximum of 165,161 individuals weighing 6,128 kg (13,512 lb) in March to a minimum of 7,673 individuals weighing 803 kg (1,770 lb) in June (Table 6B-4). Impingement of select species by number and weight was greatest for queenfish in March, for white croaker in February, for white surfperch in February, and for walleye surfperch in January (Table 6B-4).

An estimated 459,573 ± 54,893 (1 standard deviation of the total) individuals weighing 21,799.85 ± 3,372.56 kg (48,069 ± 7,437 lbs) were impinged under normal operational conditions by San Onofre Unit 1 in 1980 (Table 6B-5). Select species

(queenfish, white croaker, walleye surfperch, and white surfperch), collectively accounted for 86.8% of the total impingement catch by number and 49.4% by weight. Individually, 70.1% of the normal flow impingement by number was accounted for by queenfish, 8.4% by white croaker, 7.2% by walleye surfperch, and 1.1% by white surfperch. Queenfish, by weight, accounted for 32.9%, white croaker for 10.6%, walleye surfperch for 5.0%, and white surfperch for 0.9%.

A total of 5,936 individuals weighing 400.89 kg (884 lb) were impinged in two heat treatments in 1980. Walleye surfperch accounted for 65.7% of the total number of individuals impinged in heat treatments while white croaker, white surfperch, and queenfish accounted for 0.4%, 0.2%, and 19.2%, respectively. By weight, walleye surfperch again dominated the catch with 42.6%, white croaker with 0.6%, white surfperch with 0.3%, and queenfish with 8.7%. The average weight per impinged fish was 0.05 kg (0.1 lb) based upon the combined normal flow and heat treatment catches by number and weight in 1980 (Table 6B-5).

LENGTH FREQUENCY ANALYSIS

Analysis of size structure of Seriphus from receiving water samples and impingement samples is presented to determine if Unit 1 is selectively removing a size class or classes from offshore populations. Seriphus was selected for study because it numerically 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 San Onofre area only. Genyonemus is not considered because impingement catches of this species were highly variable in 1980.

Figures 6B-1 through 6B-3 depict the size structure of Seriphus for impingement, gill net, and otter trawl catches in February, April, and June 1980.

The length structure of juvenile queenfish (< 120 mm, 4.7 in. SL) impinged in 1980 displayed seasonal patterns similar to those observed in 1979 (SCE 1980e). Length distribution was unimodal from February through June with modal length generally increasing from 75 mm (3.0 in.) SL in February to 90 mm (3.5 in.) SL in June (Figures 6B-1 through 6B-3). Juveniles as small as 30 mm (1.2 in.) SL were sampled in the impingement catch (Figure 6B-3) in June.

Otter trawl catch of juvenile queenfish was limited to February (Figure 6B-1). Length structure of juveniles caught in otter trawls during this time was similar to that observed for impinged juveniles (Figure 6B-1) in February.

Adult queenfish length structure in-plant and offshore was similar throughout 1980 (Figures 6B-1 through 6B-3). Modal lengths varied little in February, April, and June for queenfish impinged or caught in the otter trawl.

Like gill net catches of adult queenfish in 1979, gill nets in 1980 were more effective at catching relatively large females and individuals no smaller than 120 mm SL. Unlike 1979, however, the length structure of adult queenfish was not bimodal (Figures 6B-1 through 6B-3). Rather than a bimodal structure, length frequency of queenfish caught in gill nets was highly variable with sizes ranging from 120 mm SL to 230 mm (9.1 in.) SL.

SEX COMPOSITION

The sex ratios of male and female Seriphus represented by impingement, gill net, and otter trawl samples are presented in Figure 6A-11. Impingement samples were grouped within each month so that they coincided, as closely as possible, with offshore fish survey dates.

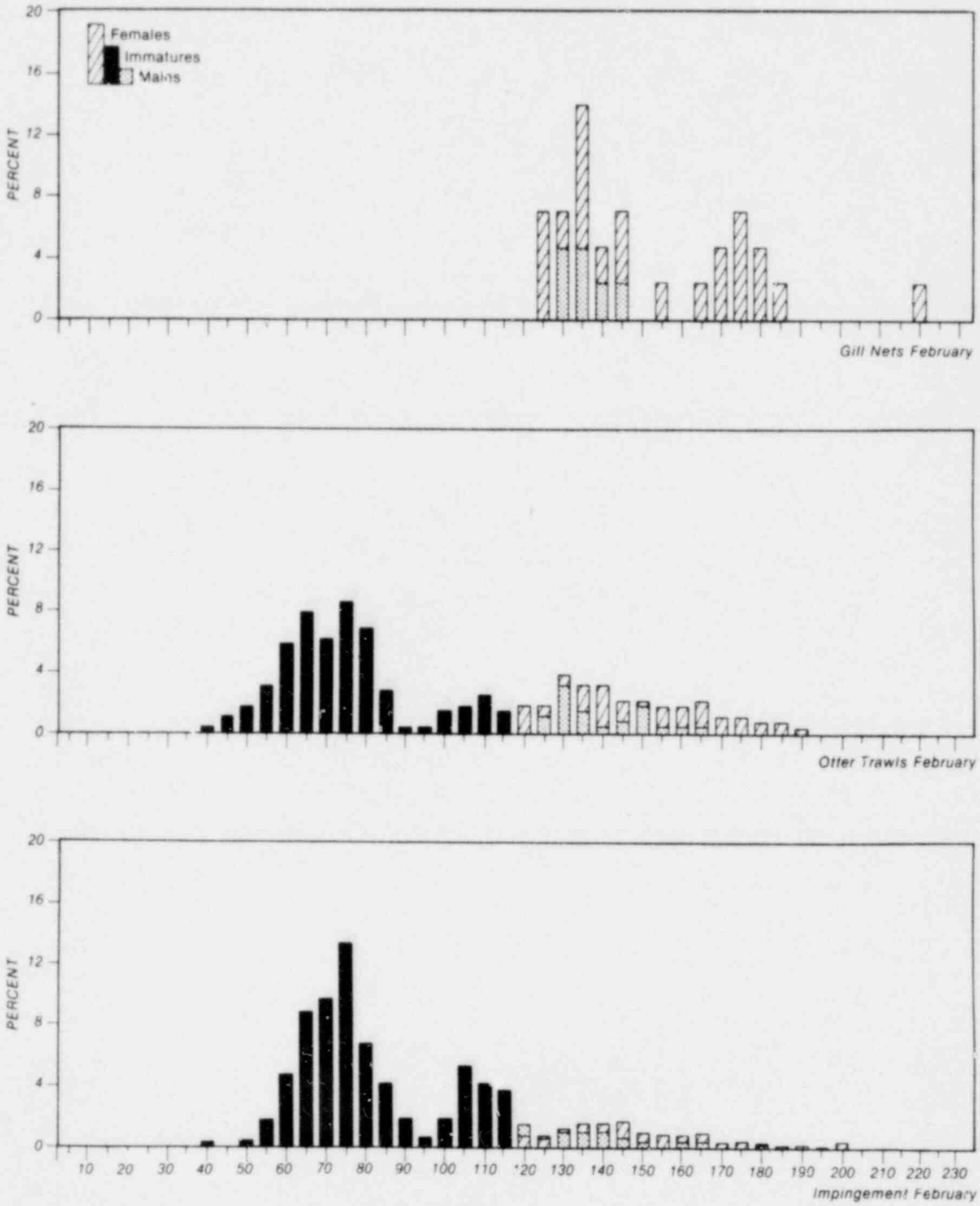

Figure 6B-1. Length frequency histograms of *Seriphus politus* from normal operation impingement, offshore gill net and otter trawl samples taken in February 1980. Percentages for males and females are not additive within a given 5-mm length increment. Asterisk (*) indicates equal number of males and females in length class.

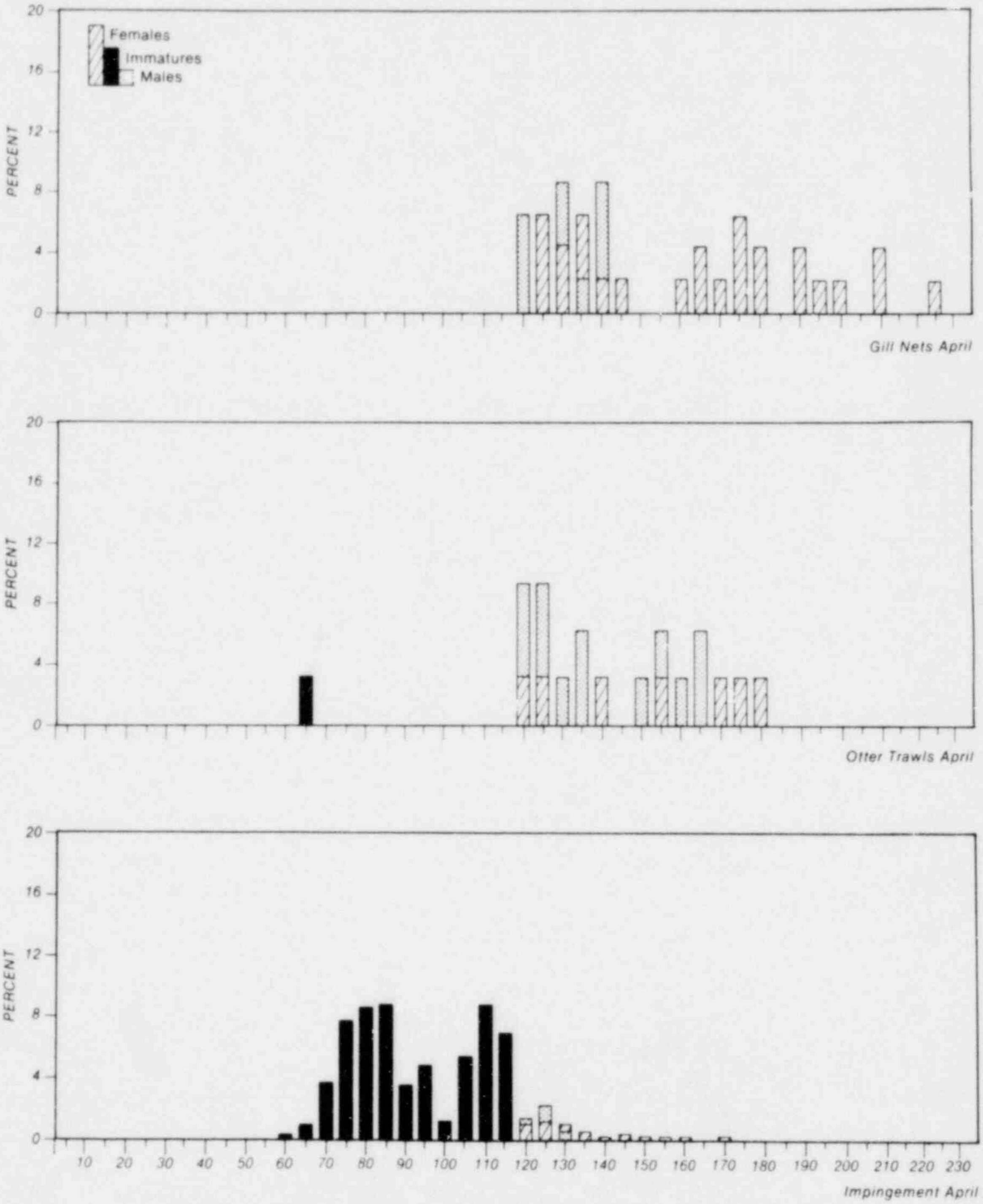

Figure 6B-2. Length frequency histograms of *Seriphus politus* from normal operation impingement, offshore gill net and otter trawl samples taken in April 1980. Percentages for males and females are not additive within a given 5-mm length increment. Asterisk (*) indicates equal number of males and females in length class.

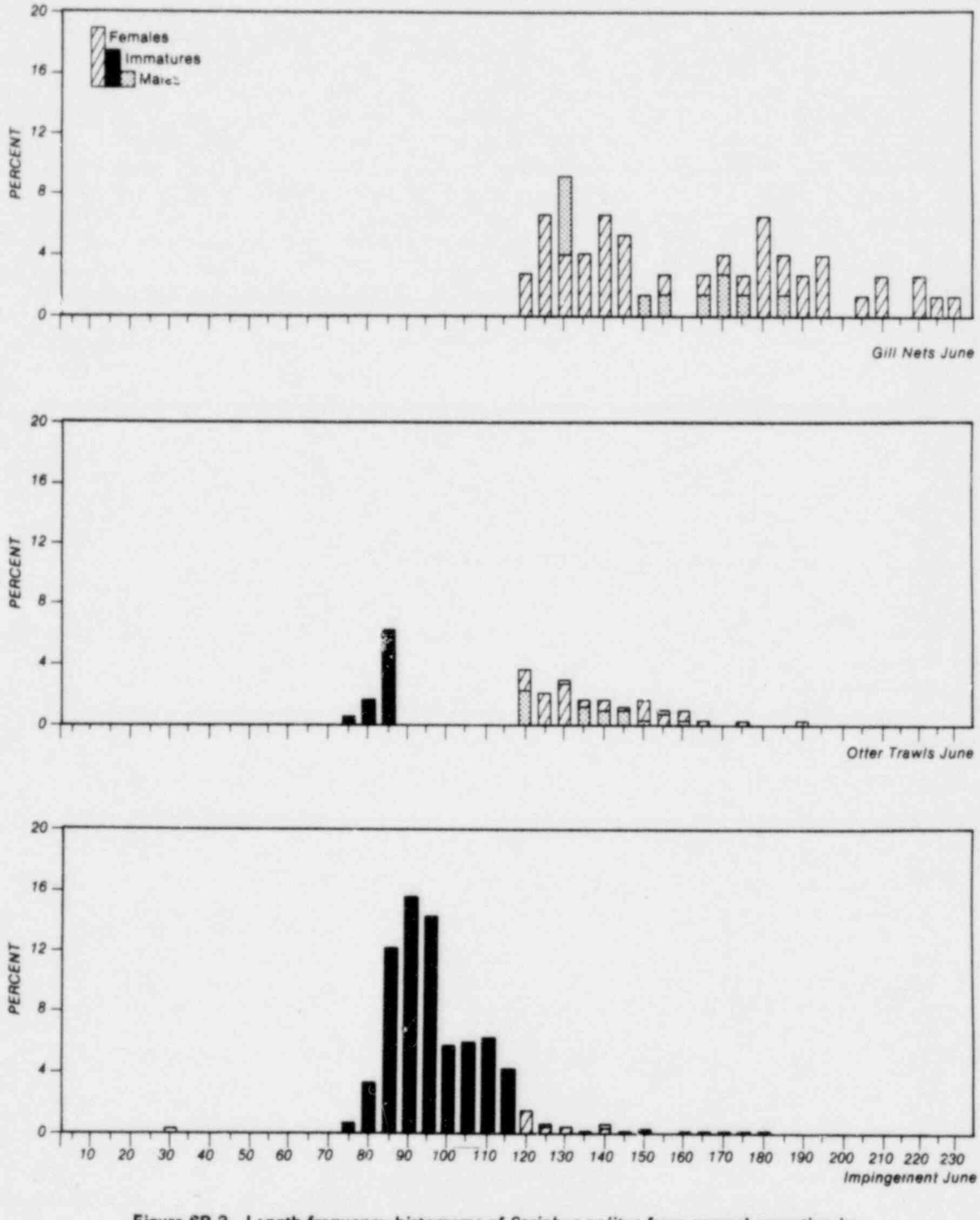

Figure 6B-3. Length frequency histograms of *Seriphus politus* from normal operation impingement, offshore gill net and otter trawl samples taken in June 1980. Percentages for males and females are not additive within a given 5-mm length increment. Asterisk (*) indicates equal number of males and females in length class.

Unlike previous years, male queenfish numerically dominated the impingement catch for San Onofre Unit 1 in February, April, and June 1980. In two of these three months (February and April) the number of males impinged was significantly greater ($P \leq 0.05$) than the number of females impinged.

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 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 this ratio was calculated for 5-mm (0.2 in.) length increments common to all gear-types. 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 for February and June. April length frequency data was omitted because of the low numbers of queenfish caught in gill nets. Results of the test indicate that Unit 1 did not impinge a disproportionately large number of female queenfish relative to numbers of females caught in gill nets and otter trawls.

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CHAPTER 7

KELP

INTRODUCTION

The kelp beds of the San Onofre region were under investigation in 1980 primarily to continue the preoperational baseline study for Units 2 and 3. Secondary objectives included continuation of the Unit 1 operational effects study and completion of the Construction Monitoring Program (CMP) for Units 2 and 3. The kelp study met all objectives and requirements of the Environmental Technical Specifications (ETS), Preoperational Monitoring Program (PMP), and the CMP. The purpose of this chapter is to present: 1) a pertinent summary of data collected in 1980; 2) analyses of the data to meet study objectives; 3) a perspective of the San Onofre kelp beds in relationship to the southern California bight kelp resource and the interaction of the resource with generating station activities.

Data collected during the San Onofre kelp investigation is provided in Volumes I and II of the San Onofre Annual Operation Report. Volume I (SCE 1981a) presented a brief summary of regulatory required data and was submitted to the regulatory agencies on 31 March 1981. Volume II (SCE 1981b) contains all data collected to meet the objectives of the 1980 program and supplementary data.

BACKGROUND

The kelp beds of the San Onofre region (Figure 7-1) have been periodically investigated over the past 70 years. The first investigation was conducted by W. C. Crandall (1912) in 1910 and 1911. His investigation consisted of mapping the areal extent of the kelp beds using surveying procedures. The San Onofre kelp beds were not investigated again until the Kelco Company (unpublished data) mapped the canopies by aerial photography in the 1950's. The San Onofre kelp beds were not studied again until 1963 when the Marine Environmental Monitoring program (MEM) was initiated. The MEM was conducted from 1963 through 1972 (Table 7-1); however no structured kelp program existed during this period. All kelp bed data collected during the MEM program were derived from hard substrate benthic investigations (Marine Advisers, Inc. 1969, 1971a-c; Intersea Research Corporation 1972, 1973a-b, 1974a-b).

In 1972, Dr. W. N. North of California Institute of Technology began quarterly mapping surveys of kelp canopies in the San Onofre region using aerial infrared photography.

Between 1972 and 1974, Dr. North also attempted to establish a warm-water tolerant strain of *Macrocystis* at the San Mateo kelp bed. The project met with initial success, but heavy sea urchin grazing eventually destroyed most of the warm water tolerant plants.

Kelp bed investigations conducted by the Southern California Edison Company (SCE) were undertaken as parts of major environmental regulatory studies such as the ETS, CMP, and PMP. SCE studies were not specifically designed to examine the

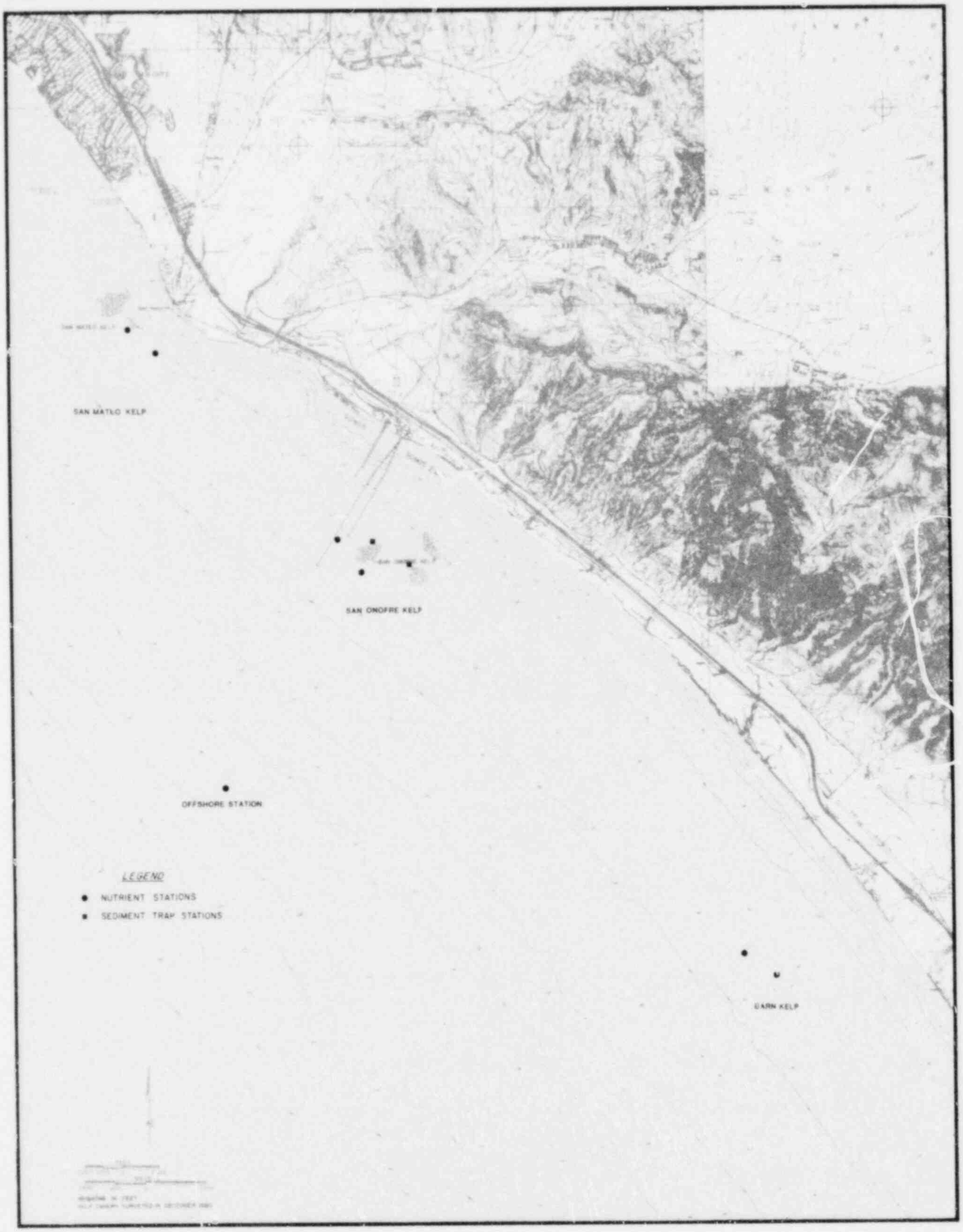


Figure 7-1. Study area of kelp bed survey.

Table 7-1 Chronological history of SCE-sponsored kelp bed studies at the San Onofre site.

Major Programs	Date	Methods	Frequency	Locality	Data Collected
Marine Environmental Monitoring	1964-1973	Qualitative and quantitative observations by various methods.		SMK, SOK, and BK	Minimal data on kelp plant densities and observations on canopy size.
Dr. W. J. North - Canopy Mapping	1972-1974	Aerial infrared photography	Quarterly	SMK, SOK, and BK	Estimation of temporal changes in kelp canopy
Dr. W. J. North - Transplant Experiments	1972-1974	Transplanting warm-water tolerant kelp plants and follow-up observations	Periodically	SMK	Minimal data collected due to grazing urchins
Sand Disposal Monitoring	1974-1976	Mapping kelp bed canopies using electronic position device	Quarterly	SMK, SOK, and BK	:Estimate of temporal changes in kelp canopies and hard substrate
Environmental Technical Specifications	1975-1980	Mapping kelp bed with infrared aerial photographs; monitoring of 11 1x10m band transects	"	"	:Estimate of temporal changes in kelp canopies and associated substrate; estimates of densities and temporal changes in the hard benthic community
Construction Monitoring Program Kelp Mapping Surveys	1976-1980	Electronic positioning devices	"	"	:Estimate of temporal changes in kelp canopies and associated hard substrate
Nutrient Surveys	1977-1980	Determination of nitrogen, phosphate and ammonia levels in water column, and nitrogen levels in kelp tissue	Monthly	"	:Temporal changes in water column and kelp tissue nutrient levels
Kelp Bed Examination	1977-1980	Qualitative examination by divers of health of kelp plants and recruitment success; occupation of two 1x10m transects at SOK	Quarterly	"	Temporal and spatial estimates of the condition of the kelp plants and associated hard benthic community at SOK
Preoperational Monitoring Program	Mid-1978 -Mid-1980	5 station-pairs, each station composed of 2 2x3 m^2 quadrat - point-contact method of enumeration	"	"	Minimal information on kelp densities at stations
Interim Program	Dec 1980	6 permanent stations plus 9 to 12 randomly placed 10 m^2 circular plots at each station	3/yr	SOK	*Macrocystis* densities and stipe counts; invertebrate and algae densities and substrate composition
Marine Review Committee Kelp Programs	1976-1980	Field experiments using kelp transplants and outplant studies	Continuous	SOK	Effects of turbidity on development and growth of kelp

SMK = San Mateo Kelp Bed SOK = San Onofre Kelp Bed BK = Barn Kelp Bed

intricacy of kelp mechanisms only, but rather were designed to monitor the overall benthos and included measurement of gross changes in kelp canopy and plant densities. The first such study was the Sand Disposal Monitoring program (SDM) conducted from 1974 through 1976 (Table 7-1). This program consisted of quarterly kelp canopy and substrate mapping in the San Onofre region using electronic positioning devices and ground truth sampling (Lockheed Marine Biology Laboratory 1974, 1975a-c; Lockheed Center for Marine Research 1976a-c). Beginning in 1975 and continuing through 1980, kelp canopies of the San Onofre region were examined quarterly as part of the ETS, using infrared aerial photography. Additional information on kelp plant and benthic invertebrate densities at the San Mateo (SMK), San Onofre (SOK) and Barn kelp (BK) beds were provided by the Unit 1 ETS operational benthic program although this program was not designed specifically to address kelp but to monitor the hard benthos.

In 1976 the SDM program was replaced by the Construction Monitoring Program (CMP) which continued into early 1980 (MBC 1978; SCE 1979, 1980). The objective of the CMP kelp investigation was to monitor the health of the San Onofre kelp beds during the construction phase of San Onofre Units 2 and 3. The CMP kelp investigation included: 1) quarterly mapping of the SMK, SOK, and BK canopies and associated substrate using electronic devices; 2) documentation of changes in the density and configuration of the three canopies using infrared aerial photography (The aerial photographs were taken at least quarterly and in 1978 and 1979 [weather permitting] the aerial photographic investigation was conducted on a monthly schedule); 3) monthly monitoring of ammonia, nitrogen, and phosphate in the water column, and nitrogen in kelp tissue; 4) the qualitative quarterly examination of kelp plant health in the SMK, SOK, and BK beds; and 5) the quarterly occupation of two 1 x 10 m^2 band transects to quantitatively examine temporal changes in the benthic community at SOK (Table 7-1).

The PMP benthic investigation conducted from mid-1978 to mid-1980 (SCE 1979, 1980) was established to monitor the community associated with the offshore rock and cobble substrate in the San Onofre region (Table 7-1). Although the PMP investigation was not specifically designed to monitor kelp beds, several stations were located within or near the beds and provided ancillary data on kelp plant densities and growth rates (i.e. rates derived from stipe counts) were obtained.

Following termination of the formal PMP program in mid-1980, basic kelp monitoring was continued as a portion of the interim program to study kelp (Macrocystis, Pterygophora) at the SOK bed where an established data base existed. The study was designed to monitor kelp densities and associated factors that apparently have measurable influence on kelp recruitment and development within the SOK forest. These factors included substrate stability, biological interaction with urchins, competition for uninhabited space, shading by lower story brown algae, and kelp canopy mapping semiannually (Table 7-1). A preliminary survey was conducted in December 1980 and the results of the survey are presented in Chapter 5B.

Beginning in 1976 and continuing to the present, the Marine Review Committee (Barilotti 1977; Deysher and Medler 1978; Dean 1979a-b, 1980) has conducted detailed investigations at SOK, SMK, and BK. These investigations, which included detailed field experiments, were oriented towards predicting the effects of San Onofre Units 2 and 3 operation on SOK.

DISCUSSION

MONITORING PROGRAM

The sea floor off San Onofre 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 boulders that the giant kelp, Macrocystis, has established itself, forming kelp beds that support relatively varied and abundant marine biota.

The areal extent of kelp canopies in the San Onofre region have undergone several major changes since they were first mapped in 1911 (Figure 7-2). The most noticeable of these changes occurred between 1963 and 1967 when the San Mateo kelp (SMK), SOK, and barn kelp (BK) canopies disappeared. A second major event occurred between June and October 1976. This event was particularly evident at SMK and SOK where approximately 80% of the kelp canopy was lost (MBC 1978). The event was not confined to SOK, but was observed throughout the

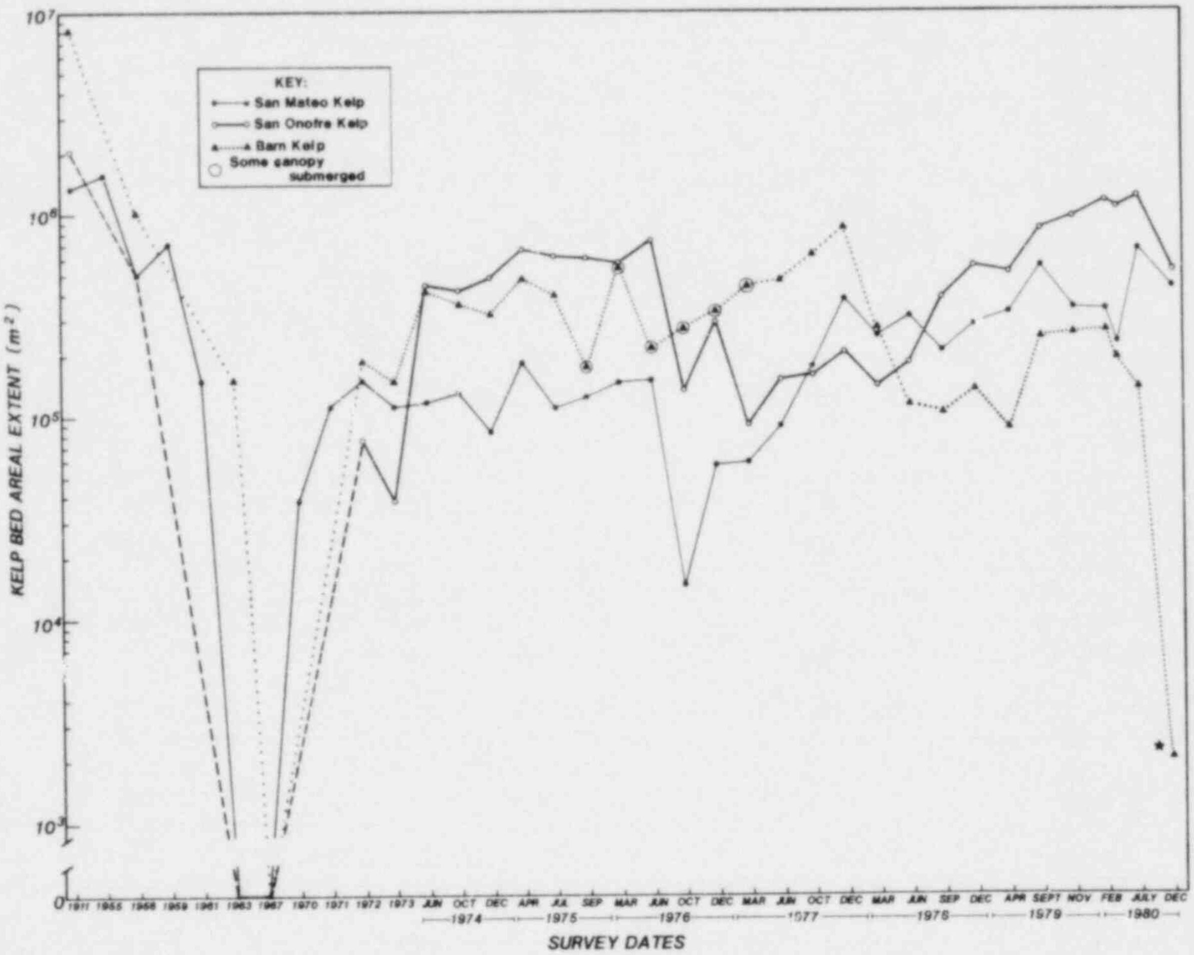


Figure 7-2. Estimated areal extent of the San Mateo, San Onofre, and Barn kelp canopy from 1911 through 1980. (determination by various methods.)

kelp beds of southern California. Although reasons for this deterioration were unknown, North (personal communication) suggested that the canopy reduction may have been related to a reduction in water column nutrient levels, a condition noted at other sites along the southern California coast during this period.

A period of canopy deterioration was again observed in the San Onofre region in 1978. The major spring storms of 1978 appear to have had a major impact on the canopies, especially the BK canopy. Between December 1977 and June 1978, BK canopy was reduced approximately 90% and as of December 1979 the BK canopy comprised only 25% of the pre-storm canopy. Aside from the destruction of kelp plants, winter storms also reduced available substrate for kelp settlement through storm related sand deposition (SCE 1980).

Kelp canopies of the San Onofre region again underwent a major period of deterioration between July and December 1980. During this period, the BK canopy, which was already in a state of deterioration (SCE 1980), disappeared. Further, the areal extent of the SOK canopy decreased approximately 60% and the SMK canopy approximately 40%. Kelp canopies normally undergo some deterioration in summer followed by a recovery period in fall and winter (North 1971). Recovery of major kelp bed canopies in the San Onofre region was not observed in 1980. Field observation indicated that healthy kelp plants were present in some areas of the kelp beds in December, but had failed to develop new growth in the water column surface layers. In other areas, substantial plant loss was observed. Field

observations further indicated that even though SOK lost approximately 60% of its surface canopy, kelp plants comprising the bed appeared to have suffered the least damage observed in the San Onofre region (North, personal communication). By comparison, kelp plants observed at BK were in a state of distress. Observations made at BK in December were further substantiated by the canopy mapping survey which indicated that no canopy existed and the area of high density fronds (above 1 m [3.3 ft]) had decreased approximately 86% from February 1980.

Concurrent with the decrease in kelp canopy extent throughout the San Onofre region were abnormally high surface and bottom water temperatures, especially in August, and reduced surface water nitrogen (i.e. NO_2+NO_3). Bottom water temperatures exceeding 25.0°C and surface water temperatures near 27.0°C were reported in the San Onofre kelp beds in August (SCE 1981b). Further, surface water levels of nitrogen exceeded 0.05 *g at/liter only rarely. The surface water nitrogen levels in 1980 represented a significant ($P \leq 0.01$) reduction over that recorded for the same time periods in 1978 and 1979.

Although kelp monitoring data suggests a direct relationship between observed canopy deterioration and the elevated temperature and reduced surface nitrogen levels, the causative factors (i.e. elevated temperatures and/or reduced levels) are not known. The effect of reduced surface water nitrogen on kelp plants was further obscured, since bottom water nitrogen levels were generally equal to or greater than those recorded in 1978 and 1979. In addition, ammonia levels, another form of nitrogen available to kelp plants in surface and bottom waters, were comparable to levels recorded in previous years.

Rates of recovery for the three kelp canopies in the San Onofre area probably differ substantially. Observations made at BK in December indicated that much of the remaining Macrocystis was heavily grazed. Grazing pressure together with the major loss of kelp plants from BK, will probably hinder recovery of BK resulting in 1) complete loss of the BK canopy for several years, and/or 2) a lengthy recovery period before the areal expanse of the canopy is equivalent to that recorded in 1978 and prior to the current period of deterioration. In contrast, observations at SMK and SOK suggest that the remaining sections of those beds are generally healthy, and can be expected to recover to their predeterioration state under favorable environmental conditions.

In addition those factors previously described, substrate composition and light availability have been suggested as major factors associated with the growth and maintenance of the SOK bed. Dean (1979) has demonstrated that reduced irradiance (below $1E/m^2$/day), and natural occurring events at SOK during the winter through summer months can suppress or prevent gametogensis and sporophyte development while elevated turbidity can significantly suppress growth of young kelp plants.

The SMK and SOK beds are unique in that they are located on low-relief cobble substrate. Benthic investigations over the past three-year period have indicted that the substrate in many areas of SOK examined was periodically covered by sand (See chapter 5B). These scouring events are likely to result in destruction of Macrocystis sporophytes and gametophytes. Further, small cobble is easily moved during heavy swell conditions resulting in: destruction of the developing Macrocystis plants by turning the cobble over; or 2) in extreme cases when the juvenile plants are large enough, the cobble and attached plant break loose from the bottom and float out of the immediate area (SCE 1980).

In summary, 1980 data indicate that the kelp beds of the San Onofre region underwent a major period of deterioration resulting from naturally occurring events. The data further show that event(s) had the most pronounced effect on the BK bed.

SOUTHERN CALIFORNIA KELP BED OVERVIEW

STUDIES OF KELP BEDS IN SOUTHERN CALIFORNIA

Most of what has been learned about the California kelp forests is in the form of unpublished reports, and has not been subjected to the scientific review that normally preceeds publication. Many of these reports have had only a limited circulation. As a consequence, many authors do not take into account much of the previous work that has been done. It is difficult to be aware of this prior work because there is no single repository for all of the "kelp reports" that have been produced. Consequently, the task of reviewing and evaluating this information is becoming increasingly difficult.

Fortunately, many of the unpublished reports can be grouped into "sets" of information. For example, the Institute of Marine Resources of the University of California conducted kelp bed studies from 1956 to 1963, the results of which are available as IMR reports. Studies of the kelp near the San Onofre Nuclear Generating Station were undertaken by eight different groups over a period of some 18 years, and these have been assembled and reviewed by Southern California Edison. At the present time, SCE is supporting a mapping study of the southern Californian kelp forests. By reviewing and evaluating all previous mapping and aerial survey work, it has been possible to produce the synthesis provided here.

Efforts by many people over the last few decades have resulted in a great deal of new information about kelp beds and kelp plants. New aerial-photographic techniques have been developed for mapping kelp beds. Subsurface vegetation has been visualized using sonar, and more recently side-scan sonar images have been used. Cine-trasects have made it possible for divers to record the distribution of fish in the forests. Measurements of productivity, and harvested yield have been made. The production of detritus and drift from kelp beds has been studies and the kelp plant itself has been the subject of several studies. A great deal has been learned about its processes of reproduction and its basic physiology. All of this information, when combined with measurements of oceanographic and climatological conditions, allows one to speculate about the causal relationships between physical and biological factors in the environment and how these might influence the development and regression of kelp forests.

After reveiwing what has been learned about the kelp plant and kelp beds, this section focuses on the results of attempts to predict yield and reproductive success in natural kelp forests. It also discusses the role of kelp as a primary producer and source of food for marine organisms in the coastal waters of southern California. Particular emphasis is given here to the kelp beds near San Onofre.

The first survey of southern California kelp beds was undertaken early in this century. At present the southern California kelp beds are numbered according to their location, and controlled by the California Department of Fish and Game (Figure 7-3). Long-term changes and losses of beds have been studied by Dr.Wheeler North and others, and, in some instances, degradation has been reversed and beds are now increasing in areas of prior decline. As understandable, the decline and loss of kelp forests stimulated considerable speculation as to its causes. Several hypotheses are discussed in this report, along with a review of what is known about responses of kelp to natural climatic and oceanographic conditions.

Mapping of the kelp beds of California was first done from boats, using triangulations with a sextant. This study was sponsored by the U. S. Department of Agriculture and ran from 1909 to 1912, during which time survey crews mapped

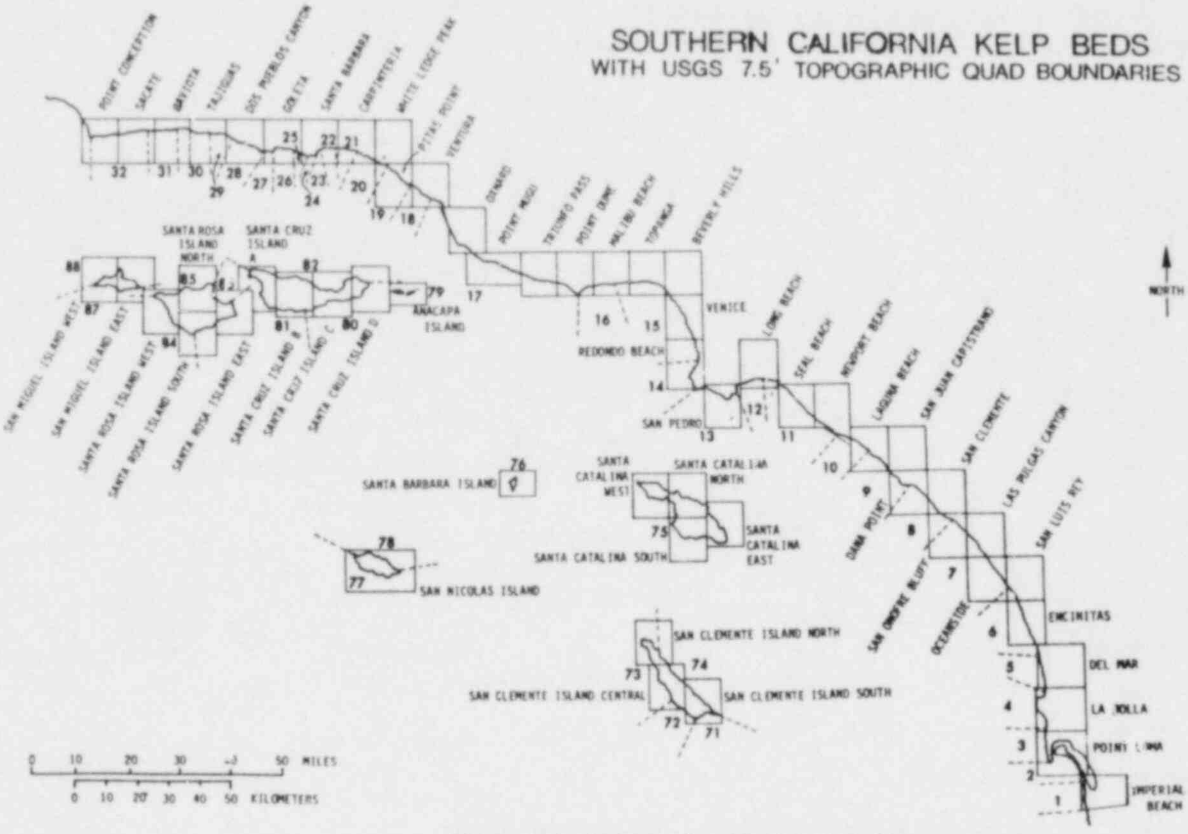


Figure 7-3. The southern California kelp beds, showing the U.S. Geological Survey 7.5' topographic quadrat map boundaries and names, and the California Department of Fish and Game numbers for the kelp beds that appear on these maps. There are 88 numbered kelp beds. The San Onofre bed is part of bed number 7.

beds along the entire Pacific coast. Crandall worked in the southern California kelp beds during the summer of 1911, determining extent of the kelp beds between San Diego and Point Conception (Crandall 1912). In 1915, the California State Legislature enacted legislation that declared the kelp beds to be the property of the state and provided for the leasing and control of the beds.

At mid-century, with the advent of scuba diving, the beds could be explored and mapped by divers who could hand-collect voucher specimens. Concern about the loss of kelp beds led to pressures from the sportsfishing community and to the introduction of a bill to stop all kelp harvesting. This controversey over management gave rise to the Institute of Marine Resources research program on kelp beds. Subsequent concern over effects of the San Onofre Nuclear Generating Station led to detailed studies of the San Onofre kelp bed. Concern about the effects of oil development resulted in surveys of coastal resources by the Bureau of Land Management. Most recently, the potential of kelp as a biomass producer has attracted attention. Trial plantings and harvests are being carried out to see if large-scale bio-energy production from planted and cultivated kelp beds might be possible in the future.

The results of the Institute of Marine Resources programs on the biology of the giant kelp has been summarized in three published volumes: a pollution study (California State Water Quality Control Board 1964); a treatise on kelp resources (North and Hubbs 1968); and the general biology of Macrocystis and the organisms

associated with it (North 1971). This body of information provides a general "baseline" desription of the kelp beds of southern California at mid-century.

As mentioned above, studies of the kelp ecosystem at San Onofre, initiated prior to construction of the generating station, have been underway for 18 years. These studies have dealt with the effects of power plant construction and operation on the coastal ecosystem with specific studies on San Onofre kelp plants and kelp beds.

THE KELP BED ECOSYSTEM

If one could make a mathematical model of the kelp ecosystem, responses to variations in environmental parameters like those modified by the San Onofre plant could be predicted. To do this the specific environmental conditions that govern the overall material balance and the energy pathways must be characterized. A firm understanding of the way that kelp bed organisms respond to variations in environmental conditions has to be available. A model would consist of both interdependent and independent subsystems. The major forcing functions, storages, flows and causal relationships would have to be based on both laboratory studies and measurements made in the sea. Some of the information needed for a kelp bed model has been obtained, and attempts have been made to develop kelp bed models. These are based on a consideration of trophic levels in a kelp forest and interactions between them.

Trophic Levels in a Kelp Ecosystem

Field et al. (1977) used a circuit diagram of the Odum type to illustrate energy flow through a South African kelp bed ecosystem. Sjoberg, Wulff, and Wahlstrom (1972) used computer simulation for ecological studies of benthic systems in the Baltic Sea. Trophic food webs in California kelp beds have been described qualitatively by Rosenthal et al. (1974), Gerard (1976), and Pearse (1976). Ebeling has considered kelp beds with particular regard to fish production (Ebeling 1980). In all of these cases, the primary producer Macrocystis pyrifera, and/or other algae, such as Ptergophyra and "understory" red algae, provide food for grazers, filter feeders, scavengers, and indirectly for predators. A simple three-level system has been outlined by Dr. John Pearse (personal communication), who considers trophic interactions.

Fish and Invertebrates in the Kelp Ecosystem

Some 125 fish species inhabit areas of reef and kelp in the southern California bight (Limbaugh 1955, Quast 1968). Yet relatively few fish are so highly specialized that they live only amongst the blades of giant kelp and nowhere else. Only a single surfperch species and a clingfish require kelp to survive. These animals are of relatively little economic and ecological significance.

Kelp and other plants in the kelp forest, form the basis for a detrital food web that sustains most of the associated animals both directly and indirectly (Simenstad et al. 1978, Estes et al. 1978, Mann 1977). Surfaces of large attached algae harbor a host of epiphytic invertebrates, which are grazed or picked by either large plant-cropping fishes such as opaleye and halfmoon, or smaller "picker types" like the kelp perch and the senorita. However, much of the productivity of the kelp forest is unaccounted for after the amounts harvested and amounts cast on the beach are considered. Kelp defoliates constantly and detached plants or parts of plants ultimately reach the bottom as drift and decay. Dissolved and detrital material forms the basis for the detrital food web. Myriads of benthic invertebrates either eat decaying kelp or consume bacteria that thrive thereon. Such invertebrates, particularly amphipods, are in turn prey

for a diverse assemblage of demersal fishes, including abundant surfperches. Large mouth predacious species such as the much-prized kelp bass and rockfish, prey on young of the invertebrate eating demersal microcarnivores.

It is important to recognize that many temperate reef fishes found in kelp beds can inhabit rock areas that contain no kelp. However, kelp in various stages of decay may accumulate from neighboring kelp beds and still contribute to the base of the food web. Defoliated reefs, without detritus, support depauperate fish communities (Simenstad et al. 1978). Thus, kelp, in one form or another, is essential to the health of kelp bed fish communities. It serves as a cover for young fish and forms a substrate for the food eaten by many grazers and pickers.

In comparison with other southern California kelp beds, fish populations in the San Onofre kelp bed are not abundant, and relatively few species are present. This is because, unlike most areas of reef and kelp, the San Onofre bed grows on cobble. This bed is less stable than others because shifting sands can cover the bottom, depriving the plants of a suitable substrate. Also, cracks, crevices, and holes trap algal drift on most reefs and also provide refuge for fishes and macroinvertebrates. This auxiliary supply of food supplements the turf that normally harbors amphipods and other fish prey. Thus, the more complex and raised the rocky substrate is, the more species and numbers of fish it can support. Bottom rockfish, a species that normally shelters in holes to avoid surge forces, is rarely found at San Onofre. There are also very few benthic surfperches, which normally forage in thick turf for amphipods and other small invertebrates.

The monitoring of fish and invertebrates in the San Onofre kelp bed before and after the activation of San Onofre Units 2 and 3 may be deceiving because even if the kelp is destroyed, the fish community may persist for varying periods in different or alternative states. Fish may disappear because of a chain of events started by covering the cobble base with sand. Kelp may disappear for any one of a number of reasons and deprive the system of its food-energy base. A cobble-based bed is inherently less stable than a kelp bed anchored to a high relief rocky bottom. The gross results of natural disturbances such as severe storms, abnormal warming trends, upwelling shifts and so on, may be difficult to distinguish from artificial disturbances associated with the operation of San Onofre. Abrupt shifts in the structure of kelp bed communities occur throughout the subtidal zone of the southern California bight as well, even in more complex reef-based systems. For example, severe storm waves defoliated a reef near Santa Barbara in February 1980. Without kelp, no drift accumulated to feed sea urchins. Without food, the urchins cropped young kelp plants before they could grow, and the reef has become barren and urchin-dominated. The assemblage of fish that persisted there was noticeably different from that present when kelp grew on the reef. Unfortunately, there is no way to predict when events will occur that might reverse this process. Thus, like forests on land, the kelp forest is very unstable and can appear and disappear in short periods of time.

Plants in the Kelp Ecosystem

It is easy to understand how an irregular, rocky bottom would provide cracks and crevices that offer habitats for animals. It is less obvious that moving water in a kelp ecosystem also defines specific habitats for plants (Figure 7-4). Current-zone, surge-zone, and boundary-layer habitats support many different kinds of plants, including morphologically different life phases of individual plants.

For example the life history of the giant kelp Macrocystis consists of a macroscopic sporophyte and a microscopic gametophyte, which occupy very different habitats. Zoospores are released into the water column by adult sporophytes.

These settle into the boundary layer of water at the rock water interface. Spores germinate and grow into microscopic gametophytes. When conditions are right, the gametophytes form gametes and fertilization of eggs may occur. Fertilized eggs germinate and may grow into juvenile sporophytes. These grow in the surge current zones. While the species present in each of these hydrodynamically-defined habitats may differ, a complement of plant forms is usually present. Turf-like filamentous plants usually inhabit the boundary layer. Stoutly-stalked bladed or bushy plants are often found in the surge zone. Large float-bearing kelps inhabit the current zone.

Since all of these plant life forms must start growth in the boundary layer of the sea floor, anything that modifies this region may influence recruitment. For example, the presence of sediment, that reduces the surface area available for spore attachment, will effect spore survival. The complex interrelationships between layers of vegetation in determining the amount of light energy reaching the bottom must also be considered. Thus a "normal" complement of boundary-layer, surge-zone, and current-zone plants may not be present in an unstable kelp bed like that at San Onofre.

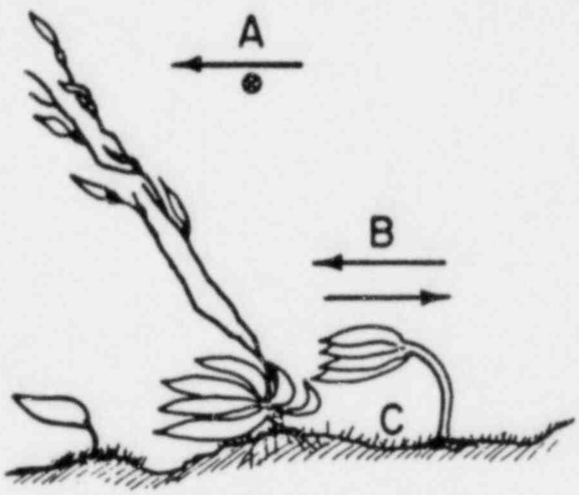


Figure 7-4. The spatial distribution of algae in kelp bed is influenced by the water motion regions that occur there. The bulk of the water is in the current zone (A) where it moves unidirectionally. Within a few meters of the bottom the wave surge produced a back-and-forth motion in a region called the surge zone (B). On the bottom itself there is a boundary layer community of plants only a few centimeters high (C). Spores settle and attach in the laminar sub-layer of this region.

THE KELP PLANT

The giant kelp is the largest known marine plant. It can, in effect, grow its own anchor, mooring lines, and buoys. These support a large surface area that captures solar energy in the blades.

Morphological Characteristics

A relatively small specimen of Macrocystis, collected in 9.5 m (31.2 ft) of water, is illustrated in Figure 7-5. This plant weighed 104.3 kg (230 lbs), and produced a total of 38 fronds. The plant had a very large holdfast that weighed nearly as much as the blades, stipes and floats in the canopy. The basal parts of the kelp plant branch repeatedly to produce the fronds which grow to the surface as well as frond initials and sporophylls.

The fertile fronds of Macrocystis, referred to as sporophylls, are clumped at the base of the plant and may or may not bear sporangia on their surfaces. Multi-bladed sporphylls are the most productive, with some plants having nearly all of the potentially sporogenous tissue bearing sporangia. In general, as plants reach a larger size they produce more fertile sporophylls.

The Species of Macrocystis. Only two species of Macrocystis are recognized by Dr. I. A. Abbot and Dr. G. Hollenberg (Abbott and Hollenberg 1976). These species are easily distinguished from one another on the basis of holdfast and basal branching system characteristics. Macrocystis integrifolia is an intertidal to shallow-water species with a strap-like basal branching system

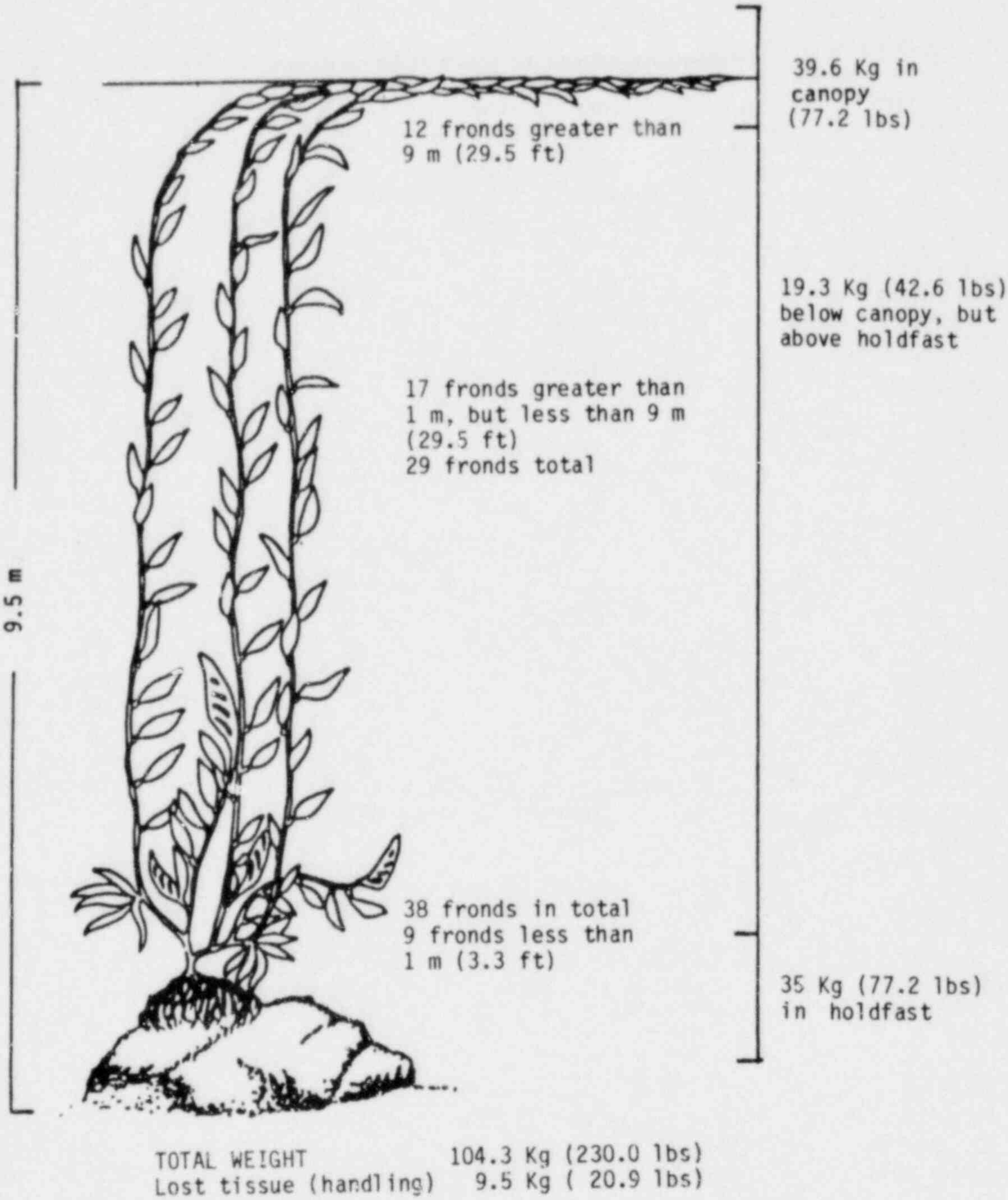


Figure 7-5. A Macrocystis plant collected from a depth of 9.5 m (31.2 ft.) in Goleta Bay, California. The plant had a total of 38 fronds and weighed 104.3 kilos (230 lbs.).

and a relatively small holdfast. In contrast Macrocystis pyrifera includes plants with a spreading holdfast and long primary stipe, with a peaked holdfast and spreading basal system, and plants that produce large loaf-like holdfasts that can accumulate sand and sediment and are "self-anchoring" and thus can grow on sandy bottoms. This latter type of plant has been referred to as Macrocystis angustifolia, and is genetically distinct from the other species, although, it is interfertile with them.

Macrocystis and Related Kelps. The giant kelp is a member of the family Lessoniaceae, which includes several other genera. The genus giving its name to the order, Lessonia does not occur in the northern hemisphere, but a similar plant, Lessoniopsis, does grow in California. Float-bearing genera related to the giant kelp are the elk kelp, Pelagophycus, and the bull kelp, Nereocystis. It is of considerable interest that Macrocystis can be crossed with these latter two genera to produce intergeneric hybrids. These plants and an intergeneric hybrid are diagrammatically illustrated in Figure 7-6.

Physiological Characteristics

The kelp plant contains a number of major chemical components, including cellulose, mannitol, alginic acid, laminarin, mucopolysaccharides, proteins and pigments. These are all synthesized from carbon dioxide and bicarbonate, nitrate and ammonia ions. The plant can produce lesser or greater amounts of its major constituents depending on the resources available. In a study of how the major constituents of kelp vary with season, Lindner et al. (1977) found that there were major differences in the composition of kelp. Proteins were highest during the winter months when nitrogen levels were high, while carbohydrates were most abundant in the kelp during the summer months where there was ample light, but less nitrogen.

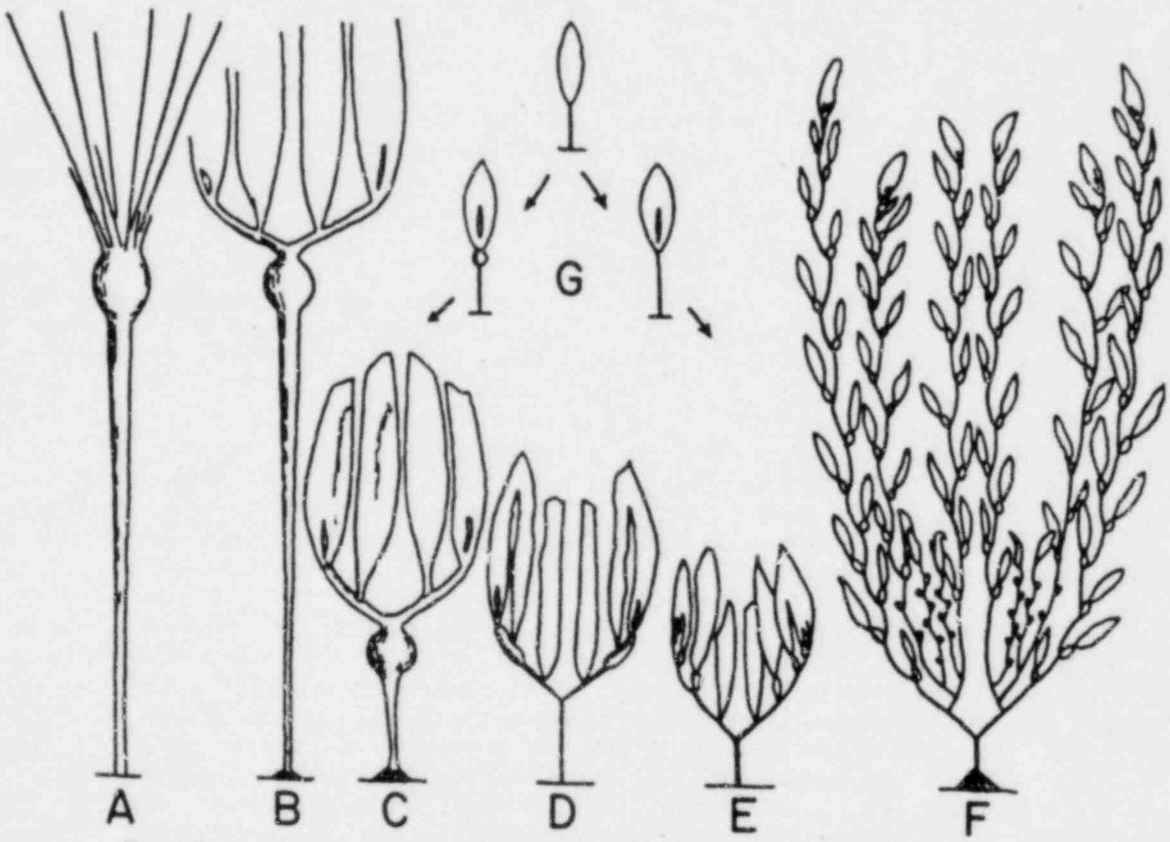


Figure 7-6. A diagrammatic representation of the relationship between Macrocystis (F, on the right) and the elk kelp (Nereocystis) and the bull kelp (Pelagophycus) on the left (A, B, C). A young Macrocystis (E) and an intergeneric hybrid between Pelagophycus and Macrocystis (D) are shown. The developmental stages leading to either a uni-pneumatocyst plant, or a multi-pneumatocyst plant is shown at G. Thus while these plants vary greatly in appearance they seem very closely related genetically.

The marine environment varies seasonally, just as the terrestrial one does. In southern California, the marine seasons are much more pronounced than those on land. Underwater irradiance in the winter at about 8 m (26.2 ft) is 22% what it is in the summer, while surface irradiance is 43% in the winter what is in the summer. Winter storms can be very destructive since water motion drag effects are much more severe than are atmospheric winds (Charters et al. 1969). The dislodging of kelp plants under storm conditions is a major source of plant loss (Rosenthal 1974).

Another important effect of water motion on kelp is its effect on the uptake of nutrients. The ocean in southern California is a "marine desert", in the sense that for most of the year, the plants are limited in their productivity by low nutrient concentrations. Nutrients in the form of nitrogen are simply not present in quantities great enough to support optimum growth. By analogy, desert plants on land compensate by storing water, while in the sea, marine plants compensate for a "nutrient drought" by storing nitrogen and carbon. The analogy can be carried even further. Many annuals appear in the desert only after spring rain storms whereas in the ocean, a "storm" often results in upwelling which provides nitrogen and with clearer upwelled water, more light. In the sea this gives rise to high plant productivity and produces a "recruitment window." The effects of light, temperature, nutrients and water motion on the gametophytic and sporophytic life history phases of the kelp plant are addressed separately.

The Effects of Light on Kelp. During the winter, when water clarity is generally low, a combination of wind and tide can cause upwelling. This cold, clear upwelled water allows more light to penetrate into the subtidal and can allow the light needed for plant maturation to reach the sea floor. Luning and Neushul (1978) have determined that between 40 and 60 μE/sq M/sec are required for gametogenesis. One of the requirements for gametogenesis is blue irradiance, and this necessary blue light is available throughout most of the year in southern California kelp beds.

Fain (1979) indicates that photosynthesis of gametophytes is saturated at quantum irradiances between 35 and 70 μE/sq M/sec. A quantum irradiance level in excess of 140 μE/sq M/sec inhibited photosynthesis. Compensating irradiances (the level at which photosynthesis just matches respiration) were on the order of 1.4 μE/sq M/sec.

Embryonic sporophytes have been studied by Fain and Murray (1979). Irradiance compensation, saturation, and inhibition occurred at 2.8, 35-70, and 210 μE/sq M/sec, respectively. Manley (1979) determined the irradiance saturation level for embryonic sporophytes to be in the region between 54 and 68 μE/sq M/sec.

For adult sporophytes, Wheeler (unpublished) has determined the saturation levels to be 125 and 300 μE/sq M/sec. Both Manley (1979) and Wheeler indicate that the saturation level appears to be related to the nutritional status and age of the blade tested. These factors also affect the maximum photosynthetic rate (Pmax) and the Ks value (the irradiance necessary to produce a photosynthetic rate of half the maximum value). Meristematic tissue and senescent tissue have lower photosynthetic rates than mature tissue. Because most of the tissue on a kelp frond is within the top third of the water column (Wheeler 1978), most photosynthesis takes place within the canopy near the surface where irradiance is the highest. However, the embryonic sporophyte and gametophytes must utilize only dim irradiance on the sea floor, but because these plants can store energy in the form of photosynthates, growth is not inhibited by lack of continuous irradiance throughout the growing period.

Luning and Neushul (1978) have shown that gametophytes of Macrocystis survive at quantum irradiances as low as 20 *E/sq M/sec. As yet young or mature sporophytes of Macrocystis have not been studied in this context. However, in Laminaria and other laminarin sporophytes, the irradiance range has been determined to be approximately 0.7% of the surface irradiance, or 15 MJ/sq M/year or 70 E/sq M per year (Luning and Dring 1979). Gametophytes of laminarian sporphytes require less irradiance, only 0.4 E/sq M/year (Luning and Dring 1979).

The Effects of Temperature on Kelp. There are very few studies on the temperature tolerance of brown algae. Even fewer have dealt with temperature tolerance of Macrocystis. Fain (1979) has determined that the photosynthetic rates of Macrocystis gametophytes vary as a function of temperature. He found that temperatures in excess of 25°C were deleterious to gametophyte photosynthetic rates. Embryonic sporophytes also showed decreased photosynthetic rates at temperatures in excess of 25°C. The problem with these short-term studies is that the tolerances are invariably much lower when imposed for longer periods of time. The incubation time for Fain's gametophytes was 24 hrs.

No studies have been done that compare the interactive effects of two variables on laboratory reared kelp plants. However, Luning (1980) has studied the blue light requirement for Laminaria gametogenesis. He has found that at higher temperatures the light requirement for gametogenesis increases greatly. He also suggested that at higher temperatures, the nutrient requirements for gametogenesis may also greatly increase.

Growth is again a much better indicator of long-term effects of temperature. Luning and Neushul (1979) have determined the growth rates of Macrocystis gametophytes over a range of temperatures. Growth rates were maximized at 17°C. Fertility patterns were even more sensitive to temperature, with gametogenesis being maximum at 12°C and declining above 12°C. Luning (personal communication) has determined that Laminaria sporophytes, whether from the Arctic or more temperate regions, cannot tolerate temperatures in excess of 20°C for periods longer than one week and continue growth. In southern California, temperatures routinely reach 20°C every summer. Californian strains of Macrocystis do not tolerate this temperature well. This may, however, be the result of a combination of high temperatures and low nitrogen (see Jackson 1977).

A strain of Macrocystis which grew in the warm waters of Turtle Bay in Baja, California, and which was presumably warm-water tolerant, was brought to southern California by W. J. North, and grown at one time at San Onofre. Conceivably, a warm-water tolerant Macrocystis species could be produced from laboratory cultures and screening methods, as has been done for Laminaria in China.

The measurement of kelp temperature tolerance has been attempted only infrequently. After 25 years of Macrocystis research, it is surprising that very few studies have dealt with the effect of temperature on Macrocystis metabolism. Pacific Gas and Electric (PG&E) has studied the behavior of plants at controlled temperatures in the thermal tolerance laboratory at Diablo power plant the last three years. Nereocystis and not Macrocystis, was the test organism.

The Effects of Nutrient Availability on Kelp. Nitrogen appears to play an important role in regulating the metabolism of most marine algae. Because of the sporadic appearances of inorganic nitrogen in temperate waters, kelps have developed strategies to cope with this problem to some extent. North (personal communication) has found that increasing the nitrogen level in kelp beds during periods of low nitrogen increases productivity. High nitrogen level may also affect the temperature tolerance of algae by improving the turnover time of

protein synthesis (Wheeler unpublished), obviating some of the deleterious effects of high temperature. The rate of senescence, which accelerates with high temperatures and low nitrogen levels can also be slowed down by increasing nitrogen levels in the sea. Laminaria growth rates are certainly influenced by varying nitrogen levels. Laminaria saccharina has a Ks of 1.6 μmol nitrate/liter, which indicates that the growth rate increases when nitrate concentrations reach 1.6 μmol/liter. Nitrogen saturation occurs around 10 μmol nitrate/liter and concentrations of nitrate above 10 μM/liter do not enhance growth rates. Previous estimates for nitrogen saturation levels in Macrocystis indicate that these are lower than in Laminaria. Both Laminaria and Alaria have been shown to accumulate nitrate in tissue in excess of 3000 times the ambient concentrations (Chapman and Craigie 1977, Buggeln 1978) when more nitrogen is available than is required for immediate use. Although Laminaria has been shown to store this excess nitrate for periods as long as two months, Alaria stores it for only a few days (Chapman and Craigie 1977, Buggeln 1978). Preliminary data suggests that Macrocystis also stores nitrate (Wheeler unpublished), and like Alaria, stores the excess nitrate for periods lasting only a few days. The ability to store nitrogen is an important factor affecting growth of algae in the southern Califoria bight where nitrate availability is so limited.

The loss of kelp canopy at San Onofre in the late 1950's was attributed to abnormally high temperatures during what were called "the warm water years." This is of interest, because if future warm water periods occur and the natural elevation of temperature is further raised by the generating station, there is a possibility that a kelp bed near the outfall could be damaged. However, the effects of temperature are difficult to distinguish from the effect of low nutrient levels. There is a high degree of correlation between water temperature and the concentration of nitrogen in the water. The higher the water temperature, the more likely it is to have very low nitrogen concentrations. Perhaps the decline and loss of kelp in the San Onofre area was due to an abnormally long period without nitrogen as well as abnormally high temperatures (see Jackson 1977). The answer will remain unknown, because while there is abundant temperature data for the period, the nitrogen levels were not measured. Fertilization experiments may provide answers in the future. Chapman and Craigie (1977) have fertilized beds in eastern Canada with some success, as has North in southern California, also with some success. Thus it might be possible to experimentally provide high nutrients at times of high temperature.

The Effects of Water Motion on Kelp. Temperature and nitrogen effects and the effects of water motion are mediated through physical interactions with the thallus surface. For example, blade characteristics which enhance turbulence generation and thus the nitrogen uptake rate certainly aid the plant in surviving periods of low nutrients. Such adaptations are physiological, morphological, and ecological. Blade features such as corrugations and spines modify the water motion around the plants to enhance boundary layer diffusion (Wheeler 1980b).

The required amount of water motion for the adequate diffusion of needed nutrients and gases to kelp blade surfaces is 5 cm/sec. Currents less than this limit the rate at which Macrocystis can take up nitrate. Currents less than 13 cm/sec even limit uptake in plants requiring high turbulence, such as Gelidium nudifrons (Anderson and Charters unpublished). Thus measurements of water motion are paramount to an understanding of kelp ecosystems.

The Responses of the Kelp Plant to the Environmental Complex

The metabolic processes of the giant kelp are responsive to all of the above-mentioned environmental factors. The availability of essential resources such as light, carbon dioxide, and plant nutrients will determine the rate at

which the cells of the kelp will photosynthesize. The amount of fixed carbon will in turn determine how rapidly the plant will grow. At times of high nitrogen and other nutrients the cells will store nutrients, while at times of high light and low nutrient levels, the cells will store carbohydrates. Thus the chemical composition of a plant will change significantly with season. This change is likely to have an effect on the rate of frond initiation and the speed with which a harvested canopy will regenerate. The weight of a frond in the spring may be twice that of a frond produced on the same plant in the fall. Of course the metabolic rate within a cell is influenced by temperature with higher temperatures producing more rapid metabolic rates up to about 20°C. At this and higher temperatures the cellular machinery is damaged.

KELP BED PRODUCTIVITY

As suggested above the productivity of individual plants, and hence also of a kelp forest, depends on many factors. In addition to those mentioned earlier, other factors are also involved. For example, the type of plant present in a bed will affect its productivity. Different kelp species reach different maximum sizes and ages. In some locations plants mature and are dislodged in a little over one year, while in other places plants may persist for 15 or more years. In addition to varying in size and age, kelp plants change in weight per unit length seasonally. The standing crop level in natural kelp forests in spring may reach over 200 wet metric tons per hectare. This high figure is for a very dense stand of young plants. In an old established bed where large plants grow with space between them, a standing crop of 70 to 91 wet metric tons per hectare is more usual (Coon 1980).

Since productivity is determined by multiplying the standing crop by the growth rate, it is important to measure the latter. The growth of plants in natural kelp beds has been measured by several workers, and rates range from 3 to over 10% per day. The former figure is the more realistic one. The average growth rate for a multi-frond plant over a year, falls in this range. It is to be expected that juvenile plants would show a higher growth rate than mature plants. Natural kelp beds can produce as much as 55 dry metric tons of kelp per hectare per year. In California this highly productive ecosystem is harvested, with some 150,000 wet tons being taken yearly.

Harger (1979) has shown that it is possible to use a kelp harvester as a "sampling tool" to measure the responses of kelp plants to environmental conditions. Correlations and regressions were used to statistically compare kelp canopy density, measured as a function of tons of kelp harvested per hour by a harvester, with current and antecedent environmental conditions. Cause and effect relationships were suggested in instances where a statistically significant link was found between kelp canopy density and an independent environmental variable.

Kelp canopy density was measured by taking the weight of harvested material from a given bed, divided by the time needed to collect it on a specific date. This information was routinely colected by kelp harvesters. This number, expressed as metric tons per hour, was a "catch per unit effort" value. The velocity of the harvester was relatively constant and independent of bed density, and harvesting was done only under relatively calm wind and swell conditions, so the catch per unit effort was not influenced by weather. Thus it was assumed that the harvesting rate was directly proportional to the density of the canopy being harvested.

As discussed above, surface irradiance was highest in June and lowest in November and December. Water temperatures were highest in August and lowest in January and February. Swell heights were lowest in August and September and

highest in March. In November and December the kelp harvest reached a maximum of 80 to 100 metric tons per hour. Thus, the various resources needed by the plants were available at maximum levels at different times of the year, and it was logical suggested that available light was limiting in winter while nutrients were limiting in summer.

The five most important environmental variables were surface irradiance, water temperature, swell height, surface nitrate concentration, and bottom nitrate concentration. A statistical model was developed to relate kelp harvest with environmental conditions. With this, Harger showed that 46.1% of the variation in kelp harvesting rate (and indirectly canopy density) could be predicted, given appropriate measurements of environmental conditions.

MAPPING STUDIES OF SPECIFIC KELP BEDS

There are at least four types of kelp beds in the southern California bight. These are described here as the San Diego, Los Angeles, Santa Barbara, and offshore island beds.

San Diego Kelp Beds

The San Diego type of kelp bed was made up of Macrocystis pyrifera. In the Point Loma area (beds 3 and 4, Figure 7-3) the beds were very dense and found on rock bottoms. North of Point Loma the beds (5 to 8) were mostly on cobble bottoms and found far offshore. These beds were the least stable and exposed to winter storms from the northwest and summer storms from the southwest.

Los Angeles Kelp Beds

The Los Angeles type of kelp bed (9 to 19) was made up of Macrocystis pyrifera and was transplanted from the offshore islands. These were originally made up of Macrocystis angustifolia as found in Santa Barbara, but this all died off in the late 1950's and early 1960's. Macrocystis pyrifera was transplanted from the offshore islands by Wheeler North, California Department of Fish and Game, and Kelco personnel in an attempt to restore the kelp beds. These beds were mostly on high relief rock bottoms. They were more stable than the San Diego beds probably because of the partial shelter provided by the offshore islands from storms that come directly from the southeast.

Santa Barbara Kelp Beds

The Santa Barbara type of kelp bed (20 to 32) was composed of Macrocystis angustifolia. Some of the beds were on shale and high-relief rock bottoms, but many were on sand. These were the most stable kelp beds in California, with regard to canopy area. They were also the most sheltered, being in the lee of the Santa Barbara Channel Islands. The beds were also sheltered from storms out of the west sine they were to east of prominent land points.

Offshore Island Kelp Beds

The offshore island type of kelp bed (71 to 88) consisted of a special variety of Macrocystis pyrifera that looked different from the mainland variety. Some of the largest kelp beds in California surround the offshore islands. The south facing beds were exposed to severe winter and summer storms while the north facing beds were relatively sheltered the year round. The oceanographic conditions were different from those found near the coast on the mainland. These beds were less well documented than the mainland beds.

Table 7-2. Twenty-five year average area, range in area, and percent variation in area for seven southern California kelp beds.

	Bed Number	Average Area (hectares)	Range (hectares)	% Variation
3	San Diego	414	23-1297	95
4	San Diego	213	64-649	90
6	Del Mar	258	118-350	66
7	San Onofre	40	0-137	96
8	San Mateo	142	2-631	99
31	Santa Barbara	539	504-594	15
32	Santa Barbara	1099	989-1217	19

Table 7-2, based on unpublished mapping studies, shows that beds can be characterized by their stability (Santa Barbara) or lack of stability (San Diego, San Onofre). Over a 25-year period, stable beds vary in area fro 15 to 19% of their maximum, while unstable ones vary in size from 66 to 95% of maximum. The latter can in effect appear and disappear.

LONG-TERM CHANGES IN SOUTHERN CALIFORNIAN KELP BEDS

Many of the disputes about the damage done by kelp harvesters, by nearshore sewage pollution, and other human activity has been prompted by the disappearance of kelp beds. Perhaps the most alarming loss of kelp beds was seen at Palos Verdes, California, where Crandall had mapped some 2.42 square miles of kelp forest in 1911. An aerial survey in 1928 showed some 2.89 square miles but by 1945 this had dropped to 1.63 square miles. In 1947 there was 1.05 square miles, which then dropped to 0.44 in 1953, 0.24 in 1955, 0.13 in 1957, and 0.05 in 1958. Only a few scattered plants remained in 1959 with a total of less than 0.01 square miles of kelp remaining. Thus, the entire kelp forest community from Palos Verdes peninsula was lost, and replaced by a depauperate, sediment-laden community dominated by urchins, crustose corraline algae and in shallow water a few hardy macroalgae other than Macrocystis. The loss of the Palos Verdes kelp beds is illustrated in Figure 7-7.

Work on Palos Verdes kelp beds by W. J. North and more recently by K. Wilson of the California Department of Fish and Game, focused on the transplanting of kelp plants from Catalina Island to Palos Verdes. These efforts have been successful and the kelp beds there are now beginning to expand from essentially nothing to significant areas.

North has studied a similar pattern of kelp disappearance at Point Loma, where a gradual degradation took place from the 1911 levels until, by 1963, there were only scattered plants present (Figure 7-8). North used quicklime, spread from the surface to kill the sea urchins that dominated the area. After this grazer was removed, the kelp began to return. At the present time there are large kelp plants at Point Loma and significant harvests are once again obtained from the bed.

A number of hypotheses have been advanced to explain the cause of kelp bed degradation. Some of these have been published while others have not. The kelp-sewage-effluent hypothesis was the first to be examined in detail. During the 1940-50 period four productive beds at Palos Verdes disappeared, and from 1950 on two beds off Point Loma also disappeared. Since there were outfalls in these areas concern was expressed that the disposal of large quantities of wastes into the sea destroyed the beds. However, no chemical or effluent was found to be sufficiently toxic to account for the widespread loss, although the effects of wastes (DDT) from a chemical company was not examined. However, beds nearest the waste outfalls deteriorated first, with losses proceeding in either direction away from the points of discharge. Only the Santa Barbara bed was unaffected. Sedimentation and disease were not implicated nor was turbidity. Grazing was identified as a significant factor in the destruction of Point Loma and Palos Verdes beds.

The realization that grazing sea urchins could destroy kelp beds led to what might be called "the urchin hypothesis." It was felt that effluent allowed

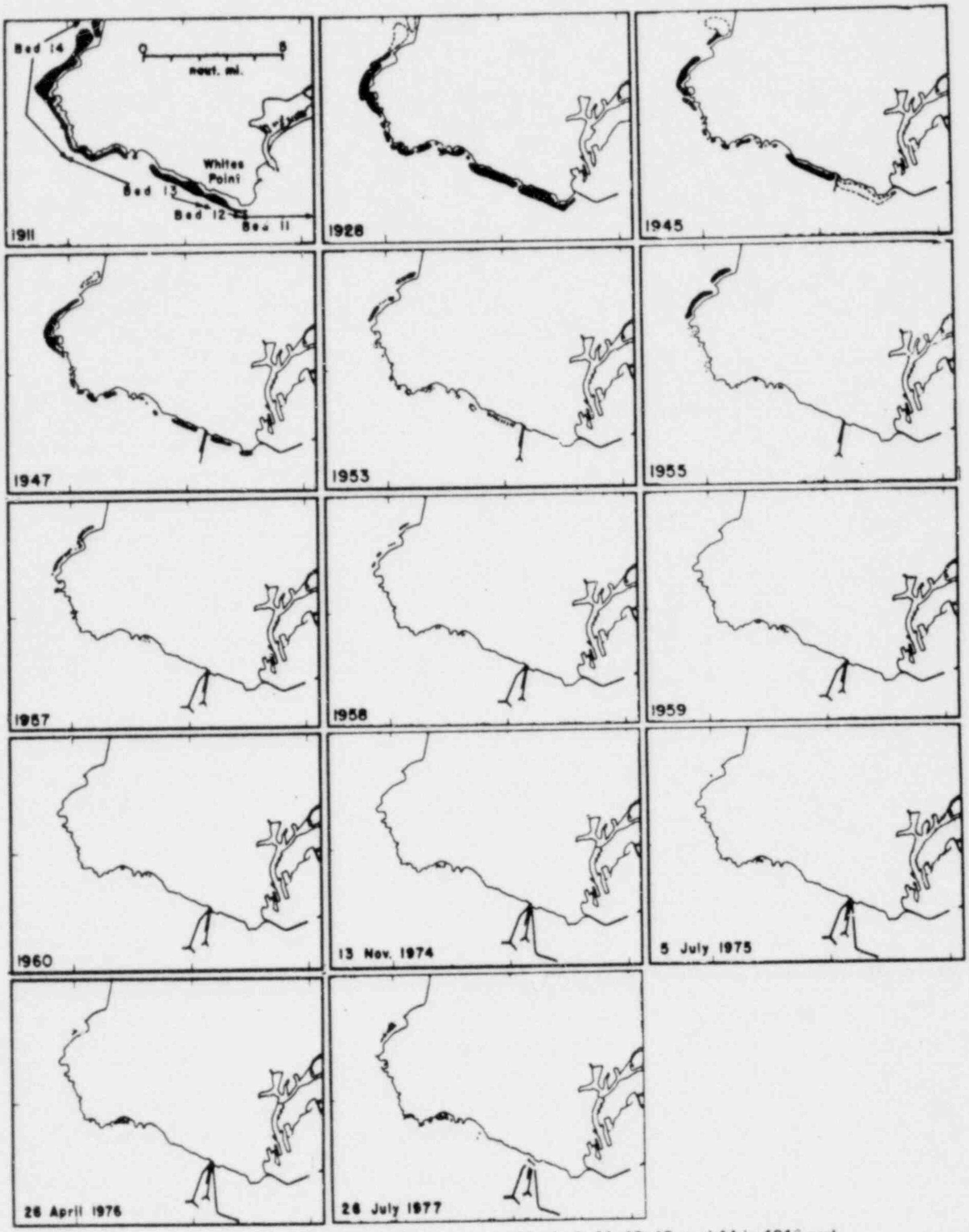


Figure 7-7. Maps illustrating the area covered by beds 11, 12, 13, and 14 in 1911 and the degradation and loss of these beds by 1959. The beds had partially recovered by 1977. Kelp is shown here in black. The installation of the San Pedro breakwater in 1928 and the development of the White's Point sewage disposal lines are shown (after North et al.).

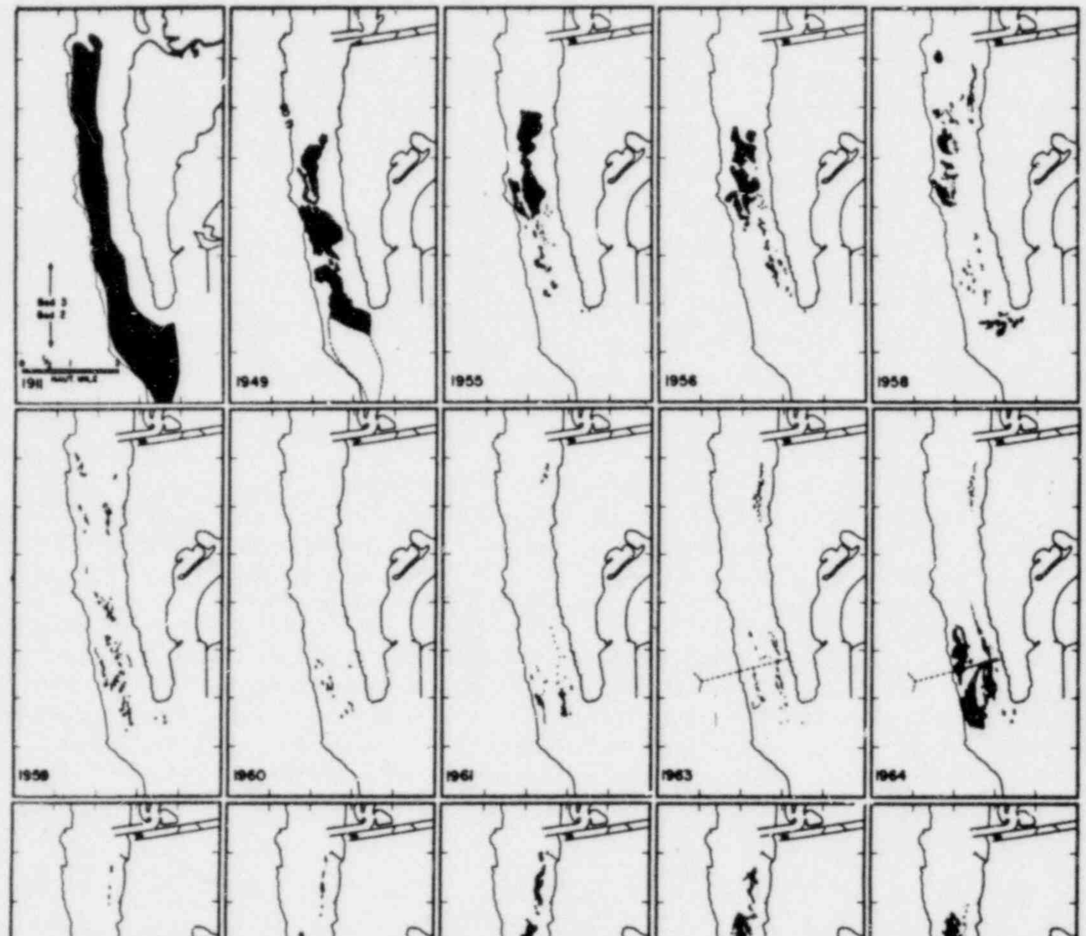


Figure 7-8. Maps illustrating the history of loss and recovery in the Point Loma kelp bed, from 1911 to 1974. Kelp is shown in black (after North).

urchins to persist and maintain populations that would remove any kelp that might be recruited. In fact, the use of quicklime (calcium oxide) to poison these echinoderms was successful. Once they were removed the benthic vegetation returned until it was again grazed away by urchins migrating into the area.

Other reasons for kelp degradation include the "temperature hypothesis." Brant (1923) describes events that occurred during an extremely warm summer in 1917, when a kelp bed was destroyed. Commonly warm water is associated with the appearance of black rot, and a general yellowing of the kelp canopy. It was felt that the so-called "warm water years" when there was widespread damage to the kelp beds of California, were destructive because of the elevated temperatures. As mentioned previously , it is known that nutrient levels in cool, upwelled waters are adequate to support plant growth, while warmer surface waters are lower in nutrients. Jackson (1977) pointed out that warm-water damage might in fact be due to low nutrient levels, thus the "temperature hypothesis" might be considered the "temperature-nutrient hypothesis."

Concern about the possible impacts of large outfalls from power plants like those at San Onofre gave rise to the hypothesis that entrained, turbid bottom water along with heated water from the plant, would both reduce light levels in adjacent kelp beds and would expose them to much heavier sedimentation levels than they would normally have. This "sedimentation-turbidity" hypothesis has been examined by several workers. Volse (1977) and Devinney and Volse (1978) studied the effects of sediment on the gametophytes of Macrocystis in the laboratory and showed that even the slightest amount of sediment in a culture dish greatly reduced the changes of gametophyte establishment and survival. Sediment on fouling plates placed in a kelp forest was studied by Neushul et al. and found to vary with season. It is evident that sedimentation levels will influence kelp recruitment in the sea, but it is not yet clear to what extent.

STUDIES OF THE KELP ECOSYSTEM AT SAN ONOFRE

There are three kelp beds in the vicinity of San Onofre: the San Mateo bed, the San Onofre bed and the Barn bed. These all declined in area in the late 1950's and early 1960's. Like other kelp beds, recruitment has been uneven through time and probably linked to the key environmental influences of light, temperature and nutrients.

Kelp Mapping at San Onofre

There have been several groups involved in measuring the areas of kelp beds at San Onofre. These include: Crandall (1912), North (unpublished maps and data), Marine Biological Consultants. (see SCE 1979), Marine Review Committee (see Barilotti 1978; Ecosystems Management Associates, Inc. 1977 to 1979; Dean 1978, 1979) and Neushul Mariculture Inc. (unpublished). The methods used have ranged from a boat and sextant, to aerial photographs and side-scan sonar and radar positioning devices.

The kelp beds in the San Onofre area have changed dramatically in this century as discussed previously (Figures 7-9 and 7-10). Some studies have cited the San Mateo kelp bed and the Barn kelp bed as unperturbed, natural kelp beds as compared with the San Onofre kelp bed, which was disturbed by man's activities, such as construction dredging and operation of the San Onofre Nuclear Generating Station. This might be a valid comparison if the beds were shown to have similar variation on a short time scale such as that over which the measurements were being made. However, this has not been done. Over a span of decades, these three beds have gone from being very well developed in 1955, to being, for the most part, gone in the early 1960's, and to being moderately well developed in the

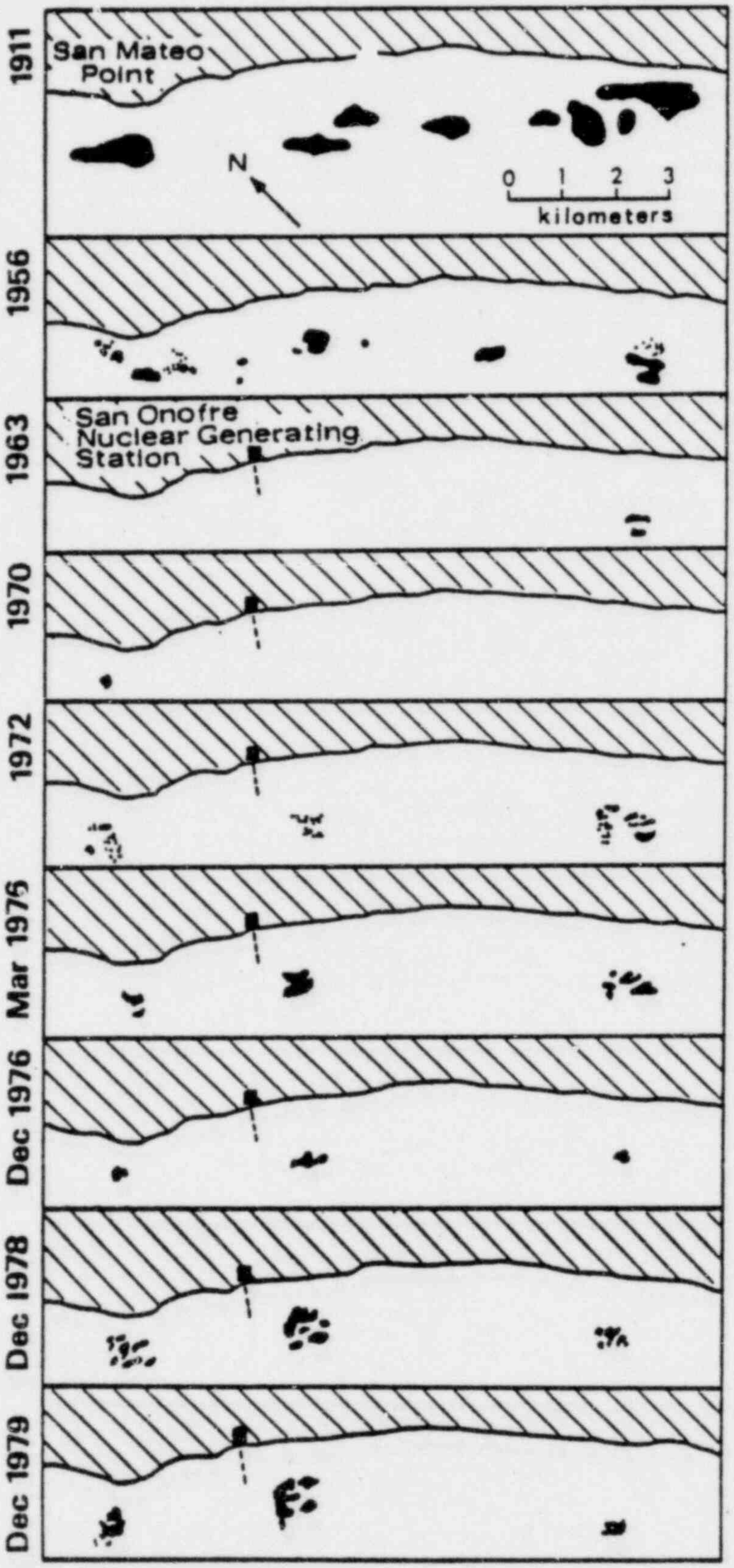


Figure 7-9. The areal extent of the San Mateo, San Onofre, and Barn kelp beds from 1911 to 1979, showing the installation of the San Onofre Nuclear Generating Station, and periodic disappearance and re-appearance of the kelp bed.

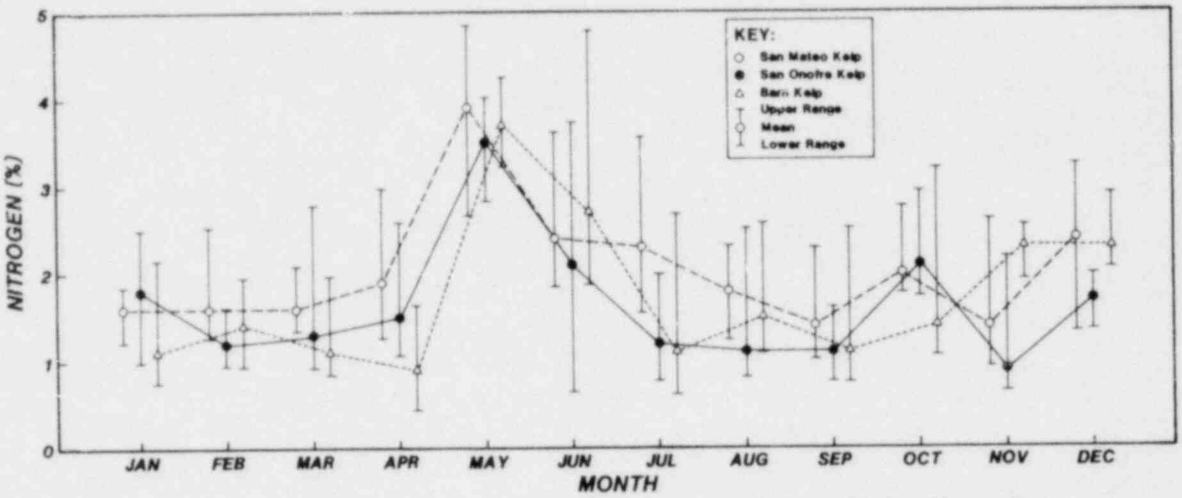


Figure 7-10. Mean nitrogen levels in kelp blades taken from the San Mateo, San Onofre, and Barn kelp beds from January 1979 through December 1979, showing an increase in blade nitrogen during the upwelling period in May.

late 1970's. Shorter term fluctuations have shown that the three beds vary independently. The San Mateo kelp bed was missing in 1963 while the Barn kelp bed was missing in 1970 and at the end of 1980 as well. It would be difficult to determine the actual causes for the relative differences in the short term fluctuations between these three beds.

Shorter term fluctuations have been studied in the more frequent survey efforts since 1977 (see Dean 1980; SCE 1979). The areas that most consistently have had dense canopy coverage have been those areas with high-relief rock bottoms. These were subjected to less sand coverage, and were more stable because the larger rocks could not be turned over like cobbles. There was a "recruitment event" in 1978 when large numbers of kelp plants grew where none had been before. This type of event probably only occurs once every few years. New surface canopy was produced by these plants after several months of growth.

Environmental Monitoring at San Onofre

Environmental monitoring has been carried out in the vicinity of the kelp beds of San Onofre for several years by groups supported by Southern California Edison Company. In addition to measuring the sizes of kelp beds, measurements were made of temperature, light, current, sedimentation rate, turbidity and inorganic nutrient concentrations The conditions off San Onofre are similar to other areas off San Diego and Orange counties. Since these measurements were made to comply with regulatory agency specifications, and since these specifications changed frequency, a multi-year synopsis of environmental conditions in the sea has not been produced.

In 1975, the California Coastal Commission, formerly the California Coastal Zone Conservation Commission, established the Marine Review Committee (MRC). The purpose of the committee was to conduct independent studies to determine the environmental impact of Unit 1 at San Onofre and to predict the future impacts of Units 2 and 3 on the marine communities.

Experimental Studies at San Onofre

A Kelp Ecology Project was started as part of the total MRC program. The findings of the first two years of this project were summarized by Barilotti

(1978). He found that the kelp canopy fluctuated widely and he observed that Macrocystis vesicles of the San Onofre bed filled with fluid and fronds sank. In addition he suggested that the rate of dislodgement and resultant loss of kelp plants was higher in the San Onofre bed than in other California kelp beds. His transplant studies near the Unit 1 discharge did not show a reduction in growth near the discharge plume. However, observations of kelp recruitment on ropes in the water column showed recruitment down to a level of 4 m (13.1 ft) from the bottom, but that none occurred near or on the bottom.

A second phase of the Kelp Ecology Project began under the supervision of Dean (1978). In this effort, kelp gametophytes were transplanted from the laboratory to the field at various times over a year long period. In addition, observations were made along transects run through the kelp bed, and gametophytes and juvenile sporophytes were outplanted. Gametophyte fertility and the production of young sporophytes were reduced in the vicinity of the Unit 1 discharge. Dean suggested that reduced light may have been responsible. Observations made of adult kelp along survey transects suggested that they were lost because of storms and grazing from invertebrates. The rate of recruitment of juvenile kelp plants was highest in the spring. Poor natural recruitment and poor survival of transplanted sporophytes suggested that high rates of sedimentation and low levels of light may have both limited recruitment and affected plant survival. Survival of juveniles near the Unit 1 discharge was not reduced, but their growth rates were significantly lower than those of kelp plants at a distance from the discharge.

It has been difficult to interpret the results of the outplant and transplant experiments because of small sample numbers and lack of some monitoring data (see discussion of sample numbers in Barilotti 1978).

It has been suggested that juvenile sporophytes transplanted near the San Onofre Unit I outfall grew slower than those transplanted far from it because of reduced light and an increase in number of fouling organisms (Dean 1980). It was also shown that outplanted gametophytes required at least 30 E/m^2 irradiance within a 40-day period to become fertile. However, sedimentation rate and inorganic nutrient concentrations have also been implicated as possible causative factors in these experiments.

In the gametophyte outplant experiment irradiance, temperature, sedimentation rate, sporophyte densities and sporophyte lengths were measured over several 43-day time periods. At the different experimental stations, sporophyte lengths were linked positively with irradiance and negatively with sedimentation rate and temperature. Increases in sporophyte length are dependent on sufficient light (high irradiance and low sedimentation rate) for high photosynthetic production. The negative link between sporophyte length and temperature could be due to the intermittent conditions of low temperature, high nutrients and high light. Sporophyte densities were linked only negatively with temperature. Again this relationship may be due to the spring upwelling conditions which often trigger Macrocystis reproduction which would be likely at low temperature, high light and high nutrient concentrations. On the other hand, this relationship could be due to the direct effects of temperature in increasing the irradiance requirement for gametogenesis (see Luning 1980). Since relatively few nutrient measurements were made, it is not possible to distinguish the effects primarily due to temperature and light from those due to nutrients.

Measurements made by other SCE contractors have shown the nitrogen contents (Figure 7-10) was over 3% in San Onofre kelp in May and June 1979. This is when the natural upwelling period (Figure 7-11) enriched the nitrogen content of the coastal waters. Nitrogen levels dropped to below 2% the rest of the year, when environmental levels of nitrogen were relatively low.

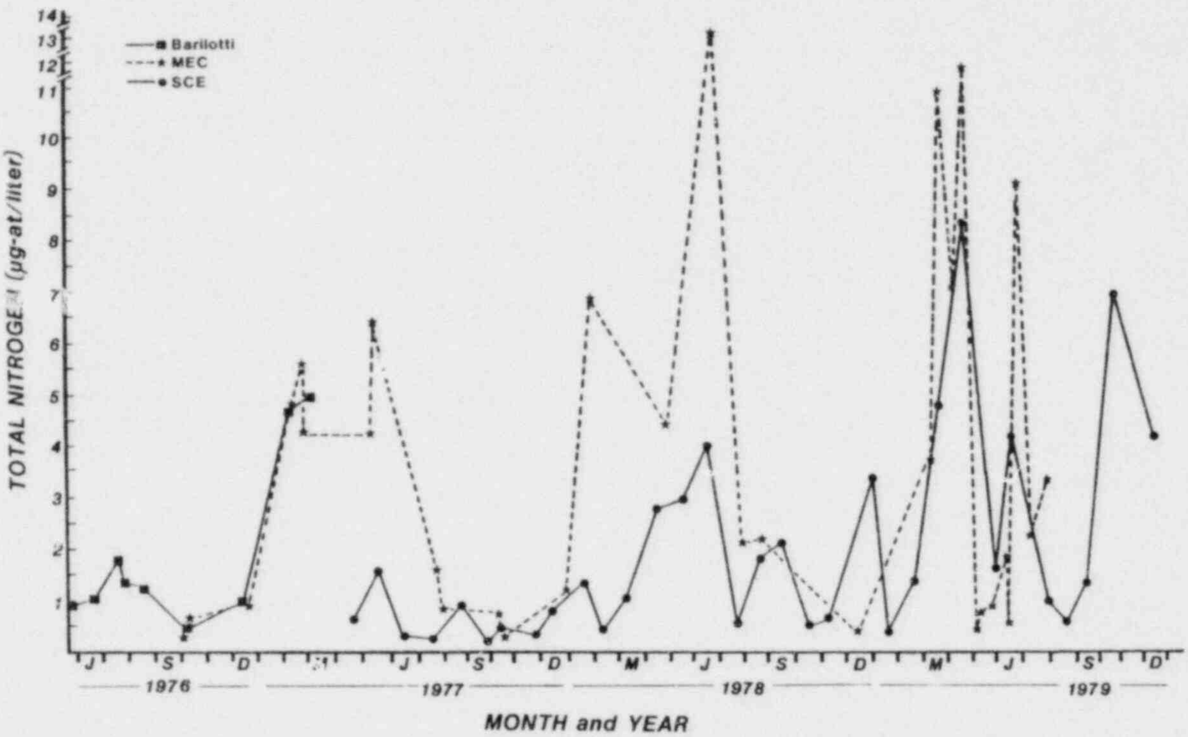


Figure 7-11. Nitrogen levels in the water at San Onofre as measured by C. Barilotti, Marine Econogical Consultants, and Southern California Edison from 1976 through 1979, showing peaks in nutrient concentration in May and June each year.

The MRC-sponsored program and its antecedents provide a preoperational baseline for the San Onofre kelp bed when combined with other studies of southern Californian kelp beds. Recent work carried out there has been experimental rather than descriptive. Attempts have been made to establish a clear relationship between physical measurements and responses of the kelp plants. The impacts of the entrainment of massive amounts of subsurface water which is heated and loaded with sediment and then discharged are thought to be considerable, and it would seem a priori to be logical to expect major impacts. However, studies to date give only some suggestions that kelp recruitment rates might be reduced, that bryozoan encrustation of plants might increase, and that light levels in general might be reduced in kelp beds near the outfalls.

CONCLUSIONS

Studies of kelp and kelp beds of the southern California bight, that provide the baseline information, fall into several categories. There are: 1) individually-pursued studies usually forming the basis for Ph.D. and M.A. thesis work; 2) studies, usually by academics, supported with state or federal funding; and 3) "forced" studies that are usually the results of public concern or controversy over management policies, such as outfall monitoring, which are imposed by the government.

All these studies represent a substantial effort and have together produced significant results that now allow one to make a much more reasoned analysis of kelp-forest ecology and the potential impacts of human activity on this ecosystem. We now have a much better appreciation of the complexities of the kelp forest ecosystem and the interactions of organisms at various trophic levels.

This is encouraging because the interrelatedness of these organisms suggests that we need not study all of them to detect perturbations in the whole system. It is unrealistic to assume that a kelp forest where recruitment is impaired and biomass production reduced, will be able to support as rich and diverse a fauna as one with ample production. Studies of the reproductive processes of macroalgae in the sea have given us some insights into the importance of microhabitats on the sea floor and events that occur there.

The appearance and disappearance of kelp beds has been recorded via aerial photographs and the loss and recovery of beds like those at Point Loma, or at Palos Verdes and San Onofre, are well documented historical events. Much speculation has been advanced as to the causes, and in the 1950's the correlation between outfall operation and kelp loss. The recovery of beds after sea urchins had been killed with quicklime, suggested that there might be some simple explanations for kelp disappearance and reappearance. Unfortunately this has not been the case. The problem, as this chapter suggests, involves multiple causal factors that concurrently can influence the kelp ecosystem. Seasonal variations in climatologic and oceanographic conditions influence the beds on a "bight-wide" scale, while at the other extreme events in the microscopic boundary layer at the sea floor determine whether recruitment does or does not occur.

In spite of persisting uncertainty as to the causes of kelp loss, and the roles played by sedimentation, light, temperature and nutrients, a general outline of causal relationships seems to be emerging. This cannot be applied to any specific area, but as an example growth rate studies now all seem to substantiate the early view that the plants grow at about 3% per day throughout the year. Similarly several workers have not found evidence to support the contention that nutrient levels are extremely important, and play a key role in determining the development and demise of kelp beds over the year.

We do know for certain, from the photographic records available to us, that kelp beds have appeared and disappeared from along our shores over a period of some 60 years. From these records we can say that some beds are stable and others are not. The reasons for stability or lack of stability are not universally agreed on, but it is clear that for whatever reason, one cannot expect the same type of stability seen in a Santa Barbara kelp bed in, for example, a bed at San Onofre. Some features of stable beds are not found in unstable ones. For example, the long-lived species of Macrocystis, (M. angustifolia) is found in the Santa Barbara beds, while a shorter-lived species (M. pyrifera) occurs in the more southern beds. Stable beds occur in regions of less water motion and southern exposure, while unstable beds occur along exposed, east-facing shorelines.

The San Onofre and Barn kelp beds together have averaged 40 hectares over the past 25 years, ranging from a minimum of 0 to a maximum of 137 hectares. Collectively they can be considered to be a small, unstable kelp bed, being less than 25% of the area of beds to the north and south. According to the California Department of Fish and Game (Smith, personal communication) the San Onofre kelp bed and Barn kelp, which together make up bed number 7 (Figure 7-3) have an area of 0.78 square miles.

Finally, if the San Onofre and Barn kelp beds are damaged or destroyed, it is unlikely that it will be possible to establish direct causal-relationships between environmental perturbations caused by the San Onofre Nuclear Generating Station and the status of the San Onofre kelp bed. There are no simple answers to "the effects of San Onofre on SOK." Changes in this kelp ecosystem produced by the San Onofre Nuclear Generating Station will have to be viewed against the background of normal seasonal and long-term environmental change that in the past

has characterized this and all other kelp beds in southern California, and it will be very difficult to separate the effects of natural processes from those that are man-induced.

This concludes the overall discussion. Detailed 1980 methods and results are presented in sections that follow.

APPROACH

The kelp bed investigation was initiated to fulfill various regulatory requirements to monitor the "health" of the San Onofre kelp bed (SOK) during the operation of San Onofre Unit 1 and the construction of San Onofre Units 2 and 3. To aid in this study, the two remaining kelp beds of the San Onofre region, the San Mateo (SMK) and Barn kelp (BK) beds, were used as reference beds.

The basic approach of this study was to quarterly monitor gross changes in the SOK canopy and then to compar these results with changes recorded at two reference kelp beds, SMK and BK. To supplement this investigation, additional parameters which could have an influence on the size and condition of the individual canopies were investigated. These parameters included: 1) composition of substrate associated with the individual kelp beds; 2) water column levels of the nutrients ammonia, nitrogen, and phosphate; 3) kelp tissue levels of nitrogen; and 4) the general health of the kelp plants that comprised the three kelp beds.

METHODS

The kelp investigation was conducted from January through December 1980 at SOK and two reference kelp beds, SMK and BK. Study tasks at each of the three kelp beds included: 1) mapping of the areal extent of the kelp canopies and contiguous bottom topography using an electronic positioning system during February, July, and December; 2) quarterly mapping of the kelp beds by aerial infrared photography; 3) monthly determination of primary nutrient (e.g. nitrogen, ammonia, and phosphate) concentrations in the surface and bottom waters; 4) monthly determination of the nitrogen content of kelp tissue from January through May; and 5) a quarterly assessment of the general health of the kelp plants.

Materials and methods for additional data collected in the various oceanographic and hard benthos studies are reported in Chapters 4A-C and 5B.

KELP CANOPY MAPPING

The areal extent of the kelp canopies and associated bottom topography were mapped during March, July, and December by Ecosystems Management Associates, Inc. The kelp canopy maps, which included both surface canopy and adolescent 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 trasversed 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 quarterly basis, 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 survey are on file with SCE.

BOTTOM TOPOGRAPHY

The bottom topography under and adjacent to the SMK, SOK, and BK canopies were determined 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) greater than 90% sand; 2) 10 to 30% cobble; 3) 31 to 60% cobble; and 4) 61 to 100% cobble and boulders.

WATER COLUMN NUTRIENTS

Stations within and approximately 100 m (328.1 ft) upcoast of the SOK, SMK, and BK together with a station approximately 4.3 km (2.7 miles) offshore of SOK (Figure 7-1) were occupied monthly from January through July to determine the water column concentrations of nitrogen (NO_2+NO_3), phosphate (PO_4), and ammonia (NH_4). Beginning in August, occupation of the offshore station and stations outside of each kelp bed were discontinued and two additional stations within SOK were added. Water samples for nutrient determination were collected from surface and bottom waters at each kelp bed station, while at offshore stations, samples were collected from surface waters and depths of 15, 35, and 45 m (49.2, 114.8, and 147.6 ft). 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 followng the methods 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 the kelp fronds from SMK, SOK, and BK from January through May. Kelp fronds from an individual stipe were collected in each of the three kelp beds. Every 10th frond on an individual stipe beginning with a sporophyll frond (i.e. reproductive portion of the 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 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 the kelp plants in the established beds of the San Onofre region were made by diver-biologists during April, June, September, and December at a single station in each of the three kelp beds (Figure 7-12). Additional observations were made along an 1100 m (3609.1 ft) transect (Transect B) in SOK. Concurrent with these observations, qualitative estimates of the success of kelp recruitment were made.

RESULTS

AREAL EXTENT OF KELP CANOPIES

The areal extent of the kelp canopies of the San Onofre region were estimated during February, July, and December 1980. 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 areal extent of SMK increased from March through July and then decreased through December (Table 7-3). The February canopy of SMK was composed of two major sections with additional minor elements scattered offshore and downcoast of the main canopy (Figure 7-13a). By July the two main elements of the canopy had fused and extended in a northerly direction (Figure 7-13b). The SMK canopy in December had decreased approximately 40% from that recorded in July. The December canopy was generally the same shape as that recorded in July although a large section of the canopy center had disappeared (Figure 7-13c).

San Onofre Kelp Bed

The areal extent of the SOK kelp canopy increased slightly from February through July and then decreased by approximately 60% between July and December (Table 7-3). The SOK canopy was composed of three sections in February, with the largest appearing offshore and downcoast of the San Onofre complex (Figure 7-14a). By July, a single offshore band of canopy had formed and the inshore sections of the canopy were expanding (Figure 7-14b). The San Onofre kelp, and particularly the main canopy, deteriorated between July and December. The main canopy had decreased substantially and was composed of four elements. The upcoast and inshore section of the canopy also decreased while the newest section of the SOK canopy appeared to increase in areal extent (Figure 7-14c).

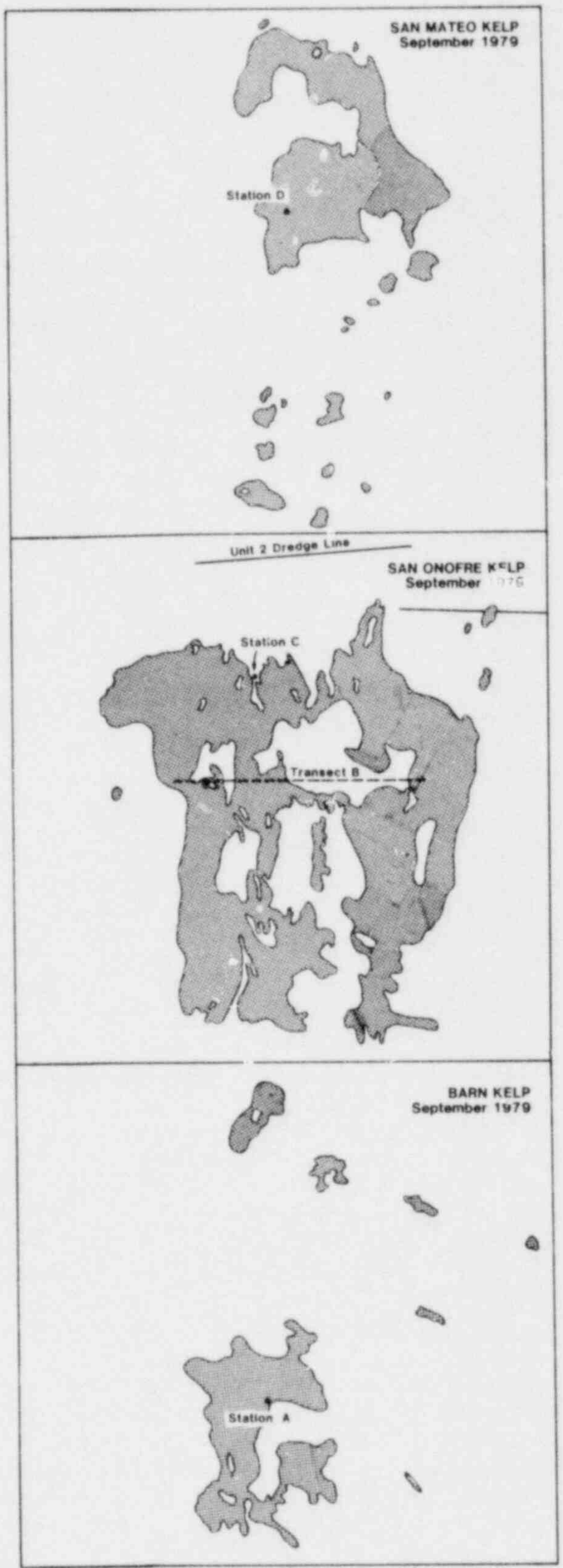


Figure 7-12. Location of stations and transect occupied for assessment of general health of kelp plants within the San Mateo, San Onofre, and Barn kelp beds from January through December 1980.

Table 7-3. Areal extent (m^3) of the San Mateo, San Onofre, and Barn kelp beds during 1980.

Month	San Mateo	San Onofre	Barn Kelp
February	334,300	1,238,800	262,700
July	675,200	1,268,800	148,700
December	420,100	523,500	2,800

Barn Kelp Bed

The BK canopy also deteriorated during the course of the 1980. The areal extent of the canopy decreased from 262,700 m^2 in February to no visible canopy in December. However in December an area of approximately 2,800 m^2 of submerged high density fronds was mapped (Table 7-3).

The BK canopy in February was composed of a single main canopy with minor canopy elements scattered upcoast and inshore of the main canopy (Figure 7-15a). The July BK canopy was similar to that observed in March although the areal extent had decreased by approximately 44% (Figure 7-15b). In December the visible surface canopy was gone and all that remained of the main section of the BK canopy was approximately 2,800 m^2 of subsurface high density fronds (Figure 7-15c).

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 rocky areas by either sediment bedload movement or sedimentation. The movement of bedload along the bottom is the result of physical processes associated with wave and current action, while sedimentation through the water column 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 and the relationship, if any, between changes in the areal extent of the kelp canopies and availability of suitable substrate.

San Mateo Kelp Bed

Substrate associated with the SMK bed was almost entirely high density (60 to 100%) cobble and boulders throughout 1980 (Figure 7-13a-c).

Availability of suitable substrate appears to have defined the limits of the SMK canopy. During all three surveys, the outer perimeter of the canopy occurred at the cobble/boulder-sand interface (Figure 7-13a-c).

San Onofre Kelp Bed

The SOK kelp canopy was associated almost entirely with a substrate of 60 to 100% cobble and boulder. The area of cobble and boulder expanded slightly in an offshore direction between February and July and then remained relatively stable through December (Figure 7-14a-c).

Kelp bed expansion between February and July apparently was related to availability of suitable substrate, especially around the outer margins of the main canopy. It appears that the outward expansion of the main canopy followed along the cobble and boulder-sand interface. The contraction of the main canopy between July and December left a large area of cobble and boulders devoid of canopy suggesting that the canopy extent was not limited by subtrate availability.

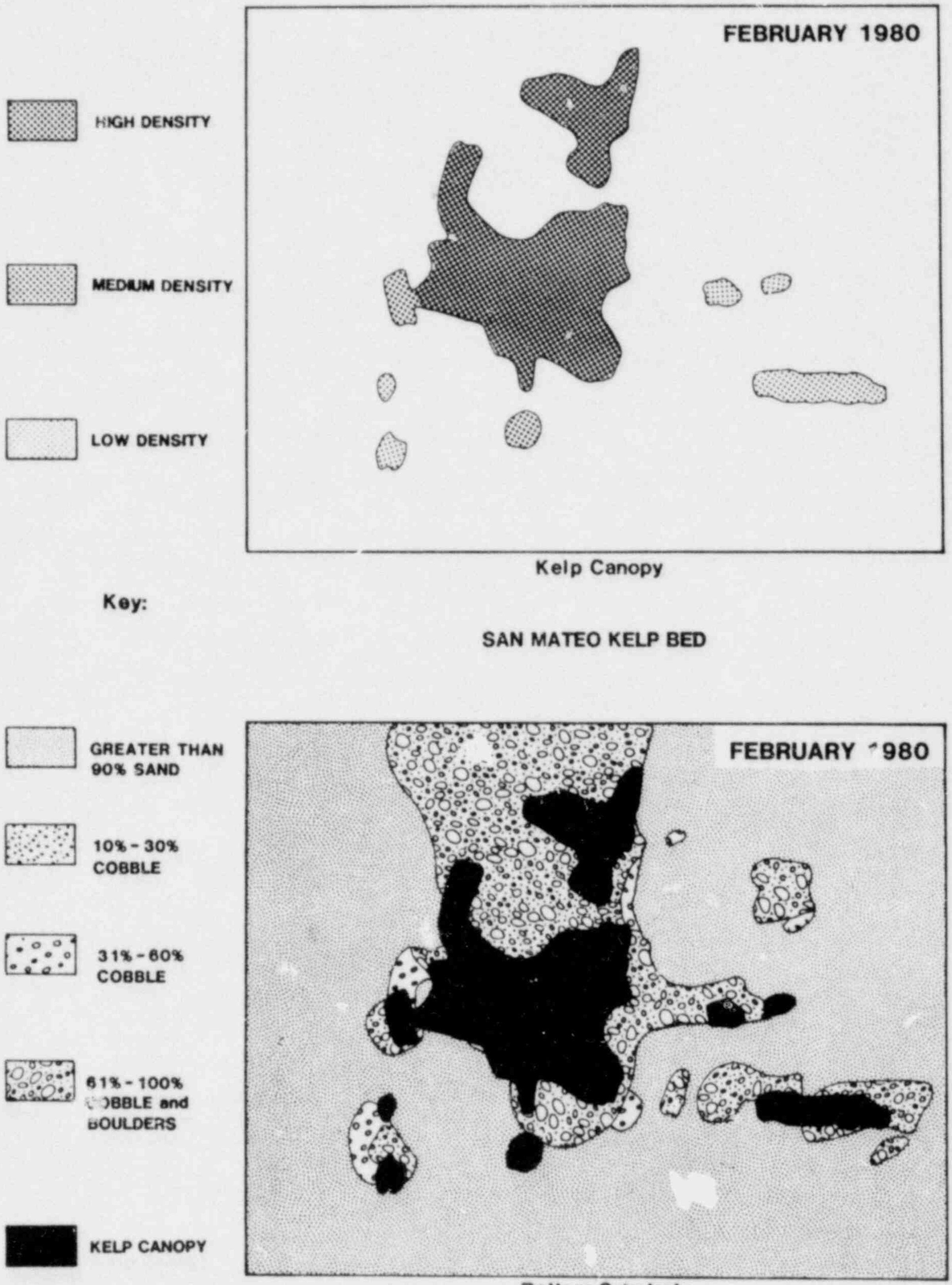


Figure 7-13 a) Kelp canopy configuration, relative canopy density, and substrate composition of the San Mateo kelp bed, February 1980.

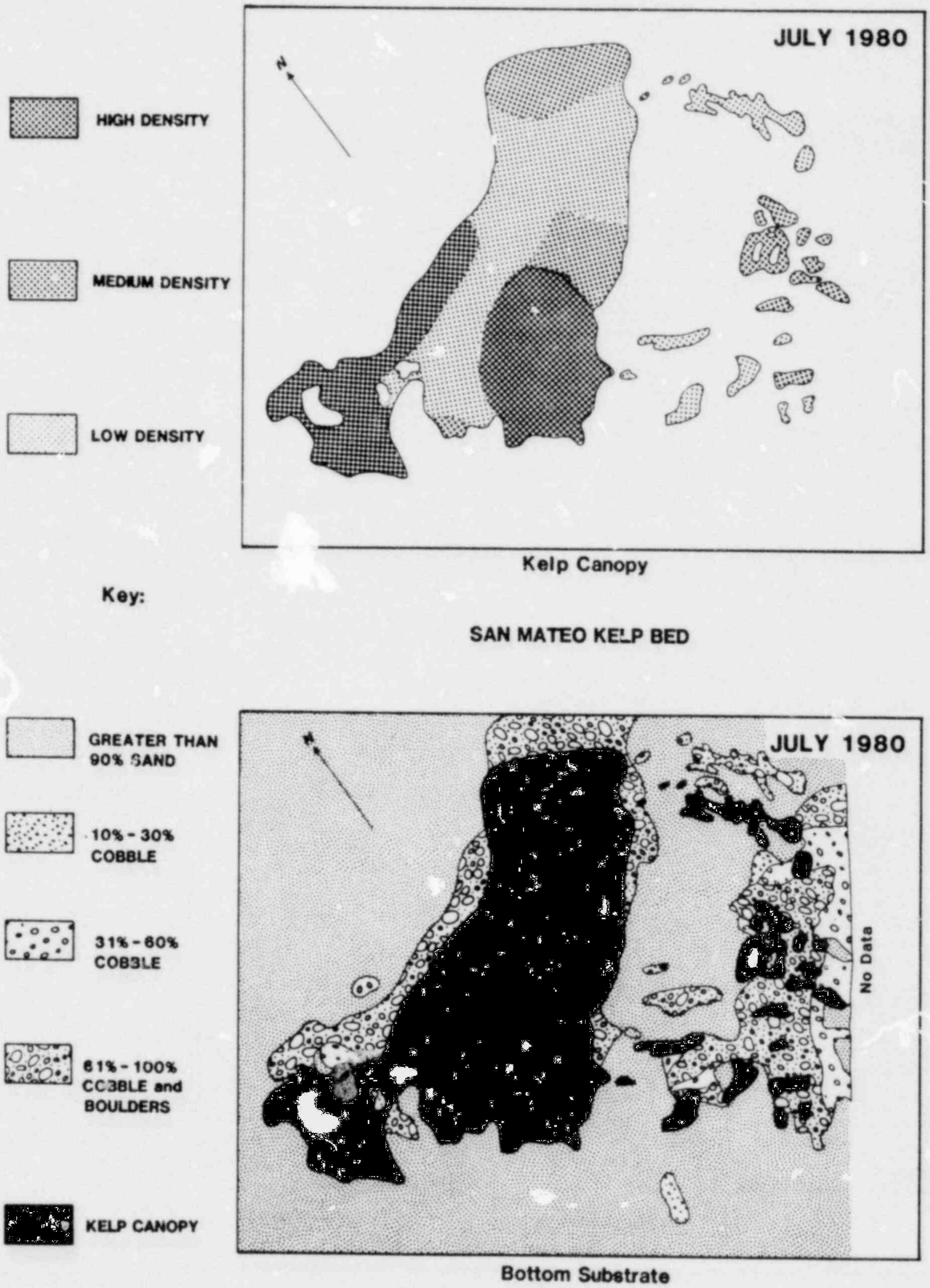


Figure 7-13 b) July 1980.

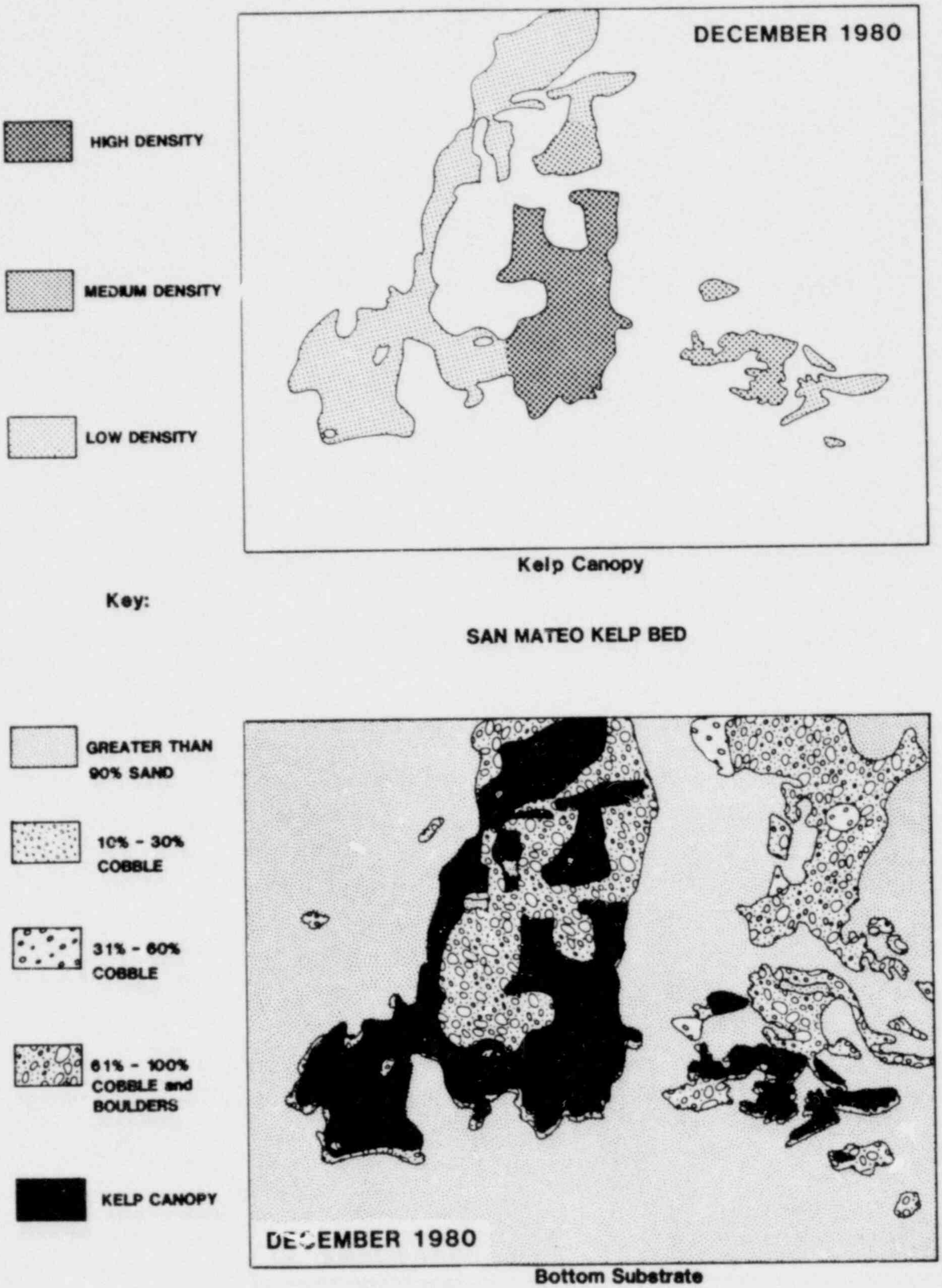


Figure 7-13 c) December 1980.

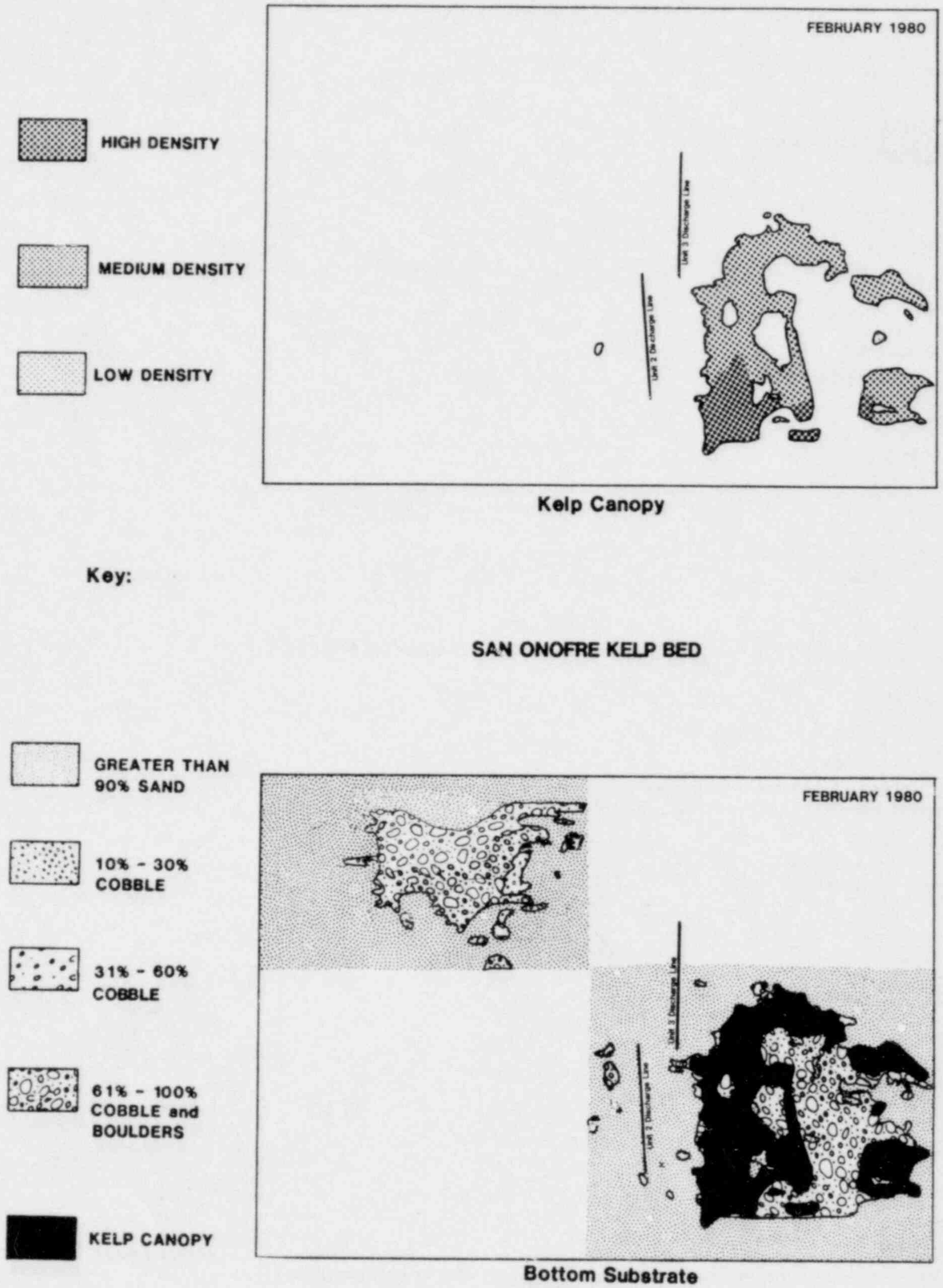
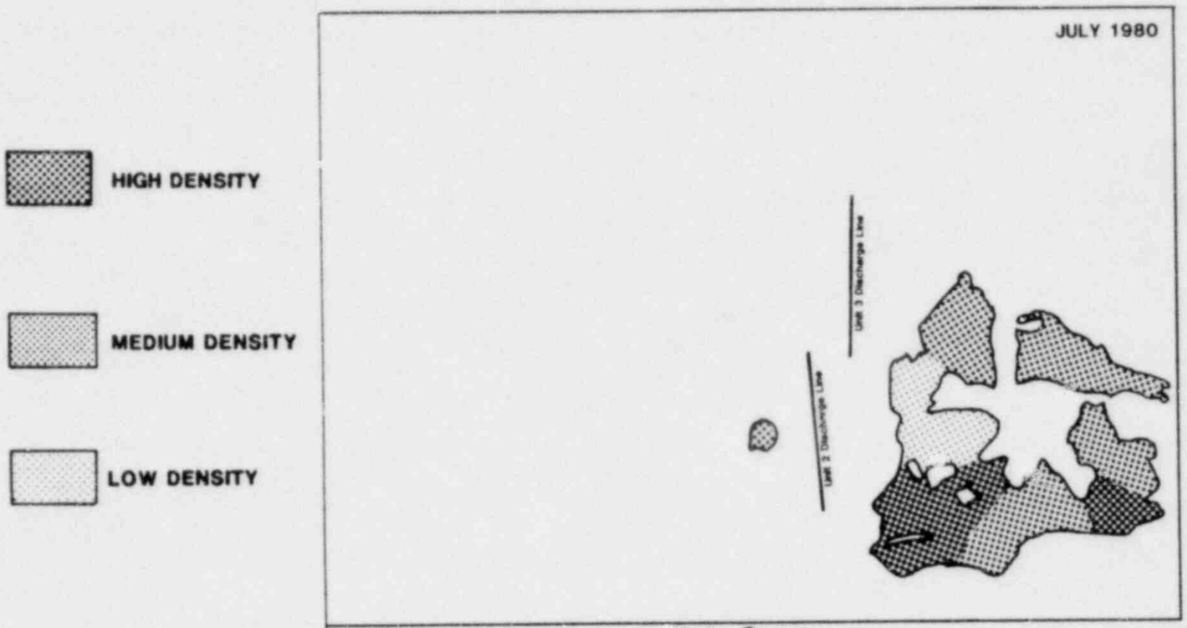


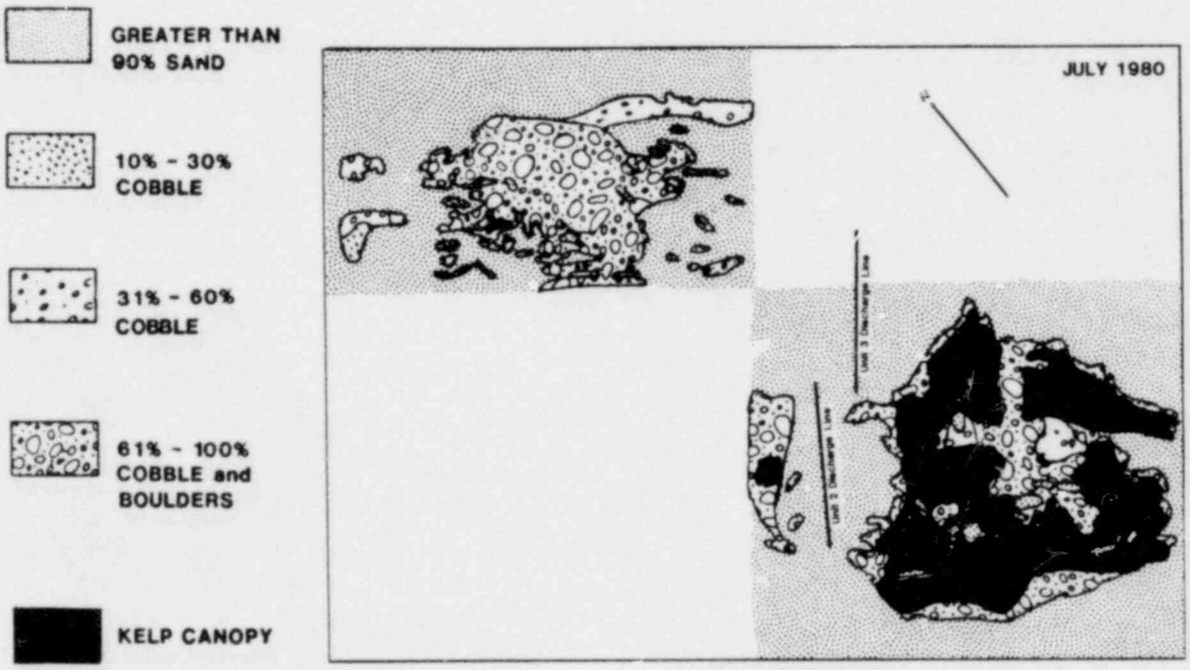
Figure 7-14 a) Kelp canopy configuration, relative canopy density, and substrate composition of the San Onofre kelp bed, February 1980.



Kelp Canopy

Key:

SAN ONOFRE KELP BED



Bottom Substrate

Figure 7-14 b) July 1980.

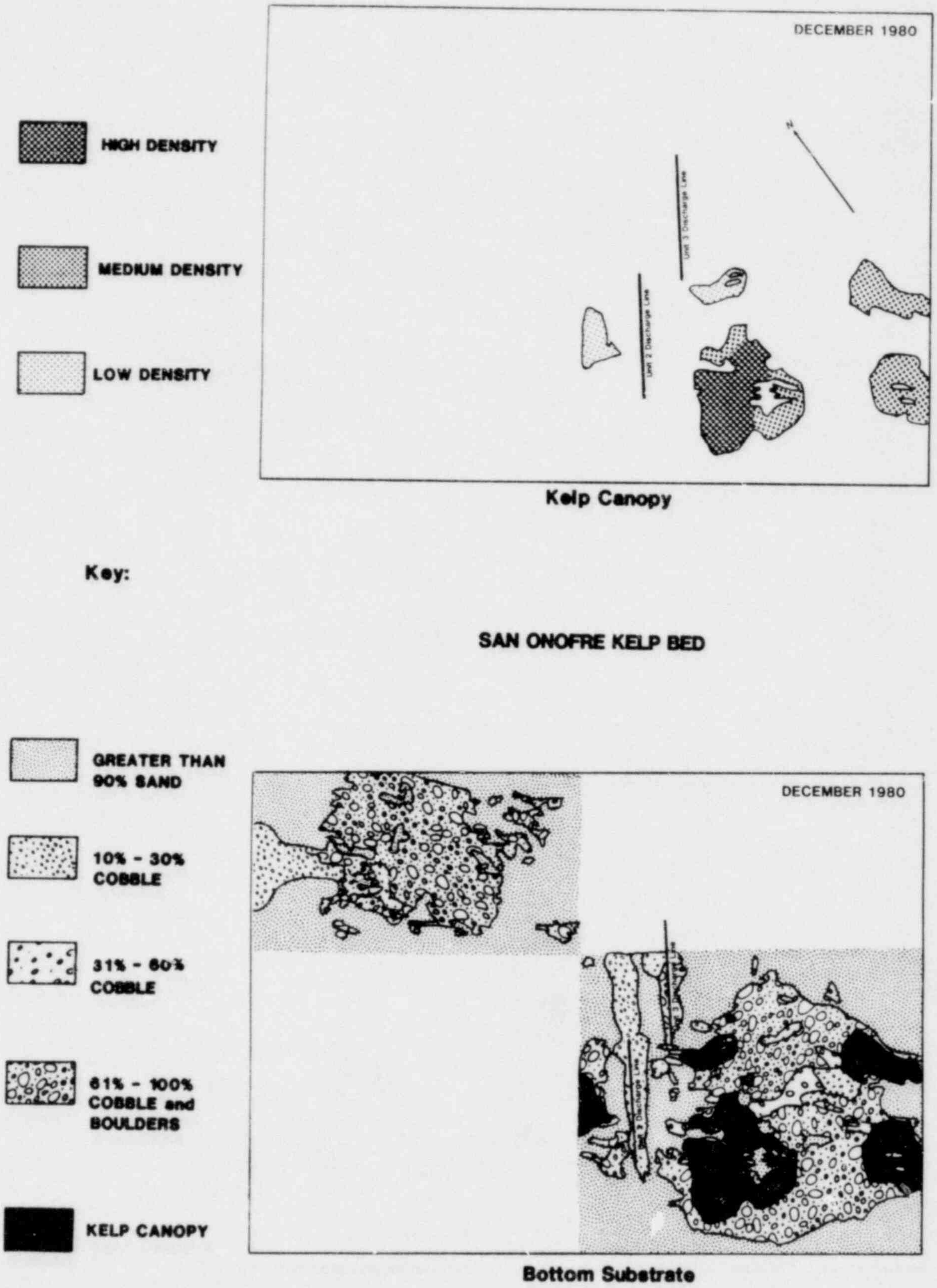


Figure 7-14 c) December 1980.

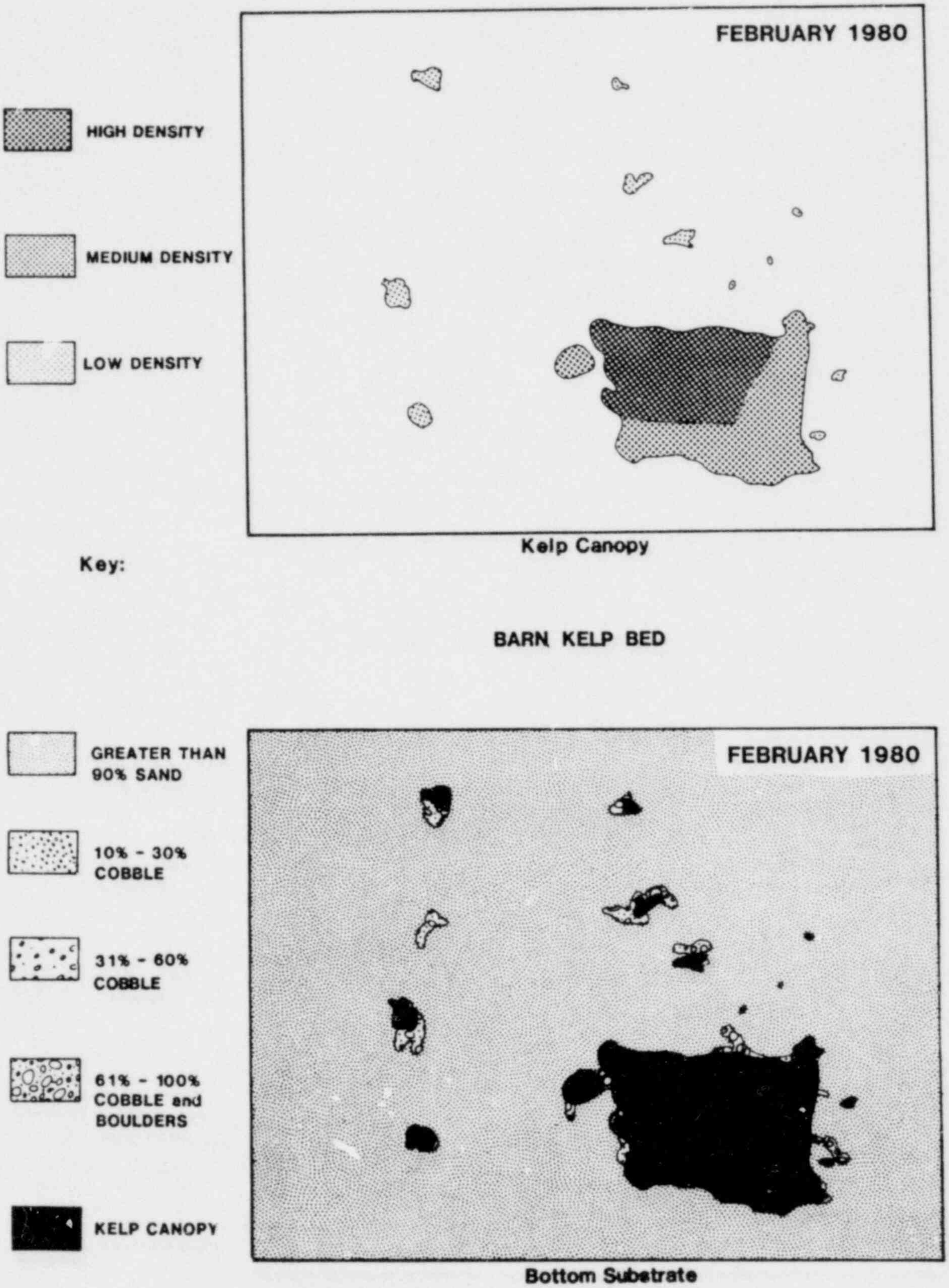
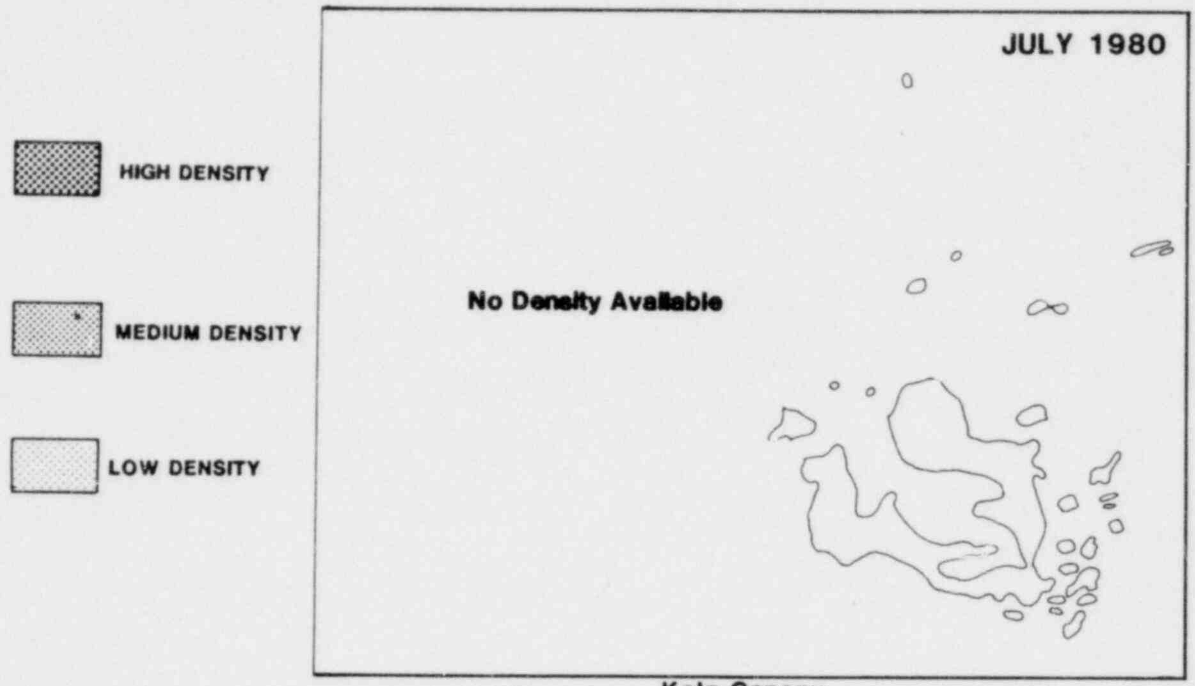


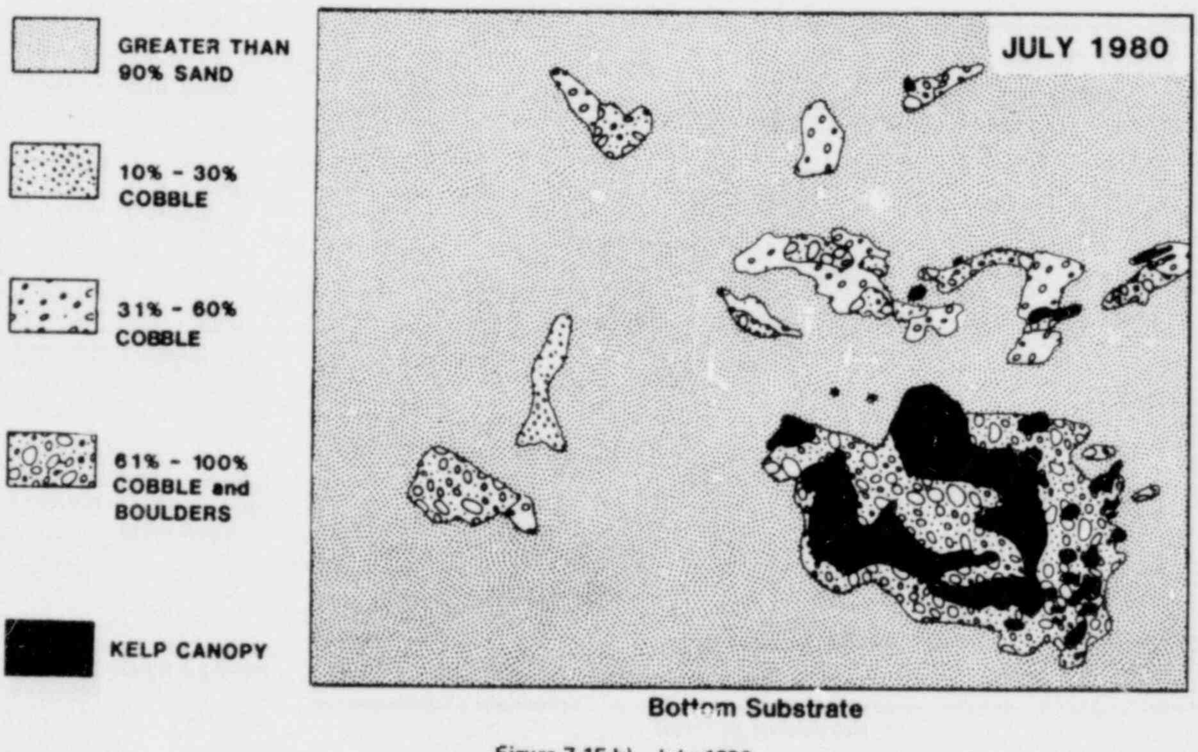
Figure 7-15 a) Kelp canopy configuration, relative canopy density, and substrate composition of the Barn kelp bed, February 1980.



Kelp Canopy

Key:

BARN KELP BED



Bottom Substrate

Figure 7-15 b) July 1980.

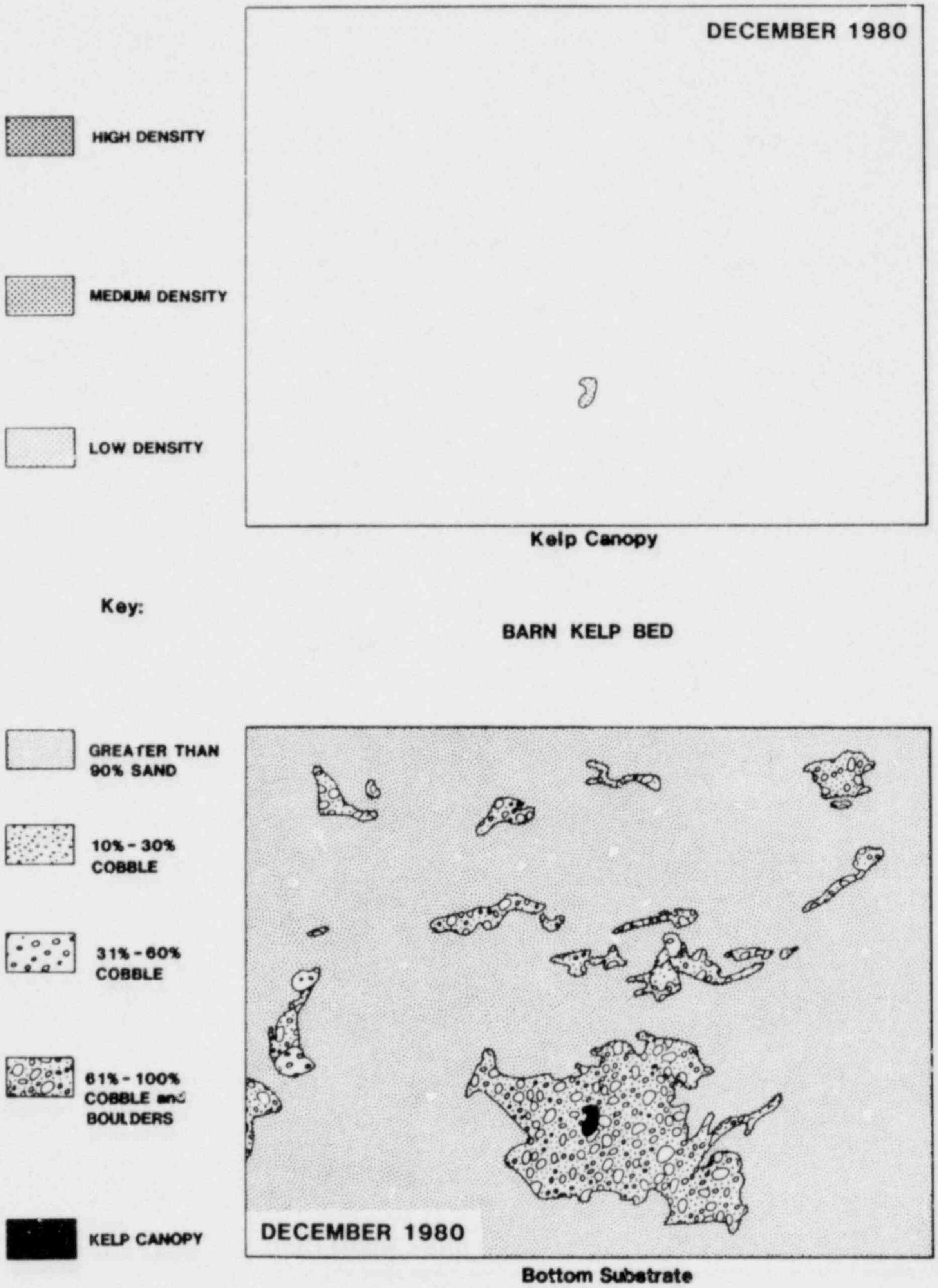


Figure 7-15 c) December 1980.

Barn Kelp Bed

Suitable substrate availability (61 to 100% cobble and boulders) changed very little between February and December 1980 at the BK (Figure 7-15a-c). Substrate at the BK was composed primarily of sand throughout the survey period. The majority of the cobble and boulder substrate occurred in the offshore-downcoast section of the study area. It was in this area that the major portion of the BK canopy occurred during March and July. This area also supported the small growth of high frond density plants recorded in December.

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 from January through July at stations inside and outside of the SMK, SOK, and BK beds. In addition, a station approximately 4.3 km (2.7 miles) offshore of the San Onofre kelp bed was occupied monthly to monitor upwelling in the area. Beginning in August, occupation of each kelp bed and offshore stations was discontinued. In their place two additional stations were added to SOK (Figure 7-1).

Nutrient concentrations from inside and outside the kelp beds and additional SOK stations, were averaged for the following presentation since no pattern between the areas was noticeable. All raw nutrient data were presented in the Comprehensive Data Supplement (SCE 1981b).

Nitrogen Concentrations

The temporal distribution of nitrogen concentrations in both surface and bottom waters was similar at all three kelp beds. In the surface waters, nitrogen concentrations reached maximum levels in January and February (0.44 µg at/liter to 1.13 µg at/liter), followed by a minor increase in April (Figure 7-16). Throughout the remainder of the year, surface nitrogen concentrations were depressed, never exceeding 0.1 µg at/liter (Figure 7-16).

Bottom water nitrogen concentrations fluctuated throughout the year at the kelp beds. Peak concentrations of the nutrient were recorded during January to February, April, and June to July (Figure 7-16).

Significant differences in nitrogen concentrations were observed in bottom waters between kelp beds during individual months, but no pattern was apparent over the entire year. No significant difference was noted in surface water nitrogen levels between the three kelp beds.

Examination of the nitrogen data collected from the 45 m (147.6 ft) depth at the offshore station, indicated that upwelling began in April and continued through July. Although there was evidence of upwelling from April through July, the surface and 15 m (49.2 ft) nitrogen levels only reflected the process in April and July (Figure 7-16).

Ammonia Concentrations

Ammonia concentrations in all three kelp beds fluctuated considerably between surveys. Both bottom and surface water ammonia levels peaked in April, June, August to September, and December (Figure 7-17). Surface and bottom water concentrations of ammonia rarely exceeded 1.0 µg at/liter at the three kelp beds except during the period August through December. Significant differences in ammonia concentrations were present between kelp beds during individual months, although on an annual basis, no significant difference was recorded between the three kelp beds.

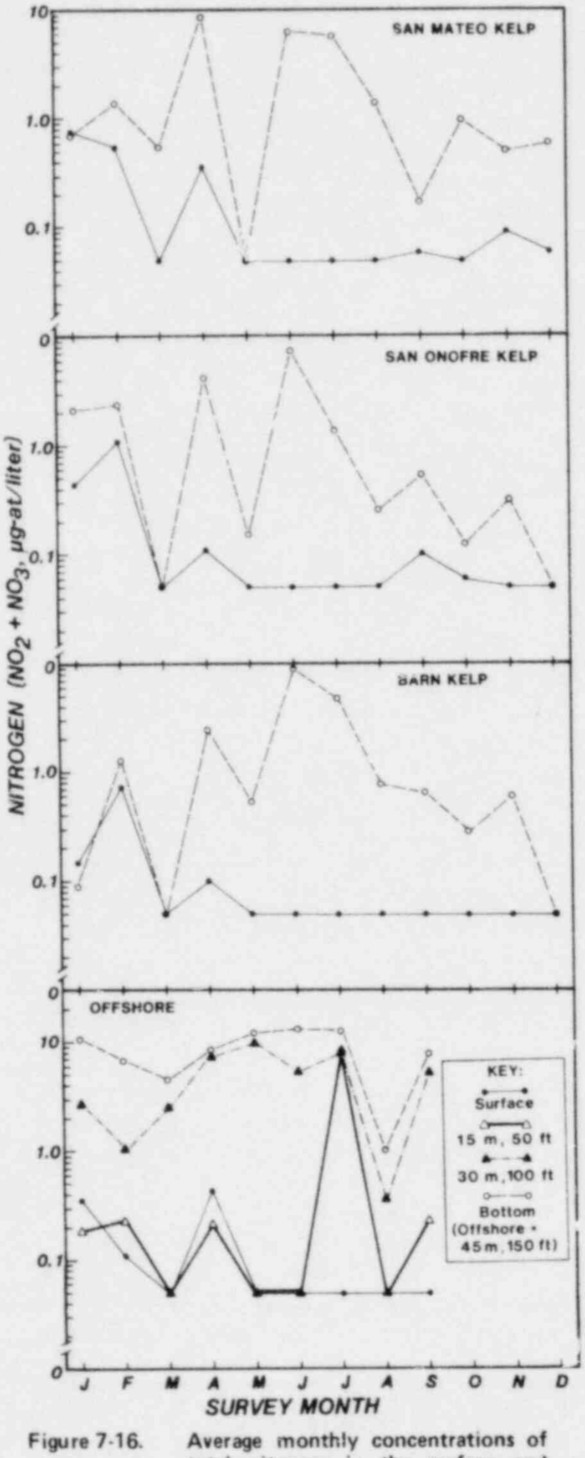


Figure 7-16. Average monthly concentrations of total nitrogen in the surface and bottom waters at the San Mateo, San Onofre, and Barn kelp beds from January through December and at the surface, 15, 30, and 45 m (48.2, 98.4, and 147.6 ft.) depths at the offshore stations from January through September 1980.

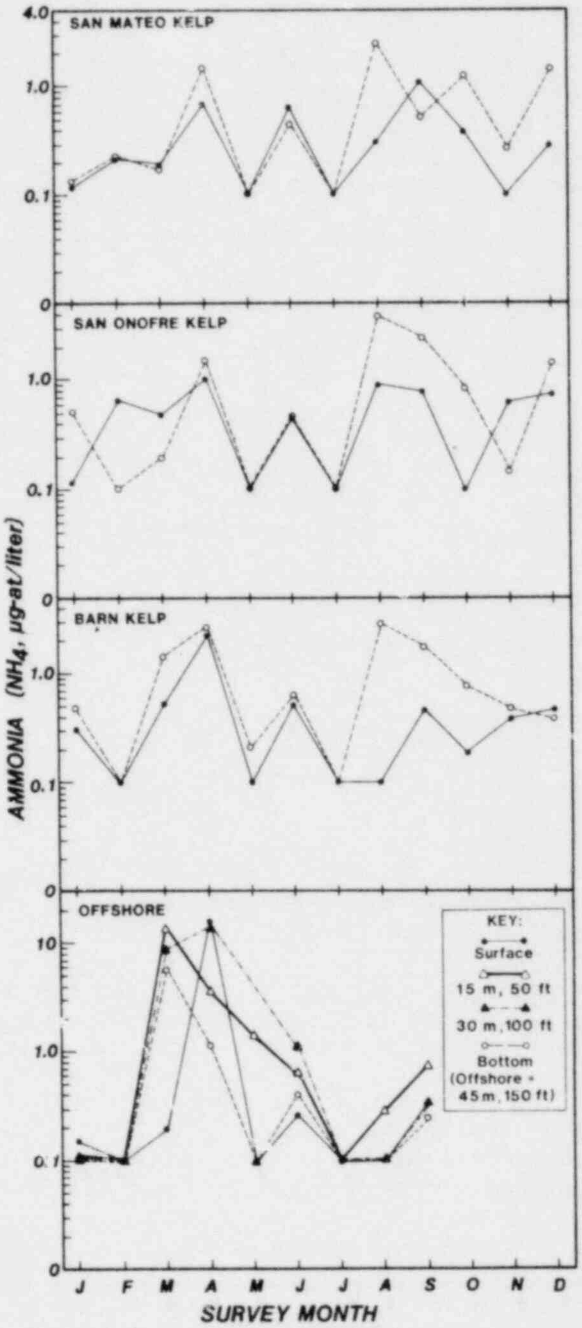


Figure 7-17. Average monthly concentrations of total ammonia in the surface and bottom waters at the San Mateo, San Onofre, and Barn kelp beds from January through December and at the surface, 15, 30, and 45 m (48.2, 98.4, and 147.6 ft.) depths at the offshore stations from January through September 1980.

Ammonia levels at the offshore station increased significantly during March and April periods with a minor, secondary increase in September (Figure 7-17).

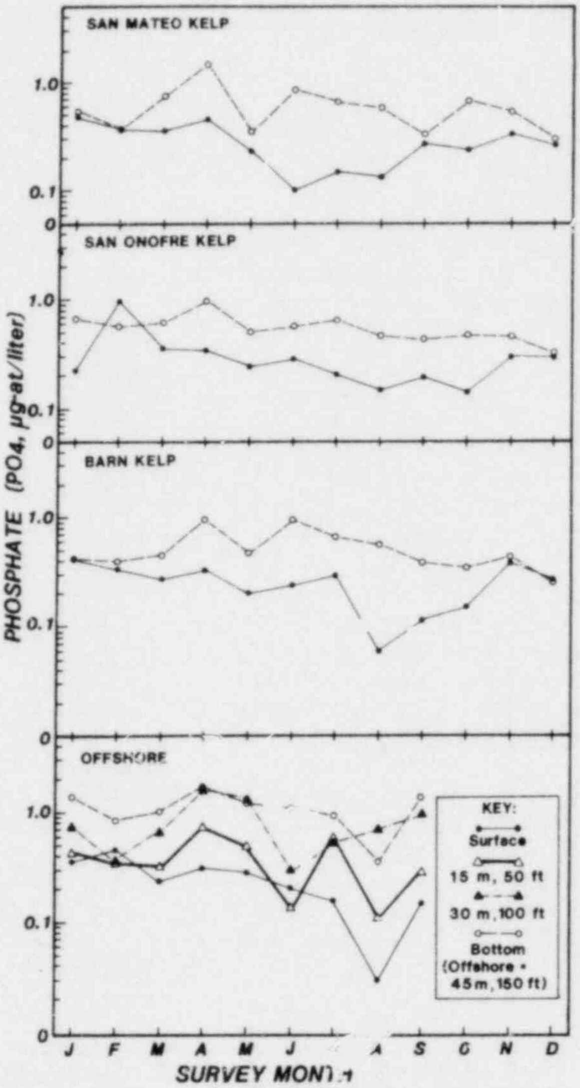


Figure 7-18. Average monthly concentrations of total phosphate in the surface and bottom waters at the San Mateo, San Onofre, and Barn kelp beds from January through December and at the surface, 15, 30, and 45 m (48.2, 98.4, and 147.6 ft.) depths at the offshore stations from January through September 1980.

Phosphate Concentrations

Phosphate concentrations at the three kelp bed stations fluctuated between 1.0 and 0.01 µg at/liter throughout the year with bottom water levels consistently higher than those recorded in surface waters. Maximum concentrations of phosphate were recorded during the period January through April at all stations. Phosphate levels were generally highest at SOK and lowest at BK (Figure 7-18) although on an annual basis, no significant difference was observed between the phosphate levels recorded at all stations.

Phosphate concentrations peaked in April and again in September at a depth of 15 m and below. Phosphate concentrations in the surface waters peaked in February and steadily declined through August (Figure 7-18).

KELP TISSUE ANALYSIS

Nitrogen content of kelp blades varies according to availability of inorganic nitrogen compounds (i.e. primarily nitrate and ammonia) in the surrounding waters. Values of 1.0 to 1.2% of dry weight kelp tissue, as nitrogen, probably represents healthy mature tissue which lacks nutrient reserves (North, personal communication). The following results represent the monthly kelp leaf nitrogen content (based on 15 observations) at SMK, SOK, and BK from January through May 1980. Raw data are presented in the Comprehensive Data Supplement (SCE 1980b).

Nitrogen levels in the kelp tissue varied between kelp beds in January and February (Figure 7-19). Kelp tissue nitrogen in January differed significantly ($P<0.05$) between the three kelp beds with maximum values occurring in BK. In February, kelp tissue nitrogen levels were very similar at BK and SOK, while tissue levels at SMK were significantly ($P<0.10$) lower. No significant difference in nitrogen levels were recorded between the three kelp beds in March and April, although tissue levels at SMK were elevated over those recorded at SOK and BK. No kelp plants could be located at BK in May. Nitrogen tissue levels at SMK and SOK in April were identical. During the five month investigation, only one kelp leaf analyzed (January at SOK) contained a nitrogen level below 1.0% of the dry weight.

GENERAL HEALTH OF THE KELP PLANTS

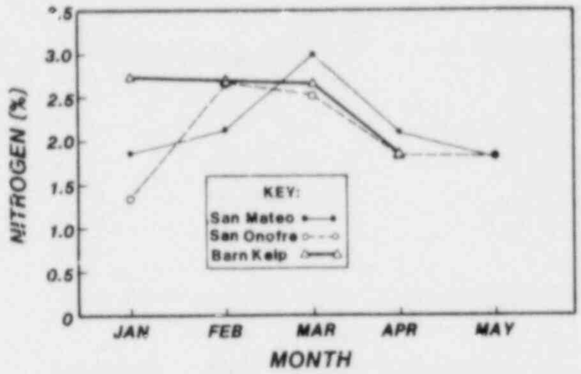


Figure 7-19. Mean nitrogen concentration, expressed as a percentage of dry weight, of the kelp leaves occurring in the San Mateo, San Onofre, and Barn kelp beds from January through May 1980.

The general health of the kelp plants of SMK, SOK, and BK was determined during four quarterly surveys in 1980. The purpose of the surveys was to quantitatively assess the health of the kelp plants within the three kelp beds and determine if the conditions present in SOK were similar to those observed at SMK and BK.

April Survey

Kelp plants observed during April were healthiest within SMK. Encrustation of the kelp fronds in the canopy ranged from moderate to substantial. Approximately 10% of the fronds were senescent. Macrocystis plants were in good condition in the bottom waters. Holdfasts were in good condition, new haptera were developing, and sporophyll growth was evident. No juvenile Macrocystis plants were observed.

The surface SOK canopy was encrusted with a light to moderate growth of bryozoan colonies. About 10% of the fronds observed were senescent. Many of the apical meristems present in the canopy appeared tattered and poorly developed. The subsurface portion of the kelp plants observed appeared healthy. At Station C of SOK, all plants encountered were young adult plants which had not reached the surface. No juvenile plants were observed at SOK.

The surface canopy at the outer BK, was in good condition although the midwater section of plants were tattered and densely encrusted with bryozoans and hydroids. Traces of black rot were observed in the outer section of the bed. At the inner section of BK, encrustation of the blades was relatively light. Surface fronds in this area exhibited moderate to heavy storm damage with many fronds stripped of part or all blade tissue. The base of the Macrocystis plants examined displayed some signs of stress, especially the sporophylls. The holdfast were generally in good condition with some new haptera. No juvenile Macrocystis were observed at BK.

June Survey

Conditions of the surface canopy differed considerably between areas of SMK. The northwest and central areas of the canopy were heavily encrusted although the individual blades were deeply colored and generally appeared healthy. The southern section of the canopy was relatively free of encrustation and blades appeared to be healthy. In the mid and bottom waters, the adult plants observed appeared to be healthy. No juvenile Macrocystis plants were observed at SMK.

A considerable amount of variation was present in the SOK canopy in June. In the offshore section approximately 50% of the blades were encrusted. At the inshore edge, the blades ranged from heavily encrusted to completely clean. All blades were a deep brown color. Visibility in the water column was very poor, making underwater examination of the kelp plants at SOK impossible.

The canopy at BK was substantially reduced from the April survey. The only visible canopy in June was located near the offshore edge of Station A

(Figure 7-12). Approximately 80% of this canopy was encrusted with bryozoans. Some of the most heavily encrusted fronds appeared to be senile. Underwater examination of the BK area revealed that Macrocystis were scarce and nearly all appeared to be in a distressed state. Holdfasts examined were extremely distressed with only a few patches of living haptera. The living plants examined consisted of only a few fronds. Sporophyll clusters examined were sparsely developed.

September Survey

The surface canopy at SMK was held under water by strong currents in September. The canopy examined appeared to be covered by bryozoans. The midwater section and holdfasts of the Macrocystis were in good condition. Approximately 5% of the fronds examined were senile. A substantial amount of new growth was observed on the SMK plants. No juvenile Macrocystis plants were observed. Sea urchin grazing was noted throughout the bed although no large urchin fronts had formed at the time of survey.

The offshore SOK canopy was very sparse in September, composed primarily of a few distressed fronds. Blades were densely encrusted with no new growth visible. No senescent fronds were observed although many individual blades were deteriorating. No surface canopy was present at the inshore edge of the SOK bed. Kelp fronds within the water column at SOK were heavily encrusted to a depth of 20 ft. Beyond a depth of 20 ft, plants were in excellent condition. Zero visibility at the bottom made observations of holdfasts impossible.

There was no visible canopy at BK during September. Ninety-five percent or more of the fronds observed in the water column were stripped of blades. Visibility was 0.3 m (1 ft) on the bottom of BK, limiting observations. Observations that were made indicated that very few sporophyll remained on the Macrocystis. Further, many deteriorated remains of Macrocystis plants were present.

December Survey

The main SMK canopy appeared to be in excellent condition in December, although not very dense. Almost no encrusting growth was observed on the kelp blades. Approximately 5 to 10% of the fronds observed were senile. The water column section of the Macrocystis and holdfasts examined appeared healthy. A few juvenile Macrocystis were observed at SMK in the open areas away from the main canopy.

The inshore section of the SOK canopy was sparse in December, being composed primarily of isolated patches of Macrocystis. Most plants observed had very few fronds reaching the surface. The offshore SOK canopy had expanded considerably since the September survey although the canopy was only moderately dense. Traces of black rot were evident in the blade tips and at the end of some fronds. New growth was evident throughout this area of the canopy.

Adult Macrocystis looked healthy at midwater and bottom levels of the inshore area of SOK. Scattered juvenile Macrocystis were observed in this area, although there was no evidence of large scale recruitment. The conditions of the midwater and bottom levels of the Macrocystis in the offshore area of SOK were similar to that observed in the inshore area.

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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.

Advection — The transfer of properties (temperature, salinity, turbidity, etc.) by currents.

Ambient Transmittance — The light transmittance in waters beyond the influence of SONGS Unit 1 and within the survey area.

Aperiodic — Of irregular occurrence, not periodic.

Assimilation — The incorporation into protoplasm.

Attenuation — The reduction in sound or light intensity caused by the adsorption and scattering of sound or 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.

Glossary

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.

California Current — The ocean current that flows southward along the west coast of the United States to northern Baja, California. It is formed by parts of the North Pacific Current and the subArctic current and is a wide current that moves sluggishly toward the southeast. Off Central America, the California Current turns toward the west and becomes the North Equatorial Current.

Carnivore — Consumer of living animal material.

Celsius Temperature — Temperatures based on a scale in which water freezes at 0° and boils at 100° (at standard atmospheric pressure). Related to Farenheit temperature by °C = 5/9 (°F-32) and (9/5 x °C) + 32.

Chi2 — Chi-square is a method of comparing observations to expected results to determine whether the observation deviates statistically from theoretical expectation.

Chlorophyll a — An important photosynthetic pigment occurring in phytoplankton. The quantity of chlorophyll a in seawater is measured by fluorescence according to the following equation.

$$\text{Chlorophyll } \underline{a}\ (mg/m^3) = \frac{\dfrac{Fo/Fa_{max}}{(Fo/Fa_{max})-1}\ (k_x)(Fo-Fa)}{\text{liters filtered}}$$

where Fo = fluorescence before acidification

Fa = fluorescence after acidification

Fo/Fa_{max} = maximum acid factor which can be expected in the absence of phaeo-pigment

k_x - calibration constant for a specific sensitivity scale

Cirripedia Subclass of crustacea: barnacles.

Coastal Currents Currents flowing roughly parallel to the shore and constituting a relatively uniform drift in the water just seaward of the surf zone.

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.

Copepoda 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:

$$r = \frac{\Sigma XY - \Sigma X \Sigma Y/N}{\sqrt{[\Sigma X^2 - (\Sigma X)^2/N]\,[\Sigma Y^2 - (\Sigma Y)^2/N]}}$$

Glossary

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.
Density Front	The boundary upon which waters of separate densities meet.
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.
Diffusion	The spontaneous movement and scattering of particles of liquid. Diffusion occurs in matter under the influence of a concentration gradient, with movement from the stronger to the weaker solution.
Diurnal	Actions recurring in cycles of 24 hrs (i.e., daily vertical migrations of plankton and fish, and tidal cycles).
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	At San Onofre, towards Oceanside (300° magnetic.)
Eddy	A small whirlpool; a whirling or circular motion which runs opposite the main current. Eddys occur frequently in the lee of islands, points, and other obstructions to current flow.
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.

Ekman Transport	The movement of ocean water caused by wind blowing steadily over the surface; net movement occurs at right angles to the wind direction.
Entrainment	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	The rate of decrease or increase of one quantity with respect to another, for example, the rate of decrease of temperature with depth.
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.

Gyre	A semiclosed current system, larger than a whirlpool or eddy. Several near-permanent gyres, such as the California Countercurrent, are present in the Southern California Bight.
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.
In situ	In the original location; at depth.
Insolation	The radiation from the sun received by a surface; the rate of such radiation per unit of surface.
Internal Wave	A wave that occurs within a fluid whose density changes with depth, either abruptly at a sharp surface of discontinuity (an interface) or gradually.
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.
Isobath	A contour line connecting points of equal water depths.
Isopleth	A line on a map connecting points of equal value.
Isotherm	A contour 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 $Y_1, Y_2, Y_3, \ldots, Y_N$, the "mean" of these values is defined by the following equation:

$$\bar{X} = \frac{\sum_{i=1}^{i=N} Y_i}{N}$$

Mean Diameter (M_z) — 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.

Glossary

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 hypotnesis 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.

Photosynthetically Active Radiation (PAR)
The portion of the solar spectrum necessary to support photosynthesis.

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.

Power Spectral Density
Describes the general frequency composition of data in terms of the spectral density of its mean square value.

Precipitation
The separation from a solution or suspension by physical or chemical change.

Predator
A species which actively preys upon other organisms.

Glossary

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 invertebrate- 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 behavior type always involving active prey capture, usually involving search for and/or chase of prey, and generally implying a degree of prey selectivity.
Relict Sediments	Mineral and rock particles washed from areas that have been eroded before the end of the last holocene transgression. These sediments were deposited under hydrodynamic conditions that existed when sea level was up to 130 m below its present level.
Regular Distribution	A quantitative description of the spatial dispersion patterns of an organism or organism group when the sample variance is less than the sample mean.
Rip Current	The return flow of water piled up on shore by incoming waves and wind. Rip currents usually appear as visible bands of turbid or agitated water extending offshore from the surf zone.
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 substatum.

Settleable Solids
The residue which settles out of a sample of seawater contained in an Imhoff cone, after a predetermined amount of time.

Shannon-Wiener Species Diversity Index
A measure of diversity in a single sample set of species.

$$H' = -\sum_{j=1}^{S} \frac{n_j}{N} \log \frac{n_j}{N}$$

where n_j = number of individuals in the j^{th} species
S = total number of species
N = number of individuals

Sigma-t
A convenient form of expressing density defined by (density - 1) x 10^3.

Skewness (SKI)
A measure of the direction and extent of departure of the mean from the median (in a normal or symmetrical curve they coincide). In symmetrical curves, SK_I = 0.00 with limits of -1.00 and+1.00. Negative values indicate the particle distribution is skewed toward the larger particle diameters, while positive values indicate the distribution is skewed toward the smaller particle diameters.

$$SK_I = \frac{\phi_{16}+\phi_{84}-2\phi_{50}}{2(\phi_{84}-\phi_{16})} + \frac{\phi_5+\phi_{95}-2\phi_{50}}{2(\phi_{95}-\phi_5)}$$

Solar Irradiance
The incident flux of solar energy striking a unit area.

Sorting Coefficient (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).

$$\sigma_I = \frac{\phi_{84}-\phi_{16}}{4} + \frac{\phi_{95}-\phi_5}{6.6}$$

Source Control
Pertaining to relict sediments of which distribution was controlled by past hydrodynamic conditions.

Southern California Bight
The Southern California Bight is defined as the open embayment of the Pacific Ocean bounded on the east by the reach of the North American coastline extending from Point Conception, California, to Cabo Colnett, Baja, California, Mexico, and on the west by the California current.

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.

Swell — Ocean waves which have traveled away from their generating area; these waves are of relatively long length and period, and regular in character.

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.

Thermal Stratification — Horizontal layers of differing densities produced by temperature changes at different depths.

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 downplaning 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 — At San Onofre, towards Dana Point (120° magnetic).

Upwelling — The process by which water rises from a deeper to a shallower depth. Upwelling often occurs at San Onofre when the wind blows downcoast, pushing surface waters offshore and drawing bottom water towards the surface. Upwelling is most intense during April, May, and June, although a significant upwelling occasionally continues into summer.

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.

Viviparous — Live bearers in which ova are fertilized internally and embryos develop within the female. The young are born in an advanced stage of development.

Glossary

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.
Wave Period	The time lapse between successive wave crests or troughs.
Wave Refraction	The change in the direction of a wave train moving in shallow water at an angle to the bottom topography.
Wind Drift	Wind induced surface currents.
Winkler Titration	A chemical method for estimating the dissolved oxygen in seawater.
Zooplankton	Portion of the plankton composed entirely of animals.