G.118, fader, PRNC - 188 FUATO AICO NUCLEAR CENTER CABO MALA PASCUA ENVIRONMENTAL STUDIES Prepared for the Puerto Rico Water Resources Authority By the Staff of Puerto Rico Nuclear Center of the University of Puerto Rico June 16, 1975 ‘OPERATED BY UNIVERSITY OF PUERTO RICO UNDER Co! 'NO. AT (40-1)1899 POR UB ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION ---Page Break--- ---Page Break--- CABO MALA PASCUA ENVIRONMENTAL STUDIES by E.D. Wood, M.J. Youngbluth, P. Yoshioka and M.J. Canoy ---Page Break--- ---Page Break--- 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-Fi). 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 18, 1975 Punta Higuero Environmental Studies May 1, 1975 (previous studies of Punta Higuero, also referred to as "Rincon" or "the BONUS site" have been reported in Wood et al., 1974), Cabo Rojo Platform Environmental Studies May 15, 1975 Punta Verraco Environmental Studies June 1, 1975, Cabo Mala Pascua Environmental Studies June 13, 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). ---Page Break--- 2a PHYSICAL AND CHEMICAL PARAMETERS ‘AT CABO MALA PASCUA by B.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 Fanta 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). 2 ---Page Break--- Sig. 2.4-FL Cabo Mata Pascua site with depth contour lines and hydrographic sampling transects each with three stations ---Page Break--- 1972 6 15 fs <0 Mor! Cirren 4 NOVEMBER 24 3 3 2 2 ° 2 t ® & 2 F-OW sW>Wws oF 1 Fig. 2.1-F2 Diurnal tides at Cabo Mala Pascua covering one of the periods of ---Page Break--- 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 #1) 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 ---Page Break--- ---Page Break--- 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, traveled 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 2.4-T1 Dye studies at Cabo Mala Pascua, November 15, 1972 NORNINGS

0850-1117 Dye Drop Velocity Direction comments Number 9300-2000) 1 23 en/sce 1 West, then slightly seaward 2 10 en/a s# Inshore, split, offshore 3 5 cm/sec very slow 6 11 ea/see ENE next, then turned west 5 10 en/sec very slow second hour é 8 cm/sec ne Little movement 7 5 enforce cy

Slow west 8 1 en/eee W NE, then slow west AFTERNOON 1325-1550 Dye Drop. Velocity Direction comments Number 1325-1535, 7 @ vo Started west, then dissipated 2 9 wow Followed shoreline 3 18(0) ¥ (started fast, then 4 38010) ® Followed in the second hour 5 5 8 (Flow was slightly shore- 8 e W (ward, but paralleled 7 a wa (the shoreline 8 1308) W Slowed after First hour ---Page Break--- ---Page Break--- ‘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 samplings. The NOAA Charts 302 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 21-3 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 wave train 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 marks 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).

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Fig. 21-15 Bottom profiles along the sampling transects of the Cabo Mala Pascua site. Gray lines indicate relative positions of the hydrographic stations. Vertical EXAGGERATION 25

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TABLE 2.1-T2 Schedule of hydrographic cruises to Cabo Mala Pascua, Winter, Spring, Summer, Fall

PA-088 1972 - Mar 26
PA-028 1973 Feb 22 May 23
PA-039
PA-042

PA-046
PA-052 1970 Feb 29 Apr 23 Aug 22 Nov 14

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 most shoreward, at 25 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 1975). 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, 12, 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, 0. A comparison of some of these depths was made for the Punta Verraco site report (Wood et al., 1975). " ---Page Break--- 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 stations by lowering a bathythermograph, BT, to 300 meters. The BT traces are in Appendix 2.1B. 2 ---Page Break--- ---Page Break--- He. Shee 34 35 36 37 TC 16 18 20,22 24 26 28 100. o E Pe T H m 200 300 mo. 1 2 3 4 5 6 POS pa-at.P/I x10 cMP=1 2A TT Averaged hydrographic parameters (temperature, T°C; salinity, $°/005 density, &; dissolved oxygen, O2; and reactive phosphate, PO4) vs. standard depth in meters for the winter season of 1979 and 1974 at Cabo Mala Pascua. 4 ---Page Break--- Fig. 2.4-18 Depth profiles of hydrographic parameters averaged by type of station for the winter season of 1973 and 1974. 34 35 36 37 Tec 82022 ee 8 Te A

8 - | 504 A eft } | 100 i b 0 0 re € T Pp , A i * if 100 m \ y 9 200 300 Opmio 2 + 2 300 4 5 6 Ph po-ct PI XI0 cMP-t ---Page Break--- Te 16 18 20. 22 24 26 28K 100 3 ra0mo 200 300 Qmno 2 1 2 3 4 5 6 POR pg-at PN X10 CMP -2 Tg. 24-19 Averaged hydrographic parameter depth profiles for the spring season of 1972 and 1974 at Cabo Mala Pascua. 16 ---Page Break--- Fig. 2.1=110 depth profiles of hydrographic parameters for the spring season of 1974 = averaged by type of station 1004 7 raumo) 100 200 300 4 mill O 1 2 pg-at P/IX10 ---Page Break--- S%eo 34 35 36 37 TC 16 18 20.222 24 26 28 100 ° E Pp H m 200 300 Qmno 2 4 2 3 4 5 6 PO} pg-at P/1X10 cMP-3 Hg. 2.1-Fit Averaged hydrographic parameter depth profiles for the summer season of 1978, 18 ---Page Break--- Fig. 21-112 Depth profiles of hydrographic parameters averaged by type of station for the summer season of 1974, 35 36 7 Re 8 20. 22d SCR srw Te A 10 a T ° 8 501 | x Q 100 I Do re E P T H 100 | 5 Nes 200 300 ee Omid. ft 7 3 a Se Py pg-at PNxI0 cMP=3 ---Page Break--- 3 raumo 200 300 Le nnn Geena nin O 1 2 3 4 5 ee PQ} pg-at P/IX10 CMP-4 Fig, 24-719 Averaged hydrographic parameter depth profiles for the fall 20 ---Page Break--- Fig. 24-78 Depth profiles of hydrographic parameters averaged by type of station for the fall season of 1974, Ste 34 38 36 37 Teco 82022 BG — = st = y—7—JA > E . r 4 m 200 300 mil O ° CMP-4 POH pg-at P/1x10 a ---Page Break--- TEMPERATURE °C 16 8 20 22 24 2628 3 raumo cm Winter + Spring 2 Summer 3 Fig. 2.1-F15 Averaged seasonal depth profiles of "C" station temperatures at Cabo Mala Pascua for 1972 and 1974, ---Page Break--- Salinity Salinity, $°/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-F? through Fide. 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 37.08°/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-Fl0. 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. 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 effect 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. Sigma-t is related to density at the temperature measured, by the following relationship: σt = 1) x 10^5 (ny). 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 23 ---Page Break--- SALINITY

“oo 34 35 36 37 ° — P T H ™, cue Winter Spring Summer Foti 300 Tig. 2.1-P16 Averaged seasonal depth profiles of "C" station salinities at Cabo Nala Pascua for 1973 and 1974, 2 ---Page Break--- of wind-induced wave mixing. This layer varies from less Sigma-t profiles are shown plotted with other parameters in Figures Pvt? eneeuge ata, surface water density decreases because of dilution and fairly 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 Nala Pascua were determined by the Winkler titration method (after Winkler and Parsons, 1968) with the analyses usually performed within a few hours of sample collection (after transportation). Values are generally good to better than the reported data. D.O. data are included with the hydrographic data reported by Food and Asencio (1975) in mg/L, and it is known that oxygen saturation is a function of both temperature and salinity. Rether shifts drastically in the near surface D.O. is expected nor were seen. Other values in milliliters per liter are placed throughout the section in Figures 2<1-FF according to station type. The highest value recorded was near saturation. A minimum occurred at about 200 meters, slightly shallower in spring and slightly deeper in the summer. The average oxygen minimum was 4.11 mg/L during the spring season. 2.2.2 NUTRIENTS Nutrients are important from two aspects. First, nutrients limit primary productivity in tropical Atlantic Ocean and Caribbean Sea surface waters. Second, 25 ---Page Break --- DENSITY OF 28 20 22 24 26 ° Aq 100: N\ DEPTH m 200 cm Winter 4 Spring 2 Summer 3 Fall 4 300 m Fig 2 24-717 Averaged water density (sigma-t)

profiles of "c" by season for Cabo Mala Pascua, 1973 and 1974, station data plotted ---Page Break --- DISSOLVED OXYGEN mV 3 4 5 6 o+ ‘i MP Spring Summer 500, Fan D E Pp T H m 200 300: Fig. 2.2-T1 Averaged dissolved oxygen depth profiles by season at Cabo Mala Pascua for 1973 and 1974, ---Page Break --- 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. The concentration of reactive phosphate was generally low (ca 0.05 µg-at. P/t) 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 230 µg-at. P/t. 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 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 30 meters in both summer and fall. 28 ---Page Break--- REACTIVE PHOSPHATE jg-at.P/i 0 43 04 o2 03 04 °. MP Winter 1 Spring 2 Summer 3 400 Far 4 o E P r H m 200 300 Fig. 2.212 Averaged reactive phosphate depth profiles by season, 1973 and 1974 ---Page Break--- NITRATE —_ pg-at. N/l 0 2 4 6 8B 10 12 14 16 18 20 100 3 I4vmo 200 300 Fig. 2,2-f2 wWitrate depth profiles for the summer and fall seasons of 197% at Cabo Mala Pascua. 30 ---Page Break--- 3a 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-diorites 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 diorite bedrock. Sediments The sediment size distribution found at a particular location reflects 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 Se1-Fl and fo. The sieving statistics are tabulated in Table 3.1-Tl. TABLE 3.4-T1 Size analyses statistics for the Cabo Mala Pascua sediments. SaaaaanREREEEmmeeeeeeeemeee MEDIAN MEAN STD. DEX STATIONS Nao Me ‘a 6A 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-GA were very fine (Mé* 3.4). Fine

Sand and coarse silt might be expected here and ---Page Break--- (was Bol-=o some £ 2 1 0 ee so * ---Page Break--- see! S66 and cumulative weight percent: ---Page Break--- since it is very near the mouth of the Maunabo River and the Jetty of Punta Tuna offers a region where fine sediments may be deposited. Sediments at the other "A" stations were coarser (sand), especially on the windward side of points such as Punta Viento and Cabo Mala Pascua. 34 ---Page Break--- 4a ZOOPLANKTON STUDIES 1973 AND 1974 by Marsh J. Youngbiuth 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 2 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., 1965). 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 to 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 seawater with the aid of a battery-driven pump (12 volt, Jabsco water-puppy). The catch was preserved in 4% seawater 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 liters. 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). ---Page Break--- uoayuetdooz 1a-1"y “Bid serys wnaseg BTeK 0geD 9y2 3B suOTIES ---Page Break--- Laboratory Procedures Within 24 hours after samples were collected, the pit was checked and adjusted, if necessary, to 7.60. 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 41-16 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 TL, Summary of ratios between the highest and lowest density values of total zooplankton during each period.
Consecutive Tows 1.30 1.62 2.2/1 1.4 1.2/0.5 1.62 4.2
Nearshore Tows 2.00 1.81 1.26 0
Offshore Tows 1.20 0.2

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 4.01). These data indicate that a large number of replicate tows would be necessary to detect density differences at the 5% level. However, on 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.

TABLE 61-12, Total zooplankton (log10 transformed) from 7 sets of replicate tows. The number of replicate tows (n) needed to detect a + 5-30% difference in density is indicated.

DATE 22 Feb 29 May 13 Feb 23 Apr 22 Aug 14 Nov 42 Dec
stato 2 2 2 2 2 2 2

2.60306 2.55630 2.91908 2.08047 2.60986
p.ounge 9.15229 2.77052 2.50000 2.90867 2.8237
Zage2 2.97589 9.07188 2.6057 2.90098
aigsoue 2.72591 5.10 2.2095 2.72534 5.03202 3.14299

Where (1) is Student's t for the 95th confidence level. G2 (dufo2) is the sample variance based on replicate tows.

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 43-19 Average density of all zooplankton collected. Total Zooplankton/ad ee 173 1974 22 Feb 22 May «19 Feb 25 Apr «22 Aug 24 Nov 12 De Range 231-654 530-840 557-695 269-812 - Median 320 663 586 619 532 - - Mean 26 863 600 591 352 - - 58 Cb. 4897 490807 ass a3 - - ‘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/m3 was observed at Station 5 on 13 February 1974. Fish eggs were more numerous on this date than any other, averaging 177/nm3 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. 39 ---Page Break--- TABLE 4.4-T 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 19-151 197-824 229 23-208 Median 38 25 48 87 Mean 52 50 88 - 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. 40 ---Page Break--- TABLE 4.2A1-TS, Copepod populations observed at the Cabo Mala Pascua Site. Species usually most numerous (7% individuals/n®): Clausocatanus funcatua, Foracalanus spp. (P. aeuleatua, P. erlssivostris, P. parvus), Ferranuia graciite, Otehona spp. (O. plunifera, O. app.), Earvia spinata, Fesoreinbtaata, Galanopia anerfeana. Species commonly present (observed on 5 or more sampling periods): Conyeaeus spp. (C. giesbrechti, C. pacificus, C. speciosus), Teenie wlgartse, Talocaianie, Nammocstanis wfaon os, Candacta, Fisiaews, Tonptcomte ia ighies. Species occasionally present spp. (O. nedivernanea, O. Torycacus spp. (C. susutatas, C. SPI), Feendodiaptomie soksrt, TPP, Galoestants pavoainas, Scolectthrix. danae, Copia apps, Spain spp., Yonstriiia spp., Nacrosetela gracilis, Pisema spinifene. ---Page

Break--- 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 mero-planktonic 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. ---Page Break--- BATUPHe “AED TH/ ANE FUE Ty - seo - oer oett owt wre - - : ee + one oMettnE oe ee ses usyecs 6 69/565 nuacee a9 a8 oe, we oan 999 ere sunoez 95 uss 935 gtz/on9 ons eee Jor coc/ete——emuzort 99 95 eu one os 108 ore exsoee 882, sez 18 ove ee ose oe euzote * s € ‘ : 2 & w see EAE aS RTS sx01 8095550 exoy e2oyes09%, cnog exearrdeg ssoyeston (eu/doquna) uobquvydoos Jo aeqane TOD aire Starr - 280) - - 60" err 80" wucter - - - - eer zi cor: onettar - s1un0" ta" 480°7650" n60°/0S0" 60"/t60" yresoze c 80° ww fs nunoee 8 ne smo"/610" 9¢0°/260" we0"/980" —yracoet neo 0 gor 260 0° exsoez zo" 010" 90" aro shor exzoze * = = z T % a oa Ra wares ToS sno 2048550 sno saoyssves, SaTe wioeeg Pity OTD (qa Fe) BONN TIO Jo TG TET Ete ore 43 ---Page Break--- 2uSrepFMo_

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quantitative baseline 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 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 of 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). 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 1975; Goldberg 1973; Kinzie 1973). - 4.2.2 MATERIALS AND METHODS Field Procedures Field stations are shown in Figure 4.2-F1 and Appendix. Field procedures were divided into three categories: 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 0.25 m² (1 x 0.5 m) or 10 m² (2 x 5m) 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. ---Page Break--- 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 epi-benthic organisms were taken from 1/4 m² 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 S3, S2, S9, S10) although boulders were encountered in the vicinity of Station S10. The most abundant encrusting organisms appear to be the zoanthid Palythoa. Gorgonian, coral, sponge, and fish species observed at Station S12 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 4.2. 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 S2 was Halophila. 52 ---Page Break--- scaly Boulders gt

Station S10 harbored many organisms typically associated with hard substrates, including Montipora cavernosa and other hard corals, and several sponges: Callyspongia vaginalis, Haliclona rubens, Verongia longissima, and Trincomalee spongia. 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 S13 and 30 species at (offshore reef) Station S8. Quantitative Samples The epifaunal and infaunal organisms collected in two 1/4 m² substrate samples at Stations S1 and S7 are listed in Appendix 4.2. The distribution of individuals among species shows the same characteristics found in 1/4 m² 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 m² quadrats at Station S8. Overall colony density was 10.4 and 17.8 colonies per m² in the two subsamples. The three

fort abundant species! A decreasing order of abundance were Plexaura homomaila, Funices clevigera, and Plexaura flesuosa. These species comprised about 71% of the total abundance. The relative abundances showed a significant correlation (Kendall-Tau = +0.71, $p < 0.01$) indicating that the relative abundances of the gorgonian community were 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 is 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. 54 ---Page Break--- 43 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 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 ~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 riperis, 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. 5s ---Page Break---

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aaa 18 -27.2388 35.729 B3y208@ «44741 m9 ew AVERAGE DATA FOR 829502 THROUGH #42734 CABO MALA PASCUA -28 DEPTH TEMPERATURE SALINITY SIGMA_T OXYGEN PHOS NITROGEN. a 27879” 35.725 4.795 Po 10271255 35.725 2 28 35.726 e 3e e 52 2 75 e 108 36.580 @ AVERAGE DATA FOR 829583 THROUGH 042735 (CABO MALA PASCUA = 2° DEPTH TEMPERATURE SALINITY SIGMA_T OXYGEN PHOS NITROGEN 27.861 $923.771 44822 BSA BeBe 2 331756 gszex 44842 2.000 22 35.783, 29a 4)802 eyeue 3 351755 Bi ay 794 a.eue 5a $5.788 24783 a, 202 75 361144 23.946 4) 683 ey2ee 127 36.529 53744575 ayeee 134 >a a6 43785 20a 67 57 ayaa 252 $8 6.394 ANAL 302 $6.413 264517 44305 ---Page Break--- AVERAGE DATA FOR 846852 THROUGH A46854 DEPTH TEMPERATURE 9 28.286 1 28.334 SALINITY SIGMA_T AVERAGE DATA FOR @48849 THROUGH 74484> DEPTH TEMP 2 18 20 3e 32 75 x08 ERATURE 28.110 28.117 23.324 27.935 28.763 25.228 23.549 SALINITY Sigma T 35.534 22.781 35.535 22.779 22.778 22.899 23.607 24.426 25.180 AVERAGE DATA FOR 246842 THROUGH 46544 DEPTH TEMP 3 rt 2e 30 52 5 sae 159 20> 252 30 ERATURE 28.130 28.132 SALINITY 35.584 351584 35.528 35.592 CABO MALA PASCUA ~ 3A, OXYGEN PHOS NITROGEN 24026 ase CABO MALA PASCUA 93 OXYGEN PHOS NITROGEN 4.762 #252 4794 e350 47a 2.239 4y785 2.228 41963 2.239 41922 aaa? CABO MALA PASCUA ~3C OXYGEN PHOS NITROGEN 4.738 74290 41734 ay 74s 41738 alpen P1735 Pines raat 262 03767 yan Oy x6 208 ---Page Break--- AVERAGE DATA FOR 952998 THROUGH 52002 ‘CABO MALA PASCUA ~ 4A DEPTH TEMPERATURE SALINITY SIGMA T OXYGEN PHOS NITROGEN. © 26.882 «SB, 94e = 25.206 4.884 Byes 8428 12 26.958 33.421 28.566 4.702 BVO Bee AVERAGE DATA FOR #52995 THROUGH 252991 CABO MALA PASCUA - 4B TEMPERATURE SALINITY SIGMA_T OXYGEN PHOS NITROGEN 33.738 214794 #030 1138 we 224165 a 2 22.534 @ 3° 22.991 a be 24.275 8 75 24638 2 08 25.231, a AVERAGE DATA FOR 982996 THROUGH e52998 DEPTH TEMPERATURE SALINITY SIGMA_T OXYGEN 27.822 «33.729 244777 fy 22.097 20 22.398 se aes 30 nas 5 667 122 25.245 452 254744 2ar 264199 259 26.448 320 26.576 ---Page Break--- APPENDIX 2.18 BATHYTHERMOGRAPHY TRACES

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Of-eK 92 -4n2 a 52 rest ‘e2 ‘adv z¥0 "ON estnag ey ee s ez Se ae S30VHL HovYOONNIML ANUS ---Page Break--- rc6i ‘12 *8ny 9¥OVd "ON osyn39 ---Page Break--- 261 ‘PL *AON Yon asrnag, zsovd 99-419 98-aN9, Ob-aKo, 8-dWO 92-aK9 athe /MV/ r + ee st ae se ee se ae 2 °930 aunLuaadWai SIDUYL Hob4IOHTHLAHLUS out ez gst aot ---Page Break--- APPENDIX 4.24 Dates of Dives and Locations of Benthic Stations Station Bt ‘Location: Date: Investigator: Station 82 Location: Date: Investigator: Station St Locat ica: Date: Depth: Invest Station $2 Lecation: Date: Depth: Investigator: Station $2 ‘Location: Dat Depth: Investigator: Station su Location: Data: Depth: Investigator: Station $5 Lacation: Date: Depth: Investigator: ator: ft Cabo Mala Pascua Shore station about one mile west of Cabo Nala Pascua 22 March 1973 Se Martin Shore station about two miles west of Cabo Nala Pascua 22 March 1973 5. vartin Reef station about 1.5 fles offshore at Punta Viento 22 Febvuery 1972 16m 3. Martin Sand station abovt 0.75 miles southeast of Punta Vento 22 August 1974 dss P. Yoshioka Sand station inshore of $2 22 February 2673 20» S. Mantin Reef station about 0.5 miles east of S2 23 May 1972 e-em V. Vicente Reef station about 1.0 miles east of St 22 February 197% ism P. Yorhioka ---Page Break--- APPENDIX 4,2 (continued) Station $6 Location: Date: Depth: Investigator: Station s7 Location: Date: Depth: Investigator: Station $8 ‘Location: Dates Dept! Investigator: Station 99 Location: Date: Depth: Investigator: Station $10 Location Date: Depth: Investigator: station Sit Loca: Date: Dept Investigator: Station $12 ‘Location: Investigator Station $23 Location: Date Depth: Investigator: Reef station about 2,0 miles east of ot 1,0 wiles offshore 23 May 1973 32 t0 18 m ¥, Vicente Reef station

about 0.5 miles east of $6 22 February 1979, aim W, Vicente Reef station about 0.5 miles east of $87 2 February 1974, 21 May 1974, 22 August 1974, 31 December 1974" (Permanent station) P. Yoshiova Sand station about 0.3 miles inshore of $7 22 February 1973 2a S. Martin Sand boulder station about 0.7 miles inshore of $7 22 February 1975 cary 8. Martin Inshore station 22 February 1972 O- 5m S. Martin Inshore station near Sit 22 August 1978 o- 5m S. Martin Reef station about 1.5 miles east of $7 22 May 1978 retry V. Vicente ---Page Break--- APPENDIX 4.28, Shoreline fishes of the Cabo Mala Pascua FAMILY Muraenidae Echidna Ophichthidae Wyrichthys Gobidae Arcos macrophthalmus ‘ieoe Bstgenoeae Tonfeodon acta Reson artiue cuninatus Sconpacna plunien: corneidae nelanopterus Ponacentridae Abudefduf taurus Hudefduf saxatilis Mugilidae Mugil Labeidae Doratonotus segmenteus Halfshoelies Soceliettna Searigae Sparisoma rubripinne Blenniidae Entonacrodus nigricans Clinidae Blenniopsis leptocirnis Blenniidae eee pense Labridae fattensts Tabelsoma auchipinnis gobiae Awaous tajasica Sipe peti seven tneatus sovenTinentus Guatholipis thompson tonatapeltur oleeona idae ast schoepet 27 Feb 73 Fry 27 Feb 73, Rotenone 2 ---Page Break--- APPENDIX 4.20 Macroinvertebrates, algae and fish observed at selected stations at Cabo Mala Pascua s2 31 se 22 hug 7 22 Aug 7 22 Aug 7H Phylum Rhodophyta Chlorophyta Caulerpa noxicana founds Fenietilus capitatus ‘doten conglutina Bates Flabellum ‘Deoten apinatoca, Phylum Spermatophyta Lents x Hauophsta ava, FONGDOM Phylum Porifera Elas Sathorigneita varians tallgepongle vag teat hs rLgepongta vap als Tinachyra cavernosa white ep Faliclonm rubene Tpeints ToereTota birotulate Wyeate angulosa Wyeale a. WeeriSulania nagsa Difgocerse Reworrages . Weranria Tacunos Verongto Longisetna Terongia op x Recteepangia muta x ---Page Break--- APPENDIX 4.26 (continued) s2 22 Aug 74 Phylum Cnidaria Class Anthozoa Subclass Octocoralita Sriareum asbestinum ‘Enythropettam eps Eunfers

Landay Eunleea ay Sengenta 2p. Tunfeca 6p. Sarfoeapeis ap. Flexaure Flextosa ‘Hisaura Ronomafia ‘Feeueplexaura sp- Reeudspeeroamt Eerogorgia ep. reroergia =p Subelass Zoantharia Acropora cervicornis eae ieee & eeiperhplta sp. BicResoeaTa atokestt Biptaris TagNIEeE Fon Diplorta +3. Eusetiia sastigia Teghylis ltt fisre Reandrina ep. EiElepora sp. Hentaserea caverncea Feet betas Sideraatrea radTans ‘Sideraaerea averea Phylum Chordata Subphylum Vertebrata

Class Pisces Family Dasyatidae Unid. Dasyaria x 2 hug 74 se 22 ang 74 x x ---Page Break--- APPENDIX 4.2¢ (continued) s2 $12 8/22 8/22 Phytun Chordata Family Muraenidae Gymnothonax noringa Tarily Holecents Holocentrus. sp. Syripristle Jacobus Fantly Aulostomidae Aulogtonus maculatus Family Sphyraenidae ‘Sphyracna barracuda Fanity Serranidae Cephalepholis fulva Gea cerrante Family Granmistiéae Rypticus sp. Family Echeneidae Echeneis aucrates Family Carangidae caranx crysos x Decapterss #p- Fanity Lutjanidae LytJanus ap. Fanily Ponadasy!éae aemslon favo ineatun Family Sciaenidae Equetus 9p. Family Sparidae Calamus bajonade Family Mullidae Peeudupeneus acu ona se 8/22 ene ---Page Break--- APPENDIX 4,20 (continued) Phylum Chordata (cont.) Pam{ly Chaetodontidae Ponacanchus Saveodss Frovnathnes a ales Family Ponacen thromis cyanqus Thromfe mule! Tineatue Pomacentrus partitus macenrad 5p. Ely Labrivae Noddanes rufus falfchoeres sp. Tar Family Seariéae Sparisona =p. thie geeria Family Acanthuridas Acanthurus ep. Panity Balictidae Balsstes ep. falletes votula s2 s12 eee 8/2228 x x x x xX x x x x x x x x se 6/22 senna ---Page Break--- APPENDIX 8.20, Cabo Mata Pascua shore collections Station 82 Station 32 22 Harch 1979 22 March 1979 Puylum Chlorophyta Cauilerpa racemosa GhanaotorTs pendeun faitmeda opuntia Pontius eapitatus x Foniortius duretosus: Uaotea Fiabeltun Siva Tactucs Phylum Phacophyta, Dictyota oitiolata Ene pcetecim Phylum Rhodophyta Sryothasnion triquetrum Terantun sp. Talaraura sp. Tanks captttace Taurene’a papitiosa Sclysipionts ep. Phylum Spermatophyta

Syringodium filiforme x ‘Seimedean sp x Thalassia testudinum x x ARTHAL EINGDOH, Phylum Mollusca Class Gastropoda Acmaea antiqua x ieteaes be x x Salle striata x ---Page Break--- APPENDIX 4.20 (continued) Phylum Mollusca (continued) Class Gastropoda Sertularia variabile Silumberre nereatoria Diotora velarata Eisauretus Bas Finmellia sp. Henitonia Sctoradiata Class Pelecypoda Barbatia dominensis Codakia orbiculata Phylum Arthropoda Order Decapoda Suborder Arachnoidea Callicer, Werophrys aniliensis Phylum Echinodermata Class Echinoidea Tripneustes esculentus Station B2 22 March 1979, Station 87 22 March 1979 ---Page Break--- APPENDIX 8.2E Species and individuals per species collected in 1/4 m² quadrat at Cabo ala Pascua PLANT Einaeo Phylum Phaeophyta Dictyota sp. Phylum Rhodophyta Laurencia sp. ayoman NCTOM Phylum Sipunculida Phylum Annelida Chase Polychaeta Arabella opatina Tunicates Fucata Tunlee sp. Ferminia verruculosa Tastmontce Kinbergia ‘Papilonotus sp. Tabrineretes sericea. sp. Varphysa regalia Narphysa sp mens. Weldon Kingergii irefaion sp. Phyllodoce papillosa Family Serpulidae style sp. Pxbale sp. Family Terebellidae Unid. polychaete 37 2pnes7a au Dees 20 ---Page Break--- APPENDIX 4.2 37 st 2/ae/7a 23a Phylum Mollusca Class Gastropoda Columbelta nercatoria 1 Tucapina sowersi? 1 Class Pelecypoda: Barbatia dominensis 2 Ghana sands Goralifophaga coralliphaga lobatus. cas taneus 1 thophaza bisuleata 4 Phylum Arthropoda Order Stomatopoda Unid. stomatopoda 2 Order Tanaidacea Crustacean parva 4 Spaereca valkert 3 Order Decapoda Suborder Natantia Family Alpheidae Alpheus sp. 1 vous nceiendons 1 eus rathbunae 3 Suborder Brachyura Mithraculus pleuracanthus Phylum Echinodermata Class Echinoidea Eucidaris tribuloides Class Asteroidea Asterina sp. 1 Class Ophiuroida Ophiuroidea 2 ---Page Break--- APPENDIX 4.26 (continued) Family Ophiuridae i.e. eresete agalaa Baisden Phylum Chordata Class Ascidacea Styela paterea 37 prez se 2022/73 ---Page Break--- APPENDIX 4.38 TREES AND SHRUBS Bucida buceras Geers Beets Teienons

grace: Randle autte a Ricinel Ti rictnetta Tabehuls hoteraphyita FIChiTT VINES Acacia riparia apEStetY purpurea ‘Stigmaph) yniba tin Taptlatun No grasses or forbs were located on the transects. ---Page Break--- NOTICE “This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their