1s PRNC ~ 187 "PUERTO RICO NUCLEAR CENTER for | CABO ROJO PLATFORM ENVIRONMENTAL STUDIES Prepared for the Puerto Rico Water Resources Authority By the Staff of Puerto Rico Nuclear Center of the University of Puerto Rico May 16, 1975 ‘OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. AT (40:11898) FOR U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION ---Page Break--- CABO ROJO PLATFORM ENVIRONMENTAL STUDIES by E.D. Wood, M.J. Youngbluth, and P. Yoshioka ---Page Break--- PREFACE This report stems from investigations carried on by the Puerto Rico Nuclear Center. The studies were designed to provide data upon which to judge the suitability of a site for the construction of power generating facilities and to allow the determination of the impact of such construction and operation upon the environment. ‘The report represents the combined effort of the scientists, technicians, and support staff of the Site Selection Survey Project. ‘The authors who contributed to the Cabo Rojo Platform Site Selection Survey are: E.D. Wood, Project Leader Physical, Chemical and Geological Parameters Marsh J. Youngbluth Zooplankton Studies Paul Yoshioka Benthic Invertebrates and Fish Studies Report Coordinator: E.D. Wood Technical Editor: Ferne Galantai Project Secretary: Pauline Ortega de Cabassa Data Processing: Rosa Asencio ---Page Break--- TABLE OF CONTENTS 1. INTRODUCTION 2. PHYSICAL AND CHEMICAL PARAMETERS 2.1.1 Introduction 2.1.2 Tides 2.1.3 Currents 2.1.4 Bathymetry 2.1.5 Temperature, Salinity and Density Temperature Salinity Density 2.2 CHEMISTRY 2.2.1 Dissolved Oxygen 2.2.2 Nutrients Reactive Phosphate Nitrate 3. GEOLOGICAL PARAMETERS 4. ZOOPLANKTON STUDIES 1974 4.1.1 Introduction 4.1.2 Materials and Methods Field Procedures Laboratory Procedures 4.1.3 Results 4.1.4 Discussion Limitations of the Data 4.2 BENTHIC INVERTEBRATES AND FISH STUDIES 4.2.1 Introduction 4.2.2 Materials and Methods Field Procedures Shore Surveys Transect Dives Station Dives Laboratory Procedures 4.2.3 Results and Discussion References

Appendices 25 25 25 25 25 26 30, 30 38 38 38 38 38 38 40 40 “4 ---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 plants 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 first of these reports is entitled, "Tortuguero Bay Environmental Studies," and is dated April 1, 1975. The second report, dated April 15, 1975, is entitled, "Punta Manati Environmental Studies." The third report, entitled "Punta Higuero Environmental Studies," is dated May 1, 1975. Previous studies of Punta Higuero, also referred to as "Rincon" or "the BONUS site," have been reported in "Punta Higuero Power Plant Environmental Studies 1973-1974" (Wood et al., 1974). ---Page Break--- . tumoys 30 0375 o301sT oTI2eg *(qND) UNOSeg ETEN OQUD pu cpg {{ha) 0981194 BIUNG !(qUD) WroyIeTg Ofoy OqUI ! (Ha) oXONBTH Brung t(wwa) F2BuRK eIUNg !(yOL) AEG oxonHmazoy “seats AeAINg WoT2>0TIS 937s vas Nv3agiuv> 400.00 oe 0009 NV390 SUNVTuV ---Page Break--- 2a PHYSICAL AND CHEMICAL PARAMETERS AT CABO ROJO PLATFORM by B.D. Wood 2.1.1 INTRODUCTION Most of the physical, chemical, and geological measurements at the Cabo Rojo Platform site were made at or near the stations shown in Figure 2.1-F1. The transects were spaced at one nautical mile with the "A" stations located as near to shore as it was safe to sample with the RMW-R.F, Palunbo. The "B" stations were located on a north-south line which passed through the center of the two basins on the Platform. One "C" station was located in a channel on the seaward side of the south basin. The sample depths for the stations were: "A" - 0, 5m; "B" - 0, 10m; "C" = 0, (5), 10, (15) and 20m.

2.1.2. TIDES

Tides that affect the Cabo Rojo Platform originate in the North Atlantic Ocean. The tides for Puerto Real, located on the east-central border of the Platform (Figure 2.1-F1), are predicted by the National Ocean Survey (1972). The tides are semi-diurnal with an average diurnal excursion of 30 cm and a mean tide level of 12 cm. The tides for the period of current measurements on the Cabo Rojo Platform are plotted in Figure 2.1-F2. An example of the tides plotted over a lunar cycle is shown in Punta Higuero Environmental Studies (Wood et al., 1975).

2.1.3. CURRENTS

The Cabo Rojo Platform site is part of a broad shallow shelf off the southern half of the west end of Puerto Rico. The shelf edge extends some 25 kilometers seaward due west of the north basin of the site. The shelf edge is about 10 kilometers from the southern basin at its closest point. The shelf edge extends along a northwest-southwest line off the southwest corner of the island. The open sea currents of the Caribbean flow generally to the west along the south coast then turn to the northwest around Cabo Rojo following the shelf contour lines. This flow is affected by wind and tide.

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1-71 Cabo Rojo Platform site with depth contour lines and one to three hydrographic sampling stations on each of the transects.

Cabo Rojo PLATFORM.

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Fig. 2.4-F2 Tides on the platform predicted for Puerto Real, January 15-17, 1974.

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There appears to be a large gyre or back eddy over the Platform which is strongly modified by wind and tides. This back eddy brings water shoreward to the vicinity of Mayaguez, where it divides, flowing north and south. The southern flow forces the plume of the Cuanajibo River south around Punta Guanajibo through Bramadero Bay, past Punta Arenas and finally seaward between Puerto Real and Soqueron Bay. Currents over the reefs are quite strong at times, in excess of 50 cm/sec (ca one knot). This current pattern contributes much fine terrestrially-derived sediment to the eastern portion of the basins, especially the northern basin. This general description is based on the work done by the author in the Puerto Rico Nuclear Center's Marine Biology Program and numerous observations in the course of PRWRA work. The currents at the site were measured during the period 0745 January 16, 1974 to 1000 January 17, 1994 at four depths near Station

CRP-4C. The weather was exceptionally calm during this period with the highest wind velocity only 8 m/sec (ca 6 knots) from the southeast in the early morning (Jan. 16) shifting to northeast for the rest of the mornings then from the northwest near noon and from the south in the afternoon. The sea surface was glassy calm the morning of January 17, 1974. The currents were measured using General Oceanics film recording inclination meters. The data were computerized, averaged and plotted for each depth. The plots are in three forms: 1) direction and velocity versus time (Appendix 2.1A), 2) a progressive vector (Figure 2.1-F9) and 3) a "current rose" (Figure 2.1-F4). The top current meter in the string of four was just beneath the surface (ca 1m). It indicated the highest currents of about 20 cm/sec to the northeast during the last of the falling tide, low tide and the beginning of the rising tide. This was against the prevailing wind. The surface currents were generally to the southwest during the evening with velocities of about 10 cm/sec. Currents were light and variable during the

night flowing to the southwest in the morning hours of January 17, 1974 at about 15 cm/sec. The currents at the deeper meters generally followed the surface current during the day of January 16. The 7 meter depth showed more variation in the direction after 1400 January 16, but generally the flow was to the southwest ---Page Break--- Fig. 2.1-F3 Progressive vectors for currents at Stations CRP-AC, Jan. 16-17, 1974 ---Page Break--- Fig. 24-FS Offset bottom profiles along the sampling transects on the Cabo Rojo Platform. Vertical lines indicate relative positions of hydrographic stations CABO_ROJO PLATFORM, VERTICAL EXAGGERATION: 673 ---Page Break--- 2.1.5 TEMPERATURE, SALINITY AND DENSITY The physical parameters of temperature and salinity were measured at the Cabo Rojo Platform on five cruises covering four seasons (Table 2.1-T1), TABLE 2.1-T1 Schedule of hydrographic services to Cabo Rojo Platform. WINTER SPRING SUMMER FALL ee PA-035 1973 - - 9/2/73, - PA-036 PA-080 PA-087 —_PA-052 1974 4/16/74 8/2 8/27/74 13/15/74 SSS The hydrographic sampling stations are shown in Figure 2.1-F1. The coordinates of the stations and hydrographic data are in the "Hydrographic Data Report Northeast Coast Of Puerto Rico" (Wood and Asencio, 1975). Nine transects were sampled on each cruise. The deepest sample was taken from 20 meters at Station CRP-4C. The "A" stations were sampled at 0 and 5 meters and the "S" stations at 0 and 10 meters. The sampling, analytical and data processing procedures are described in "A Manual for Hydrographic Cruises" (Wood 1975). Temperatures were measured using deep sea reversing thermometers, accurate to better than + 0.05°C. The thermometers were used in pairs or threes at a time. Although usually only one temperature is shown in the data for each depth, these values are often the average of two or three thermometer readings. Averaged temperature depth profiles are shown plotted by type of station and by season along with other hydrographic parameters in Figures.

2.1-F6 and F7. The temperature profiles are flanked by dashed lines in most cases to indicate the range of temperatures found. Temperatures were highest in the summer with the September 1973 sampling registering temperatures of over 29°C. These were the highest temperatures measured at any of the sites and they are due to the water being shallow and protected. The lowest temperatures were measured in a ---Page Break--- Pig. 204-76 Averaged hydrographic parameters (temperature, T°C, salinity, %o/oo, density, #; dissolved oxygen, O2, and reactive phosphate, P04) vs. depth in meters for the winter and spring seasons of 1974 for the Cabo Rojo Platform. S % 33 34 35 36 SE ee T°C 18 20 22 24 28 RPA, O2 [a 5 0%, t a 11 | ils fo w 10 ' 04 c 104 >| . sr fo D E 104 >| o rs jo ds fF 204 o > HW oz - 2 v4 Pa maz amid FT 2 3 4. 8 86 PO4 pg-at. PF x10 cRP-2 ---Page Break--- Fig. 2.A-F7 Averaged hydrographic parameters vs. standard depth in meters for the summer (1973 and 1974) and fall (1974) seasons on the Cabo Rojo Platform. Dashed lines show the range of the temperatures. S % 33 34 35 36 Ftp T°C 20 22 24 26 o olf wo > 27 s U M ° e

Te! i [Se of | o| s{ o) ifr | > ye ye i E : P20 ‘ ee To 4 wh ray a 5 i m 07 lB 3 Reon o w | Omnrd ~ F 2 3 a 5 6 PO4 po-ot. #1 x10 cRP-4 ---Page Break--- January 1974 (~25.5°C). Figure 2.1-F8 shows the distribution of temperatures along the line of the "B" stations. The dashed lines indicate the average for the quarter sampled. The winter and spring samplings show very little spread or trend in the temperatures with distance along the "B" line. However, the plots for other seasons show generally lower temperatures at the southern edge of the south basin and higher temperatures in the north basin. Low temperatures were found opposite Boquerón Bay in the fall season of 1974 which probably reflects run-off from the lowlands of southeastern Puerto Rico through Boquerón Bay. Temperature profiles (Figures 2.1-F6 and F7) show that the water is fairly well mixed with very weak gradients usually.

Cooling with depth except that during the fall at the "C" station the water column warmed with depth. Temperatures increased with distance from shore in the winter and summer but showed little or no trend during the spring and fall seasons. Salinities for the Cabo Rojo Platform "B" stations are shown plotted by season in Figure 2.1-F9. The averages are indicated by dashed lines. Averages are also plotted with other hydrographic parameters by season in Figures 3, 10Fe, and F7. The highest salinities (~35.85"/oo) were found in the spring and the lowest in the fall season (~33.75"/oo). Salinities for the spring and summer seasons show little variation from their respective averages. Some trends are seen with distance. Salinities generally decreased from south to north in the spring of 1974 with the opposite trend seen in the late summer of 1973. Low salinity anomalies such as those found at Station 38, fall of 1974, and Station 5B, summer of 1974, were accompanied by low temperature anomalies for the corresponding measurements (Figure 2.1-F8). A sharp difference in salinity was seen between the south and north basins in the winter of 1974. Lower salinities were noticed in September 1973 than in August 1974, probably reflecting the effects of the summer-fall rainy season. Salinity profiles in Figures 2.1-F6 and F7 showed little or no gradient for the spring and summer seasons. The highest gradient occurred during the fall season in all types of stations and at the "C" station in the winter season. Salinity gradients with distance from shore reflected the seasons, that is, they were positive during the fall (rainy) and negative during the summer (end of dry season). ---Page Break--- macabamvima a Fig. 24-78 Cabo Rojo Platform "B" Stations si 23.4 56 7 8 On Boqueron Puerto Bay a [0 o ° 8 2 27. 3456789 Surface temperatures plotted by "B" stations for each of the five sampling trips. Dashed lines indicate the average temperature. ---Page Break--- Cabo Rojo Platform si 2.3 4 Boqueron Bay ty values vs. cate

average salinities. Y" Stations 5 6 7 8 ON Puerto Real 'BY stations for the five cruises. ---Page Break--- Density, The stability of the water column is a function of the density gradient. Density, is a function of temperature and salinity (pressure is significant only at great depths) and always increases with depth in a stable water column. Density is usually converted for convenience to an expression, sigma-t, 4 fa(ft- 1) x 10. Any small changes in sigma-t with depth indicate a well-mixed or unstable zone, whereas a high gradient is indicative of a very stable region of the water column. The average density is plotted by station for the four seasons in Figures 2.1-F6 and F7 with other hydrographic parameters. The density increased from fall through winter to spring as the salinity increased, then decreased through summer to fall as the salinity decreased and temperature increased (through summer). The density, as indicated by sigma-t, was nearly uniform with depth having only a slight positive gradient, except for the fall season nearshore ("A" stations). Yost density anomalies coincided with major changes in salinity as the temperature changed little with depth. There were two seasons where density gradients with respect to distance from shore existed. A negative gradient was detected in the summer with more saline water nearshore and a positive gradient in the winter from the low salinity run-off from the land. 2.2 CHEMISTRY 2.2.1 DISSOLVED OXYGEN The amount of dissolved oxygen in the waters of the Cabo Rojo Platform was determined by the Winkler titration method described by Strickland and Parsons (1968). The samples were titrated within a few hours after being sampled. The values are usually good to better than + 1% although an occasional value seems to deviate somewhat from the norm. The data are reported by Wood and Asencio (1975). The averaged data are plotted in Figures 2.1-F6 and F7. All of the oxygen values are near saturation for all seasons with little or no gradient with depth or distance.

from shore. The discharges from the Guanajibo River to the north and Boqueron Bay to the south are the only significant sources of biological oxygen demand. They do not appear to be sufficiently large enough to make an impression upon the oxygen levels of the Cabo Rojo Platform because of the constant mixing and flushing. 2.2.2 NUTRIENTS Nutrients are important from two aspects. First, nutrients are generally low in the tropical Atlantic Ocean and Caribbean Sea, limiting primary productivity. Second, 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 complex method (Strickland and Parsons, 1968) and is a good indicator of pollution. Only limited nitrate analysis has been performed on the waters of the Cabo Rojo Platform because there exists a good relationship between phosphate, PO4, and nitrate, NO3, in the open ocean (1:14) (except that nitrate is somewhat deficient in the tropical and sub-tropical Atlantic Ocean surface waters). Reactive silica is usually not regarded as a problem from a pollutant aspect. Reactive Phosphate Samples for reactive phosphate were frozen soon after sampling and returned to the laboratory for analyses. The phosphate values are given in the Hydrographic Data Report West Coast of Puerto Rico (Wood and Asencio, 1975) and the averages plotted in Figures 2.1-F6 and F7. Phosphate levels are low over most of the Platform for all seasons (~0.05 µg-at, P/l) with the highest values being at "A" stations in the fall (rainy) season. The only distance gradient noticed was during the fall when an inverse relationship of phosphate and salinity occurred with distance from shore. That is, it appeared that the phosphate coincided with terrestrial run-off. Nitrate A limited number of nitrate samples were analyzed for the Cabo Rojo Platform during the fall 1974.

season only. The data are too spotty to establish trends. The values were all less than 2 ug-at. N/1 with the higher values nearshore. 18 ---Page Break--- 5.1 GEOLOGICAL PARAMETERS ON THE CABO ROJO PLATFORM by E.D. Wood The Cabo Rojo Platform is composed mainly of calcium carbonate in the form of sand shelf and coral fragments or coral formations. The nearshore sediments are principally non-carbonate, terrestrially derived. A series of grab samples were taken at the stations and at Station 4C (Figure 2.1-F1) and analyzed by sieving for size. The histograms and cumulative weight percent plots are shown in Figures 3.1-F1 through F2. The larger sediment sizes (phi equal to 1 to +1) were mainly shell fragments. The fine material (90-95%) is finer than phi equal to one (<0.5 mm) with the mean phi equal to about 3.0 (0.125 mm). The histogram plots for the Stations at the north and south basin boundaries were poorly sorted (phi 2.0 - 4) with significant sediment fractions larger than 1.0 mm. The largest mean in the center of the north basin was 3.3 + 0.9 at Station 8A. The south basin had its finest sediments just seaward of Boqueron Bay (mean = 3.7 + 0.7). Fine, well-sorted sediment was also sampled at CRP-4C (mean = 3.7 + 0.6). The currents measured there January 16-17, 1974 were very weak near the bottom which allows for the deposition of fine sediments. Twenty to fifty percent of the basin sediments were finer than 0.063 mm (>4 phi). This shows that weak currents occur often enough to allow appreciable amounts of fine material to settle out. This does not preclude the occurrence of strong currents as fine, plate-shaped sediments require much higher currents to resuspend them than to keep them in suspension. The sieving statistics are given in Table 3.1-T1. TABLE 3.1-T1. Sieving statistics for Cabo Rojo Platform grab samples. Mean Median Standard Dev. STATION 307 2.2 2.8 2.0 308 1.0 3.3 3.0 309 3.2 0.9 3.2 310 3.0 3.0 0.9 3.7 4.0 0.6 ---Page Break--- cove, ge 2 bok (uwds Ho)-2 9 nay € Z |

O t nab € @ oy os] ol ge -ddd @z-duo @l-ddo jes see ‘S66 stations showing pee Fig Sediment size analyses plots for CRP=t, 2 and 3."2 20 ---Page Break--- cower £2 tok (us 20-29 nab € 2 tO Lwap € 2 i)] I | oy og} 1 jos 4 joc © log 3 o¢| g9-d4D Gs-dud L 8r-dyo = los sé es S66 SJ S66 Pig. 9,1-F2 Sediment size analyses plots for CRP-4, 5 and 6" cumulative weight percent and histograms. 2 ---Page Break--- 7° 10 so os, | 23 4 Pan CRP-9B, 1 a 23 4 PAN CRP-8B O71 2 3 4 PAN 1 : HE 98) 95] go} o = 995, €80 o & -o: + 60} o ° = a woe Fig. 3.1-f3 Sediment size analyses plots for CRP-7, 8 and 9 "B" stay cumulative weight percent and histograms. 22 “109, Simm ® ---Page Break--- 995 ° ° 0 2 Oo fs oy ev lo a is _4 lo | E | ee. - | | Q T rs | a + & | Oo o © © oO 0 Do OO0O OG OH OO 2 89 83 © @kSHFa w 3 ° BwW-OTr aweowze Fig. 944-P Sediment size analyses plot for CRP-NC showing cumulative weight percent and histogram. 23 ---Page Break--- Most of the terrestrial sediments are carried onto the Cabo Rojo Platform by the Guanajibo River plume. This plume flows south around Punta Guanajibo, south along the shore and then seaward over the Platform. The river flow is greatest in the late summer and fall (rainy season) and least in the spring (dry season). ---Page Break--- 4a ‘OOPLANKTON. STUDIES 1974 by Marsh J. Young 4.1.1 INTRODUCTION The following report provides estimates of the abundance and diversity of zooplankton in the surface waters near the Southwestern coast of Puerto Rico. These data represent one part of an environmental survey conducted by the Puerto Rico Nuclear Center in an area proposed for offshore siting of power stations. Samples were gathered on 4 days during 1974: 20 January, 2 April, 29 August, and 15 November. MATERIALS AND METHODS 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 ft. skiff in a circular path through the upper 2 meters. The speed of

The vessel ranged from 2 to 8 knots (determined with @ 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 43 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 oF 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 ±% 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).

Laboratory Procedures: Within 24 hours of samples being collected, the pH was checked and adjusted, if necessary, to 7.6. If a sample contained a non-recoverable conglomerate of phytoplankton or detritus, the zooplankton were separated from such material by pentic 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 (Ahistrom 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 proportions 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 1A for a listing of the program.

4.1.3. RESULTS

A total of 49 samples were collected from 9 stations (Figure 4.1-F1). The concentrations of several taxonomic groups of zooplankton at each station have been calculated (Table 4.1-T6 through 17). These data are arranged to facilitate comparisons between sets of consecutive tows, nearshore tows, and offshore tows. Densities usually differed more between samples gathered from different areas than between consecutive tows from one area. This observation is summarized in Table 4.1-T1.

TABLE 4.1-T1

Summary of ratios between the highest and lowest density values of total zooplankton during each sampling period.

DATE	January	April	August	November
Consecutive Tows	1.4	5.6	1.2	4.7
Nearshore Tows	29	-	-	-
Offshore tows	1.3	1.0	16	-
ALL Tows	2.8	-	-	-

The degree of variation between samples is expressed as a ratio formed by dividing the largest total number of zooplankton by the smallest within each set. The rates are similar to those observed in other coastal regions around Puerto Rico (Youngbluth 1973, 1974). Another way of judging differences between samples is also present (Table 4.1-T2). By calculating the variance between consecutive samples, the number of tows needed to detect various levels of difference was determined.

TABLE 4.1-T2

Total zooplankton count, transformed from products of replicate tows.

The number of replicate tows needed to detect	+5	~	505	difference in density
2.98278				
2. Sess				
2.99551				
2.92694				
2.80862				
3.2306	8	10	81	18

Where (α) is the significance level. The variance based on replicate tows, and degrees of freedom are shown in the confidence interval desired.

These data indicate that a large number of replicate tows would be necessary to detect density differences at the 5% level. However, in most cases, with only three tows, differences of 30% could be noted and significant differences of 50% or more can be detected with a single tow. These data agree with estimates of field sampling error found in other studies of zooplankton (Wiebe and Holland 1968, Carpenter et al., 1974). Differences larger than 50% were found between samples from different stations, but these higher densities were rarely more than an order of magnitude greater. Seasonal differences in the average abundance of total zooplankton were small, i.e., less than 8% (Table 4.1-T3). ---Page Break --- TABLE 4.1-79, Average density of all zooplankton collected Total Zooplankton/m³ January April August November — Range 252-852 112-1267 362-1776 Median 800 510 810 Mean 59 590 967 958 CL, 600-1288 227-872 290-802 509-1945 ee The highest concentrations appeared in January and November. These larger densities, however, probably represent the range of variation among tropical zooplankton communities in the coastal waters around Puerto Rico rather than recurrent seasonal pulses since the 95% confidence intervals from each period overlap. The foregoing remarks refer primarily to holoplanktonic forms as they composed 65 to 97% of the total zooplankton. Meroplankton tended to be slightly more numerous in January and August. However, the wide range of abundances recorded during any sampling period obscures any noticeable seasonal fluctuations in their densities. Fish eggs were not abundant in this area (Table 4.1-T4). The largest density observed, 5/dm³, occurred at Station 9 during January. The mean number of eggs during this period was 10/m³ and twice the densities found at other times of the year. Fish eggs were usually round and 0.5 to 2 mm in diameter, but oblong eggs were common. It is not known which groups of fish are represented by most of the eggs. Copepods dominated the samples.

forming 57-921 of the zooplankton community. "A total of 6 species was observed. Time did not allow a detailed study of species abundances at all stations." Consequently, one station out of nine was randomly selected from each period for quantitative analysis. In addition to these counts, all samples collected in January were scanned to form as complete a species list as possible. On the basis of these data the species most numerous, those commonly observed, and others occasionally found, are listed in Table 4.1. 13-29 ---Page Break--- TABLE 4.1-6, Summary of densities of fish eggs sampled at Cabo Rojo. 4.1.4 DISCUSSION The diversity of zooplankton and the levels of their abundances at Cabo Rojo within each sampling period were similar. Somewhat higher average abundances were noted in January and November. The range of density encountered among the stations was not associated with nearness to shore, depth, or current flow. This lack of pattern suggests that the density fluctuations probably present the patchy dispersion commonly observed among planktonic organisms. 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, 30 ---Page Break--- TABLE 441-15, Copepod populations at Cabo Rojo Platform. a Species usually most numerous (> 5 individuals /e3) Clausocatanus furcatus Faracalanus spp. (P. aculeatus, P. crassostris, P. parvus) Farranal grec ants pee femora turbinata Species commonly present (observed among 6 or 9 stations and 3 or more sampling periods) sein ynjaegs eed eee PP) Species occasionally present Euchaeta marina eae Tatar rseaT snus Thor Beolectthrfs datae Mivecia effets a pF fete spe. Gandacia pachydactyla Hecynsosie els 31 ---Page Break--- eser ore Sort uss ers cunt Sho Z3e SLUT nse nes 908 surest sss nse tock 6sh Tes tert th SEE Tae ozs ont nue0se oon TIS neo nee aetE gen bmn BRL ETS Tere m@ BE senor ses een 00g ene GLOT TRST 664 BENE TOME seer sutosr “ z 6 8 8 6 7 © F 29 ao e300 SES BES eS enor 93048350 soy, s20ysxE9K, smoy sreoytday axoysaon (qayaeqana) Wonyuvidoor go woqeru THIOL aes STevE zt ct za0" 90" tho" Loz" oso" = ett a 190" seo" 60° Lz0" 20" 90" zo" 20" $50" seo" Teo" ao" tp 08 z90" ss" 10" Reo" Tso" neo" B50" Z90" ERO 960" sho neo" uno eso" cho" ‘n90" 620" 990" 90" 960" Z60" S80" eo uo tor 7 @ °° 8 8 *w © + 38 e 8 oad TOS BEARS Teas exo, 23048530 soy, axoysaeoy snoy saeoyTdey euoqsseox TeiOssUTa OFC Ome) (gu/Ta) woaqueTdoce Jo eama0yq THIOL ote save ---Page Break--- ee woe on 8 a a eer cor 8 ser se ~ an ce cr en ust ee 8 6 ye + 9 @ *s ae SERRE TSTRS seo, suoyszee, sox sxboptdey ssoyszeey (gu/aoqanay wexquetdozeu go Tequna Teron errs Te Best Tens ease 90e din amu u062 seer 98k use mane. corte - mcr ncr09F T 2 ano 03 BIS wroH ETE ofoy ORE) (,u/aeqU) uosxumTdoTeY Jo TeTSW TeioD 33 ---Page Break--- ur 8 ost oor sez - sst 6. 8 9 6 7 t 39 % eC oar svoj axoyaseey sno, sxe0;tdey sacysaEeN {,a0r/aeqana) syseufoseeys go weqana Toso] Tet TMVE 199 ers uoe ext ser tes sez Fa 9st zen nae me ose we su see eee sz, 09 Ltt s90r mes = ere ncrost “ z oe 8 § se t 29 © rr! Opes RTS

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communities. Quantitative samples, when taken, were replicated to assess the magnitude of sampling variability. No permanent stations were established nor was any single area visited in all seasons; consequently, no data on seasonal or other temporal changes in the benthic communities are available. 4.2.2. MATERIALS AND METHODS Field Procedures Field stations at the Cabo Rojo Platform site are shown in Figure 4.2-F1. Field procedures are divided into three categories: shore surveys, transect dives, 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 lab. The shore biota investigated at the Cabo Rojo site were the mangrove root communities and shoreline fishes. Transect dives. Transects were traversed on a predetermined compass direction by two divers either swimming or propelled by a diver propulsion vehicle (DPV). Notes were taken on depth, bottom type, topography, and dominant or unusual organisms. Station dives. Dives were made at various stations to collect qualitative and quantitative samples. Quantitative samples were replicated whenever possible. Gorgonians were collected at Stations 3 and 9 in 5 m² (1 x 5 m) or 10 m² (2 x 5 m) subsamples. Gorgonians were collected from a total area of 10 or 20 m² at each station. A qualitative sample only was taken at Station 8. 38 ---Page Break--- Fig. 4.2-P1 Benthic studies field stations at the Cabo Rojo Platform site. ---Page Break--- All large macroinvertebrates were collected in 10 m² (2 x 5 m) quadrats at Stations 4 and 6. All macroinvertebrates were surveyed in a Thalassia bed (Station 1) in three 50 m² (2 x 25 m) quadrats. Photographs were taken to aid in gaining a general description of the area. The presence and absence of the larger invertebrates and fish were also noted whenever possible. 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. Samples were often frozen prior to sorting. Taxonomic references used to identify organisms are listed in the bibliography. 4.2.3 RESULTS AND DISCUSSION The Cabo Rojo Platform site encompasses a large variety of benthic habitats, mangroves, seagrass beds, soft-bottomed basins, and coral reef communities. Organisms observed on mangrove roots in a small bay bordering Punta Ostiones (Station 1) are listed in Table 4.2-T1. Organisms observed are commonly found on mangrove root communities in embayments (PRNC, 1972). Except for filamentous algae, few organisms were found on mangrove roots at Punta Ostiones, a few hundred meters away. This large difference in mangrove root communities agrees with observations by McNae and Kalk (1962), who found that no unique community is associated with mangrove roots, but rather that the composition of mangrove root communities is dependent upon other environmental parameters. Similarly, mangrove root communities differ greatly in species composition in Jobos Bay depending upon location. Shoreline fishes collected with rotenone at Punta Guanaguilla are listed in Appendix 4.24. Gorgonians sampled at Station B, an inshore reef, are listed in Appendix 4.B. Over 80% of the colonies were represented by two species: Pseudopterogorgia acerosa and Pseudopterogorgia americana. Gorgonians collected at a deeper offshore reef, Station D, are also listed in Appendix 4.26. The more abundant gorgonians at Station 9 were Pseudopterogorgia acerosa, Eunicea tourneforti, Funicea laxispica, and Pseudoplexaura salyculata. However, the relative abundances of gorgonian species were not significantly correlated at the 0.05 level between replicate samples. A sand-mud mixture dominates the substrate in the two basins of the Cabo Rojo site (Stations 4 and 5). TPOLE. RTL Vangrove records orranfans observed at the Cabo Rojo Platform site Station 1. PANT xIneoS Phylum SkeJophyta Acanthophoma sp. Taurenc Phylum Mollusca Phylum Arthropoda Batanus 29. Rratus planus: Packyrnapens Phylum Chordata Botrytis planus an ---Page Break --- REFERENCES Ahistrom, D.H. and J.R. Thraikill, 1962. Plankton volume loss with time of preservation. CALCOFI Rept, 9:57-73. Almy, C.C., Jr, and C. Carrion-Torres, 1963. Shallow-water Stony Corals of Puerto Rico. Carib. J. Sci. 3(243):133-162. Anikouchine, N.A, and R.W. Sternberg, 1973. The World Ocean: An Introduction to Oceanography, Prentice-Hall, Inc., Englewood Cliffs, N.J. Bailey, R.M. (Chairman), 1970. A List of Common and Scientific Names of Fishes from the United States and Canada (Third Edition. Amer. Fish. Soc. Publ.) No. 6:1-149. Bayer, F.M., 1961, The Shallow-water Octocorallia of the West Indian Region: Martinus Nijhoff, The Hague, Netherlands. Bigelow, H.B. and N.C. Schroeder, 1953, Fishes of the Gulf of Maine, Fish and Wildl. Serv. Fish. Bull. 74, Vol. 53, U.S. Dept. of the Interior, GOP, Washington, D.C. Bohike, J.B. and C.C.G. Chaplin, 1968. Fishes of the Bahamas and Adjacent Tropical Waters. Acad. of Nat. Sei. of Phila., Livingston Publ. Co., Wynnewood, Pa. Breder, C.M. Jr., 1948. Field Book of Marine Fishes of the Atlantic Coast, G.M. Putnam's Sons, New York. Briggs, R.P. and J.P. Akey, 1962. Hydrogeologic map of Puerto Rico and adjacent islands. Atlas NA-197, U.S. Geological Society, Washington, D.C. Briggs, R-P., 1965. Geologic Map of the Barceloneta Quadrangle, Puerto Rico: 12142. U.S. Geological Survey. Brinton, E., 1962. Variable factors affecting the range and estimated concentration of euphausiids in the North Pacific, Pac. Sci. 16:374-408. Brock, V.B., 1954. A preliminary report on a method of estimating reef fish populations. J. of Wildl. Mgmt. 18 (3) 297-308. Brooks, J.L. and S. L. Dodson, 1965. Predation, body size, and competition of plankton,

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KINGDOM Phylum Porifera Axinelia polyeapella Chondrilla nucula Desmapsama anchorata Falkorona rubens Walictona vindia Halictonia molitba Unid. Haliclonidae sinacidon sp. ifeate gatos Microciona sp. ‘Trachygellius sp. Verongia sp. Under Fossiliosalerina Unid. sponge Sponge fragments Phylum Cnidaria Diodogorgia nodulifera Phylum Echinodermata Oreaster reticulatus = eribulotdes Phylum Chordata Microcosmus helleri ‘PLANT KINGDOM Halophila baillonis 23 STATION 4 30 May 1974 2g. wet weight su 36 2.0 832 1.0 10.0 370 867 51.5 2 138 STATION 5 40 May 1974 &. wet weight 25.0 26.0 31.6 ---Page Break--- [APPENDIX 4.20, Smaller invertebrates collected at the Cabo Rojo Basin. ANIMAL KINGDOM Phylum Porifera Signadocea caerulea Phylum Cnidaria Diodogorgia nodulifera Echinodermata Phylum Sipunculoidea Sipunculid sp. 7 sipunculid sp. Phylum Echinodermata nid. Echinodroid Phylum Annelida Eunice sp. Fineris sp. Unid. world Poratostegus otellatus Unid. Serpulid Unid. sy2iia Unid. Ferebert Phylum Mollusca Class Gastropoda Mabina cerithidiodies Galatostoma Jujubius Sulypeten cements Grepitate aculeatus Sine a bedded spines Tiracle figis bieeatea fants ora Taner brevifacies apes Pecurvivestis rubrioculea sp. Silvera perplexa Wavincing cancetiata Torebra protexta ‘Turletia variegata Veracutenta Keeest ie boats 74 STATION 6 STATION 5 ---Page Break--- APPENDIX 4. D (continued) Phylum Mollusca (continued) Class Pelecypoda Acquipecten musosus Anadara notable Ansalara: tranaversa Knodontta alba imbricata Barbatia domi Sarbatia tenera Family Cordidae Chata aacerophylla Fae sles Chione lacilinata ‘Chione sp. Sodeida gacttnenta Cris ibaea Set Pyne Brassata La guadalupeensis Caen Sesion getting sens Sat eu Tevieaeae op. ries a rere 5 Tyropecten ~ Warum Tysonta Beara Mucalana acuta Getren queria Papyridea soleniformis rape prmnidce Placticula gibbosa Feeudochona radians jenele purpura Feilina alternata Telitna sartiavcenots: Telling sera felling ope Trangennelia stinpsont Telgontocardia ant ftiarum 75 STATION 6 STATION 5 ---Page Break---

APPENDIX 4.20 (continued) STATION 6 Phylum Mollusca (continued) Class Cephalopoda Pontaliun gouldi portoricense. x Phylum Arthropoda Class Crustacea Tatreutes parvulus x Syoalpheua aploceros x Sangha sino Phylum Echinodermata Amphiura sp. ‘Spetoehrix sngutaca ‘pitochate Breclyactte Phylum Chordata Und. Ascidians Merceosmus 16 STATION 5 ---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 employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.” ---Page Break---