a. McB. Bloch

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CABO MALA PASCUA ENVIRONMENTAL STUDIES

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CABO MALA PASCUA ENVIRONMENTAL STUDIES

by

E.D. Wood, M.J. Youngbluth, P. Yoshioka
and M.J. Canoy

1.1 INTRODUCTION

The Puerto Rico Nuclear Center of the University of Puerto Rico has been under contract to the Puerto Rico Water Resources Authority since 1972 to conduct site selection surveys and environmental research studies of seven coastal sites. Experience gained from these investigations will add to the knowledge about these areas, and provide useful data which will aid in the assessment of the desirability and practicability of locating power generating facilities on one or more of these sites.

Puerto Rico Nuclear Center scientists have studied the physical, chemical and geological parameters of the sites, and the ecological parameters of zooplankton, benthic invertebrate and fish communities. Plant associations, except for the Cabo Rojo Platform site, have been included.

The sites chosen for study were: Tortuguero Bay, Punta Manati, Punta Higuero, Cabo Rojo Platform, Punta Verraco, and Cabo Mala Pascua (see Figure 1.1-F1). The seventh site, Barrio Islote, was studied and reported under a separate contract.

The reports in order of their dates of completion are:

Tortuguero Bay Environmental Studies	April 1, 1975
Punta Manati Environmental Studies	April 15, 1975
Punta Higuero Environmental Studies (previous studies of Punta Higuero, also referred to as "Rincon" or "the BONUS site" have been reported in Wood et al., 1974).	May 1, 1975
Cabo Rojo Platform Environmental Studies	May 15, 1975
Punta Verraco Environmental Studies	June 1, 1975
Cabo Mala Pascua Environmental Studies	June 15, 1975

The present report on Cabo Mala Pascua concludes this series of reports. For environmental research study reports on the Barrio Islote site, see Final Report of Environmental Research Studies for a North Coast Nuclear Power Plant (June, 1975).

2.1 PHYSICAL AND CHEMICAL PARAMETERS AT CABO MALA PASCUA

by

E.D. Wood

2.1.1 INTRODUCTION

The Cabo Mala Pascua site is located on the southeast corner of the island of Puerto Rico (Figure 2.1-F1). The sampling program has been centered on a valley immediately west of Cabo Mala Pascua. The point at Cabo Mala Pascua rises very steeply within 700 meters from the shore to a height of 323 meters. The only other location suitable for building power plants is in the Maunabo River flood plain on the east side of Cabo Mala Pascua. The sampling zone lies between Punta Tuna to the east and Punta Viento to the west (Figure 2.1-F1).

Some preliminary work was done in 1972 at Punta Viento (Beck, 1972). The Cabo Mala Pascua site work began with currents in late 1972 followed by other work in 1973 and 1974. The factors affecting nearshore currents such as winds, tides, bathymetry and density structure of the water column are discussed in the following sections.

2.1.2 TIDES

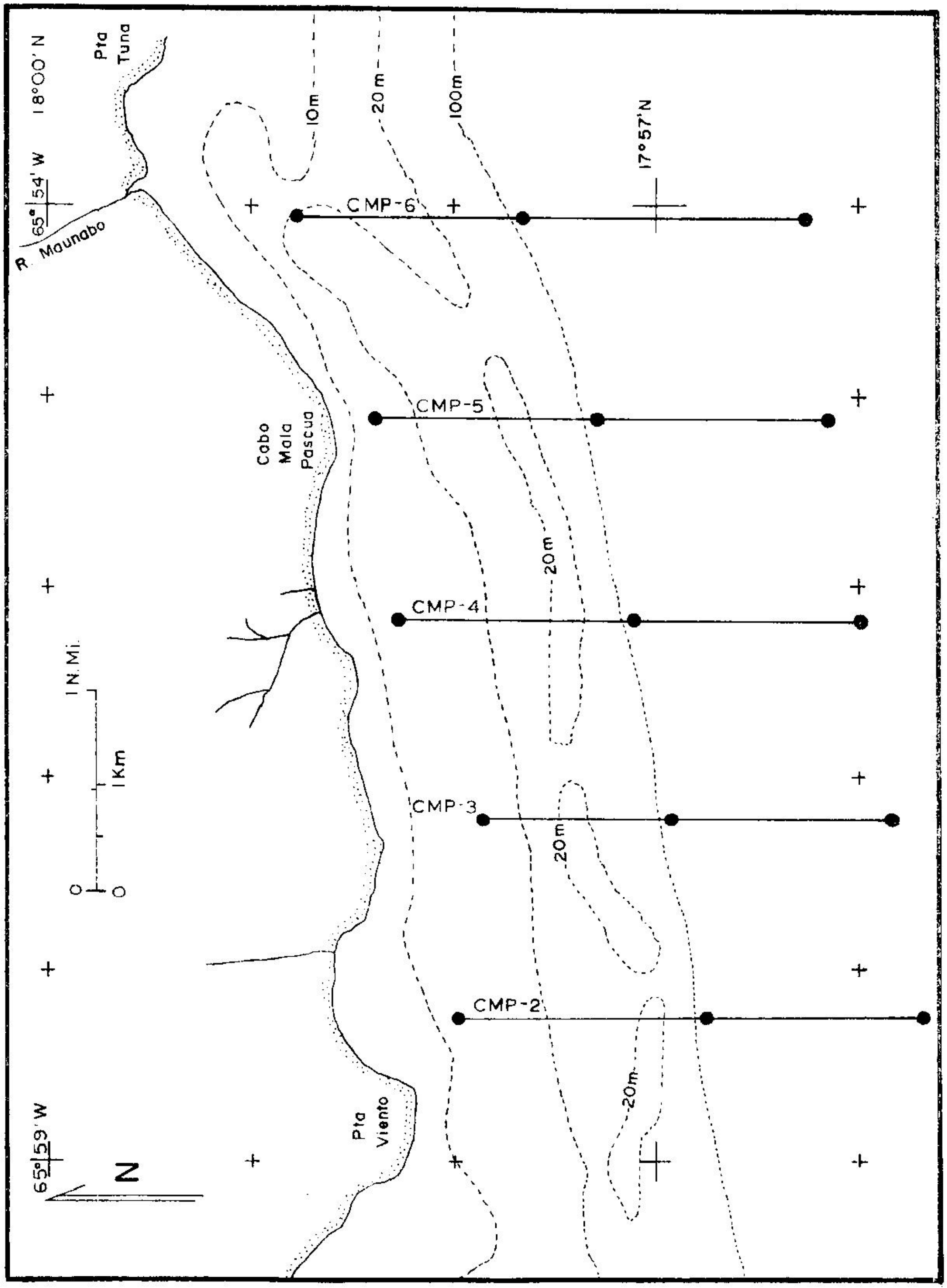
The tidal waves that affect the south coast of Puerto Rico have their amphidromic point in the eastern Caribbean Sea. The waves move in a counterclockwise direction (Anikouchine and Sternberg, 1973), that is, from east to west past Cabo Mala Pascua. The south coast tides are diurnal. Two waves exist, but one is dominant for about ten days, followed by about four days of neap tide conditions as one wave decreases in amplitude and the second wave builds. Then, the second wave is dominant for about ten days. Predicted tides for the south coast are shown in Figure 2.1-F2. These predictions were made from the National Oceanic Survey (1972).

The tidal excursion is about 25 ± 15 cm. The tidal plot in Figure 2.1-F2 is for the period November 14-16, 1972 covering a period of current measurements using dye markers discussed below.

2.1.3 CURRENTS

Ocean currents in the Caribbean Sea flow generally to the west northwest with velocities at times in excess of 1 knot (50.83 cm/sec). The current near the south coast of Puerto Rico rarely exceeds 0.5 knots (25 cm/sec).

Fig. 2.1-F1 Cabo Mala Pascua site with depth contour lines and hydrographic sampling transects each with three stations.



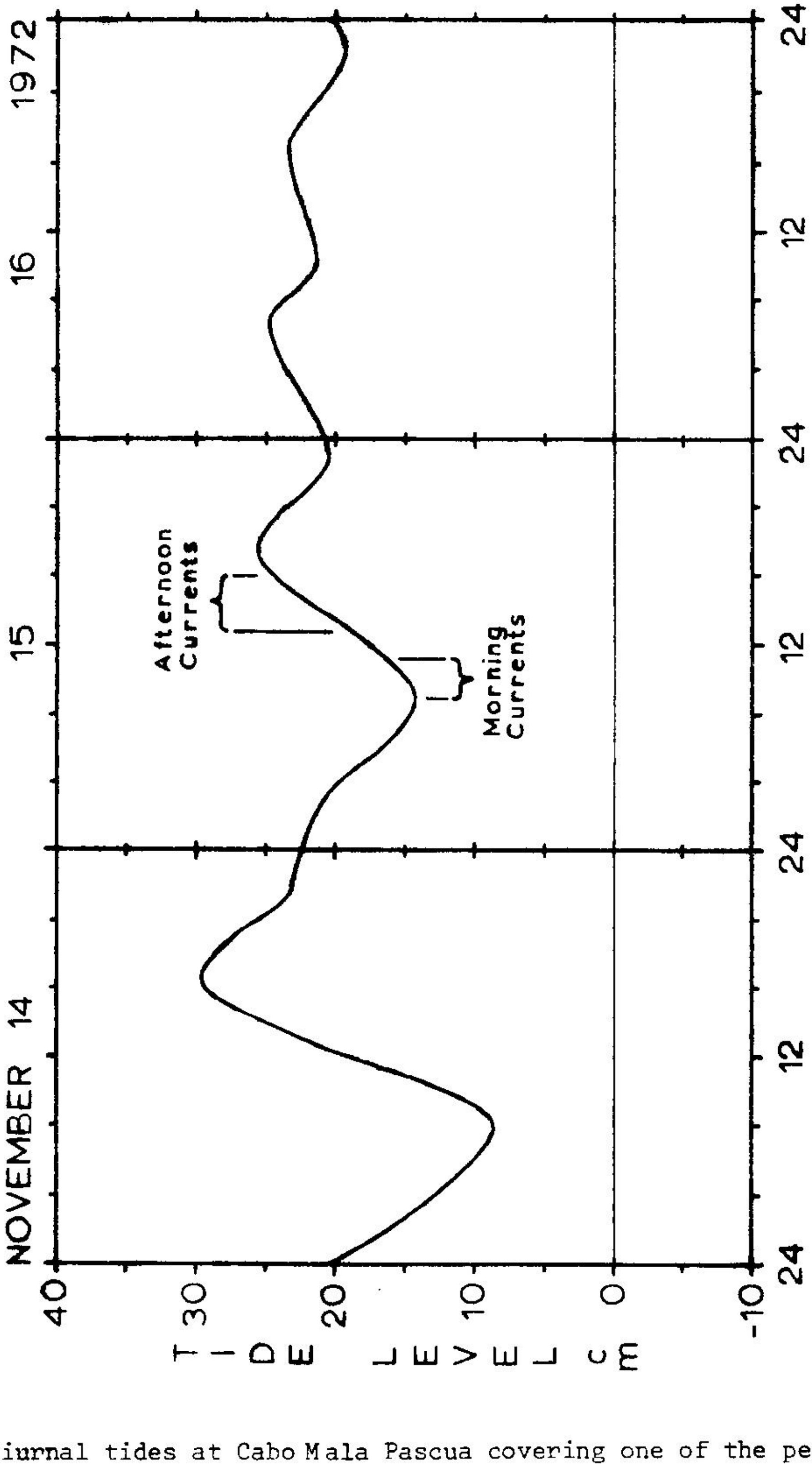


Fig. 2.1- F2 Diurnal tides at Cabo Mala Pascua covering one of the periods of current measurements.

The current pattern near Cabo Mala Pascua is affected by wind, tide, river discharge and the shape of the shoreline.

The wind is predominantly out of the east (Wood, 1975a) tending to come from the east southeast during the day with mid-day velocities of about 7.5 m/sec (15 knots). Four out of the six major hurricanes that hit Puerto Rico since 1893 struck at Cabo Mala Pascua. This tends to push surface water onshore toward the west. Back eddies form at times on the lee sides of Punta Tuna and Cabo Mala Pascua.

No major embayments exist near Cabo Mala Pascua, therefore the tidal effect is small and tends to be overshadowed by the dominant offshore current and by the prevailing winds.

Current studies reported by the Oceanographic Section of Public Works (1972) were made east and west of Cabo Mala Pascua. They experienced anomalies in the dominant westward flow that were difficult to interpret. They found little correlation with tides. However, I feel they may have misinterpreted the tide book as it is complicated to predict tides for the south coast of Puerto Rico without a basic understanding of the factors involved.

There is a considerable flow to the north around the east end of Puerto Rico as evidenced by flows reported by Public Works (1972). The open sea currents seem to split near the southeast corner of the island with one flow to the west along the south coast and the other north along the east coast. Variable currents would then be expected for Cabo Mala Pascua. Measurements in the Vieques Passage showed that the flood current went to the west and ebb current to the east (Public Works, 1972).

Currents at Punta Viento were measured by PRNC staff in 1972 and reported by Beck (1972). Surface currents tended to be onshore to the northwest while subsurface currents were offshore and varied from southwest to southeast. Little tidal effect was seen.

Currents at Cabo Mala Pascua were measured using dye drops and aerial photography in the morning and again in the afternoon of November 15, 1972. The first drop started shortly before 0900 in the spots shown in Figure 2.1-F3 which coincided with low tide (Figure 2.1-F2). The currents were very weak, but most tended to the west. The current near the garbage dump at Cabo Mala Pascua (drop #4) started to the east as did drop #8. Drop #8 turned west slowly as the tide began to rise, but drop #4 continued to the east for about one hour at about 11 cm/sec before turning slightly seaward and then west. Drop #6 started west, then turned shoreward toward drop #3. Drop #2 went into

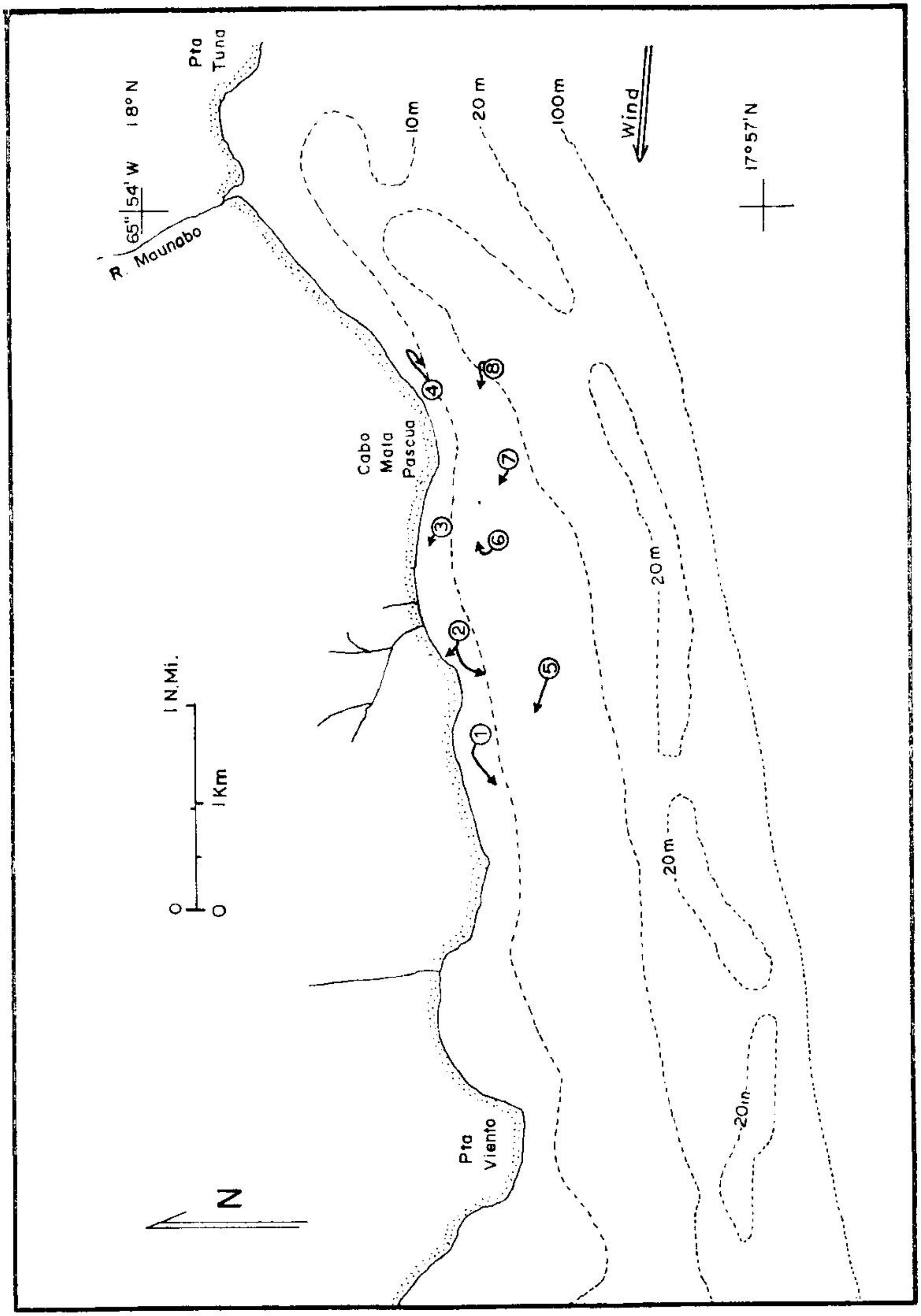


Fig. 2.1-B Dye study at Cabo Mala Pascua the morning of November 15, 1972.

the shallow nearshore reef zone, split, and then most of the dye went offshore to the southwest, possibly subsurface. The most westerly drops, #1 and #5, travelled west at 13 and 11 cm/sec, respectively.

The motion of the afternoon drops is shown in Figure 2.1-F4. All dye spots moved west with velocities of 4 to 18 cm/sec. The fastest currents were nearshore adjacent Cabo Mala Pascua (drops #3 and #4) and the slowest was drop #5. Drop #1 disappeared soon after being put in place. It started to the west then dissipated in surf. The tide was in full flood and the afternoon wind was from the east southeast during the period of measurements. The afternoon currents had the highest velocities between 1325 and 1435, then seemed to decrease between 1435 and 1535. Individual current velocities are shown in Table 2.1-T1.

TABLE 2.1-T1 Dye studies at Cabo Mala Pascua, November 15, 1972

MORNING 0850-1117

Dye Drop Number	Velocity	Direction	Comments
	0900-1000		
1	13 cm/sec	WSW	West, then slightly seaward
2	10 cm/sec	SW	Inshore, split, offshore
3	6 cm/sec	WNW	Very slow
4	11 cm/sec	ENE	East, then turned west
5	10 cm/sec	WNW	Very slow second hour
6	4 cm/sec	NNW	Little movement
7	5 cm/sec	NW	Slow west
8	7 cm/sec	W	NE, then slow west

AFTERNOON 1325-1550

Dy Drop Number	Velocity	Direction	Comments
	1325-1535		
1	(7)	WSW	Started west, then dissipated
2	9	WSW	Followed shoreline
3	18(8)	W	(Started fast, then
4	18(10)	W	(slowed in the second (hour
5	5	W	(Flow was slightly shore-
6	8	W	(ward, but paralleled
7	8	WNW	(the shoreline
8	13(8)	W	Slowed after first hour

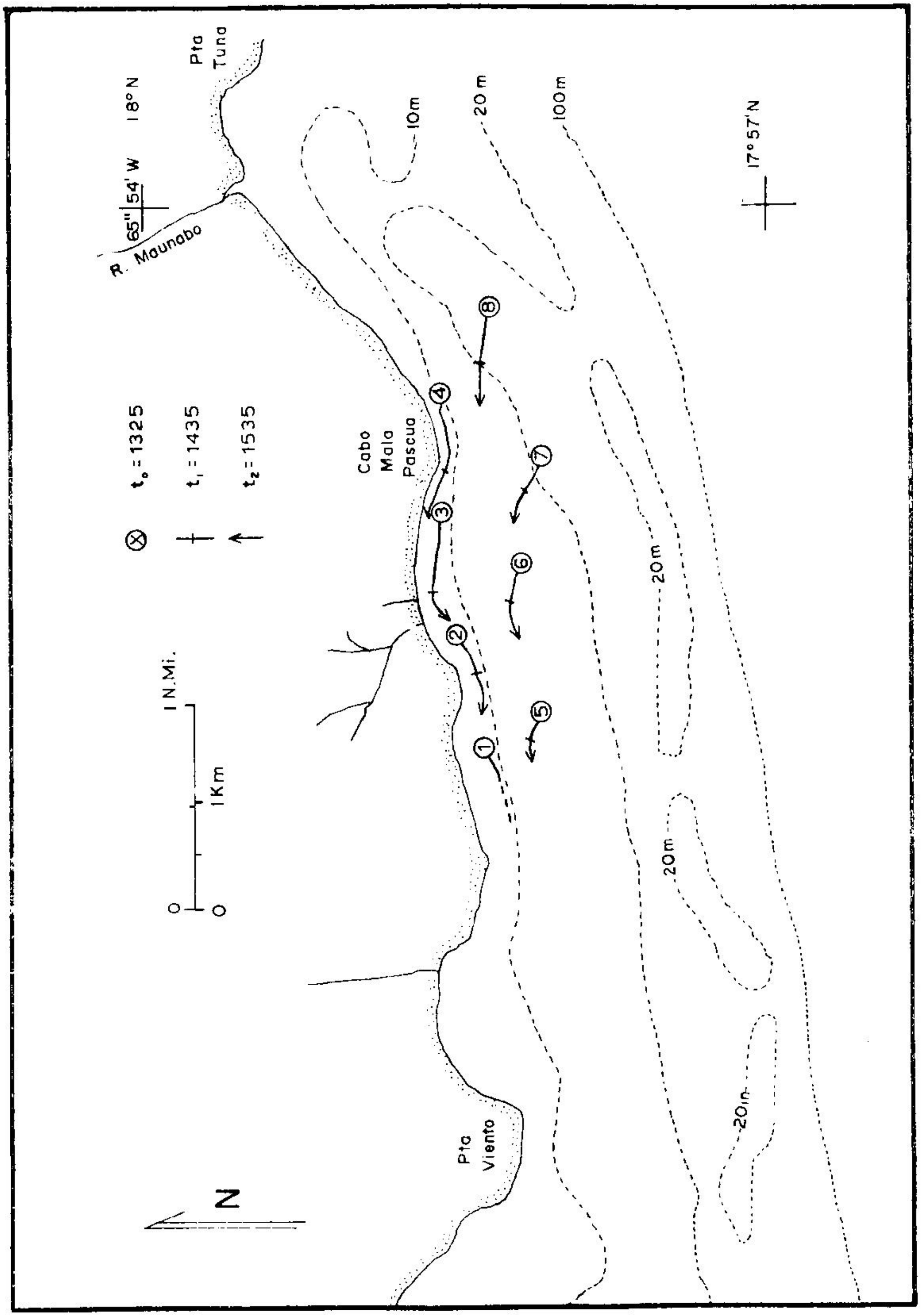


Fig. 2.1-F4 Dye study at Cabo Mala Pascua the afternoon of November 15, 1972.

The aerial photographs showed a definite contribution of turbid water from the Maunabo River to the nearshore region, especially around Cabo Mala Pascua in the afternoon. Some turbid water also flowed westward around Punta Tuna.

Current measurements in the vicinity of Cabo Mala Pascua indicate that the flow is generally to the west with velocities of 4 to 18 cm/sec (.08 to .36 knots). The surface currents tend to be onshore to the west while subsurface currents tend to be offshore and variable in direction. The wind affects the currents more than the tides. However, the trend seems to be that flood current is to the west while ebb current is to the east.

2.1.4 BATHYMETRY

The Puerto Rico Nuclear Center has undertaken no detailed bathymetry of the Cabo Mala Pascua site beyond that done during benthic and hydrographic sampling. The C&G Charts 902 and 928 (National Ocean Survey, 1972) are inadequate, especially with regard to the definition of shelf edge and deep water soundings south of the outer reefs. Also, there are some discrepancies in the shallow regions caused by coral growth and shifting sediments. The contour lines shown in Figure 2.1-F1 and the depth profiles in Figure 2.1-F5 were drawn using depths shown in the above mentioned charts and sonic depths obtained during hydrographic work.

The shallow region immediately west of Punta Tuna is slightly protected from the dominant wavetrain and receives sediments from the Maunabo River. This high siltation retards coral growth to Cabo Mala Pascua. Nearshore coral reefs exist westward from Cabo Mala Pascua to the bay just east of Punta Viento. A shallow basin exists seaward of these nearshore reefs bounded on the south by a series of long narrow reefs about 2 kilometers off and parallel to the shoreline. The seaward side of these outer reefs mark the shelf edge. The shelf slope is very steep in this region especially between Cabo Mala Pascua and Punta Tuna where the bottom drops from 20 meters to over 1000 meters in a distance of 2 kilometers as shown in Figure 2.1-F5.

2.1.5 TEMPERATURE, SALINITY AND DENSITY

The physical parameters of temperature and salinity were measured at the Cabo Mala Pascua site on seven cruises covering four seasons (Table 2.1-T2).

Fig. 2.1- F5 Bottom profiles along the sampling transects of the Cabo Mala Pascua site. Vertical lines indicate relative positions of the hydrographic stations.

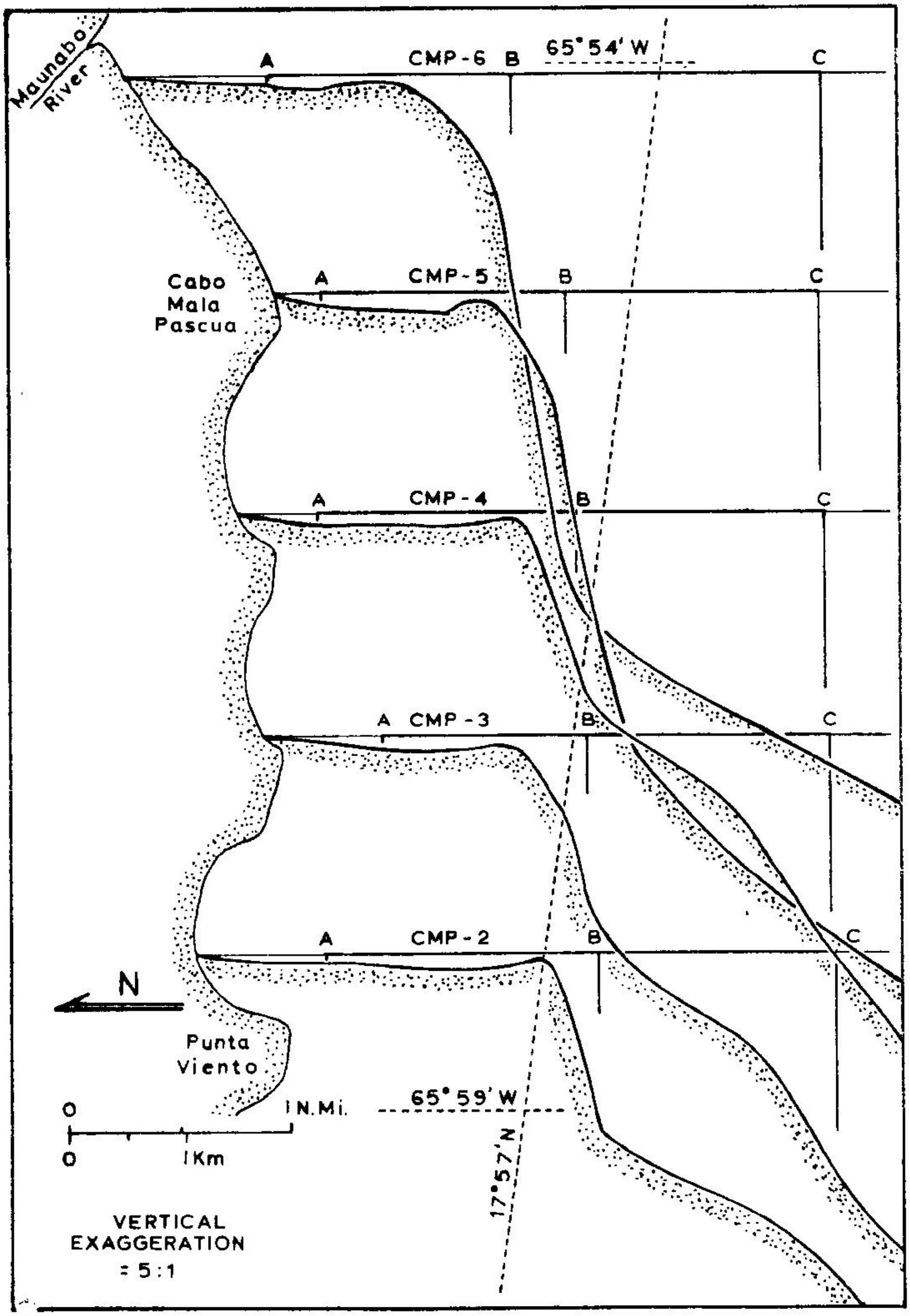


TABLE 2.1-T2 Schedule of hydrographic cruises to Cabo Mala Pascua.

	WINTER	SPRING	SUMMER	FALL
1972	-	PA-088 Mar 26*	-	-
1973	PA-023 Feb 22	May 23	-	-
1974	PA-039 Feb 13	PA-042 Apr 23	PA-046 Aug 22	PA-052 Nov 14

* For Punta Viento, results reported by Beck, 1972.

The hydrographic sampling stations are shown in Figure 2.1-F1. Five transects were sampled on most cruises. The transects are nearly normal to the shoreline, each with three stations. The "A" stations were most shoreward, the "B" stations were in excess of 125 meters of water, and the most seaward stations ("C") were in excess of 325 meters. Fourteen depths were sampled on each transect. Temperatures were measured using deep-sea reversing thermometers with readings accurate to ± 0.03°C. Salinities were determined with an induction salinometer to an accuracy of ± 0.005°/oo. The values are included in a report of hydrographic data for the south coast of Puerto Rico (Wood and Asencio 1975). These data were converted to standard depths and averaged by season and type of stations. The sampling, analytical and data processing procedures are described in "A Manual for Hydrographic Cruises" (Wood 1975b).

Temperature

Temperatures were determined using reversing thermometers in pairs, or in triplicate when possible. Although only one temperature is shown on the computer printout of the data (Wood and Asencio 1975) for each depth, these values are often the average of two or three thermometers. Most temperatures below 50 meters were measured using both "protected" and "unprotected" reversing thermometers. A thermometer depth, TZ, was then calculated for the sampling depths and correlated quite well with the calculated depth, CZ, obtained from the amount of hydrowire paid out, WZ, and the cosine of the wire angle, Ø. A comparison of some of these depths was made for the Punta Verraco site report (Wood et al., 1975).

The data were averaged by a computer program which first interpolated between the depths sampled to provide temperatures (and other hydrographic parameters) at "standard depths." The averaged standard depth temperatures and salinities are plotted by season in Figure 2.1-F6. The diagonal lines indicate density as sigma-t. Depth is not shown on the plot, but generally increases to the lower right corner of the plot, i.e., density increases with depth. Very little change is seen seasonally where sigma-t is greater than 26.0. However, a definite change can be seen in the lower densities (surface waters). The temperature increases between winter and summer, while salinity increases between fall and spring.

The averaging for the depth profiles was done first for all stations by season (Figures 2.1-F7, 9, 11 and 13) then by type of station by season (Figures 2.1-F8, 10, 12 and 14). The tabulated data are in Appendix 2.1A.

A comparison of the averaged "C" station standard depth temperature data by season is shown in Figure 2.1-F15. A sequence of events can be seen from this comparison. Surface thermocline (100 m) occurred in the winter and is caused by cooling and deep mixing by winter storms. This mixing process tends to carry heat to the depths so that the highest temperatures between 100 and 200 meters occur during the winter and spring. (This condition is part of a phenomenon one might call "seasonal lag.")

Little seasonal change was seen below 150 meters except that the fall temperatures were generally lower than the other seasons. There was a general temperature decrease in the 100 to 200 meter depth interval between winter and fall. The thermocline during spring was 50 meters and in the summer and fall was about 25 meters with a temperature inversion existing in the fall as surface cooling and land runoff occurred.

Surface temperatures were at a maximum in the summer (28.3°). There was an average temperature range of about 2.3° between summer and winter in the nearshore surface water at Cabo Mala Pascua.

Very little change in surface temperatures with distance from shore was seen at Cabo Mala Pascua. Slightly warmer nearshore temperatures existed in spring and summer and slightly cooler temperatures in the fall. Nearly uniform surface temperatures were noted in the infrared scans made here, also, (Wood 1975a) except for slightly cooler than ambient temperatures in the plume of the Maunabo River.

Temperature depth profiles were obtained at all "C" stations by lowering a bathythermography, BT, to 300 meters. The BT traces are in Appendix 2.1B.

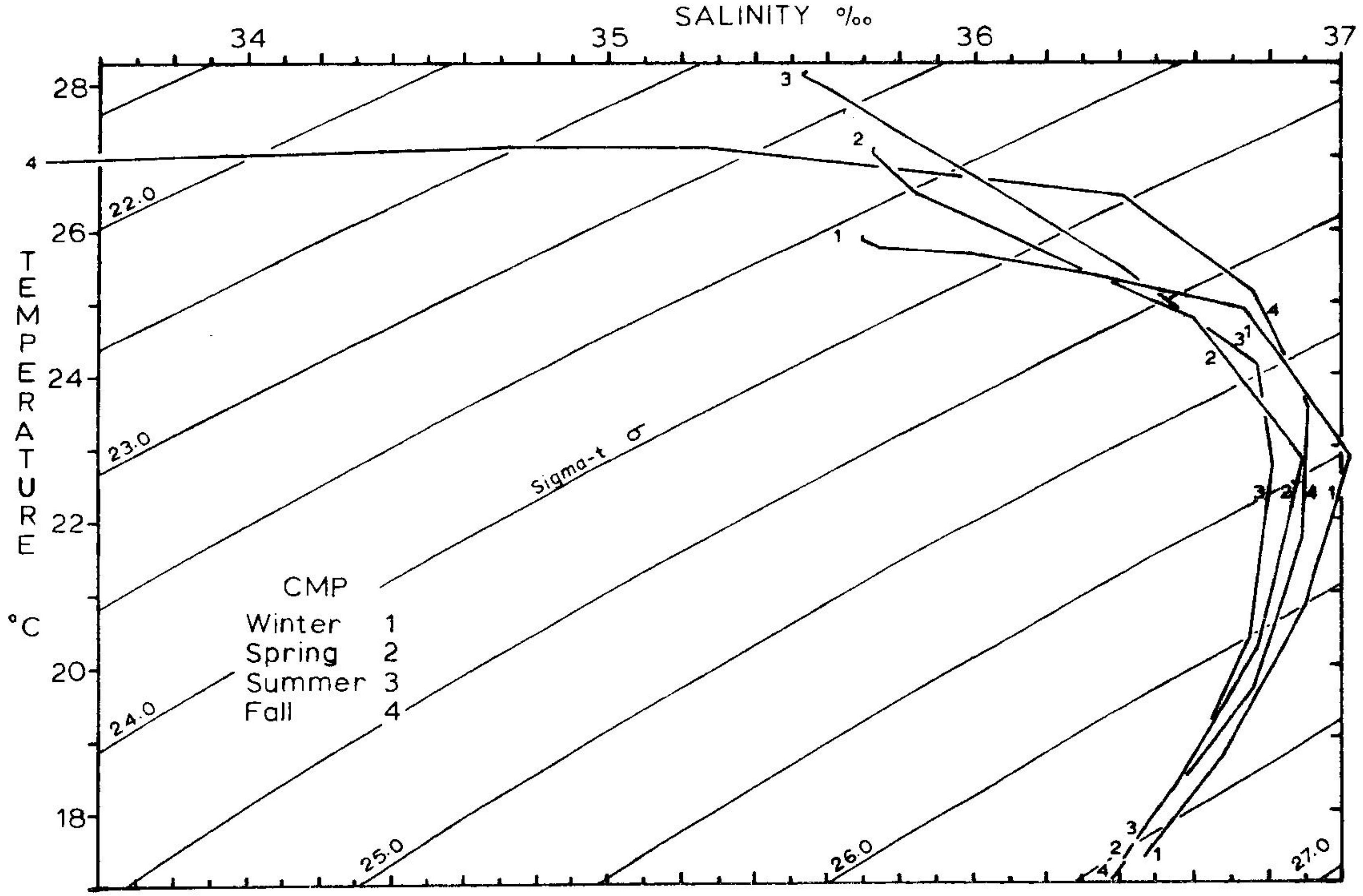


Fig. 2.1- F6 Temperature-salinity diagram of averaged data plotted by season for Cabo Mala Pascua, 1973-1974. Diagonal lines indicate density as sigma-t.

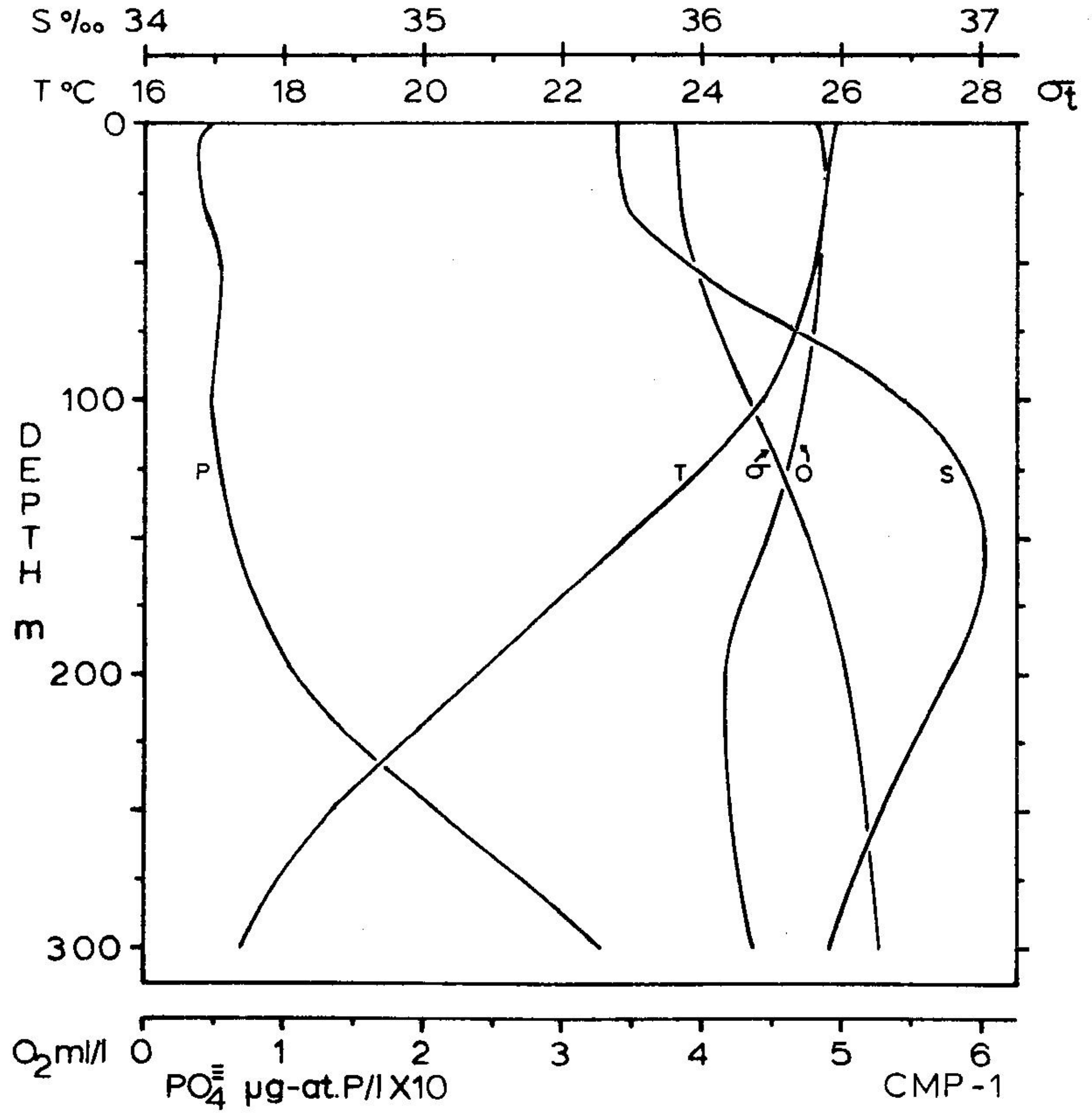
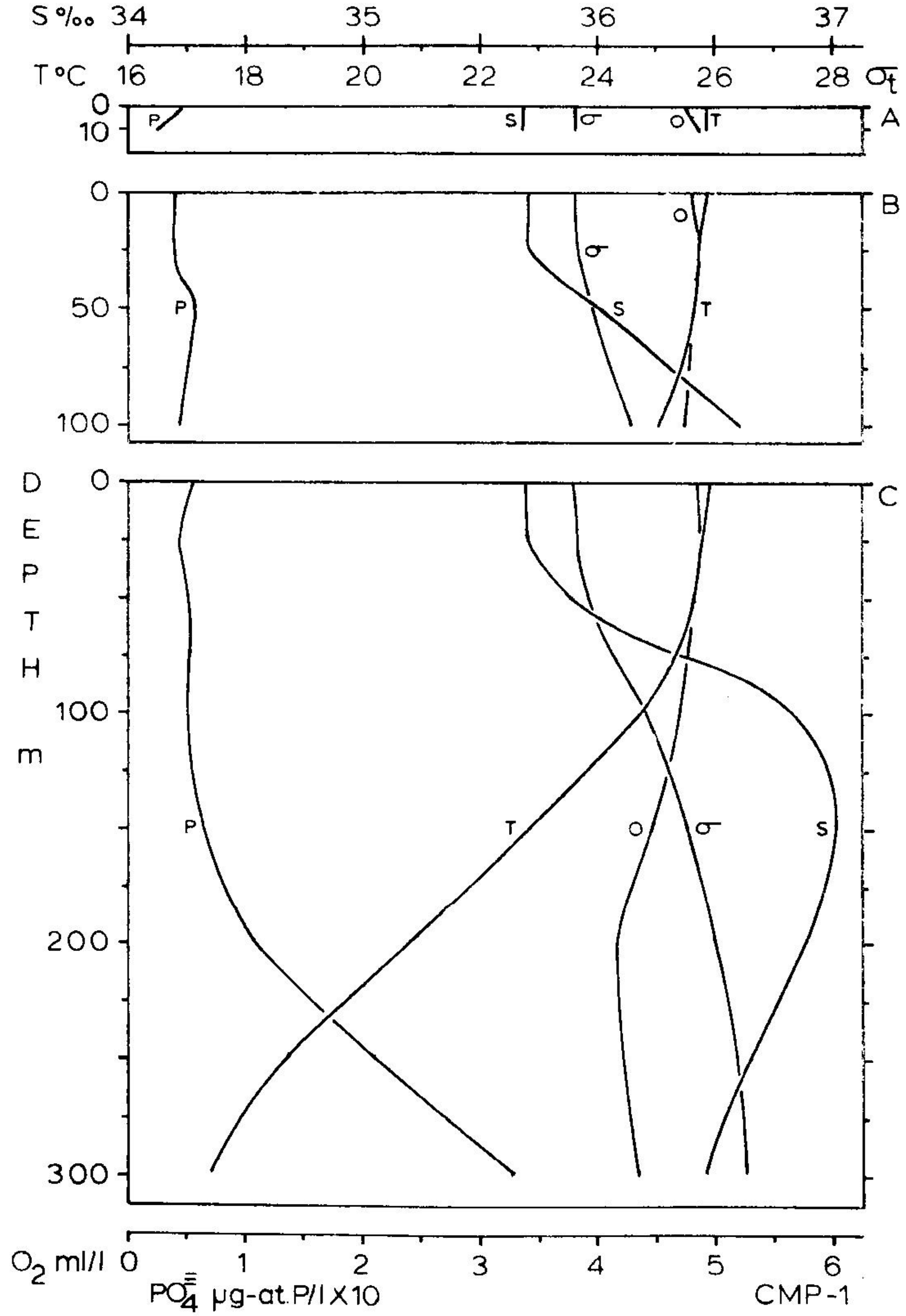


Fig. 2.1- F7 Averaged hydrographic parameter (temperature, T°C; salinity, S°/oo; density, σ_t; dissolved oxygen, O_2; and reactive phosphate, $PO_4^{\equiv}$) vs. standard depth in meters for the winter season of 1973 and 1974 at Cabo Mala Pascua.

Fig. 2.1- F8 Depth profiles of hydrographic parameters averaged by type of station for the winter season of 1973 and 1974.



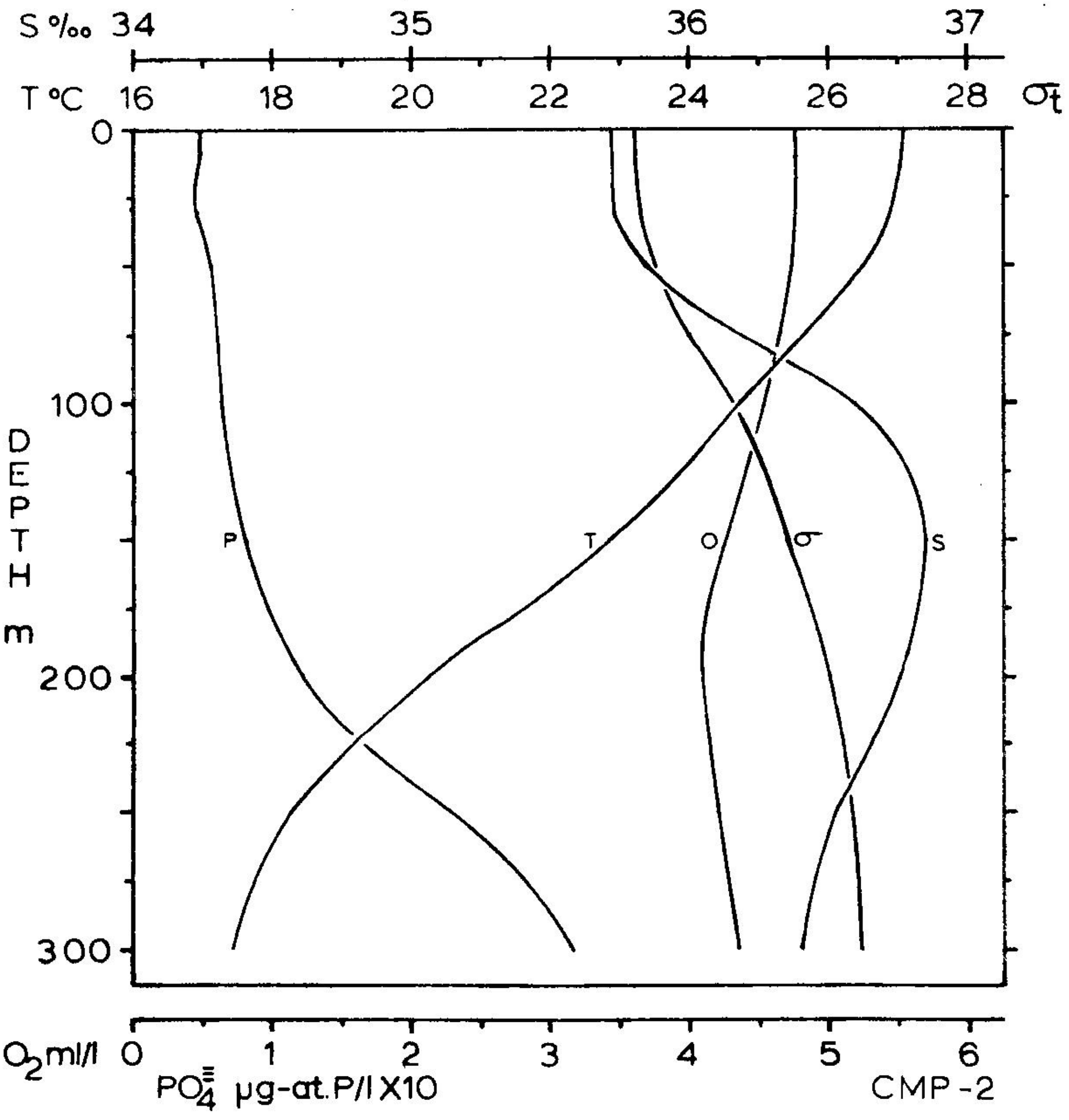
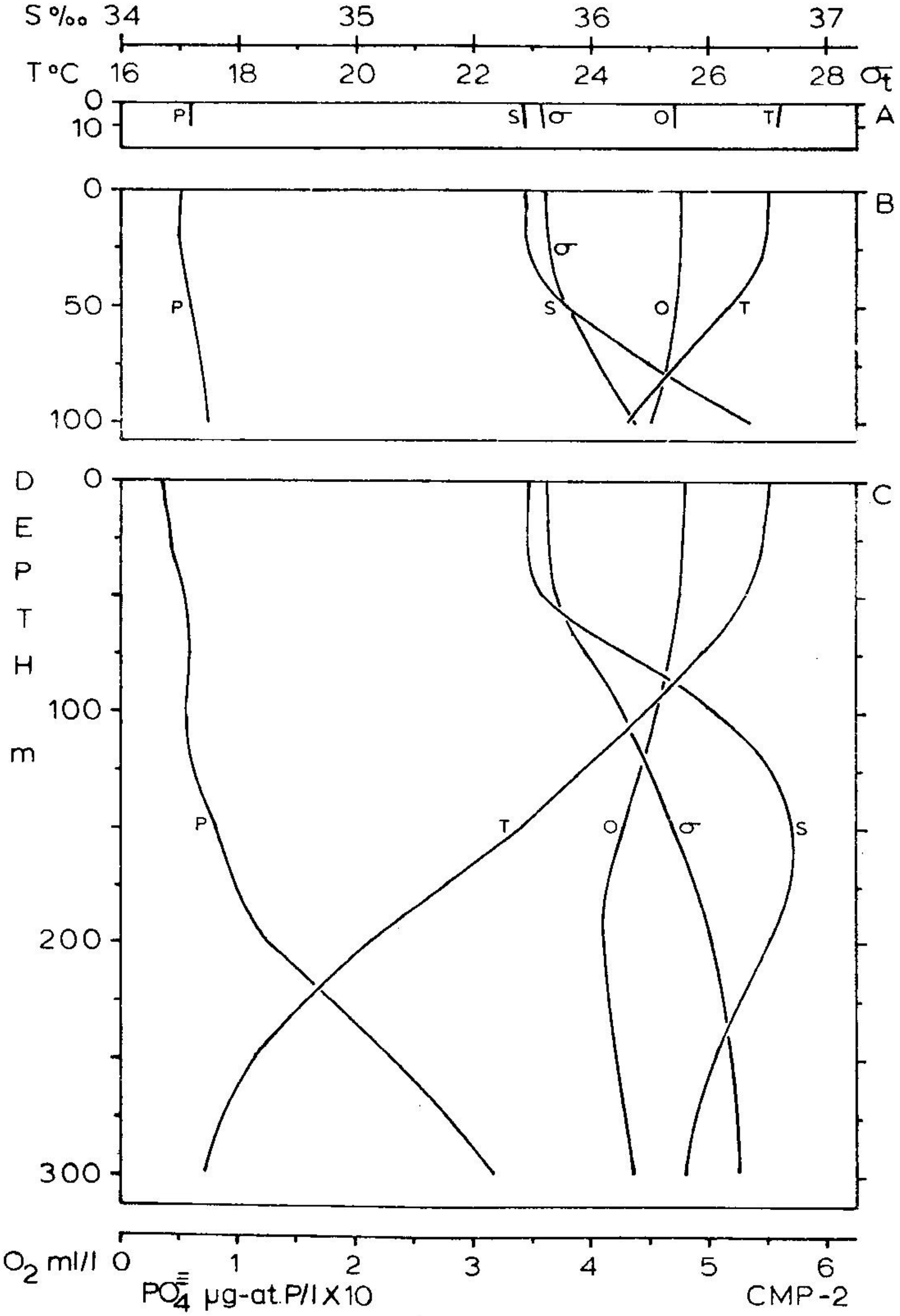


Fig. 2.1-F9 Averaged hydrographic parameter depth profiles for the spring season of 1973 and 1974 at Cabo Mala Pascua.

Fig. 2.1-F10 Depth profiles of hydrographic parameters averaged by type of station for the spring season of 1973 and 1974.



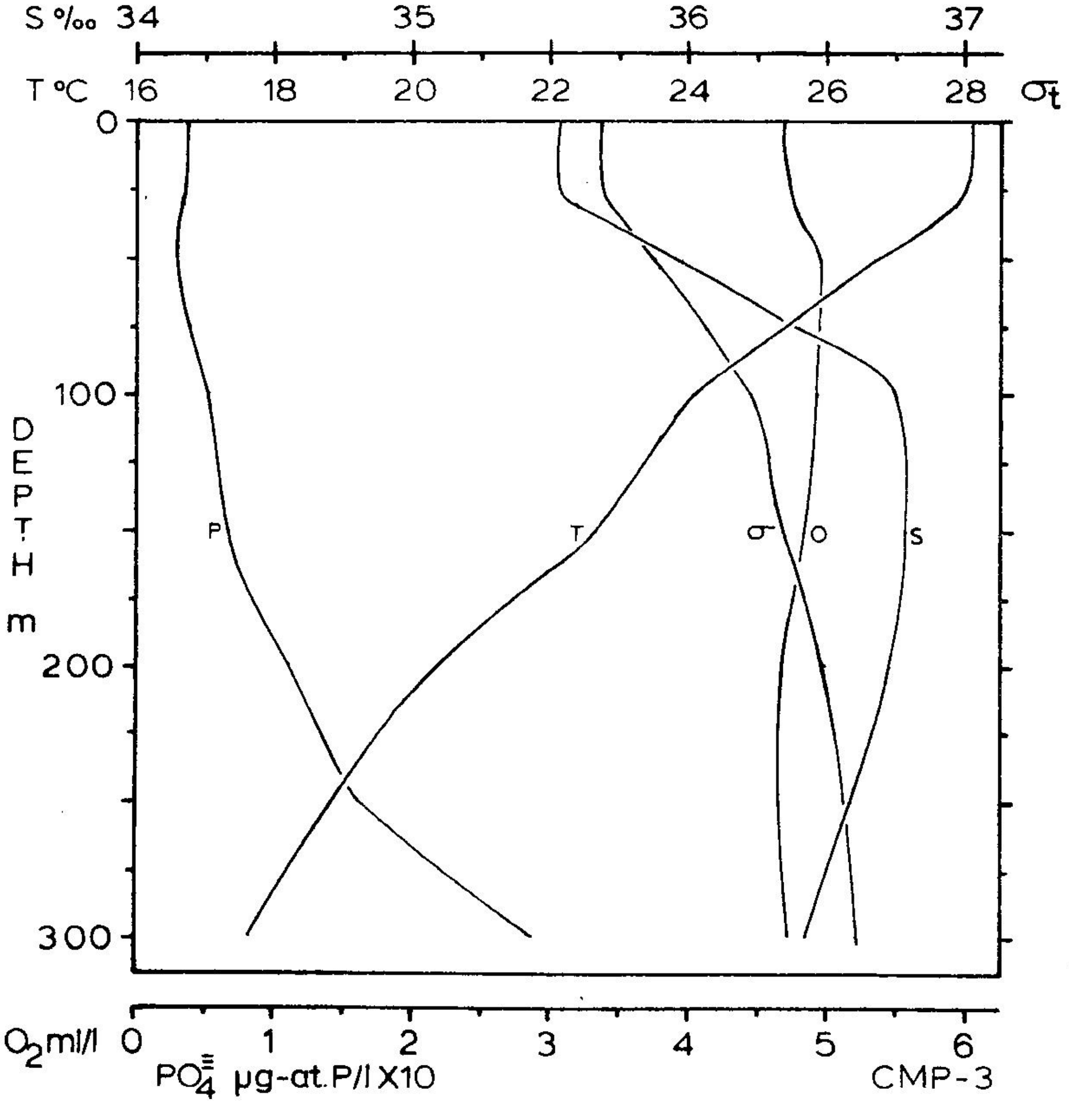
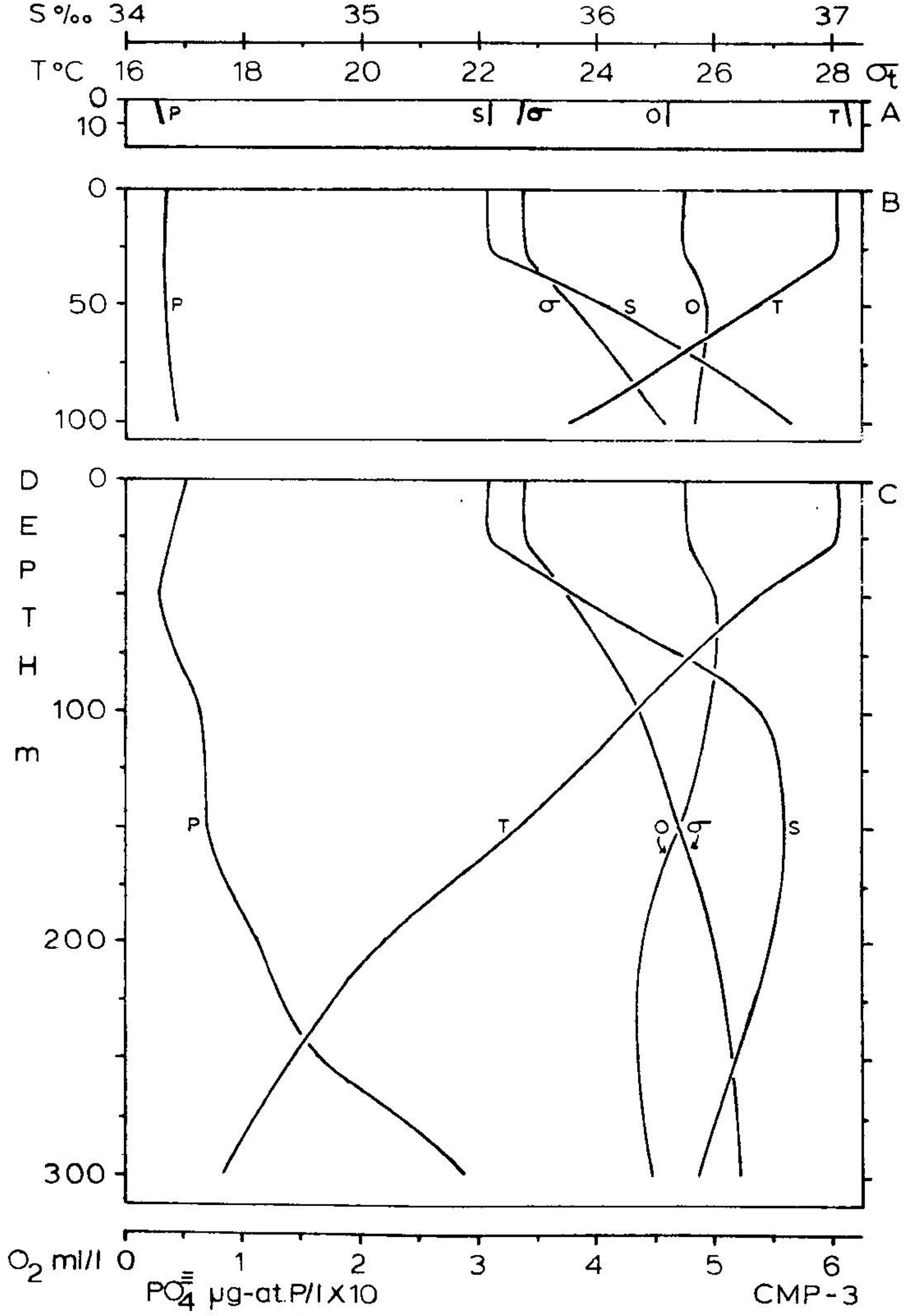


Fig. 2.1- F11 Averaged hydrographic parameter depth profiles for the summer season of 1974.

Fig. 2.1- F12 Depth profiles of hydrographic parameters averaged by type of station for the summer season of 1974.



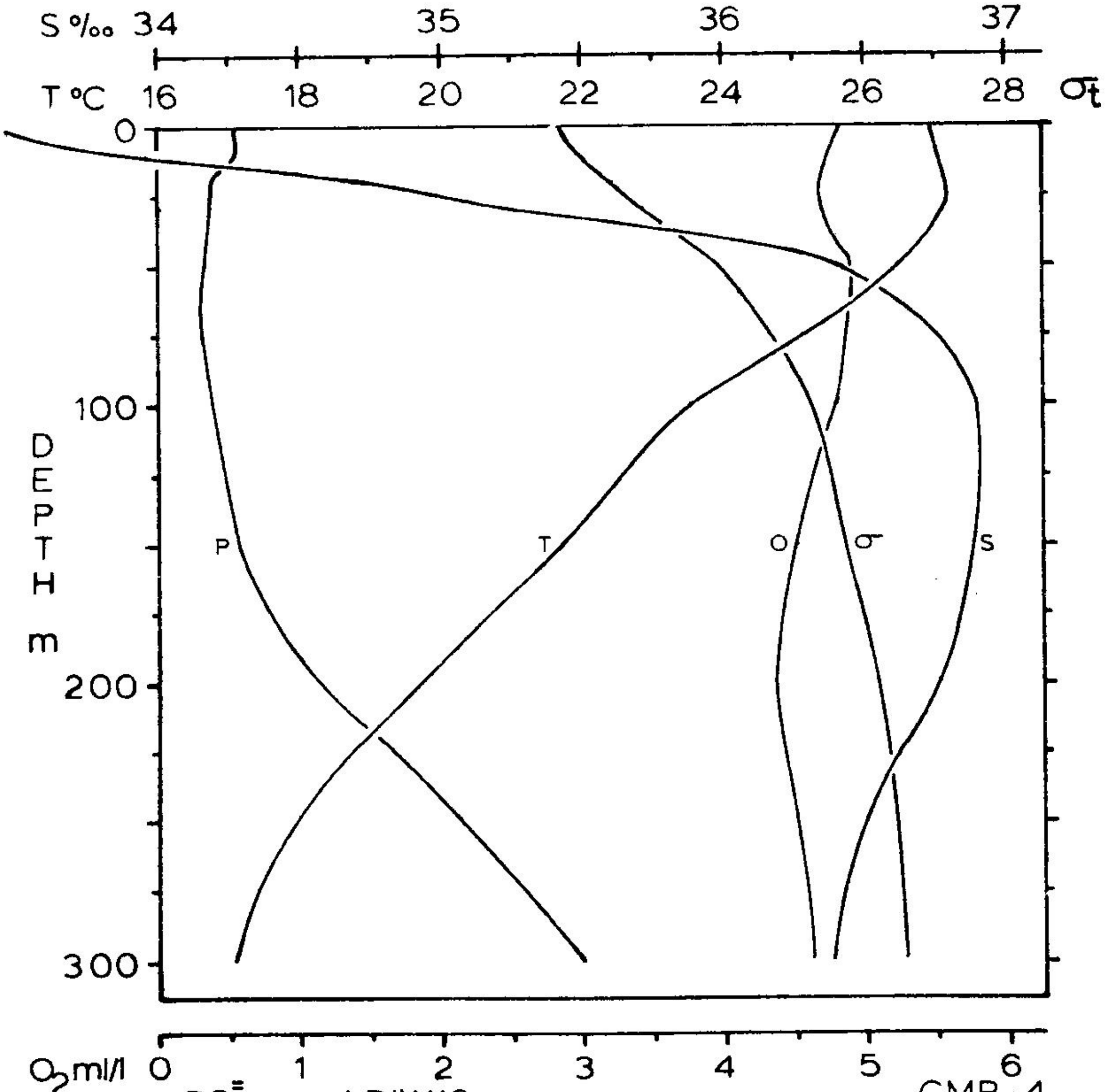
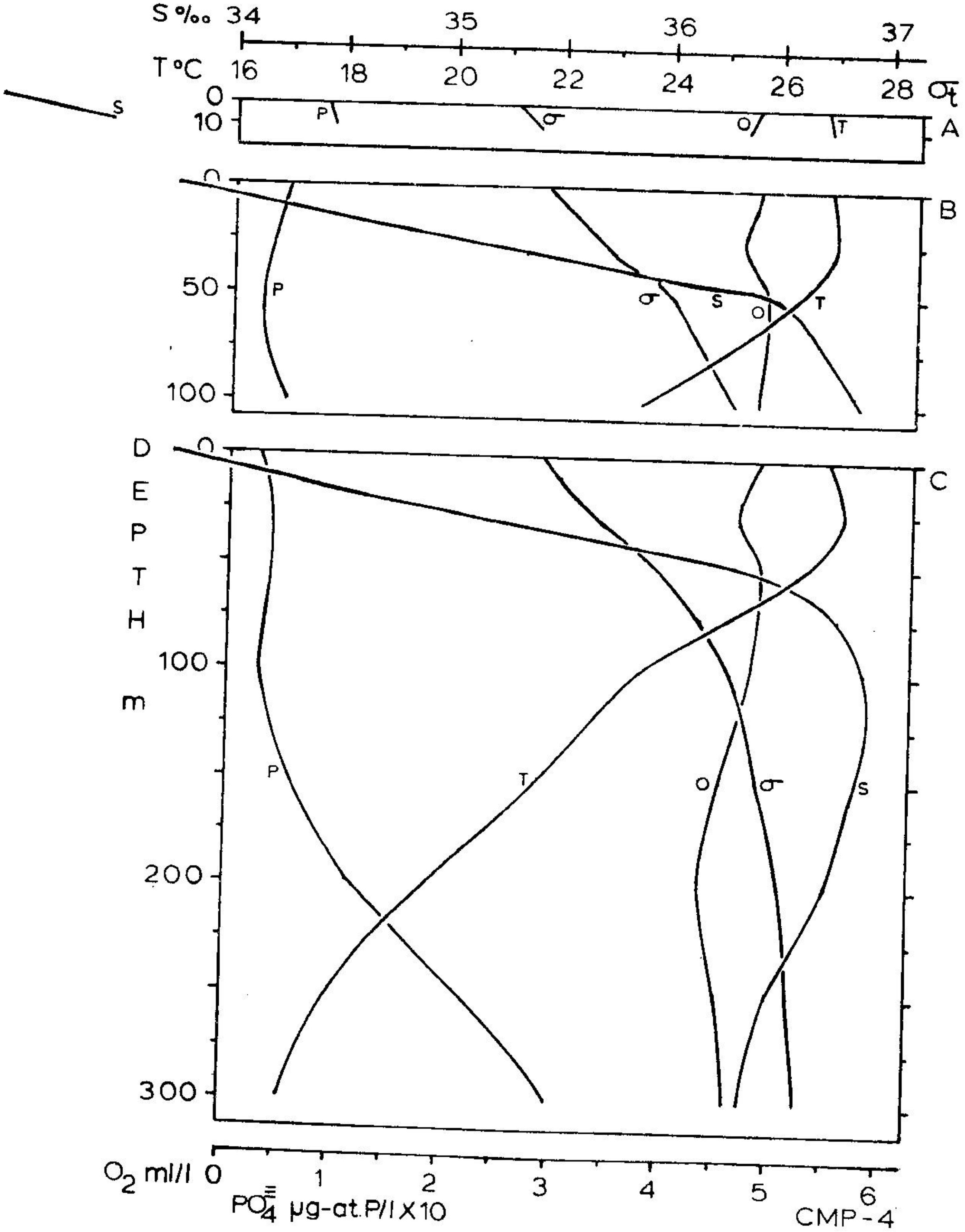


Fig. 2.1- F13 Averaged hydrographic parameter depth profiles for the fall season of 1974.

Fig. 2.1-F14 Depth profiles of hydrographic parameters averaged by type of station for the fall season of 1974.



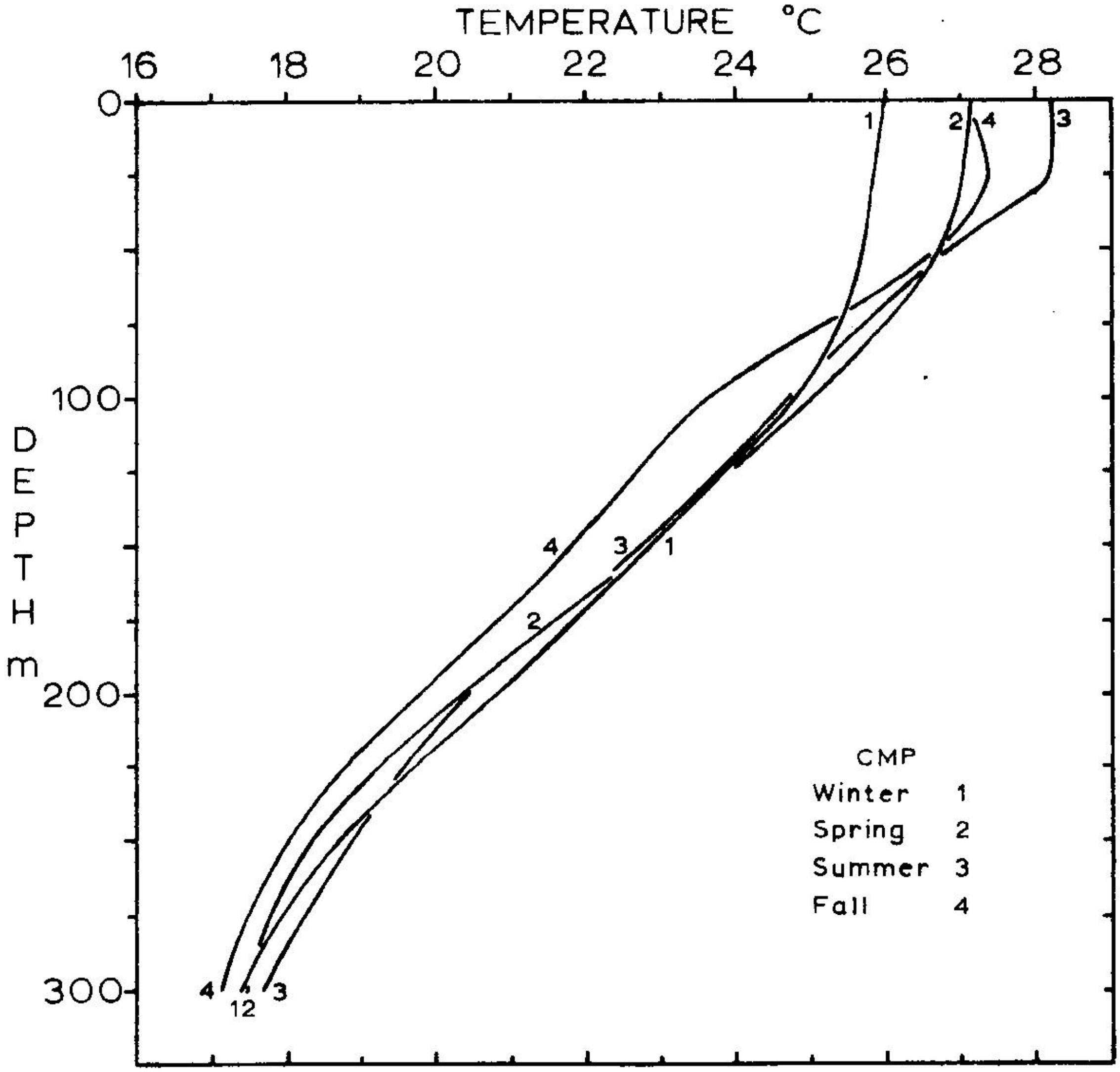


Fig. 2.1- F15 Averaged seasonal depth profiles of "C" station temperatures at Cabo Mala Pascua for 1973 and 1974.

Salinity

Salinity, S°/oo, is the total salt content of water expressed in parts per thousand. It is used along with temperature to typify ocean water masses. Low salinity usually occurs at the surface and indicates dilution by precipitation, runoff, or fresh water intrusions. High salinities are found in subtropical regions and are the result of high rates of evaporation. The salinities at Cabo Mala Pascua were determined using an induction salinometer with the readings good to better than + 0.005°/oo. The average seasonal salinity data are shown plotted against depth with the other hydrographic parameters in Figures 2.1-F7 through F14. In general, the salinities increased with depth to about 150 meters then decreased slightly. The layer of high salinity water with a maximum of about 37.0°/oo was formed by evaporation in the subtropical North Atlantic Ocean.

A comparison of the averaged "C" station data by season is shown in Figure 2.1-F16. The lowest surface salinities are found in the fall season coinciding with the end of the tropical rainy season. The highest surface salinities occur in the spring toward the end of the winter-spring dry season. The salinity depth profiles are very similar, below 75 meters for all seasons except fall. A sharp pycnocline exists at about 50 meters during the fall where the salinity increases from about 33.7 to 36.9°/oo between the depths of 25 and 100 meters. The salinity maximum is shallower for the fall season also. Little seasonal change was noticed below 150 meters where the salinity decreased from 36.8 to about 36.4°/oo at 300 meters except that the winter salinities were slightly higher than for other seasons.

Little difference was seen in surface salinities with distance from shore for all seasons except fall. The affect of the summer-fall wet season is reflected in low salinity values caused by land runoff.

Density

Water densities were calculated from temperature and salinity data and included with the other parameters as sigma-t, σt. Sigma-t is related to density at the temperature measured, ρt, by the following relationship:

$$\sigma t - (\rho t - 1) \times 10^3 \qquad (2.1)$$

Changes in sigma-t with depth are an indication of the stability of the water column. A small sigma-t gradient indicates a well-mixed or unstable zone, whereas a high gradient is indicative of a very stable portion of the water column. The surface layer usually has a very small density gradient because

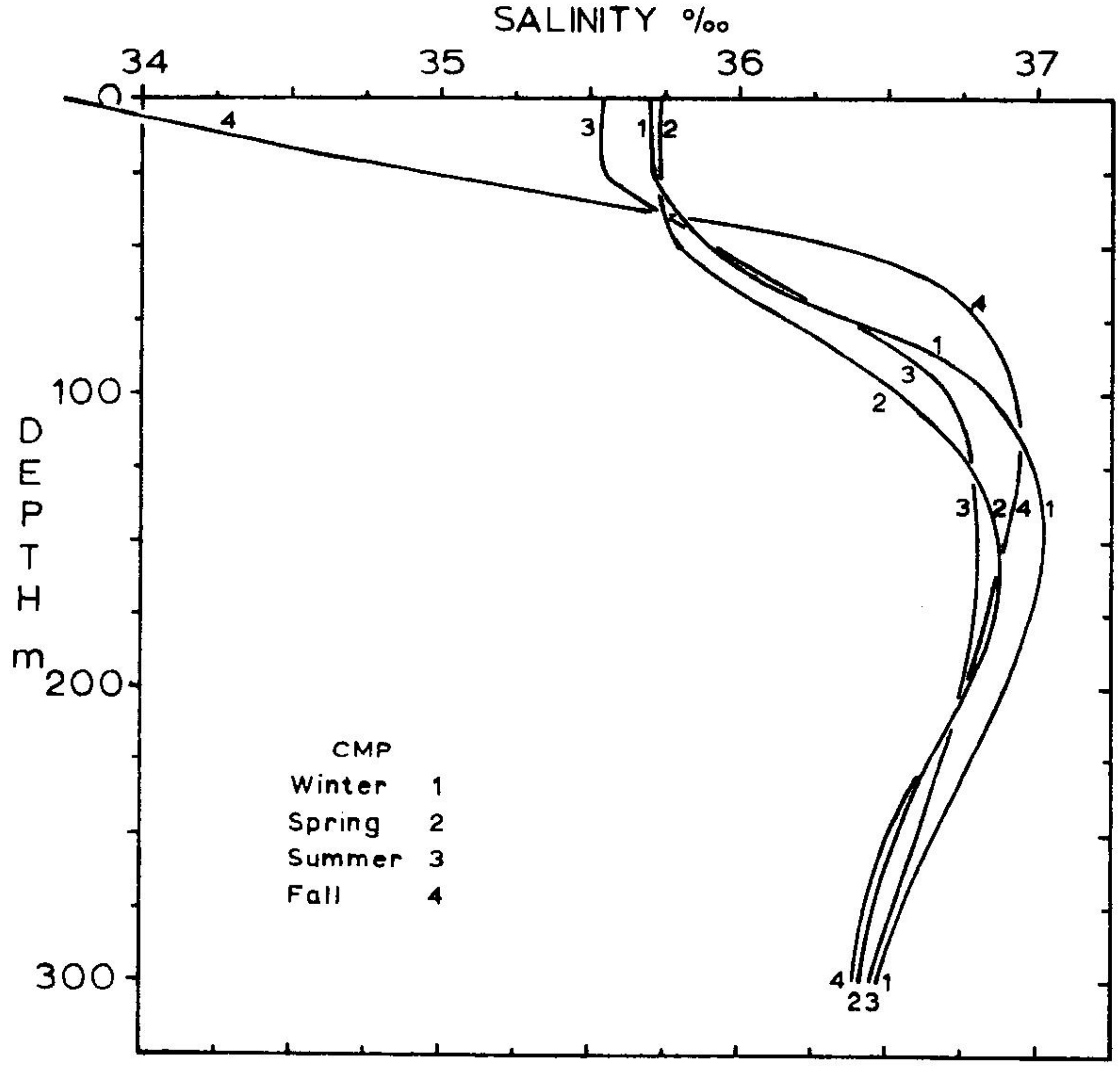


Fig. 2.1-F16 Averaged seasonal depth profiles of "C" station salinities at Cabo Mala Pascua for 1973 and 1974.

of wind-induced wave mixing. This layer varies from less than 50 meters in the summer to about 100 meters in the winter. Sigma-t profiles are shown plotted with other parameters in Figures 2.1-F7 through F14.

A comparison of the averaged seasonal sigma-t profiles is shown in Figure 2.1-F17. Sigma-t varies from 21.8 to 23.6 in the surface waters and is highest in the winter and spring months due principally to generally cooler surface temperatures in winter and higher salinities in the spring. The pycnocline occurs at about 100 meters in winter because of the deep storm mixing. The most stable water column occurs in the fall when surface water density decreases because of dilution and fairly warm surface temperatures. Sigma-t at the surface decreases from winter through fall. Little seasonal change in density occurs below 150 meters.

There was no significant difference in surface density with distance from shore except during the fall season when the "A" station densities were lower than for the "B" or "C" stations (Figure 2.1-F14) due to low salinities.

2.2 CHEMISTRY

2.2.1 DISSOLVED OXYGEN

The amounts of dissolved oxygen, D.O., in the water off Cabo Mala Pascua were determined by the Winkler titration method (Strickland and Parsons, 1968) with the analyses usually performed on shipboard within a few hours of sample collection. The titration values are generally good to better than ± %. Dissolved oxygen data are included with the hydrographic data reported by Wood and Asencio (1975) in mℓ/ℓ, mg/ℓ and % sat.

Oxygen saturation is a function of both temperature and salinity. Since neither shifts drastically in the tropics, little change in near surface D.O. is expected nor was it seen. Averaged D.O. values in milliliters per liter are plotted with other hydrographic parameters in Figures 2.1-F7 through F14 by season and type of station. The highest values were in the winter season. Surface values were near saturation. A comparison of seasonal averaged values is shown in Figure 2.2-F1. The oxygen minimum occurred at about 200 meters, slightly shallower in the spring and slightly deeper in the summer. The lowest average oxygen minimum was 4.11 mℓ/ℓ during the spring season.

2.2.2 NUTRIENTS

Nutrients are important from two aspects. First, nutrients are generally low in the tropical Atlantic Ocean and Caribbean Sea surface waters and limit primary productivity. Second,

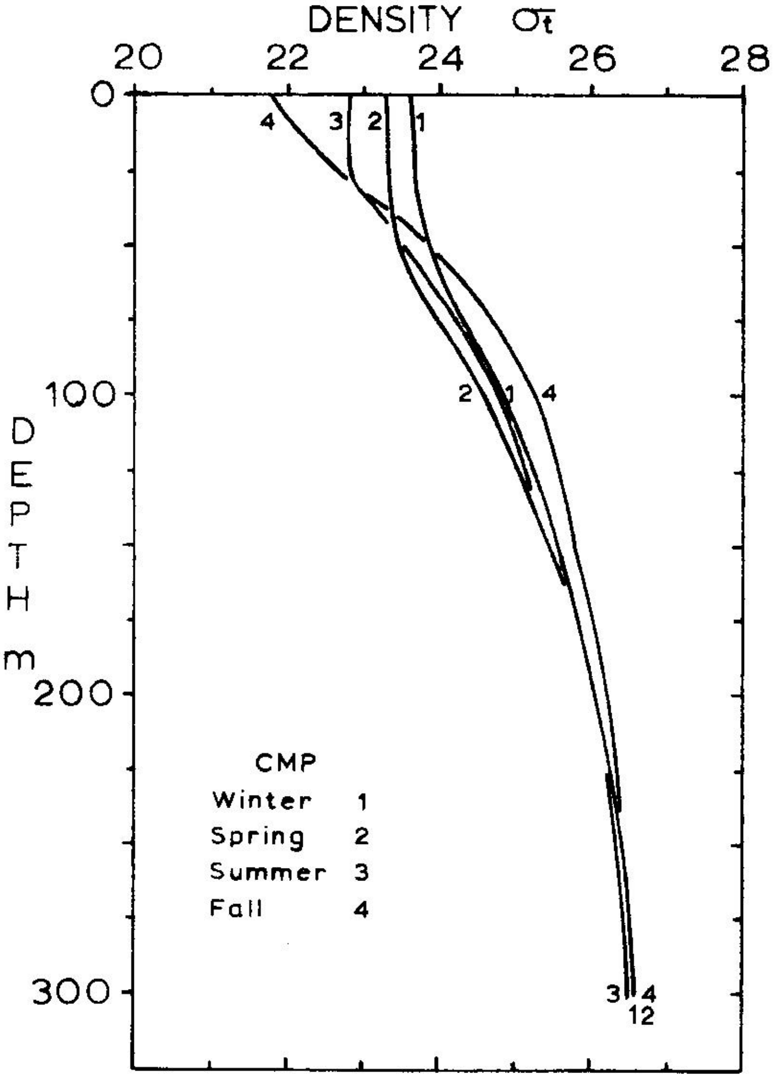


Fig. 2.1-F17 Averaged water density (sigma-t) profiles of "C" station data plotted by season for Cabo Mala Pascua, 1973 and 1974.

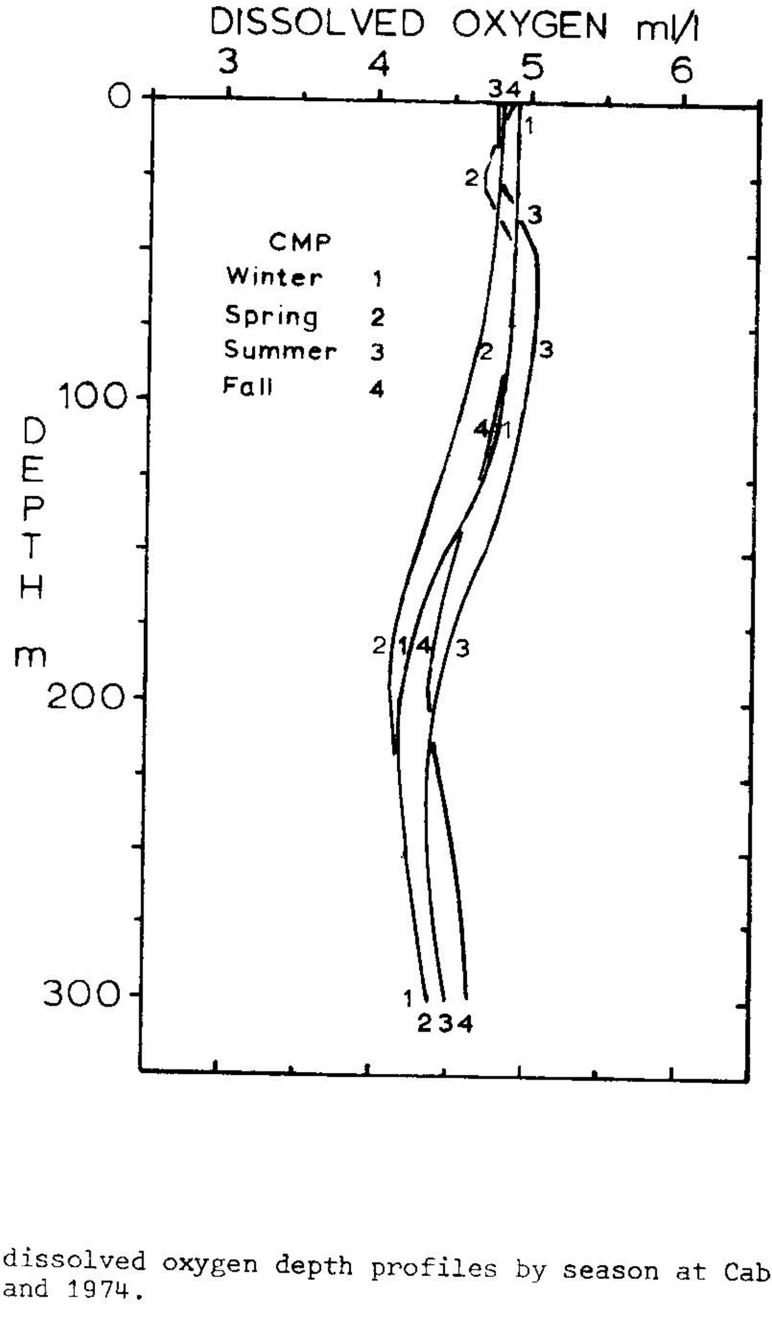


Fig. 2.2-F1 Averaged dissolved oxygen depth profiles by season at Cabo Mala Pascua for 1973 and 1974.

the discharge of wastes from agricultural, municipal or industrial sources may contain such high nutrient levels that they cause eutrophication and local ecological degradation.

Reactive phosphate can be determined quickly and accurately with the Murphy and Riley molybdate blue complex method (Strickland and Parson, 1968) and is a good indicator of pollution. A limited number of nitrate analyses were performed on the waters off Cabo Mala Pascua. The tropical regions around Puerto Rico are generally deficient in surface water nutrients, especially nitrate. Reactive silica is usually not regarded as a pollution problem.

Reactive Phosphate

The concentration of reactive phosphate was generally low (ca 0.05 µg-at. P/ℓ) in the surface waters off Cabo Mala Pascua as seen by the averaged "C" station seasonal phosphate profiles shown in Figure 2.2-F2. The phosphate values remained low with depth to nearly 200 meters before increasing to about 0.30 µg-at. P/ℓ.

There was very little difference in surface phosphate concentrations with distance from shore except in the fall. This anomaly coincided with low salinity (runoff) in the fall season.

Nitrate

Nitrate was determined by the cadmium-copper reduction method (Wood et al., 1967). A limited number of samples were analyzed for nitrate at Cabo Mala Pascua for the summer and fall seasons of 1974. The transect CMP-4 was sampled for nitrate in both the summer and fall of 1974. The "A", "B" and "C" station data were averaged and the resulting depth profiles for the two seasons are shown plotted in Figure 2.2-F3. The nearshore nitrate surface values were higher than those at the offshore stations for both summer and fall. Surface nitrate was generally low to 150 meters where a general increase began. The values at 300 meters appear low in the summer season and high in the fall season. Nitrates were near zero at 50 meters in both summer and fall.

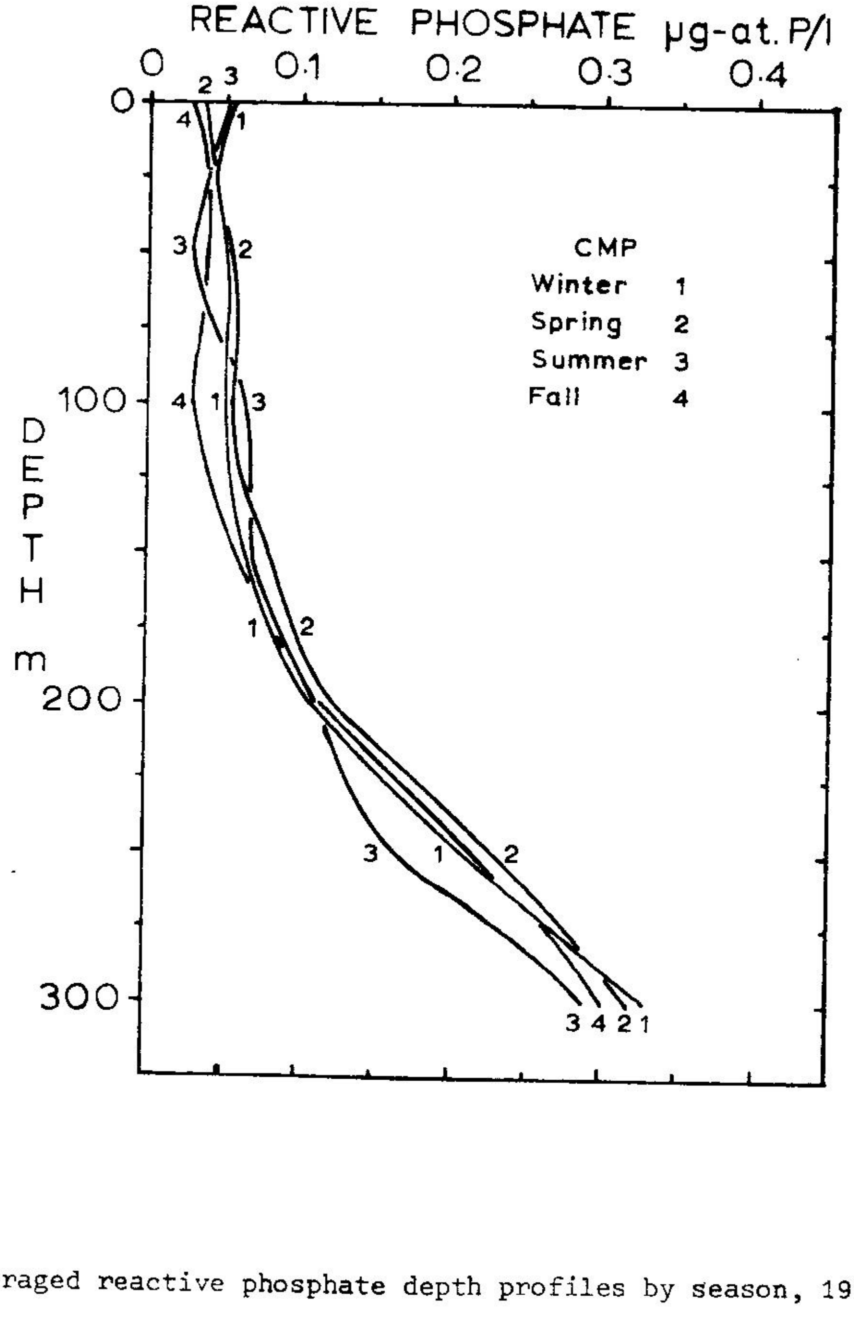


Fig. 2.2-F2 Averaged reactive phosphate depth profiles by season, 1973 and 1974.

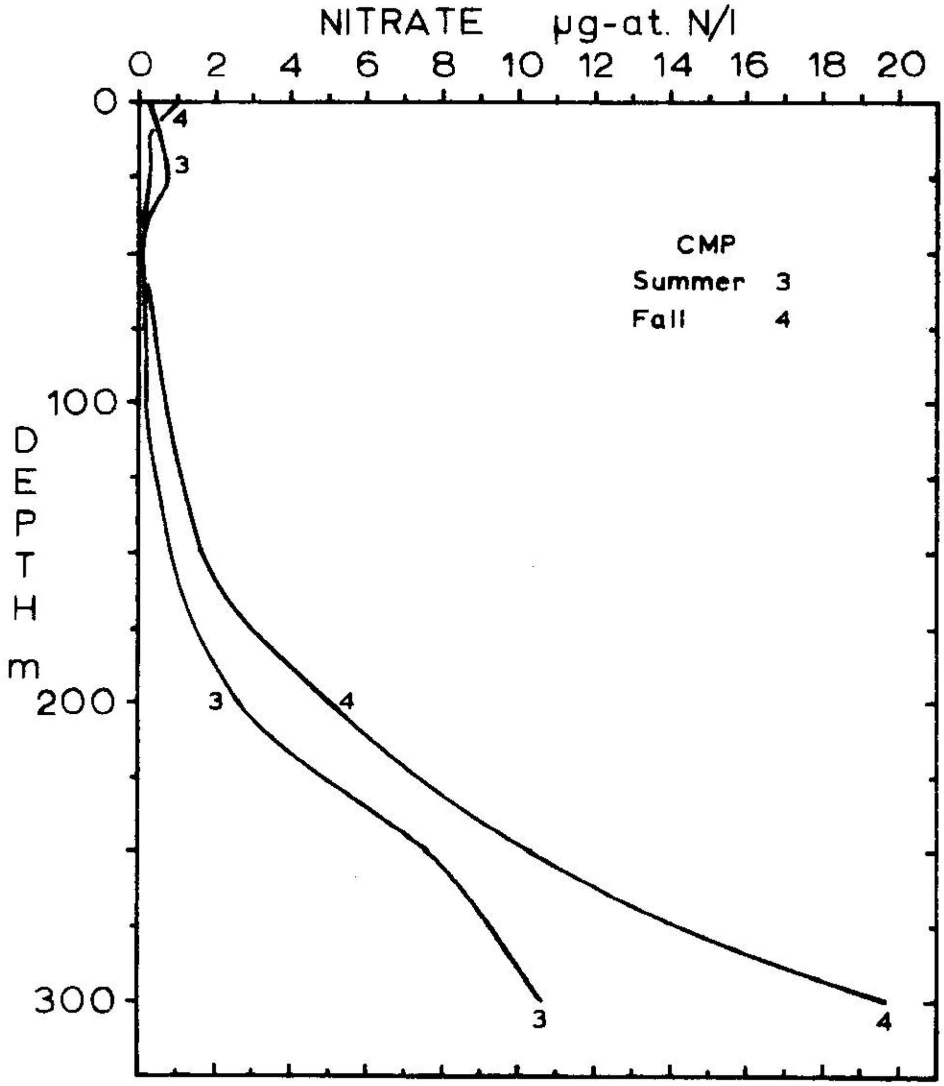


Fig. 2.2-F3 Nitrate depth profiles for the summer and fall seasons of 1974 at Cabo Mala Pascua.

3.1 GEOLOGICAL PARAMETERS AT CABO MALA PASCUA

by

E.D. Wood

3.1.1 INTRODUCTION

The geology of the Cabo Mala Pascua site has been described in Beck, 1972. Portions of that report will be repeated here along with a brief description of the marine sediments.

Cabo Mala Pascua itself is located on a wedge of volcanic rock which is very hard and resistant to erosion. The plant site would most likely be located slightly to the west in a valley which is underlain by quartz-diorite, and granite-like rock. Both rock types are Cretaceous in age; the diorite being considered part of the San Lorenzo batholith.

The Maunabo River flood plain lies to the east between Cabo Mala Pascua and Punta Tuna. Another flood plain makes up Punta Viento. This alluvium covers dioritic bedrock.

Sediments

The sediment size distribution found at a particular location reflect two factors, supply and transport. Sediment samples were collected at all "A" stations and sieved. Plots of cumulative weight percent and weight percent histograms for the fine sediments are shown in Figures 3.1-F1 and F2. The sieving statistics are tabulated in Table 3.1-T1.

TABLE 3.1-T1 Size analyses statistics for the Cabo Mala Pascua sediments.

STATIONS	MEDIAN $Md\phi$	MEAN $M\phi$	STD. DEV. $\sigma\phi$
CMP-2A	0.2	0.3	1.2
3A	1.1	0.7	1.1
4A	1.2	1.1	0.6
5A	0.6	0.8	0.8
6A	3.7	3.4	0.8

The major supply of sediment in the Cabo Mala Pascua region is the Maunabo River. Some sediments are carried around Punta Tuna, also. The sediments at CMP-6A were very fine ($M\phi = 3.4$). Fine sand and course silt might be expected here

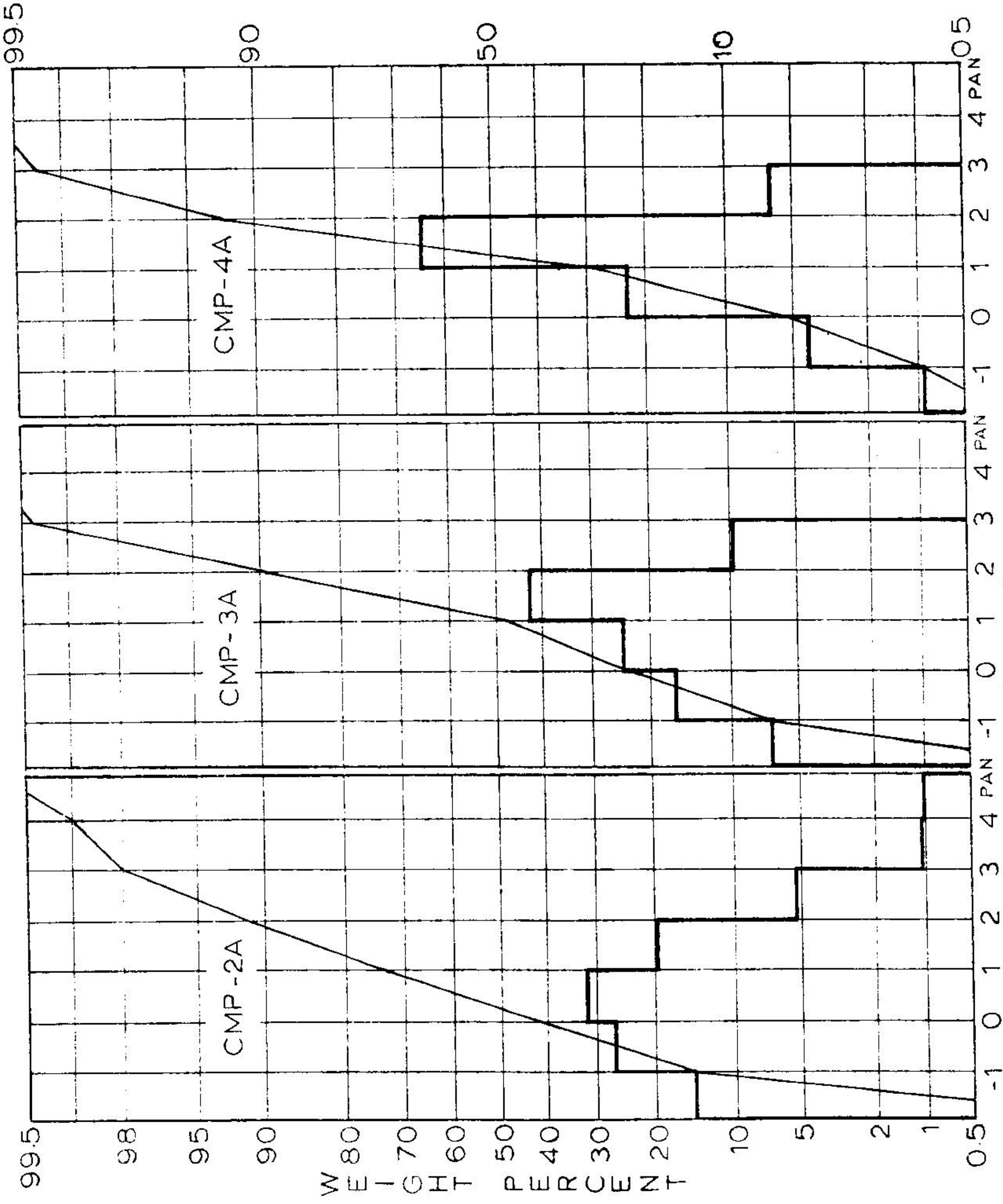


Fig. 3.1-F1 Histograms and cumulative weight percent plots of sediments at Stations CMP-2A, 3A and 4A.

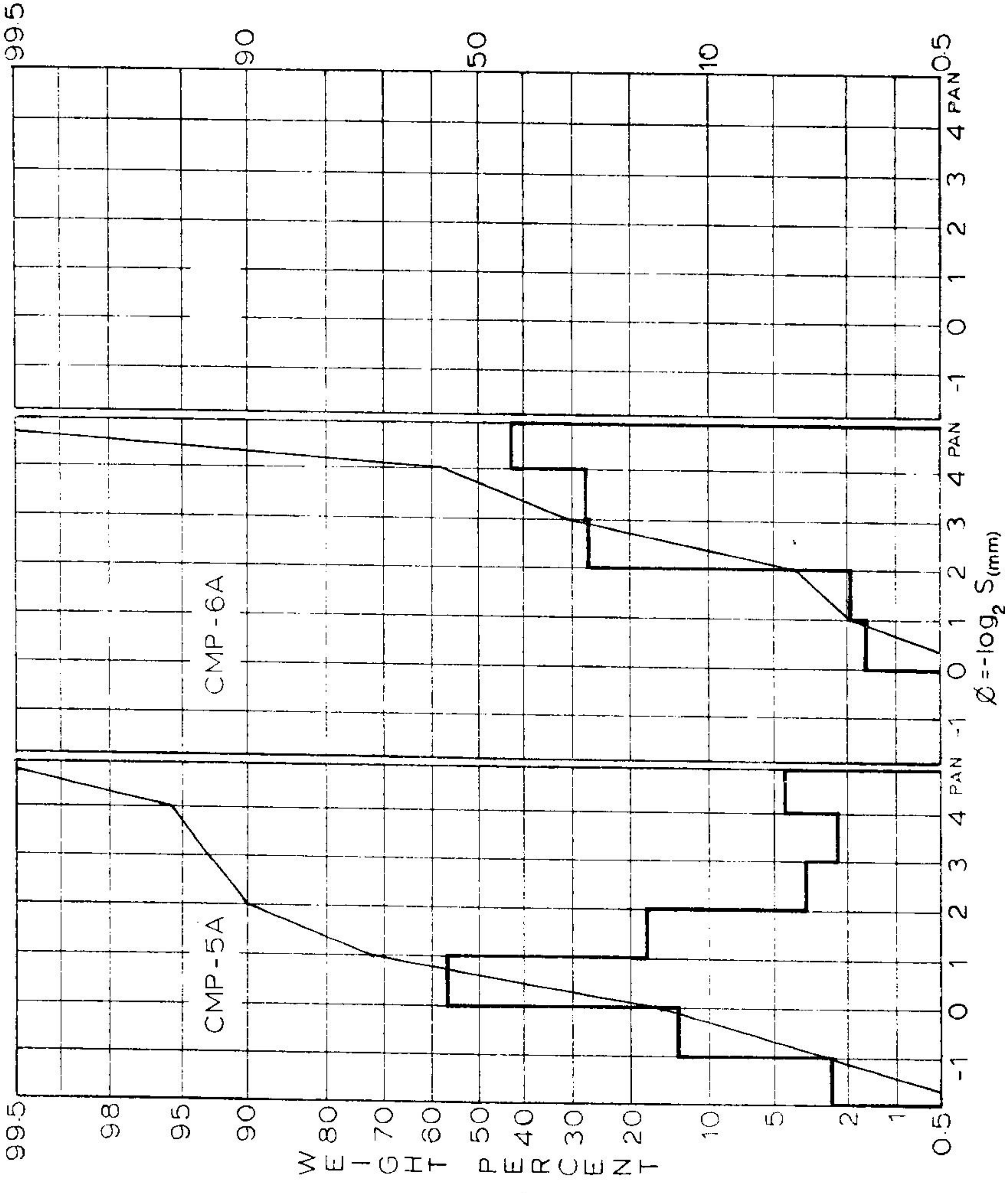


Fig. 3.1-F2 Histograms and cumulative weight percent plots of sediments at Stations CMP-5A and 6A.

since it is very near the mouth of the Maunabo River and the lee of Punta Tuna offers a region where fine sediments may be deposited.

Sediments at the other "A" stations were more coarse (sand) especially on the windward side of points such as Punta Viento and Cabo Mala Pascua.

4.1 ZOOPLANKTON STUDIES 1973 AND 1974

by

Marsh J. Youngbluth

4.1.1 INTRODUCTION

The following report provides estimates of the abundance and diversity of zooplankton in the surface waters along an eastern portion of the south coast of Puerto Rico. These data form one part of an environmental survey conducted by the Puerto Rico Nuclear Center. All collections were gathered in an area adjacent to the region proposed for the siting of a future power plant. Samples were gathered on 7 days during 1973 and 1974; 22 February, 23 May, 13 February, 23 April, 22 August, 14 November, and 12 December.

4.1.2 MATERIALS AND METHODS

Field Procedures

Zooplankton were collected with a 1/2 meter diameter cylinder-cone shaped nylon net. This net was designed to reduce clogging error (Smith et al., 1968). Mesh size was 233 microns. The net was towed from a 17 foot skiff in a circular path through the upper 2 meters. The speed of the vessel ranged from 2 and 3 knots (determined with a Sims yacht speedometer). The duration of a tow was 10 minutes. After each tow, before the cod end was removed, the net was washed with sea water with the aid of a battery driven pump (12 volt, Jabsco water-puppy). The catch was preserved in 4% sea water formalin buffered to pH 7.6. All samples were gathered during the daylight hours. The volume of water filtered through a net was estimated with a flowmeter (TSK or General Oceanics Model 2030) suspended off-center in the mouth of the net. The volumes usually ranged from 100 to 150 m^3. The meters were calibrated every 2 months. Calibration factors fell within 8% of the mean.

At each site three tows were made in the area adjacent to the region where a power station may be located. Single tows were taken at the other stations. The regions sampled were chosen in such a way as to collect within and around the area where thermal alteration is likely to occur (Figure 4.1-F1).

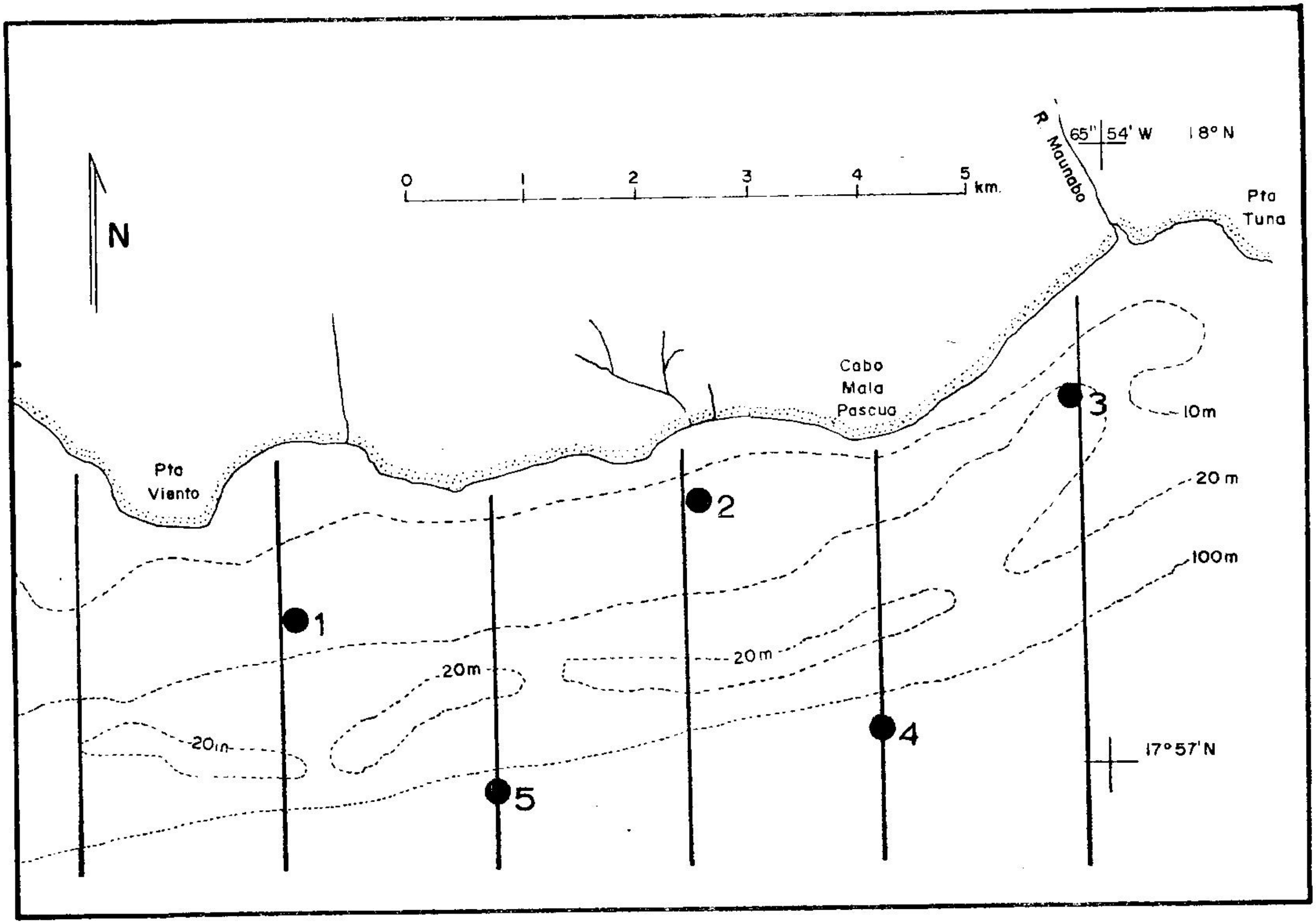


Fig. 4.1-F1 Zooplankton stations at the Cabo Mala Pascua site.

Laboratory Procedures

Within 24 hours after samples were collected the pH was checked and adjusted, if necessary, to 7.6. If a sample contained a noticeable conglomerate of phytoplankton or detritus, the zooplankton were separated from such material by gentle filtration through 202 micron mesh netting. Before estimates of biomass or numbers were made all organisms larger than 1 cm, usually hydrozoan medusae, were removed.

Biomass was calculated as wet volume (Ahlstrom and Thraikill, 1962). This estimate is subject to considerable error and should be viewed only as a rough measure of standing stock. The measurements were reproducible but are undoubtedly biased toward higher than actual values by the variable proportion of interstitial water and detritus.

The total number of organisms was estimated by volumetric subsampling with replacement (Brinton 1962). Three aliquots from each sample were counted. The abundance of major taxonomic groups of holoplankton and meroplankton were determined from dilutions of 300 to 500 organisms. Copepods, usually the most numerous of the zooplankters, were identified to species.

All biomass and enumeration data were standardized to a per cubic meter basis or multiple thereof. Data were initially reduced with hand calculators (Hewlett Packard Model 45) and more recently with a computer (PDP-10). See Appendix 4.1A for a listing of the program.

4.1.3 RESULTS

A total of 46 samples was collected from 5 stations (Figure 4.1-F1). The abundances of several taxonomic groups of zooplankton at each station have been determined (Tables 4.1-T6 through T17). These data are arranged to facilitate comparisons among sets of consecutive tows, nearshore tows, and offshore tows.

The densities of total zooplankton usually differed more between catches from different areas than between consecutive samples from one area. One measure of the variation between samples is the ratio formed by dividing the largest total number of zooplankton by the smallest within each set (Table 4.1-T1).

TABLE 4.1-T1. Summary of ratios between the highest and lowest density values of total zooplankton during each period.

	1973		1974				
	22 Feb	23 May	13 Feb	23 Apr	22 Aug	14 Nov	12 Dec
Consecutive Tows	1.3	1.1	1.2/1.1	1.4	1.2/1.5	1.2	1.2
Nearshore Tows	2.0	1.6	1.1	2.6	1.6	-	-
Offshore Tows	1.2	1.2	1.1	1.3	1.3	-	-
All Tows	2.8	1.6	1.2	2.6	2.8	-	2.1

The ratios are similar but generally smaller than those observed in other coastal regions around Puerto Rico (Youngbluth 1975). Another way of judging differences between samples was determined by calculating the variance between consecutive samples and estimating the number of tows needed to detect various levels of difference (Table 4.1-T2). These data indicate that a large number of replicate

TABLE 4.1-T2. Total zooplankton ($\log_{10}$ transformed) from 7 sets of replicate tows. The number of replicate tows (n) needed to detect a $\pm$ 5-30% difference in density is indicated.*

DATE	22 Feb	23 May	13 Feb	23 Apr	22 Aug	14 Nov	12 Dec
STATION	2	2	2	2	2	2	2
	2.55630	2.91908	2.79024 2.30750	2.96047	2.80346 2.77452	2.94498	3.15229
	2.54407	2.90687	2.85126 2.34830	2.82347	2.77452 2.83822	2.97589	3.07188
	2.68574	2.94498	2.78604 2.36173	2.83948	2.72591 2.64836	3.03302	3.14239
n 5%	46	52	10/6	41	11/69	15	15
n 20%	3	3	1/1	3	1/4	1	1
n 30%	1	1	1/1	1	1/2	1	1

*$n = \frac{t^2 \times s^2}{d^2}$ Where (t) is Student's t for the 95% confidence level (d.f=2), s^2 is the sample variance based on replicate tows and d is the half-width of the confidence interval desired.

tows would be necessary to detect density differences at the 5% level. However, on the average, differences of 20% can be noted with only 3 tows. Differences of 30% may be revealed with a single tow. Density estimates larger than 30% were found between nearshore and offshore catches. The range of density values during a sampling period was usually two to three-fold. Seasonal changes in the abundance of total zooplankton at any station or among all samples were within the same range (Table 4.1-T6). The highest concentrations occurred in December. These larger densities, however, probably represent the range of variation among tropical zooplankton communities in the coastal waters around Puerto Rico rather than a recurrent seasonal pulse since the 95% confidence intervals from each station overlap (Table 4.1-T3).

TABLE 4.1-T3 Average density of all zooplankton collected.

Total Zooplankton/m^3

	1973		1974				
	22 Feb	23 May	13 Feb	23 Apr	22 Aug	14 Nov	12 Dec
Range	231-654	530-840	557-646	289-812	304-836	-	-
Median	320	663	586	613	532	-	-
Mean	424	663	600	591	552	-	-
95% C.L.	±497	±308	±107	±525	±538	-	-

These fluctuations in density refer primarily to holoplanktonic organisms since they composed, in most cases, 60 to 90% of the total zooplankton. Meroplankton formed 3 to 27% and were more numerous during April and August. The dominant meroplanktonic groups were prosobranch veligers and caridean larvae.

Fish eggs were abundant in this area forming 2 to 40% of the total zooplankton (Table 4.1-T4). The largest density 229/m^3, was observed at Station 5 on 13 February 1974. Fish eggs were more numerous on this date than any other, averaging 177/m^3 and forming 31% of all zooplankton collected. Most of the eggs were round and 0.5 to 2 mm in diameter. Oblong eggs were common. It is not known which groups of fish are represented by most of the eggs.

TABLE 4.1-T4 Summary of densities of fish eggs from all stations sampled at the Cabo Mala Pascua site.

	STATION 1	2	3	4	5
Range	12-96	19-151	4-197	32-229	23-204
Median	34	35	25	46	57
Mean	41	51	60	88	81

Diurnal changes in density were large in February and small in August. A detailed account of the magnitude of fluctuations among several groups has been reported earlier (Youngbluth 1974). Nearly all organisms were much more numerous at night during this period but only two groups were observed in greater numbers at night during August, the larvaceans and the gastropod larvae. Sea state and sky conditions were similar during each period, i.e., calm and moonless at night, light chop and sunny during the day.

Copepods formed 60 to 85% of the zooplankton community. A total of 39 species was identified. Time did not allow a detailed examination of species abundances at all stations, consequently, one sample from Station 2 for each period was selected for study. The entire sample was scanned to form a species list and subsampled for quantitative analysis. Using these data, the species most numerous, those commonly observed, and others occasionally found are listed in Table 4.1-T5.

TABLE 4.1A1-T5. Copepod populations observed at the Cabo Mala Pascua Site.

Species usually most numerous (>5 individuals/m^3)

- *Clausocalanus furcatus*
- *Paracalanus* spp. (*P. aculeatus*, *P. crissirostris*, *P. parvus*)
- *Farranula gracilis*
- *Oithona* spp. (*O. plumifera*, *O.* spp.)
- *Acartia spinata*
- *Temora turbinata*
- *Calanopia americana*

Species commonly present (observed on 5 or more sampling periods)

- *Corycaeus* spp. (*C giesbrechti*, *C. pacificus*, *C. speciosus*)
- *Undinula vulgaris*
- *Calocalanus pavo*
- *Euchaeta marina*
- *Nannocalanus minor*
- *Labidocera* spp.
- *Candacia pachydactyla*
- *Mecynocera clausi*
- *Acrocalanus longicornis*
- *Temora stylifera*

Species occasionally present

- *Oncaea* spp. (*O. mediterranea*, *O. venusta*, *O.* spp.)
- *Corycaeus* spp. (*C. subulatus*, *C.* spp.)
- *Pseudodiaptomus cokeri*
- *Calocalanus pavoninus*
- *Scolecithrix danae*
- *Centropages furcatus*
- *Eucalanus* spp.
- *Lucicutia flavicornis*
- *Miracia efferata*
- *Copilia* spp.
- *Sapphirina* spp.
- *Monstrilla* spp.
- *Macrosetella gracilis*
- *Phaenna spinifera*

4.1.4 DISCUSSION

The variety and abundance of zooplankton observed at the Cabo Mala Pascua site were similar throughout the year. Diurnal changes in density varied. Large increases in nearly all groups were observed at night during February. In August no obvious differences were noticed except among larvaceans and prosobranch veligers.

Copepods always dominated the zooplankton community. The larvae of gastropods and decapods were the major meroplanktonic organisms. The largest proportion of meroplankton occurred during April and August. Fish eggs were very numerous during February 1974.

Limitations of the Data

The sampling program was designed to provide quantitative estimates of: 1) the standing stock of zooplankton, 2) the variety of major taxonomic groups, and 3) the diversity and abundance of the more numerous copepod species. The manner of field sampling determined the variety and biomass of organisms encountered. The data in this report are based on collections made in the surface waters during the daylight hours. The sampling gear and methods were kept uniform, i.e., net type, net mesh, towing speed, and depth range sampled. A small number of replicate tows were gathered at each site to obtain some measure of the variability between samples. To obtain a better understanding of the zooplankton community more sampling with replication should be done at frequent intervals, at a greater number of stations, at different depths, during the day and night, and during different seasons for several years. Information gathered in these ways will be necessary to interpret fluctuations in standing stock and diversity in relation to environmental changes and biotic interactions.

Table 4.1-T5 Total biomass of zooplankton (ml/m^3) Cabo Mala Pascua Site

	Nearshore Replicate Tows Stations			Nearshore Tows Stations			Offshore Tows Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	.045	.048	.063	.070	.052	.098	.063	.085
230573	.078	.097	.108	.046	.094	.065	.108	.119
130274*	.086/.034	.082/.036	.079/.044	.071	.083/.038	.039	.079	.124
230474	.137	.087	.081	.061	.101	.087	.084	.101
220874*	.031/.094	.050/.094	.059/.067	.062	.047/.080	.081	-	.074
141174°	.103	.112	.133	-	.116	-	-	-
121274	.083	.113	.097	-	.104	-	.062	-

Table 4.1-T6 Total number of zooplankton (number/m^3)

	Nearshore Replicate Tows Stations			Nearshore Tows Stations			Offshore Tows Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	360	350	485	626	320	654	231	288
230573	830	807	881	530	840	718	564	663
130274*	617/203	710/ 223	611/230	646	646/219	566	557	586
230474	913	666	691	486	757	289	812	613
220874*	636/595	595/689	532/445	693	532/577	836	393	304
141174°	881	946	1079	-	969	-	-	-
121274	1420	1180	1388	-	1330	-	636	-

*Midnight/Midday; °Midnight

Table 4.1-T7 Total number of holoplankton (number/m^3) Cabo Mala Pascua Site.

	Nearshore Replicate Tows			Nearshore Tows			Offshore Tows	
	Stations			Stations			Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	98	303	400	559	267	544	182	237
230573	678	662	755	455	698	630	521	456
130274*	347/70	471/84	388/98	492	402/84	352	262	336
230474	761	543	530	314	611	197	586	473
220874*	278/452	483/536	455/371	532	405/453	710	320	209
141174°	743	738	896	-	792	-	-	-
121274	1330	1099	1315	-	1248	-	573	-

Table 4.1-T8 Total number of meroplankton (number/m^3)

	Nearshore Replicate Tows			Nearshore Tows			Offshore Tows	
	Stations			Stations			Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	6	17	22	22	15	21	9	67
230573	108	95	72	43	91	59	35	46
130274*	97/8	45/1	42/11	53	62/6	14	56	32
230474	95	55	93	131	81	72	87	80
220874*	56/110	101/122	87/48	148	81/93	114	37	62
141174°	108	155	138	-	134	-	-	-
121274	68	53	51	-	58	-	37	-

*Midnight/Midday; °Midnight

Table 4.1-T9 Total number of copepods (number/m) Cabo Mala Pascua Site.

	Nearshore Replicate Tows Stations			Nearshore Tows Stations			Offshore Tows Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	82	273	348	483	234	438	140	198
230573	530	510	593	390	544	571	355	405
130274*	303/58	349/70	308/80	471	320/69	327	226	278
230474	648	496	486	270	543	183	510	416
220874*	240/427	402/496	401/358	513	348/426	683	296	186
141174°	663	660	820	-	714	-	-	-
121274	1238	988	1198	-	1141	-	495	-

Table 4.1-T10 Total number of chaetognaths (number/10m^3)

	Nearshore Replicate Tows Stations			Nearshore Tows Stations			Offshore Tows Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	95	172	227	421	165	514	66	137
230573	212	259	204	100	225	33	37	462
130274*	108/6	150/10	79/18	45	113/11	56	101	97
230474	482	228	169	122	293	12	252	193
220874*	7/99	43/159	50/44	22	33/101	75	39	54
141174°	355	415	481	-	417	-	-	-
121274	367	441	340	-	383	-	150	-

*Midnight/Midday; °Midnight

Table 4.1-T11 Total number of larvaceans (number/10m^3) Cabo Mala Pascua Site.

	Nearshore Replicate Tows			Nearshore Tows			Offshore Tows	
	Stations			Stations			Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	26	91	250	234	122	333	244	278
230573	1024	1113	1389	437	1176	381	583	594
130274*	137/27	479/48	529/23	84	382/33	143	57	138
230474	511	189	242	245	314	105	294	324
220874*	355/116	718/112	486/22	103	520/83	129	70	125
141174°	266	115	151	-	178	-	-	-
121274	330	510	632	-	490	-	143	-

Table 4.1-T12 Total number of veliger larvae (number/10m^3)

	Nearshore Replicate Tows			Nearshore Tows			Offshore Tows	
	Stations			Stations			Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	20	22	110	140	50	136	26	66
230573	568	414	431	91	471	65	140	40
130274*	151/81	527/65	112/113	148	263/86	135	458	214
230474	496	378	669	978	547	365	578	534
220874*	297/289	488/393	554/192	427	442/291	775	132	207
141174°	284	185	231	-	233	-	-	-
121274	489	325	316	-	377	-	278	-

*Midnight/Midday; °Midnight

Table 4.1-T13 Total number of caridean larvae (number/10m^3) Cabo Mala Pascua Site.

	Nearshore Replicate Tows Stations			Nearshore Tows Stations			Offshore Tows Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	6	59	44	31	37	45	19	15
230573	156	52	96	173	101	370	+	26
130274*	618/1	246/1	185/1	321	350/1	+	57	41
230474	99	47	73	69	73	192	42	114
220874*	137/421	316/+	134/148	912	196/190	301	109	198
141174°	213	277	320	-	270	-	-	-
121274	49	70	49	-	56	-	83	-

Table 4.1-T14 Total number of brachyuran larvae (number/10m^3)

	Nearshore Replicate Tows Stations			Nearshore Tows Stations			Offshore Tows Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	21	54	34	+	36	15	4	4
230573	122	155	120	109	133	33	+	13
130274*	237/1	48/1	119/2	26	135/1	+	31	7
230474	99	32	+	+	44	12	21	18
220874*	34/231	43/178	50/111	52	43/173	11	128	55
141174°	36	254	116	-	135	-	-	-
121274	24	46	+	-	24	-	23	-

*Midnight/Midday; °Midnight

Table 4.1-T15 Total number of cirripede nauplii (number/10m^3) Cabo Mala Pascua Site.

	Nearshore Replicate Tows Stations			Nearshore Tows Stations			Offshore Tows Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	+	38	3	31	13	15	11	4
230573	178	194	48	27	140	76	76	317
130274*	58/4	48/1	60/1	25	55/2	+	4	+
230474	113	55	56	31	75	68	+	26
220874*	34/66	86/19	84/+	74	68/28	+	11	4
141174[c]	87	69	107	-	88	-	-	-
121274	37	46	49	-	44	-	90	-

Table 4.1-T16 Total number of fish eggs (number/m^3)

	Nearshore Replicate Tows Stations			Nearshore Tows Stations			Offshore Tows Stations	
Date	2a	2b	2c	1	2	3	5	4
220273	42	26	56	39	33	59	37	37
230573	30	38	38	23	35	25	54	82
130274*	164/129	181/134	165/126	96	170/30	197	229	204
230474	47	43	67	34	52	17	139	57
220874*	27/32	49/22	49/20	12	42/25	4	34	-
141174[c]	43	46	43	-	44	-	-	-
121274	18	16	23	-	19	-	32	-

*Midnight/Midday; [c]Midnight

4.2 BENTHIC INVERTEBRATES AND FISH STUDIES

by

Paul Yoshioka

4.2.1 INTRODUCTION

This report gives the results of benthic and fish studies conducted at the Cabo Mala Pascua site from February 1973 through August 1974.

Most of the investigative effort involved mapping and describing major benthic communities. Quantitative samples were also taken in an attempt to assess the biological structure of selected communities, as well as to provide quantitative base line information.

The qualitative and quantitative descriptions of communities are important aspects of community studies. However, these aspects represent only preliminary levels of community investigations and are often insufficient to satisfy the demands of contemporary environmental concerns. It is often necessary to ascertain the direct effect of a perturbation on populations of specific species and also its secondary and tertiary ecological effects upon the entire community.

The role of such secondary or tertiary ecological effects should not be underestimated. Several studies have demonstrated that the structure and diversity of many natural communities are determined by ecological interactions (Dayton 1971; Paine 1966; Paine and Vadas 1969; Kitching and Ebling 1961; Huffaker 1959; Harper 1969). In such cases predictions based solely upon the direct effects of any physicochemical perturbation on single species populations would be inadequate and misleading if extrapolated to the community level.

What, then, is required to predict the effect on an environmental pollutant on a community? Of utmost importance is an insight into those factors responsible for the ecological organization of communities. Descriptive or structural aspects of communities, no matter how accurate or precise, provide only a static, steady state outlook upon a community. Species lists provide little insight into the interactions of their component species populations. Diversity indices, which are derived from the biological structure of communities, are highly speculative in their origin and their ecological implications remain a point of controversy (Hedgpeth 1973, Fager 1972).

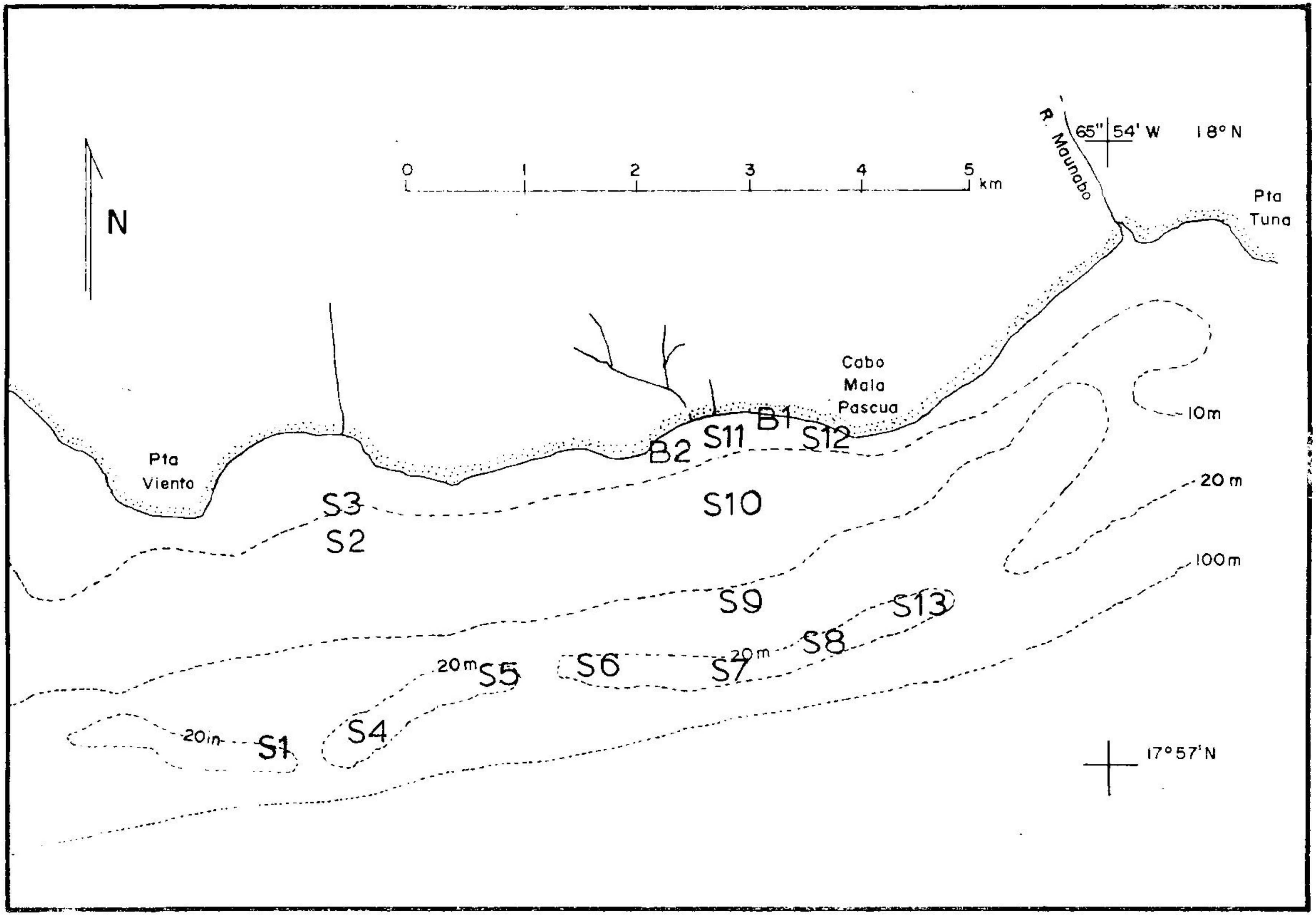


Fig. 4.2-F1 Benthic studies field stations at the Cabo Mala Pascua site.

What is needed is an awareness of the dynamic processes responsible for the control and regulation of a given community. This, in turn, entails a knowledge of the functional roles of various species comprising the natural community.

With these considerations in mind, and after mapping the area, a series of preliminary field experiments was begun in May 1974 to ascertain the functional roles of the species in selected communities.

The gorgonian communities were selected as the major object of investigation during the latter phases of this study. The gorgonians represent a dominant feature of the benthic communities at the Cabo Mala Pascua site. The growth form of gorgonians adds a considerable amount of physical structure and heterogeneity to the benthic environment. Such physical structure greatly influences the remainder of the biological community (Elton 1966). Gorgonians may be useful indicators of environmental parameters such as wave action, currents, and turbidity, also. (Grigg 1972; Opresko 1973; Goldberg 1973; Kinzie 1973).

4.2.2 MATERIALS AND METHODS

Field Procedures

Field stations are shown in Figure 4.2-F1 and Appendix 4.2A. Field procedures were divided into three categories: shore surveys, shore fish collections, and station dives.

Shore surveys. Shore surveys were descriptive in nature. The larger, more familiar organisms were identified in the field. Specimens of smaller or unfamiliar organisms were collected and identified in the laboratory.

Shore fish collections. Both seining and rotenone were used to collect shoreline fish. Seining was done in a shallow Thalassia bed and the rotenone was used in a rocky beach environment.

Station dives. Station dives were made at the various stations to collect quantitative samples and to observe the presence of macroinvertebrates and fish. Gorgonians were collected in 5 m^2 (1 x 5 m) or 10 m^2 (2 x 5 m) quadrats depending upon the diversity of gorgonians and limitations of diving bottom time. Gorgonian samples were taken in April, August, and December 1974. Two replicate samples were usually taken.

The quadrats cleared of gorgonians in April were observed thereafter to assess the effect of established colonies on recruitment of new colonies.

Quantitative samples of infaunal and smaller epibenthic organisms were taken from 1/4 m^2 quadrats. These samples were placed in a plastic bag held as close to the sampling site as possible to minimize the loss of organisms. Substrate was removed with the aid of a hammer and chisel. Vicente (1974) provides further description of the sampling method.

Laboratory Procedures

Gorgonian samples were dried for several weeks, then weighed, measured and identified. The more familiar species were identified on the basis of external characteristics. Questionable individuals were identified with the aid of spicule preparations.

Other samples were sorted into phylogenetic groups and preserved in 70% ethyl alcohol or 10% formalin for later identification. Taxonomic references used to identify organisms are listed in the bibliography.

4.2.3 RESULTS

Both rocky shore and sandy beach habitats are found at the Cabo Mala Pascua site. At the shoremost subtidal stations the bottom consists of rock boulders, ledges, and sandy areas (Stations S11 and S12). At distances of about 500-1500 meters offshore sand dominates the bottom substrate (Stations 3, S2, S9, S10) although boulders were encountered in the vicinity of Station CS10. The most abundant encrusting organisms appear to be the zoanthid *Palythoa*. Gorgonian, coral, sponge, and fish species observed at Station 12 are listed in Appendix 4.2C. In general, the diversity (in the number of species) was less at the inshore stations than at hard-bottomed stations further offshore. For example, four genera of gorgonians were observed at Station S12 versus nine at Station S8. Shoreline fishes collected at the Cabo Mala Pascua site by rotenone and seining are listed in Appendix 4.2B. Organisms at shore stations S1 and S2 are listed in Appendix 4.2D.

Several plant species were observed growing on the sandy substrate at Stations S2 and S3. Among these were *Caulerpa*, *Udotea*, *Halophila*, and *Halimeda* (see Appendix 4.2C). The dominant plant at Station S9 was *Halophila*.

The boulders at Station S10 harbored many organisms typically associated with hard substrates, including Montastrea cavernosa and other hard corals, and several sponges Callyspongia vaginalis, Haliclona rubens, Verongia longissima, and Ircinia strobilina.

The reefs, occurring about 2.5 kilometers offshore, offer the most visually impressive benthic communities (Stations S1, S5, S4, S6, S7, S8, S13). The rocky substrate contains relatively little topographic relief. No large outcrops, ledges, or depressions were encountered. The major features of the benthic fauna appeared similar in all offshore reef areas. A list of the larger organisms observed at Station S8 is found in Appendix 4.2C. Although the larger algae are conspicuously scarce, in general the richest diversity of larger benthic and fish life was observed at these offshore reef stations. For instance, three species of fish were observed at (inshore) Station S12 and 30 species at (offshore reef) Station 8.

Quantitative Samples

The epifaunal and infaunal organisms collected in two 1/4 m^2 substrate samples at Stations S1 and S7 are listed in Appendix 4.2E. The distribution of individuals among species shows the same characteristics found in 1/4 m^2 quadrat samples collected from other sites. In particular, there is an equitable distribution of individuals among species. Eighty-two individuals were divided among 38 species at Station S1 (excluding algae) and 66 individuals among 30 species at Station S7. The species were represented by 66 and 67% single individuals, respectively. Of a total of 58 species, only 12 occurred in both samples. The lack of similarity between the samples in terms of species co-occurrences probably cannot be attributed to differences between the stations because samples taken within a few meters of each other at other sites have also shown a similar amount of disparity.

Gorgonian colonies were collected on 22 April 1974 from two 5 m^2 quadrats at Station S8. Overall colony density was 10.4 and 17.8 colonies per m^2 in the two subsamples. The three most abundant species in decreasing order of abundance were Plexaura homomalla, Eunicea clavigera and Plexaura flexuosa. These species comprised about 57% of the total number of colonies. The relative abundances showed a significant correlation (Kendall-Tau = +0.71, $p<0.01$) indicating that the relative abundances of the gorgonian community was adequately sampled.

On 22 August 1974 25 colonies were removed from the previously cleared areas. Only 13 colonies of an equivalent size range were collected on 22 April 1974. This indicates that the presence of old colonies inhibits the recruitment of new colonies.

4.2.4 DISCUSSION

The intertidal biota observed at the Cabo Mala Pascua site are typical of this environment along the southeast coast of Puerto Rico (Glynn 1964).

The infaunal populations possess a high species diversity and an equitable distribution of individuals among species. This feature has been found to be common to all substrate samples taken at the Tortuguero Bay, Punta Manati and Punta Verraco sites. Due to high sampling variability, other features of the structure of this community could not be deduced.

The greatest abundance of fish life was observed at the Cabo Mala Pascua site in rocky areas with moderately high topographic relief. This feature is common to several sites around the island and is probably related to the shelter provided in such areas (Smith 1973). Only 13% (4/30) of the fish species identified at the permanent stations were observed during all three visits to that site. This indicates that only a small portion of the fish fauna are observed during any single dive.

Clearing experiments show that gorgonians play a role in the control and regulation of the benthic community at the Cabo Mala Pascua study site. The increase of recruitment rates of gorgonian colonies following the removal of all colonies indicates that the presence of established colonies limits the recruitment of other colonies. The mechanism by which this occurs is unknown. It is impossible to predict the effect of an environmental perturbation such as thermal pollution on this community at this time. However, it is not unlikely that the ultimate effects of thermal pollution will be manifested through its effect on the biological processes responsible for the control and regulation of this community.

4.3 PLANT ASSOCIATIONS

by

M.J. Canoy

4.3.1 INTRODUCTION

The general aspect of Cabo Mala Pascua is one of an advanced tertiary successional forest. It has a deceptive form in that the difference between wet and dry seasons is so pronounced. During the dry season the leaf area index (LAI) is between 1 and 2 or as high as 3 on the ridges and northwest slopes of the hills. During wet seasons the LAI changes to 3-6 and the _apparent_ dominant species shifts as trees and shrubs that stood bare previously begin to leaf out. The change seems to be from a xerophytic to a mesophytic forest in two weeks time.

The trees and shrubs found on the study site range from _Bucida buceras_ to _Trichilia hirta_ and the vines are predominantly _Acacia riperia_, _Banisteria purpurea_, and _Stigmaphyllon lingulatum_. No grasses or forbs were observed on the site, during either the wet or dry seasons. (See Appendix 4.3A)

4.3.2 MATERIALS AND METHODS

The study site was walked twice, once during the winter months (dry season) and again during the summer-fall months (wet season).

4.3.3 SUMMARY

Three relevant points should be remembered.

(A) The forest is novel for Puerto Rico.

(B) As a tropical successional highly seasonal forest, it is likely to be easily disturbed.

(C) If the large highway now being planned for the area is built, in view of points (A) and (B), there may be nothing left to protect.

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APPENDIX 2.1A

Tabulated Averaged Hydrographic Data

AVERAGE DATA FOR 023357 THROUGH 039679 **CABO MALA PASO UA - 1**

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS.	NITROGEN
0	25.926	35.697	23.417	4.838	0.045	0.376
10	25.889	35.693	23.422	4.870	0.036	0.261
20	25.827	35.727	23.446	4.878	0.039	0.242
30	25.752	35.747	23.692	4.882	0.041	0.239
50	25.631	35.759	23.[illegible]76	4.892	0.053	0.298
75	25.383	35.829	24.254	4.799	0.051	0.263
100	24.985	35.73[illegible]	24.456	4.737	0.046	0.228
150	22.865	37.[illegible]22	25.544	4.477	[illegible]	0.098
200	20.791	34.[illegible]43	25.829	4.173	0.166	1.097
250	19.737	34.664	25.361	4.222	0.269	2.[illegible]
300	17.397	36.474	26.564	4.365	0.327	2.001

AVERAGE DATA FOR 02[illegible] THROUGH 042733 **CABO MALA PASO UA - 2**

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	27.138	35.720	23.741	4.785	0.049	0.082
10	27.106	35.73[illegible]	23.231	4.782	0.048	0.080
20	27.015	35.729	23.279	4.796	0.044	0.[illegible]
30	26.930	35.743	23.317	4.789	0.047	0.08[illegible]
50	26.519	35.[illegible]45	23.528	4.754	0.056	0.08[illegible]
75	25.094	36.197	24.252	4.471	[illegible]	[illegible]
100	24.753	36.605	24.648	4.554	[illegible]	0.[illegible]
150	22.845	36.[illegible]	2[illegible].426	4.265	0.[illegible]	[illegible]
200	20.239	34.[illegible]57	2[illegible].[illegible]57	4.114	0.122	0.[illegible]
250	19.294	[illegible]	2[illegible].394	4.211	.223	3.[illegible]
300	17.466	34.[illegible]	2[illegible].317	4.365	0.317	[illegible]

AVERAGE [illegible] THROUGH [illegible]

CABO MALA PASCUA - 3

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	27,175	[illegible]	22,763	4,711	0,036	0,039
10	28,188	35,533	22,758	4,712	0,036	0,114
20	28,130	35,530	22,775	4,754	0,036	0,141
30	27,934	35,6[illegible]	22,893	4,796	0,032	0,144
50	[illegible]	35,[illegible]	23,557	4,997	0,029	0,017
75	[illegible],434	[illegible],414	24,296	4,972	0,038	0,027
100	[illegible]	[illegible]	24,964	4,924	0,052	0,059
150	[illegible],772	[illegible]	[illegible]	4,731	0,067	0,165
200	[illegible],373	[illegible]	[illegible]	[illegible]	0,111	0,526
250	[illegible],347	[illegible]	[illegible]	4,365	0,161	1,515
300	[illegible],047	35,443	26,494	[illegible]	0,288	2,120

AVERAGE DATA FOR 282990 THROUGH [illegible]52990

CABO MALA PASCUA - 4

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	28,965	[illegible],459	21,597	4,853	0,054	0,195
10	27,043	[illegible]	21,941	4,751	0,055	0,046
20	27,107	[illegible]	[illegible]	4,696	0,036	0,259
30	27,131	35,205	22,599	4,701	0,036	0,042
50	26,493	[illegible]	[illegible],954	4,907	0,032	0,011
75	25,128	[illegible]	24,653	4,874	0,031	0,081
100	23,538	[illegible]	[illegible]	[illegible]	0,038	0,235
150	21,724	[illegible]	[illegible]	4,522	0,026	[illegible]
200	[illegible],712	[illegible]	26,199	4,367	0,113	0,994
250	17,973	[illegible]	[illegible]	[illegible]	0,213	[illegible]
300	17,076	[illegible]	26,576	[illegible]	0,299	3,958

AVERAGE DATA FOR 023330 THROUGH 039684 CABO MALA PASCUA-1A

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	25,888	35,681	23,601	4,782	0,044	0,152
10	25,885	35,682	23,603	4,879	0,024	0,201

AVERAGE DATA FOR 023321 THROUGH 039692 CABO MALA PASCUA-1B

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	25,895	35,712	23,623	4,827	0,038	0,367
10	25,842	35,713	23,640	4,847	0,037	0,283
20	25,787	35,714	23,657	4,868	0,036	0,176
30	25,746	35,765	23,709	4,873	0,039	0,107
50	25,691	36,232	23,928	4,847	0,056	0,096
75	25,438	36,310	24,216	4,803	0,050	0,136
100	25,044	36,615	24,567	4,762	0,043	0,184

AVERAGE DATA FOR 023331 THROUGH 039679 CABO MALA PASCUA-1C

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	25,936	35,696	23,597	4,857	0,052	0,290
10	25,881	35,698	23,616	4,863	0,048	0,300
20	25,826	35,701	23,635	4,871	0,043	0,309
30	25,779	35,728	23,671	4,869	0,043	0,352
50	25,671	35,886	23,824	4,839	0,052	0,500
75	25,329	36,367	24,293	4,781	0,051	0,389
100	24,766	36,844	24,825	4,701	0,050	0,231
150	22,865	37,022	25,524	4,477	0,064	0,690
200	20,791	36,693	26,029	4,173	0,106	1,695
250	18,727	36,664	26,384	4,222	0,209	2,282
300	17,397	36,471	26,564	4,365	0,327	2,991

AVERAGE DATA FOR 029493 THROUGH 042735 CABO MALA PASCUA -2A

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	27,258	35,721	23,195	4,738	0,059	0,000
10	27,238	35,729	23,208	4,741	0,059	0,000

AVERAGE DATA FOR 029502 THROUGH 042734 CABO MALA PASCUA -2B

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	27,070	35,725	23,258	4,795	0,051	0,000
10	27,055	35,725	23,263	4,793	0,050	0,000
20	27,040	35,726	23,268	4,790	0,049	0,000
30	26,929	35,751	23,323	4,783	0,052	0,000
50	26,348	35,902	23,625	4,746	0,059	0,000
75	25,485	36,251	24,157	4,659	0,067	0,000
100	24,575	36,680	24,759	4,532	0,074	0,000

AVERAGE DATA FOR 029503 THROUGH 042733 CABO MALA PASCUA - 2C

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	27,061	35,739	23,271	4,822	0,034	0,000
10	27,024	35,736	23,281	4,812	0,036	0,000
20	26,989	35,733	23,290	4,802	0,039	0,000
30	26,931	35,735	23,311	4,794	0,042	0,000
50	26,682	35,788	23,432	4,763	0,053	0,000
75	25,902	36,144	23,946	4,683	0,058	0,000
100	24,931	36,529	24,537	4,575	0,055	0,000
150	22,845	36,658	25,406	4,285	0,060	0,000
200	20,259	36,767	26,057	4,114	0,122	0,000
250	18,290	36,538	26,394	4,211	0,228	0,000
300	17,406	36,413	26,517	4,365	0,317	0,000

AVERAGE DATA FOR 046850 THROUGH 046854 CABO MALA PASCUA - 3A

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	28,286	35,549	22,734	4,621	0,024	0,066
10	28,314	35,548	22,724	4,620	0,030	0,182

AVERAGE DATA FOR 046849 THROUGH 046845 CABO MALA PASCUA - 3B

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	28,110	35,534	22,781	4,760	0,034	0,050
10	28,117	35,535	22,779	4,754	0,032	0,130
20	28,124	35,536	22,778	4,749	0,031	0,219
30	27,935	35,615	22,899	4,785	0,030	0,221
50	26,760	36,052	23,607	4,961	0,032	0,035
75	25,220	36,473	24,406	4,922	0,035	0,055
100	23,549	36,831	25,180	4,847	0,042	0,074

AVERAGE DATA FOR 046840 THROUGH 046844 CABO MALA PASCUA -3C

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	28,130	35,534	22,774	4,750	0,030	0,000
10	28,132	35,531	22,771	4,754	0,045	0,030
20	28,135	35,528	22,768	4,758	0,040	0,064
30	27,925	35,592	22,886	4,807	0,035	0,066
50	26,761	35,919	23,507	5,019	0,026	0,000
75	25,649	36,356	24,186	5,021	0,041	0,000
100	24,667	36,701	24,748	4,961	0,062	0,003
150	22,702	36,801	25,403	4,731	0,067	0,166
200	20,375	36,745	26,029	4,399	0,111	0,526
250	18,847	36,607	26,306	4,365	0,161	1,515
300	17.647	36,443	26,494	4,490	0,288	2,120

AVERAGE DATA FOR 052998 THROUGH 052002 CABO MALA PASCUA - 4A

DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	26,882	32,910	21,206	4,804	0,084	0,428
10	26,958	33,421	21,566	4,702	0,090	0,000

AVERAGE DATA FOR 052995 THROUGH 052991 CABO MALA PASCUA - 4B

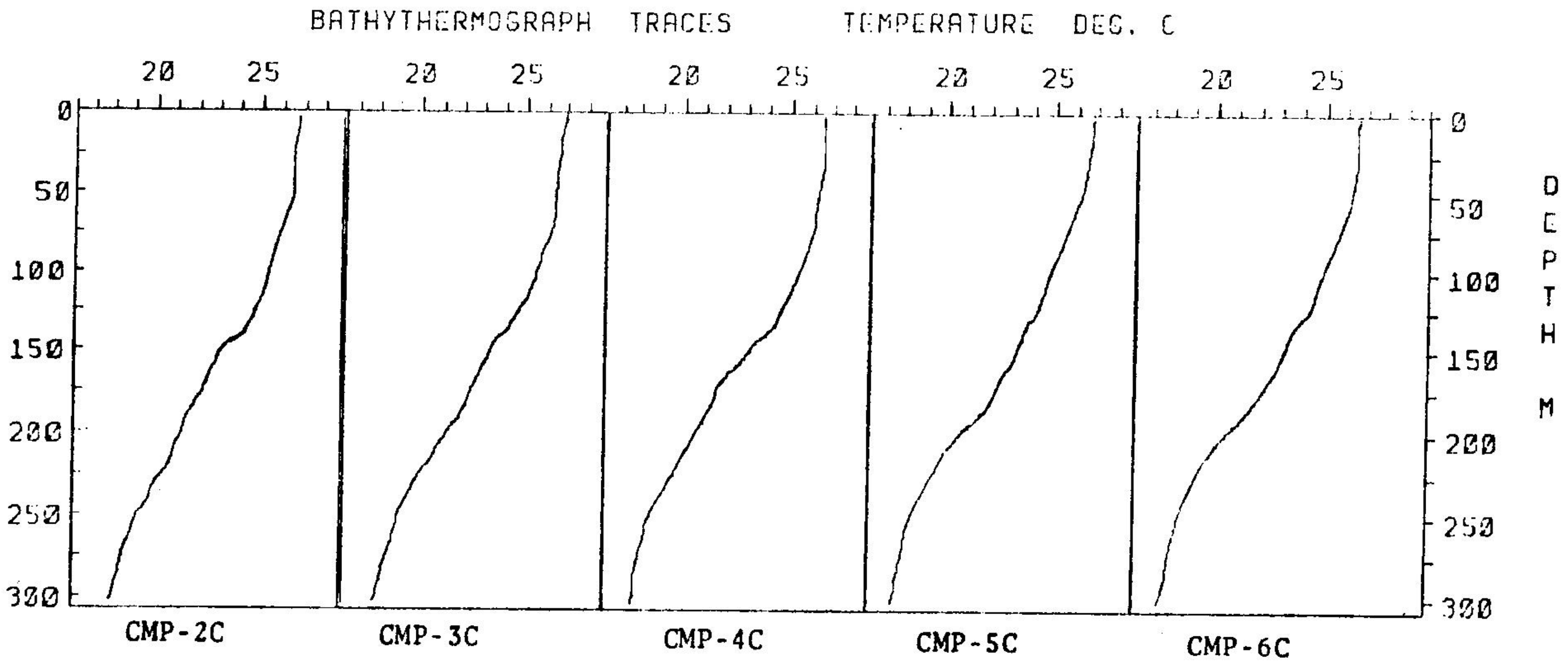
DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	26,990	33,738	21,794	4,835	0,050	0,138
10	27,035	34,252	22,165	4,769	0,044	0,112
20	27,079	34,762	22,534	4,697	0,039	0,087
30	27,013	35,341	22,991	4,711	0,033	0,055
50	26,338	36,495	24,075	4,939	0,026	0,002
75	25,074	36,720	24,638	4,888	0,028	0,069
100	23,513	36,884	25,231	4,818	0,048	0,274

AVERAGE DATA FOR 052996 THROUGH 052990 CABO MALA PASCUA - 4C

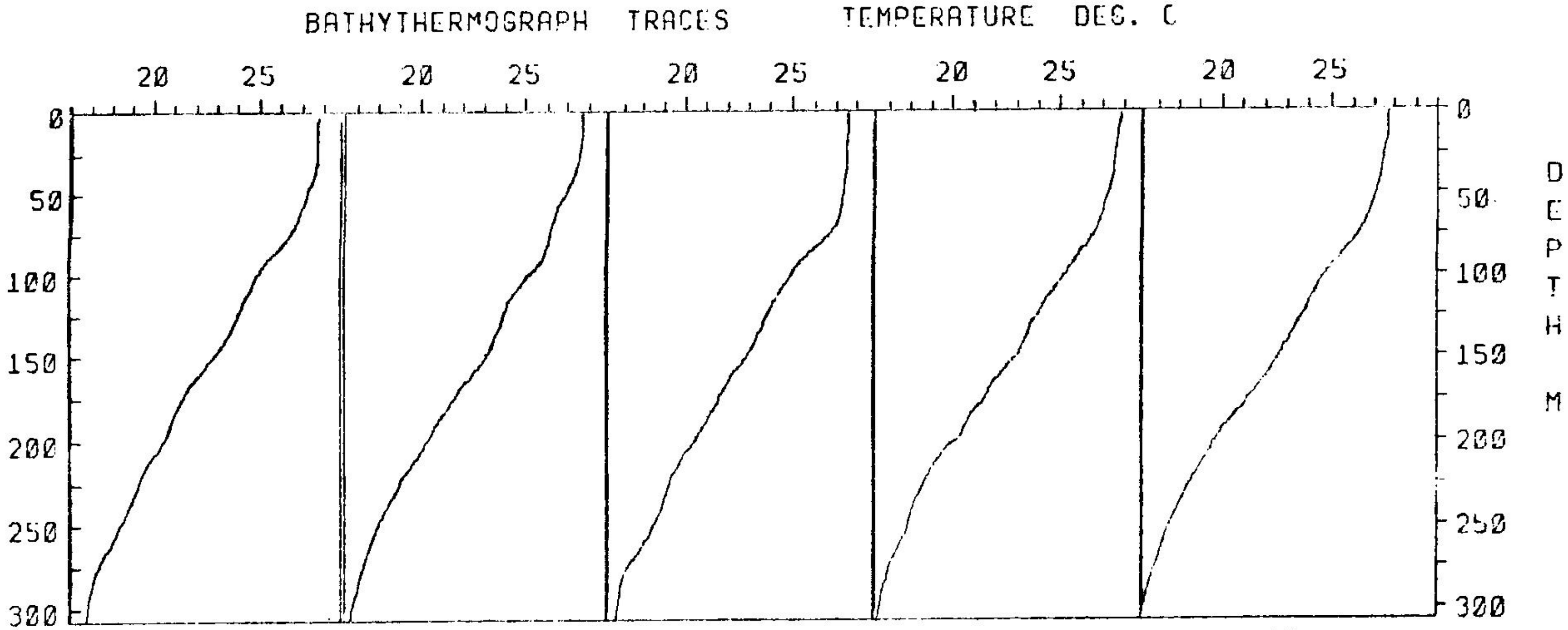
DEPTH	TEMPERATURE	SALINITY	SIGMA T	OXYGEN	PHOS	NITROGEN
0	27,022	33,729	21,777	4,862	0,028	0,020
10	27,136	34,195	22,097	4,782	0,032	0,025
20	27,255	34,655	22,398	4,696	0,036	0,030
30	27,249	35,196	22,806	4,691	0,039	0,030
50	26,648	36,318	23,843	4,876	0,038	0,020
75	25,166	36,797	24,667	4,859	0,034	0,094
100	23,564	36,922	25,245	4,795	0,028	0,196
150	21,724	36,883	25,744	4,522	0,056	0,337
200	19,719	36,765	26,199	4,363	0,113	0,994
250	17,973	36,503	26,446	4,516	0,213	2,062
300	17,076	36,386	26,576	4,633	0,299	3,958

APPENDIX 2.1B

BATHYTHERMOGRAPHY TRACES



Cruise No. PA023
Feb. 22, 1973



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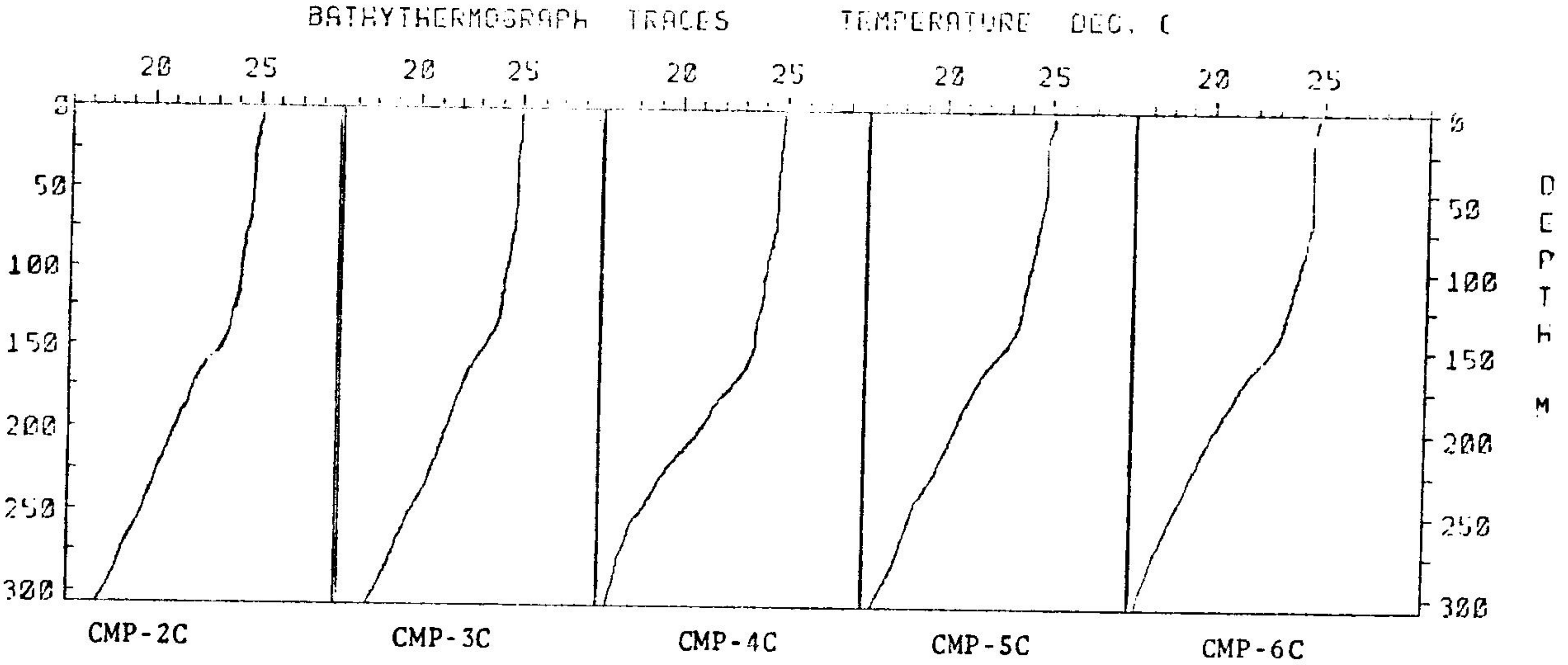
Cruise No. PA0 29
May 23, 1973



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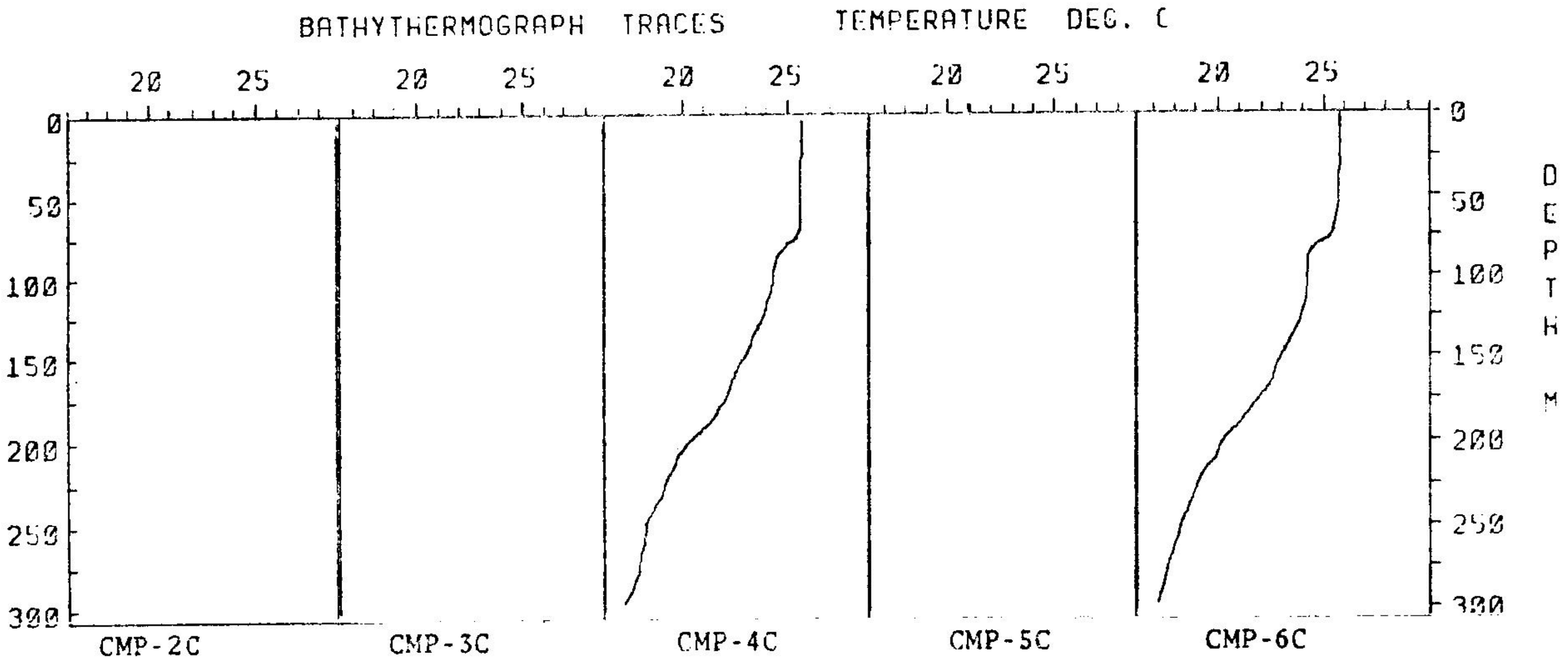
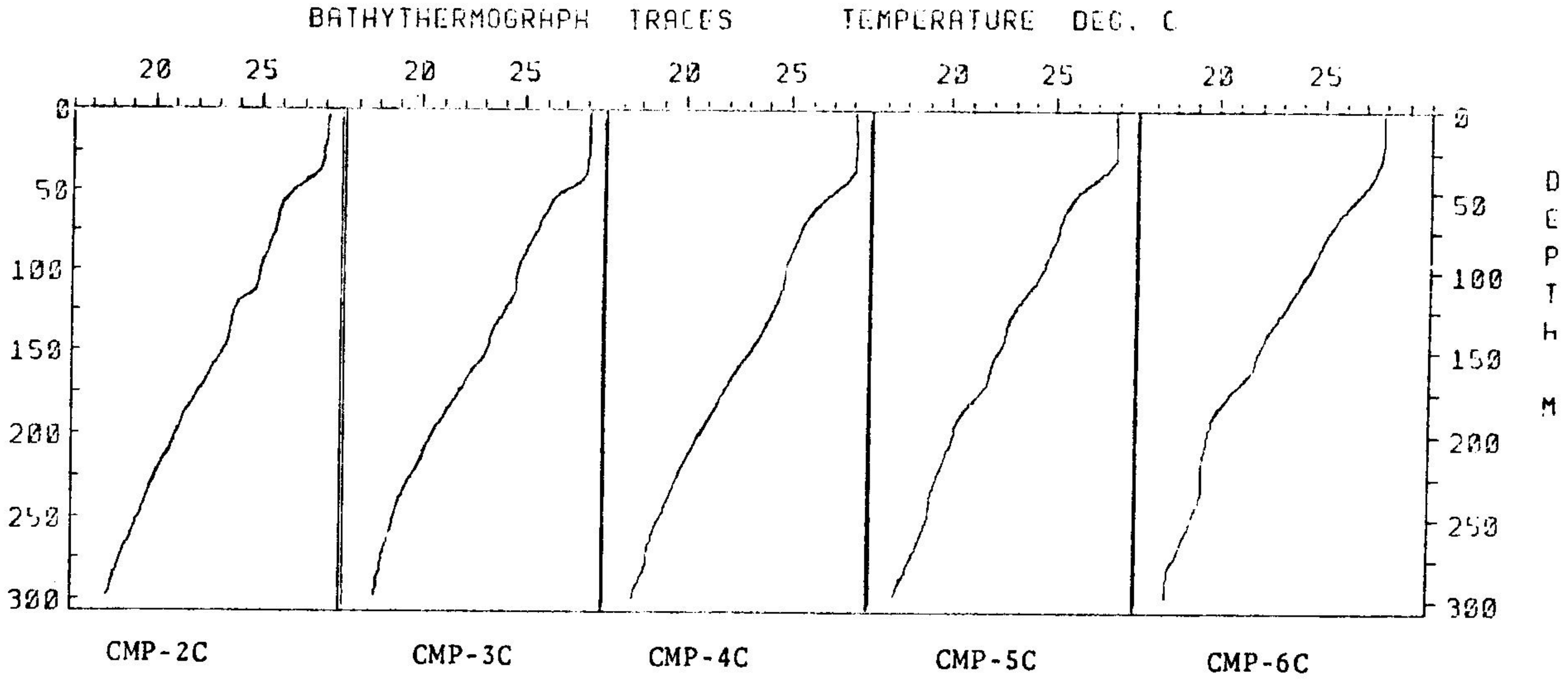
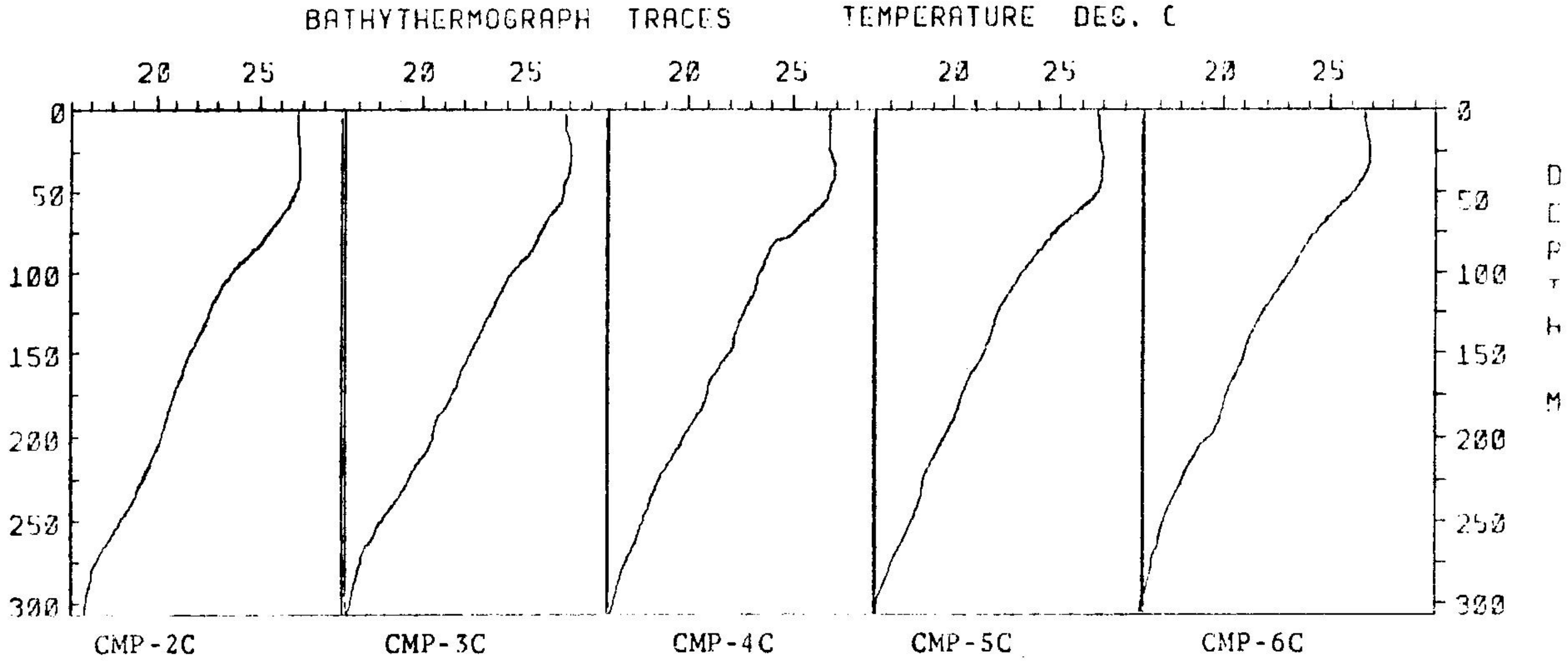


Cruise No. 042
Apr. 23, 1974



Cruise No. PA046
Aug. 21, 1974



Cruise No. PA052
Nov. 14, 1974

APPENDIX 4.2A

Dates of Dives and Locations of Benthic Stations at Cabo Mala Pascua

Station B1
Location: Shore station about one mile west of Cabo Mala Pascua
Date: 22 March 1973
Investigator: S. Martin

Station B2
Location: Shore station about two miles west of Cabo Mala Pascua
Date: 22 March 1973
Investigator: S. Martin

Station S1
Location: Reef station about 1.5 miles offshore at Punta Viento
Date: 22 February 1973
Depth: 16 m
Investigator: S. Martin

Station S2
Location: Sand station about 0.75 miles southeast of Punta Viento
Date: 22 August 1974
Depth: 14 - 15 m
Investigator: P. Yoshioka

Station S3
Location: Sand station inshore of S2
Date: 22 February 1973
Depth: 10 m
Investigator: S. Martin

Station S4
Location: Reef station about 0.5 miles east of S1
Date: 23 May 1973
Depth: 14 - 18 m
Investigator: V. Vicente

Station S5
Location: Reef station about 1.0 miles east of S1
Date: 22 February 1974
Depth: 15 m
Investigator: P. Yoshioka

APPENDIX 4.2A (continued)

Station S6
Location: Reef station about 2.0 miles east of S1, 1.0 miles offshore
Date: 23 May 1973
Depth: 12 to 18 m
Investigator: V. Vicente

Station S7
Location: Reef station about 0.5 miles east of S6
Date: 22 February 1973
Depth: 14 m
Investigator: V. Vicente

Station S8
Location: Reef station about 0.5 miles east of S7
Dates: 21 February 1974, 21 May 1974, 22 August 1974, 12 December 1974 (Permanent station)
Depth: 19 m
Investigator: P. Yoshioka

Station S9
Location: Sand station about 0.3 miles inshore of S7
Date: 22 February 1973
Depth: 23 m
Investigator: S. Martin

Station S10
Location: Sand boulder station about 0.7 miles inshore of S7
Date: 22 February 1973
Depth: 15 m
Investigator: S. Martin

Station S11
Location: Inshore station
Date: 22 February 1973
Depth: 0 - 5 m
Investigator: S. Martin

Station S12
Location: Inshore station near S11
Date: 22 August 1974
Depth: 0 - 5 m
Investigator: S. Martin

Station S13
Location: Reef station about 1.5 miles east of S7
Date: 22 May 1974
Depth: 14 - 18 m
Investigator: V. Vicente

APPENDIX 4.2B

Shoreline fishes of the Cabo Mala Pascua site

FAMILY	27 Feb 73 Seine	27 Feb 73 Rotenone
Muraenidae		
Echidna catenata		12
Ophichthidae		
Myrichthys acuminatus	1	1
Gobusocidae		
Arcos macrophthalmus		1
Arcos rubringenosus		35
Tomicodon fasciatus		1
Arcos artius		2
Scorpaenidae		
Scorpaena plumieri	1	
Gerreidae		
Eucinostomus melanopterus	1	
Pomacentridae		
Abudefduf taurus		6
Abudefduf saxatilis		19
Mugilidae		
Mugil liza	2	
Labridae		
Doratonotus megalepis	1	1
Halichoeres maculipinna		1
Scaridae		
Sparisoma rubripinne		2
Blenniidae		
Entomacrodus nigricans		10
Clinidae		
Emblemariopsis leptocirris		1
Labrisomus guppyi		7
Labrisomus haitiensis		1
Labrisomus nuchipinnis	1	
Gobiidae		
Awaous tajasica	11	
Bathygobius soporator		8
Gingsburgellus novemlineatus		1
Gnatholipis thompsoni	7	
Gonionellus boleosoma	1	
Balistidae		
Aluterus schoepfi	1	

APPENDIX 4.2C

Macroinvertebrates, algae and fish observed at selected stations at Cabo Mala Pascua

	S2 22 Aug 74	S12 22 Aug 74	S8 22 Aug 74
PLANT KINGDOM			
Phylum Rhodophyta			
Gracileria sp.	X		
Phylum Chlorophyta			
Caulerpa mexicana	X		
Halimeda sp.	X		
Penicillus capitatus	X		
Udotea conglutina	X		
Udotea flabellum	X		
Udotea spinulosa	X		
Phylum Spermatophyta			
Halophila baillonis	X		
ANIMAL KINGDOM			
Phylum Porifera			
Agelas			X
Anthosigmella varians		X	X
Callyspongia vaginalis			X
Chondrilla nucula		X	X
Cinachyra cavernosa		X	
Gelliodes sp.		X	X
Haliclona rubens		X	X
Ircinia sp.		X	X
Iotrochota birotulata		X	
Mycale angulosa			X
Mycale sp.		X	
Neofibularia massa			X
Oligoceros hemorrhages			X
Verongia lacunosa		X	X
Verongia longissima			X
Verongia sp.		X	X
Xestospongia muta		X	X

APPENDIX 4.2C (continued)

	S2	S12	S8
	22 Aug 74	22 Aug 74	22 Aug 74
Phylum Cnidaria			
Class Anthozoa			
Subclass Octocorallia			
Briareum asbestinum			X
Erythropodium sp.			X
Eunicea laxispica			X
Eunicea sp.		X	X
Gorgonia sp.		X	X
Muricea sp.			X
Muriceopsis sp.		X	
Plexaura flexuosa			X
Plexaura homomalla			X
Pseudoplexaura sp.			X
Pseudopterogorgia sp.			X
Pterogorgia sp.		X	X
Subclass Zoantharia			
Acropora cervicornis		X	X
Acropora palmata		X	
Agaricia sp.			X
Colpophyllia sp.			X
Dichocoenia stokesii			X
Diploria labyrinthiformis			X
Diploria sp.		X	X
Eusmilia fastigiata			X
Isophyllia maltiflora			X
Meandrina sp.			X
Millepora sp.		X	X
Montastrea cavernosa		X	X
Palythoa sp.		X	
Porites astreoides		X	X
Siderastrea radians		X	
Siderastrea siderea			X
Stephanocoenia			X
Phylum Chordata			
Subphylum Vertebrata			
Class Pisces			
Family Dasyatidae			
Unid. Dasyatid	X		

APPENDIX 4.2C (continued)

	S2	S12		S8	
	8/22	8/22	2/13	8/22	12/12
Phylum Chordata					
Family Muraenidae					
Gymnothorax moringa				X	
Family Holocentridae					
Holocentrus sp.			X	X	
Myripristis jacobus			X		X
Family Aulostomidae					
Aulostomus maculatus			X		
Family Sphyraenidae					
Sphyraena barracuda			X		
Family Serranidae					
Cephalopholis fulva				X	X
Unid. serranid			X		
Family Grammistidae					
Rypticus sp.			X		
Family Echeneidae					
Echeneis naucrates				X	
Family Carangidae					
Caranx crysos	X				
Decapterus sp.				X	
Family Lutjanidae					
Lutjanus sp.			X		
Family Pomadasyidae					
Haemulon flavolineatum			X		
Family Sciaenidae					
Equetus sp.			X		
Family Sparidae					
Calamus bajonado			X	X	
Family Mullidae					
Pseudupeneus maculatus				X	

APPENDIX 4.2C (continued)

	S2	S12		S8	
	8/22	8/22	2/13	8/22	12/12
Phylum Chordata (cont.)					
Family Chaetodontidae					
Pomacanthus para			X	X	
Holocanthus tricolor			X	X	
Chaetodon capistratus					X
Prognathodes aculeatus					X
Family Pomacentridae					
Chromis cyaneus			X	X	X
Chromis multilineatus				X	X
Pomacentrus partitus		X	X	X	X
Pomacentrus sp.		X	X		
Family Labridae					
Bodianus rufus			X		X
Thalassoma bifasciatum			X	X	X
Halichoeres sp.			X		X
Unid. labrid	X				
Family Scaridae					
Sparisoma sp.			X		
Unid. scarid		X		X	
Family Acanthuridae					
Acanthurus sp.				X	X
Family Balistidae					
Balistes sp.			X	X	
Balistes vetula					X

APPENDIX 4.2D

Cabo Mala Pascua shore collections

	Station B1 22 March 1973	Station B2 22 March 1973
PLANT KINGDOM		
Phylum Chlorophyta		
Caulerpa racemosa	X	
Chamaedoris peniculum	X	
Enteromorpha sp.	X	
Halimeda opuntia	X	
Penicillus capitatus		X
Penicillus dumetosus	X	
Udotea flabellum	X	
Ulva lactuca	X	
Phylum Phaeophyta		
Dictyota ciliolata	X	
Dictyota dentata	X	
Dictyota sp.	X	
Padina sp.	X	X
Sargassum hystrix	X	
Sargassum polyceratium	X	
Phylum Rhodophyta		
Bryothamnion triquetrum	X	
Ceramium sp.	X	
Galaxaura sp.	X	X
Jania adherens	X	
Jania capillacea	X	
Laurencia papillosa	X	
Polysiphonia sp.	X	
Phylum Spermatophyta		
Syringodium filiforme	X	
Syringodium sp.		X
Thalassia testudinum	X	X
ANIMAL KINGDOM		
Phylum Mollusca		
Class Gastropoda		
Acmaea antillarum	X	
Astraea tuber	X	X
Bulla striata	X	

APPENDIX 4.2D (continued)

	Station B1 22 March 1973	Station B2 22 March 1973
Phylum Mollusca (continued)		
Class Gastropoda		
Cerithium veriabile		X
Columbella mercatoria		X
Diodora viridula	X	
Fissurella barbadensis	X	
Fissurella sp.	X	
Hemitoma octoradiata	X	
Hipponix antiquatus	X	
Littorina ziczac	X	
Nerita tessellata	X	
Nitidella laevigata	X	
Tegula excavata	X	
Class Pelecypoda		
Barbatia domingensis	X	
Codakia orbicularis	X	
Phylum Arthropoda		
Order Decapoda		
Suborder Brachyura		
Callinectes danae		X
Microphrys antillensis	X	X
Phylum Echinodermata		
Class Echinoidea		
Tripneustes esculentus	X	X

APPENDIX 4.2E

Species and individuals per species collected in 1/4 m^2 quadrat at Cabo Mala Pascua

	S7 2/22/73	S[illegible] 2/22/73
PLANT KINGDOM		
Phylum Phaeophyta		
Dictyota sp.	X	
Phylum Rhodophyta		
Amphiroa sp.	X	
ANIMAL KINGDOM		
Phylum Sipunculida	24	20
Phylum Annelida		
Class Polychoeta		
Arabella opalina	1	
Eunice fucata	2	1
Eunice sp.	1	1
Hermenia verruculosa	1	
Laetmonice kinbergii		3
Lepidonotus sp.	2	1
Lumbrinereis sp.		2
Lysidice sulcata	3	3
Marphysa regalis	6	
Marphysa sp.		3
Nereis sp.		1
Nicidion kingergii		5
Nicidion sp.	2	
Phyllodoce papillosa	1	1
Family Sabellidae	1	1
Family Serpulidae	3	
Syllis sp.	1	1
Terebella sp.	2	
Family Terebellidae		2
Unid. polychaete	1	2

APPENDIX 4.2E

	S7 2/22/73	S1 2/22/73
Phylum Mollusca		
Class Gastropoda		
Columbella mercatoria		1
Lucapina sowerbii		1
Class Pelecypoda		
Barbatia domingensis	2	3
Chama sarda		1
Coralliophaga coralliophaga		1
Lioberus castaneus	1	
Lithophaga bisulcata	1	
Lithophaga nigra		1
Unid. pelecypod		1
Phylum Arthropoda		
Order Stomatopoda		
Unid. stomatopoda	1	
Order Isopoda		
Cirolana parva	1	
Spaeroma walkeri		3
Unid. isopod	1	
Order Decapoda		
Suborder Natantia		
Family Alphaeida		
Unid. alphaeid	2	
Alpheus amblyonyx	1	
Pontonia mexicana		1
Synalpheus mcclendoni	1	
Synalpheus rathbunae	1	
Suborder Brachyura		
Mithrax pleuracanthus		1
Phylum Echinodermata		
Class Echinoidea		
Eucidarus tribuloides	1	
Class Asteroidea		
Asterinides sp.	1	
Class Ophiuroidea		
Unid ophiuroid	2	

APPENDIX 4.2E (continued)

	S7 2/22/73	S8 2/22/73
Family Amphiuridae		
Unid. amphiurid	1	1
Ophiactis savignyi	1	
Ophiocoma echinata	4	
Ophiocoma pumila	1	
Ophionereis squamulosa	1	
Ophiophragmus sp.	1	
Ophiopsila sp.	1	
Ophiopsila riisei		1
Ophiothrix angulata	3	1
Ophiothrix orstedii	1	
Ophiothrix sp.		1
Phylum Chordata		
Class Ascidacea		
Styela partita	1	

APPENDIX 4.3A

TREES AND SHRUBS

Bucida buceras
Casearia guianensis
Capparis flexuosa
Leucaena glauca
Randia mitis
Ricinella ricinella
Tabebuia heterophylla
Trichilia hirta

VINES

Acacia riparia
Banisteria purpurea
Stigmaphyllon lingulatum

No grasses or forbs were located on the transects.