PRNG ~ 174 PUERTO RICO NUCLEAR CENTER PUNTA HIGUERO POWER PLANT ENVIRONMENTAL STUDIES 1973-1974 Prepared for the Puerto Rico Water Resources Authority By the Staff of Puerto Rico Nuclear Center of the University of Puerto Rico ‘OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. AT (40-1)=1833 FOR U S ATOMIC ENERGY COMMISSION ---Page Break--- ---Page Break--- PRNC ~ 174 PUNTA HIGUERO POWER PLANT ENVIRONMENTAL STUDIES 1973-1974 Prepared for the Puerto Rico Water Resources Authority By the Staff of Puerto Rico Nuclear Center of the University of Puerto Rico May 1974 ---Page Break--- ---Page Break--- PUERTO RICO NUCLEAR CENTER PUNTA HIGUERO POWER PLANT ENVIRONMENTAL STUDIES 1973-1974 Prepared for the Puerto Rico Water Resources Authority By the staff of Puerto Rico Nuclear Center of the University of Puerto Rico - May 1974 ---Page Break--- ---Page Break--- vii PREFACE This report stems from investigations being 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. This report is the combined effort of the scientists, engineers, and support staff of the Site Selection Survey Project: B.D. Wood, Project Leader Physical and Chemical Parameters March J. Youngbluth Zooplankton Vance P. Vicente Benthic Invertebrates F.D. Martin Fish Made Cancy Terrestrial surveys Alina Samant Froelich Benthic Invertebrates Report assembled by B.D. Wood ---Page Break--- ---Page Break--- TABLE OF CONTENTS Preface 6.1.2.1 Physical and Chemical Parameters Physical parameters a. Tides b. Currents Dye releases 7-8 October 1972 Current meters 30 October - 2 November 1972 Current meters 17-19 January 1973 Current meters 7-8 June 1973 Current meters c. Bathymetry d. Temperature and salinity e. Temperature salinity Density, f. Marine Geology and Sediment Transport g. Chemical Parameters Dissolved oxygen Reactive phosphate 6.1.1.2 Biological

Parameters - Marine 8. Phytoplankton (No PRC input) 1b. Zooplankton Introduction Materials and methods Laboratory procedure Results Discussion Limitations of the data References cited ©. Benthic Invertebrates Introduction Materials and methods Formats Station A, Station Ay Station B, Station C, Station Discussion References 25-28 June 1973 5-26 January 1974 2-28 June 1973 25-28 June 1973 1-16 January 1974 ---Page Break--- a. Fish Collecting sites Additions to the fish species list 6,144.3 Biological Parameters - Terrestrial, Introduction History Plant communities Secondary successional for Probable unavoidable adverse effects Possible remedial actions APPENDICES Appendix A Current studies: Hydrographic data Appendix B Plant kingdom Animal. Kingdom Appendix C ‘Terrestrial photographs (Original photographs sent to PRWRA) Appendix D Preliminary Observations of the Benthic Communities of the Punta Higuero site. 104 207 13 15 July 328 30 ---Page Break--- MEASUREMENTS AND MONITORING PROGRAMS OPERATIONAL ENVIRONMENTAL PROGRAM Surface Water Physical and Chemical Parameters Physical Parameters Pta. Higuero commonly referred to as “Rincon” or the "BONUS site” is the most westerly point on the Island of Puerto Rico (Fig. 1). Some environmental work has been done in the Pta. Higuero region related to the construction and operation of the BONUS-Reactor power plant. Data from independent studies in the Mona Passage are also available. The Puerto Rico Nuclear Center has been collecting and analyzing data from the immediate region of Pta. Higuero for about one year on a regular basis. The nearshore currents have been measured on several occasions. The factors affecting nearshore currents such as winds, tides, bathymetry, and density structure of the water column have been studied and are being presented here. The tidal excursion at Pta. Higuero is on the order of 30 cm and its period is semi-diurnal. The tides here were not measured, but can be calculated from the San Juan tidal data. Calculated tidal data (Fig. 2) are presented for the period 6/7/73 to 6/8/73 relating to currents covered in the following subsection. In addition, a plot of the tides for the month of June, 1973 is shown in Fig. 3 to cover lunar cycles. Currents in general, the currents are toward the west, both north and south of Puerto Rico. The current north of the ---Page Break--- "Rincón (Rincón), west coast of Puerto Rico. 61°20" DISTANCE (nautical miles) ---Page Break--- TIOWBTH "wid 9 ELET "B-L ome wooN 04 wooN poRLOM 943 LOS STAAOT OPFT PeUBTHOTEO = 2 +H ---Page Break--- Fig. 3 - Calculated tides for Pte. Higuero for the period May 28 to June 24 to show the variation over a lunar cycle. ---Page Break--- island, eddies around Pta. Borinquen in Aguadilla Bay and westward north of Pta. Higuero, the current along the south coast turns northward through Mona Passage and is generally to the north along the west coast of Puerto Rico with numerous eddies and reversals in the nearshore waters because of a complex bottom topography, tides, wind fluctuations, and surface runoff. These two currents tend to meet at Pta. Higuero and turn westward, although the convergence has been observed to oscillate from south to north depending upon wind and tide conditions. The currents off Pta. Higuero have been measured on five different occasions. In the fall of 1972, the currents were measured using dye drops and aerial photography. Eight drops were made on the afternoon of Oct. 7, 1972 and photographed periodically for about two hours. The results are tabulated in the Appendix and shown in Fig. 4. There was a 4.5-5 m/sec. wind from the south and the beginning of a flood tide which caused the surface waters to move north at 15-30 cm/sec. The following morning, a similar drop pattern was repeated and followed photographically for about two hours Fig. 5. The same current trend was seen. The wind had been near calm, then picked up to 5-5.5 m/sec. The drop began. The tide was high slack. The currents north of Pta. Higuero were

sluggish, moving north and west converging with the north flowing west coast current. the offshore ---Page Break--- DISTANCE (nent) ---Page Break--- Fig. 67°20" i 5 + Dye Study at Pt. Hignero Morning of 8-X-72. ---Page Break--- 3) currents were nearly twice as strong as in the nearshore region, current Meters October 30 ~ November 2, 1972. two current meters were anchored very near station FiT-NA (Fig. 1) at depths of 3 and 6 m. The tides (plotted from tide book - appendix) were semi-diurnal with highs at 0400-0700 and 1500-1800; lows from 0900-1200 and 2200-2400. The average range of the tide for this period was about 33 cm, and the average water level was about 21 cm. Maximum flood was about 0300 and 1300 with maximum ebb near 0800 and 1900. It is the convention to describe water currents by the direction they are traveling and wind by the direction they are from. However, in order to correlate wind and currents, both will be described by the direction they are traveling. The station log data in the Appendix retains the "from" convention for winds. The nearest source of wind data was Raney AFB. The air surface winds are plotted in the Appendix. The direction was to the west northwest at about 3.5 m/sec. The winds were generally strongest and about 1. from 1000-1600 at about 5.1 m/sec. during the early morning hours. A combination of wind and tide should give the strongest currents about noon. However, the nearly ---Page Break--- 4) three days of continuous recordings (Appendix) showed that the strongest currents (M6 cn/eee.) were about 0400 to the north at 3m. The highest velocity at 6 m depth was 25 cm/sec. In general, the strongest currents were to the northeast. The 3 m currents oscillated between NE and 5, while the 6 m currents were between E and I. The average 3 m current was about 23 cm/sec, and the average of 6 m current was 1 cm/sec. The 3 m current was about 80% of the outer surface current measured October 7-8, there was a weak trend for the highest velocities (3 m) to the north to coincide.

With the slack tide, current velocities (3 m) were to the south. At low slack tide, the trend was less pronounced. Currents at 3 m and 6 m were directly opposed on several occasions. One of these times was during a rim current when the surface wind at Ramey was calm. This trend was common on several occasions. It may be that the winds to the west over Aguadilla Bay retard the northbound currents west of Playa Higuero so that when the wind calms, it allows high flow to the north.

Current meters January 17-19, 1973. Current meters were suspended from an anchored buoy at station FI-NA during the period of cruise FA-021. The tides were more extreme during this period than during the Oct.-Nov. 1972 sampling periods. The maximum range was 76 cm with the average range 13 cm. The average water level was 15.5 cm. The period of maximum flood was 0500 and maximum ebb about 1200. The winds were generally to the west and northwest at velocities from 0 to 7.6 m/sec. Winds recorded on the ship, together with the Ramey AFB surface winds, are plotted along with current data in the Appendix and show only general correlation. There were several brief occasions when the wind was to the east during the sampling period. Average velocity and directions were 2.7 m/sec to the west. Surface currents were variable from NE through south around to NW, the average velocity and direction were 27 cm/sec to the SE. The strongest currents were 66 cm/sec to the NE, and the weakest surface currents were 15 cm/sec to the south. No direction was available for the 3 m depth, but the velocity tended to follow the surface currents in pattern at about 15 cm/sec, or about 56% of the surface current value. Great differences are seen in both the current velocity and direction between the surface and 6 m depths. The average velocity was 18 cm/sec, about 67% of the surface average. The direction varied between NE and NW with the highest velocities to the SE. Flow in opposing directions was frequent between surface and 6 m.

Also, when surface currents were strong, bottom currents were weak and vice versa. There were periods when the surface currents appeared to be onshore coinciding with offshore currents at depth. The currents at Pta, Higuero were measured for a 24-hour period, noon on June 7, to noon on June 8, 1973, at four depths with General Oceanics inclination meters. The data were recorded on film at 2-minute intervals. In computer reducing the data, every nine points were averaged to smooth the data and reduce computer and plotter time. The data are presented in three forms: 1) Current velocity and direction are plotted separately against time. An independent plot is given for each depth and each day (Appendix). 2) A progressive vector for each depth, combining velocity and direction, is shown in Fig. 6. The times are indicated. This approach treats the water passing the current meter as a point in motion which may not be exactly correct, but does give the reader a feel for the extent of water movement. The four depths are plotted on one page with a land reference drawn to scale. ---Page Break--- as Fig. 6 = Progressive vectors for currents at four depths (2, 4, 7, and 13) at station PHI-4 on June 7-8, 1973, 24 hrs. The current vectors were summed in 10° increments and plotted on a "compass rose." A separate plot for each day and each depth is given in the Appendix. The currents during the period measured were strongest to the north. The changes in velocity and direction were periodic and appeared to be related to tide. The afternoon period of northward flow was faster and more erratic than the morning period, probably due to the influence of wind. Surface velocities reached a high of 60 cm/sec in the afternoon, but were more commonly 40-50 cm/sec during the northward flow. During the slack periods between northward flows, the currents were weak at about 10 cm/sec, generally southward, but the direction was

sporadic. In the progressive vector plot, a noticeable trend toward right-hand twist to the current with depth exists. This appears to be a Coriolis effect. The WAV R.F. Palumbo was anchored about 250 meters west of the current meters during the period of data collection, releasing dye continuously and collecting surface weather data. The direction of flow, as indicated by the dye release, coincided well with the data from the surface current meter. The dye was not traceable for any great distance as it was dispersed and diffused within about 0.5 km of the point of release. The release was photographed from an aircraft periodically during daylight hours. Summary of Current: The currents at Pta. Higuero have been measured on five occasions during three seasons with varying wind and tidal conditions. The currents are generally strongest to the north during flood tide. Weakest currents are during ebb tide to the south. Generally, good mixing can be expected in the waters of Pta. Higuero with an ultimate offshore movement of surface water. The highest currents observed were 60 cm/sec (2.2 kt) to the north. The northward flow was about 25-30 cm/sec, while southward currents were 10-20 cm/sec. At 28 cm/sec, a body of water would flow about 4 km in a one-hour period, typical of flood tide currents at Pta. Higuero. The data also show that there may be periods of nearly four hours when very little water movement occurs. With this in mind, a heated water discharge should be far enough offshore so that the build-up of heated water during slack periods would not seriously affect biologically sensitive regions. In addition, the discharge velocity should be sufficient to cause rapid initial mixing (150-300 cm/sec). An alternative would be a diffuser discharge. Current Measurements: Current measurements will continue at Pta. Higuero generally on a quarterly basis. The period of sampling will increase up to about one week at a time, and the points of current meter locations expanded to better define the

currents in the region of convergence off Pta. Higuero, Dye releases and aerial photography coincidental with current meter measurements will be used to determine flow past a point, path of a point in motion and mixing characteristics of the body of waters. Bathymetry The Puerto Rico Nuclear Center has undertaken no detailed bathymetry of the Pta. Higuero region to date. Beyond that done during benthic samplings, the C&GS chart 901 (Fig. 1) has been found to be adequate for most work. The narrowest shelf (400 m) on the island of Puerto Rico is just south of Pta. Higuero in the region of Corcega. The narrow shelf gradually widens to about 5000 m off the point, then turns east and narrows to about 3000 m north of Pta. Higuero. Now that a recording depth sounder is available on the AMV Altana, detailed bathymetry is planned for the region; the bottom traces will be correlated with photographs taken by swimmers. Temperature and salinity Hydrographic cruises have been made to Pta. Higuero quarterly since January 1973 except for the fall quarter of 1973. Temperature and salinity were measured at 70 depths on each cruise. Three stations on each of the 6 transects 2-6 (Fig. 1) were sampled each time collecting data from the surface to 10, 100, and 300 m for A, B, and C stations respectively. Fifteen surface samples were measured for temperature and salinity. Temperatures are measured using oceanographic reversing thermometers with readings good to ± 0.03 °C. Salinity samples are returned to the laboratory and determined with an induction salinometer to an accuracy of ± 0.005 /ooe. The data for the four cruises (PA-021, PA-OPT, PA-033, and PA-036) are found in the Appendix along with the plots of temperature, salinity, and sigma-t versus depth. Sigma-t, St, is a measure of the water density, Pt or (A-1x? a). Sigma-t indicates the stability of the water column. A gradual sigma-t gradient with depth indicates a well-mixed or unstable condition, whereas a high gradient is indicative of a very stable portion of.

the water column, ‘The near surface mixing zone varies from 50 m in the summer to about 130 m in the winter as shown in Fig. 7 by seasonal bathy-thermograph plots. The BY recorded temperature with depth as it was lowered and retrieved at the 300 m station: The BY data for all cruises are in the Appendix. 2) Temperature It can be seen from Fig. 7 that there is very little seasonal change in temperature below about 200 m, the mixing zone is the deepest and the surface temperature is the lowest in the winter season with surface warming in the spring. ‘the ---Page Break--- Fig. 7 -

Corrected bathythermograph trace from FAI-3C for the sampling quarters: Bl, T3-2, 73-3 and Thal, wo 2 hb ww uv ---Page Break--- shallow mixing zone and the highest surface temperatures occur in the summer followed by a return to winter conditions through the fall. The winter-summer surface temperature difference is about 2.5 °C, 25-285 °C, Some of the BT traces show a sharp break in the temperature gradient at about 225 m which indicates a shear zone between two layers of water, ‘the shear zone is 30 to 50 m thick. Surface temperatures vary by less than 0.5 °C in any one quarter sampling and relate as well to time of day as to their lateral distribution (Fig. 8) except for the spring sample PA-O27 when a tongue of warm water appeared north and east of Pta, Iguero to include stations 4B, 5B, 50 and 6C (Fig. 9). At least part of this difference can be explained by the fact that transects PHT-2 and 3 were sampled a day after PHI-1, 5 and 6 when the air temperature was about 3 °C lower than the first day, 27 versus 30. Table 1 gives an “average” temperature for the depths measured plus the range over the year. The wide range near the surface is due to seasonal changes. A wide range is seen at the 150 m depth also and is due to high gradient, thermocline, at this depth and the fact that the depth of the thermocline (Fig. 1) changes from station to station, The range narrows below 260 m and one finds greater differences between stations in

any one sampling period than between seasons. ---Page Break--- w shop 30 omy youuu PonzoTd oath “wg 03 sovTnio mmoz maj somyUedaR, gous - Tia ---Page Break--- 61°20" ast Oo] + pigs 9 murface temperature distribution, %, for Pia. Higuero May 1-2, 197k, PHT-T3-2. DISTANCE (nomi) ---Page Break--- ‘TABLE 1 ‘Temperatures at Pta. itiguero, averaged with depth and ranges for the year 1973-7 ‘Temperature, “C Depth Average Range « s Ar ° 27.2(5) 2.8 = BT 29 25 21.2(0) 2.9 = 85 2.6 50 27.2(0) 5.9 = 285 26 100 25.9(0) 25.0 = 6.8 18 150 22.0(5) 2.7 = 23h a7 200 29.8(5) 19.3 = 20h aa 250 17.9(0) w6 - Be 6 300 26.95) WT - Te 5 ---Page Break--- Fig. 10 ~ Temperature, Average, and Range for the year 1973-74 ® plotted against depth for Pta. Higuero 618 20 22 ah 5 BB 30 rc oH Fig. 11 - Salinity, Average, and Range for the year 1973-74 plotted against depth for Pta. Higuero 35.00 36.00 37.00 .8*/oo ---Page Break--- 3 2) salinity The salinity of the surface waters of Pta. Higuero varied from 35.00 °/oo in summer and winter to 35.90 "/oo in the spring, reflecting the heavy runoff from June to November and the relatively dry season, December through May. The averages and ranges of salinities with depth are listed in Table 2 and plotted in Figs HL. the average salinity is constant at 35.5 °/oo in the mixing zone (50 m) then increases rapidly to about 36.45 °/oo at 130 m. A further increase to 36.7 °/oo is observed at 200 m with lower salinities to 300 (38.2 °/oo), salinities at 200 m have been measured as high as 37.00 °/oo. This is usually at the deep stations north of Pta. Higuero. The high salinity water between 100 and 250 m originates in the tropical Atlantic and flows westward north and south of Puerto Rico. Mixing in the Mona Passage probably accounts for the generally lower salinities at 200 m south of Pta. Higuero. 3+ Density, As mentioned above, the stability of the water column is determined by density differences. Density expressed as sigma-t (Equation 2) is a function of temperature, salinity, and to a lesser extent, pressure.

A plot of temperature versus salinity is shown in Fig. 12. ---Page Break--- BSSRER see TABLE @ salinities for Pta, Higuero, averaged with depth and ranges for year 1973 - The Range: 35.0 = 35.9, 35.2 = 35.8, 35.3 - 37.4, 36.8, 35.7 = 36.6, 36.6, 36.8 - 37.0, 36.4, 36.2 - 36.5, 36.2, 36.0 - 36.3. ---Page Break--- Fig. 12 - A diagram showing visually averaged temperatures and salinities for four sampling quarters at Pt. Higuero. Diagonal lines show the density factor, sigma-t. Salinity, Temperature °C. ---Page Break--- Each line is the average of the data collected at the "C" stations for each cruise. The greatest seasonal density difference is in the surface waters denoted by "A" on Fig. 12. Each lower sigma-t is seen in the summer data (73-3) where σt = 22.4. Even though the temperatures and salinities do differ for the winter and spring data, sigma-t does not change appreciably, 25.1 = 23.3. This dry season-wet season difference in sigma-t probably accounts for most of the difference seen in the monthly mean tide levels. The monthly mean tide levels are generally low in the winter-spring (dry season) and high in the summer-fall (wet season). The difference in sigma-t decreases with depth from "s" to "c" and is nearly uniform throughout the year below "c". Temperature and salinity measurements will continue on a quarterly basis at Pta, Higuero to determine seasonal variation and will be expanded to better explain mixing processes that occur in the convergence of the west coast current and the north coast current. More detailed nearshore temperatures will also be taken; the region has been scanned on three occasions with an aerial infrared camera (9/73, 11/73, 3/74). The surface temperature distribution patterns from the scans are being worked up. ---Page Break--- 8. Marine Geology and Sediment Transport No FRNC inputs. Chemical Parameters: Dissolved oxygen (O2) and reactive phosphate (PO4) were determined at the same time and depths that temperature and salinity were measured on all cruises to Pta.

Higuero, as part of the regular hydrographic work, ALL of the data are listed and plotted in the Appendix. Dissolved oxygen is given in mg/L, m/e (commonly called ppb even though it is incorrect), and percent saturation. Reactive phosphate is given in µg/L. Dissolved Oxygen: the amount of dissolved oxygen in seawater was determined by the standard Winkler titration method. In addition, oxygen on the Pi-Th1 cruise was measured with a YSI probe on the same samples that were titrated. A comparison of the two methods is plotted in Fig. 13. The agreement is fairly good; however, the titrated values are consistently higher than the probe values. Since the titrated values are at or near saturation in the surface waters, they appear to be more reliable. The oxygen concentrations were near saturation in the surface waters (6.7-7.0 mg O2/L). Some supersaturation was noted at 25 to 50 m due to photosynthesis (1031). A typical plot of oxygen versus depth is shown in Fig. 14. Below about 100 m, the concentration of O2 decreased to a minimum of 9475 ng O2/L, 70% saturation. At 300 m, the lowest surface O2 was no lower than 95% saturation and may have been due to the BOD of surface runoff. Reactive Phosphate: Reactive phosphate was determined by the Murphy and Riley molybdate complex method using a Beckman DU spectrophotometer. Phosphate can be determined rapidly with good accuracy; there exists a good relationship between phosphate and nitrate in seawater (1:24) so that phosphate can be used as a nutrient indicator. Phosphate is very low in most surface waters of the Caribbean except near very highly populated regions. Surface values characteristically range from 0.05 to 0.8 µg-at. PO4/L from surface to 100 m. A slight increase in PO4 occurs at 150 m, followed by a steady increase to about 2.90 µg-at PO4/L at 300 m. A typical plot is seen in Fig. 28. Phosphate is withdrawn from the surface waters during photosynthesis, incorporated in biota which sinks and decomposes, using up oxygen and releasing nutrients into the

vater column, the turnover rate of the near surface nutrients is vastly rapid to allow what little productivity there is to occur, probably a matter of hours or a few days at most. The distribution of phosphate in the surface waters seems to be spotty as in plankton. Probably low phosphate conditions exist where productivity is active. ---Page Break--- The chemical parameters of dissolved oxygen and reactive phosphate will continue to be sampled as part of the quarterly hydrographic work with attention given to diurnal changes and possible sources of nutrients or BOD from terrestrial sources. ---Page Break--- ---Page Break--- Hg 10 - bioluminescent oxygen and reactive phosphate typical in the Permittees region, Wis), ve 2 Puy 3 ---Page Break--- 32 PLANKTON SURVEY AT THE PUNTA HIGUERO SITE, I. Standing stock estimates of the major taxonomic groups. By Marsh J. Youngbluth INTRODUCTION The following report provides quantitative estimates of the biomass and number of zooplankton collected in the surface waters near the coast. The data represent one part of an environmental survey conducted by the Puerto Rico Nuclear Center in the vicinity of the proposed site for fossil power plants at Punta Higuero, samples were gathered on 5 days during 1973 - 17 January, 2 May, 16 August, 3 December, and 11 December. MATERIALS AND METHODS Plankton were collected with 1/2-meter diameter, cylinder-cone shaped nylon nets of two mesh sizes (64 and 202 microns). These nets were designed to reduce clogging error (Smith, Counts and Clutter 1968). The larger mesh netting retains most of the macrozooplankton. The smaller mesh captures the larger microzooplankton and phytoplankton. Nets of finer porosity are impractical to use in coastal areas since the mesh clogs very quickly. 221 samples were gathered in a standard manner, the nets were towed from a 17 ft. skiff in a circular path through the upper 2 meters. The speed of the vessel was about 3 knots (determined with a Sine yacht speedometer). The smaller mesh net was hauled for 5 minutes, the

larger ---Page Break--- 3 for 10 minutes. After each tow, before the cod end was removed, the nets were thoroughly washed by sea water with the aid of a battery-powered pump (12 volt, Jabsco water-puppy). Samples were preserved in 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 (General Oceanics, Model 2030) suspended off-center in the mouth of the net. One tow was made with each net at every station except in the area adjacent to the proposed site for the power plant (station 2), where triplicate tows were made with the coarser net. These replicate samples were used to determine the range of variability between six live tows and to provide more reliable estimates of the organisms present. The stations were situated in such a way as to sample within and around the area where thermal alteration is likely to occur (see Fig. 1). Station 1 to the north is upcurrent from the proposed site and should depict a plankton community unaffected by a pollution source. Plankton populations in areas downcurrent (station 3) and offshore (stations 4 and 5) may show pollution-related stresses. Laboratory Procedure Within 2 hours after samples were collected, the pH was checked and adjusted, if necessary, to 7.6. If a sample contained a noticeable conglomerate of phytoplankton or detritus, the zooplankton were separated by gently filtering such material through 202-micron mesh netting. Before estimates of biomass and numbers were made, all organisms larger than 2 centimeters, usually hydromedusae, ctenophores, or scyphozoans, were removed. ---Page Break--- PUNTA CADERA mo 7 NAUTICAL, He. MILE, Le the locations at Punta Higuero where zooplankton were collected. ---Page Break--- Biomass was calculated as wet volume (Ahlstrom and Threlkeld 1962). This wet volume was employed to measure biomass because it is quick and does not damage the organisms. Conversion factors for wet volume to wet weight or dry weight have been

determined from other studies of zooplankton along the south coast of Puerto Rico (see Youngbluth 1974). These factors are cited in a footnote on Table 1. ‘The number of organisms in the coarse net catches was estimated by Volumetric subsampling with replacement (Brinton 1962). Three aliquots from each sample were counted unless otherwise noted. The choice of which organisms are counted and identified to species needs some clarification. Plankton tows collect many different kinds of organisms. It is extremely difficult and time-consuming to identify all organisms to the species level. Fortunately, this is not necessary to detect changes in the abundance of the plankton community. Usually, the more abundant of the most numerous organisms receive primary attention. In the plankton, copepods are usually numerically dominant. In this report, the majority of these animals have been identified to species. Quantitative estimates of their relative abundances will be the subject of a later report. The other fauna have been grouped into two categories, being identified by their history and taxonomic position. Dilutions were made so that about 200-100 organisms were categorized into major taxonomic groups. All biomass and enumeration data were standardized to a per cubic meter basis or multiple thereof. Data were initially reduced ---Page Break--- saroayqoadsot s66or0 were 4640 828 3HRFON LID EW aHBFO 30K 03 SAMOA yan BuTRENAD s4OyRT TOTETIAND © sso wo ete fer oe KE euattt ero" - £0" vio 100" Oso" oo eno" neor 90" To" git GeO" 190° nue es02 - ow ve sev eLtOlt 2 on of ee ze Oe sive mae mrs T=aeS eno, 92008550 sroq, ex0ysz00H ono, savorrden, sot vON “ea/ts) vonconons 3p eeMBEY TeAE “TATE ---Page Break--- 37 with hand calculators (Hewlett Packard Model 35) and, more recently, with a larger computer (P10). See Appendix A for a listing of the program. A total of 96 samples were collected from five sites around Punta Higuero. Variations in the biomass and number of zooplankton from 27 coarse net tows are presented in this paper. An

Earlier report (Youngbluth 1973) discussed the zooplankton caught in coarse and fine net tows during January 1973. For the sake of completeness, data from coarse mesh tows taken at Punta Higuero in 1973 are included in this report. Because of time and manpower limitations, no further attention will be given to microzooplankton from the fine mesh tows for some time. The range of variation for those subsamples that were counted three times was always within the range expected for subsamples drawn from a Poisson distribution. Thus, counts were made on organisms from randomly dispersed populations. Previous testing and continual checks on the subsampling technique manifested that there is no significant variation between replicate counts or counters. Thus, three counts per sample are now made less frequently. The magnitude of variation among the replicate, inshore, and offshore tows and between inshore and offshore tows during each collection period was summarized by dividing the highest total number of organisms by the lowest within each set. Among the replicate nearshore tows, the factors were 2.5, 1, 1.9, and 1.2 for January, May, August, and December. ---Page Break--- These variations are similar to those observed at Quebrada de Toro, Punta Manati, and Tortuguero (see Youngbluth 1973). Among the nearshore tows, the differences were 3.0, 3.1, and 6.0 for May, August, and December. The ratio among offshore samples during May was 2.3. Thus it appears that there is usually more variation between tows from different stations than from replicate tows at the same station. Variation in terms of total numbers between tows at different stations must therefore be greater than 2.5 to be significant. Zooplankton biomass was usually greater near the coast. The largest concentrations were found just off the tip of Punta Higuero at station 2. Volumes in this area were 4 to 5 times higher in January and December (Table 1). In terms of numbers per cubic meter, 6 to 10 times more zooplankton were present in December (Table 2).

Holoplanktonic fauna dominated the catches, composing 58 to 97% of the total numbers nearshore and 61 to 85% offshore. Numbers per m^3 are listed in Table 3. During January and December, copepods accounted for about 60% of the zooplankton in either area (Table 4). In May and August, copepods composed around 60% of the zooplankton. Chaetognaths were abundant in January and May (Table 5). Larvaceans, Oikopleura spp. and Fritillaria spp. were proportionately most numerous in May and December (Table 6). Cladocerans were not conspicuous at any time of the year. Pteropods, mostly Creseis spp. and coiled forms, were an order of magnitude more dense in December than in other months (Table 7). The abundance of meroplanktonic organisms was low, and concentrations averaging 30 individuals per m^3 were common in May, August, and December (Table 8). About half this amount was recorded in January. Brachyura ---Page Break--- 39 LTT itt sow Bits gock gee eect cate ees 99. 6 tg Egor 290T Goer gté eo. eso 16 SUE oget a6 extout a a fe ae we suva mae ae Sra, exoys.r009 Saou over Toy axoyevay ¢& #90 wowueptoo: jo soqmu Tear +2 aTaVE ---Page Break--- ot ow lee got 6 on mS req, 9x0K530 glot got 2199 sist om Ed wn ez ak 066, 299 cy ox TS erog, sx04s-T00N 209 202d. ers. 262 oxet Sep 66 Stet me ae maT snoy sqeoytdou axous voy ort we 126 an we uate Egor €1s02 eLt0lt avo <2 206 wopuvetorod Jo coq Teak *E STEM ---Page Break--- x6 6 Sie S69 zecs 6599 eal arte - eect - gate 65 8 ety a a Elgort uw te oe eg Rot th TL eLs0z 8 fog Toth eutout 96 on of ote fe aoe toe sue Tones TRS Tone rex, 92098550 ray, axoyes¥0y Srex oqvorTioy ozoysvey = 40M spodiadoo go requ Twa “hy STEVE ---Page Break--- we ee aT ‘ray 2002550 a seat asoys.veH me 66 zot. 99 ete wee 869 ee ae mie snay sqvorTdo axoussvoN 60%, lax 69 me we. wart euare eLgont eut0lt sive 8 OF od syyMBoqowo Jo toqmE THEE *S gTEKL ---Page Break--- ait 2 60n wart eats cet. o> o> ELgont 9 BED GOT es02 Tit OTe ote extolt foe mete awa TmrRS snoy oquorTdoy axorveN (OT sod suvosvarwr Jo toqmu TeIOL *9RTENE

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Toueacis gloeehtt copeaeus pasifieus Coryeneus azilte Goryeneus spectorue oryoasus anglicus Toryeucus Fartamia gracilis Farranula =p. A Uidinula wigarts ‘amocalame minor Gentropages furcatus ‘Getosetmnss pero Tneleutia flavicomnts Catanopia americana Wacrosetella gracilis Mlcroseteria norvegica ‘Herovalanas longicomis Saat mages Bichaeta marina icalande of, sttematus Tabidocera spp+ Miracia efferata ‘Baterping acutifrons 52 ---Page Break--- 3 Previous stuites of zooplankton in the coastal areas of Puerto Rico faze restricted to the bays and shelf regions along the southwestern Portion of the island (Duran 1957, Coker and Gonzales 1950, Bowman and Gonzalez 1961, Gonzalez and

Bowman 1955). The species found at Punta Liiguero included many of those mentioned in the papers just cited, as well as those encountered in several recent surveys around Puerto Rico (Youngbluth 1973). The range of variability between replicate tows is similar to previous observations observed in other plankton investigations (e.g., the review by Wiebe and Holland 1968). The seasonal increase in the abundance of most zooplankton populations during December and January and the tendency for most groups to be more numerous nearshore probably reflect greater mixing of the water column and a higher level of primary production. 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, e.g., 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. The aim of the information gathered in these ways is necessary to interpret fluctuations in standing stock and diversity in relation to environmental changes and biotic interactions. ACKNOWLEDGMENTS Several people helped collect and analyze the samples, including Ramon E. Cintron, Lin Craft, Juan Miguel Munoz, Gary P. Oven, and Oscar Mendez Ortiz. The majority of the chaetognaths were identified by Dr. Jose A. Suarez-Cebro. Mr. Peter Willmann wrote the

program appearing in Appendix A Root Ms Asensio cheerfully punched data on computer cards, ‘This work was supported by Puerto Rico Water Resources Authority Contract No. At(IO-1)K079.
---Page Break--- ” Josquetomatos del Atlantico, Distribucion y notas cacontales de estetenatica. ‘Tarb. Inst. Español de Ocean No 37, pp. 1-290, Abletron, Es. and J.R. Thraikil, 1962, Plankton volume loss with time of preservation. CALCOPI Rept. 9: 57-736 Bjornberg, T.K.S. 1971 Distribution of plankton relative to the general circulation system in the area of the Caribbean Sea and adjacent regions, Symp. Invest. Res. Caribbean Sea UNESCO, Paris, pp. 343-355. Poway, TEs and J.C. Gonzalez, 1961. Four new species of Peoutocyclops (see Calanoida) from Puerto Rico. Proc. U.S. Nat. Mus. tip 31-59 Brinton, E. 1962, Variable factors affecting the range and estimated concentration of euphausiids in the North Pacific. Puc. Sol. 37: 1-10. Coker, R.E., and J.G. Gonzalez 1960, Limnetic copepod populations of HEnuA [ostoresconte and adjacent waters, Puerto Rico, J. Fish. Mitchel Sci. Soc. 76: 8-23. Duran, M. 1957, Nota sobre los tintinnoides del plankton de Puerto Rico. Inv. Biol. 0: 97-120. Gonzalez, J.C., and T.Z. Bowen 1955, Planktonic copepods from Bahia Fostorescente, Puerto Rico and adjacent waters. Proc. U.S. Nat. Mus. 117 (3513): 210-304, Pierce, Esl. and M.L. Wass 1952, Chaetognaths from the Florida Current and coastal waters of the Atlantic States, Dull. Mar. Sci. 12, 1-20. Guith, P.A.E., R.C. Counts, and R.I.

Clutter 1968. Changes in filtering efficiency of plankton nets due to clogging under tow. J. Cons. Perm. Int. Explor. Mer. 32: 232-248, Suarez-Cabro, J.A. 1955. Quetognatos de los mares cubanos. Mens. Soc. Búbana de Hist. Nat. 22; 125-280, Wiebe, P.J. and W.R. Holland 1968, Plankton patchiness: Repeated net tows. Limnol. Oceanogr. 13: 315-321. Youngbluth, M.J. 1973a. Results of plankton survey at Pinta Liguero, I, January 1973. Unpublished Report. Puerto Rico Nuclear Center. Bp wvr+ 19T3be Results of plankton survey at Bahia de Tortuguero,

Panta Minati, ané Quebrada de Toro, T. Jamiary and March, 4973. Unpublished Report. Puerto Rico Nuclear Center. 9p. Effects on ---Page Break--- 97ha, Plankton survey at the Islote Alto. I. standing stock percentages of the major taxonomic groups. Unpublished Report. Puerto Rico Nuclear Center. 18p. 19TH. survey of zooplankton populations in Jobos Bay. Unpublished Report. Puerto Rico Nuclear Center. 58 p. ---Page Break--- 3 © Benthic OCCURRENCE AND DISTRIBUTION OF THE MAJOR TYPES OF EPIBENTHIC COMMUNITIES AT PUNTA HIGUERO! by: Vance P. Vicente Benthic Overview ‘A decrease of electrical power has become mandatory in Puerto Rico, due to population growth and technological advances. A proposed site for a fossil fuel plant is located at Punta Higuero on the west coast of Puerto Rico. Sea water from the immediate area will be used as coolant and then discharged at temperatures above ambient. In the past, there has been much misuse of coastal waters by power plants, and their detrimental effect upon marine life has been well documented (Zieman 1970, Roessler and Zieman 1969). To prevent continuing adverse environmental impacts, it has also become mandatory to evaluate the ecological and economic character of existing marine communities before exposing them to industrial processes. The purpose of this study was to make a preliminary survey of the benthic communities at the Punta Higuero site. In order to study benthic communities adequately, three important aspects should be taken into consideration: 1) Determination of the types of communities, populations, and species of a particular area at a particular time, 2) Natural changes (i.e. seasonal) occurring within a particular community and within its components, 3) Their tolerance to the forthcoming environmental impacts. The present field study deals with the first of these aspects. For additional information consult a previous study of this site (Zieman 1972). ---Page Break--- MATERIALS AND METHODS sampling was done during two periods - 25-28 June 1973 and 24-26 January 1974. Three stations were

designated as sampling Station A, located north of the dam at Pinta Hguero; Station B, located perpendicular to the dune and slightly northwest of the Points; and Station C, located south of the Point (Fig. 1). Although basically the same method was used during both sampling periods, Station B was omitted from the second period due to unfavorable weather conditions. The field work involved a total effort of three divers and 69 man hours (48 man hours during the first sampling and 21 during the second). The survey was done using SCUBA apparatus, underwater cameras (Nikonos), and collecting bags. Data on the types of benthos, dominant species, types of substrate, and other geographical characteristics of the areas were recorded on an underwater plexiglass slate. Three transects were made. Each transect spanned a distance of approximately 1 nautical mile. The divers swam along the transects, taking pictures, sampling, and recording data. Benthic communities in depths from 3-27 m were surveyed in this manner. During the second sampling period, four samples were collected with a 1/4 m grid by removing all epibenthic forms by hand. A species list, biomass, and the relative abundance of each species were obtained from each of the samples. In summary, the results of this study are based on three aspects: 1) Field observations and notes. 2) The samples collected. 3) Detailed studies from the photographs taken of the area. Where otherwise cited, all photographs included were taken by Vance P. Vicente. 38 ---Page Break--- Ponta Itguore ---Page Break--- SOANTON A = 26-08 June 1973. The sediments characteristic of the bottom at such depths in Station A consisted of a sandy substrate except where sponge communities occurred. The sand consisted of large particles (approximately 1/2 cm) and could be classified as coarse sand, according to the Wentworth scale (Bird 1969). On the bare spots, wide ripple marks (wave length of .3 - 6 m and wave height of a few centimeters) were observed, arranged in a westward direction. A thin layer of

Precipitated organic sediments covered the substrate. On some sections, this layer had a green tinge probably due to small filamentous algal forms. Dominant Organisms: Sponges. As mentioned before, sponges (Porifera) were the dominant group, particularly the basket sponge Xestospongia muta; however, other forms were quite abundant, including Sbecctomponcia veparia, Neofibularis massa (stinging sponge), Incinia sp., and Verongia sp. (Fig. 2). Two other groups of organisms were present despite their limited distribution at such depths: the red algae. ---Page Break --- The sponges X. muta (basket-shaped) and Verongia sp. (tubular shape in the lower left corner) at 2 ---Page Break --- Laurencia intricata covered some parts of the bottom, and sediments covered some of the sponges, and to a lesser extent the brown algae Dictyota dentata and others. Coral (Octocorallia): one gorgonian was observed at this depth. This was Pseudopterogorgia sp. ALGAL COVER; SPONGES substrate: the bottom at these depths was practically all covered by algae and sponges. The substrate is covered by sand but the inner substrate consisted of hard rock. Detrital algae: Most of the bottom substrate was covered by an aggregation of algae. A sample of this algal cover revealed that it was composed mostly of the red algae Amphiroa rigida entangled with other red, brown, and green algae, but the predominant form being Rhodophytes (red algae). Sponges were quite abundant throughout the water. At these depths, the basket sponge X. muta, Desmopegnia anchorata, Verongia sp., and others, to a lesser extent, were quite common. --- Page Break --- Very few coral formations were observed. Only scattered small patches of Neandrinia sp. were observed. CORALS: Dominant Organism: At 18 m, a transitional zone (ecotone) occurred between the algal and coral gorgonian communities. This culminated at 16 m where corals and gorgonians formed most of the epibenthic (Figs. 3 and). Many fishes live among the coral formations. Various types of coral.

Formations were present. Corgontane such as Flexaurella sp., Peerogorgia anceps, Pooudepterogorgia anceps, and others occurred. Hard corals included Meandrina sp., Montastrea cavernosa, Diploria sp., and Dendrogyre eylindrteue (Fig. 4). Algal fauna were attached to the hard substrate free of coral formations; however, the specific dominant algal species were not recorded. ---Page Break--- ---Page Break--- ---Page Break--- FISHES Many fishes, mostly small ones, aggregated in and around the gorgonian coral formations. These included: a school of over 50 specimens of blue chromis, Chromis cyaneus (Pomacentridae); 4 adult forms and a school of 30 juvenile forms of the blue head Thalassoma bifasciatum (Labridae); 1 rock beauty, Holocentrus tricolor (Chaetodontidae); a small school of the brom Chromis, Chromis multilineatus; 1 black durgon, Melichthys niger (Balistidae); and 2 schools of surgeon fish, Acanthurus sp. (Acanthuridae). Four queen trigger fish, Balistes vetula (Balistidae) and a few bicolor damselfish, Eupomacentrus bipartitus (Pomacentridae) were observed in the deeper water. ---Page Break--- 6 omar; the coral formations were restricted to a depth of 16-18 m. + SPONGES; ALGAE At 15-5 m coral formations were non-existent except for a few specimens of Peerogorgia anceps, Dichocoenia stokesii, and Meandrina sp. At 12 m, patches of the sponge Anthosignella varians were observed. From 9-12 m the bottom was covered by two main types of growth; 1) turf mats consisting mostly of the red algae Sargassum rigige and stained with other less common colors. 2) large patches of the sponge Asvarians (Fig. 5). The sediment in this location consisted mostly of skeletons of the dominant algal form (coralline) Amphiroa sp. At 7.5 m the bottom consisted of algal mat formations, a few scattered patches of A. varius and a few gorgonians, such as Yragena sp. At 6 m the bottom was practically covered by an algal mat of a different composition than those found at greater depths. The algal over at this depth consisted primarily.

of the red algae Corallina sp. and Jania sp., entangled with other algae. A sandy bottom, and heavily silted water was encountered at 4-5 m. From 31.5 m the benthos consisted of miscellaneous forms. However, patches of algae, primarily Corallina sp., seemed to be dominant. ---Page Break--- 68 Fig. 5. The sponge A. varians (pale patches on lower left and upper right corners) and red alga in apparent competition for substrate at 912 m at Station A. ---Page Break--- 6 Many other forms of life made up the benthos of this shallow region including Thalassia testudinum, patches of the coral, Siderastrea sidera, and the sponge Verongia sp. The observations at this time were limited due to poor visibility. ---Page Break--- 70 STATION A = 14-26 January ‘the relative distribution of the dominant forms are discussed below in relation to their occurrence during the first sampling period. SPONGE AGGREGATION The substrate was generally unchanged from the first sampling period. Sponges, the macro-epibenthic fauna consisted primarily of sponge aggregations (Porifera: Demospongiae). Specimens of the basket sponge Xestospongia muta and Ircinia sp. occurred quite commonly. This is similar to the observations made during June 1973. 2. Green brown algae (Phaeophyta) such as Dictyota sp. and Dictyopteris sp. were observed growing over portions of many sponges. This observation was not made during the previous trip. At that time, the red alga (Rhodophyta) Laurencia intricata was observed growing on similar habitats. 3. Corals The coral fauna observed was considerably sparse. There were few scleractinian corals, and the coral ---Page Break--- fauna was represented only by scattered gorgonians dwelling among and on the sponges. 628, BENTHOS Substrate Most of the bottom consisted of a hard substrate, occasionally interrupted by sandy channels and sand holes. Dominant Community Algae A dominant algal community attached to the hard substrate was observed. The dominant alga was the red alga (Rhodophyta), existing in a

complex arrangement with other brown (Phaeophyta) and green (Chlorophyta) algae. The most common Rhodophytes included the articulated coralline red algae Corallina cubensis, Amphiroa fragilissima, and Jan. However, at 16.5 m (Table 1), the calcareous red algae Lithothamnion ocedentalis and Coelarthrum albertisi constituted a large part of the total biomass; while at 7.5 m, the coralline algal were the principal component (Table 2). At both depths mentioned above, most of the algae and articulated corallines were entangled with the brown alga Dictyota linearis and to a lesser extent ---Page Break--- TABLE 1 UW-16 January 1974 the relative abundance of the algae obtained at 16.7 m in samples at station A. The numbers represent the dry weight obtained for each species within the 1/4 m sample. Dry Weight (g) 18.9 Lithothamnion ocedentalis 6 Coelarthrum albertisi 7 Dictyota linearis 8 Dictyopteris plagiogramma 9 Caulerpa vickersiae 10 Caulerpa microphylla 11 Miscellaneous Total ---Page Break--- TABLE 2 1-16 January 1974 the relative abundance of the algae obtained at 7.6 m at Station A. The numbers represent the dry weight obtained for each species within the 1/4 m sample. Dry weight (g) 88 Martensia pavonia 9 Dictyota occidentalis 10 Hypnea matossis 11 Gelidiium pacilinum 12 Cryptonemia 13 Phacelocarpus 14 Dictyopteris sp. 15 Dictyota linearis 16 Dictyota sp. 17 miscellaneous algae 25 total ---Page Break--- by Dictyopteris sp. and Dictyota divaricata. A possibility is that a brown alga bloom may have been occurring at this site, since this was observed in many locations along the transect. Sponges The sponges Iroinia fasciculata, Cynochire sp., Vorongia sp. occurred rather sparsely. However, the heavily encrusting sponge Anthosigmella varians commonly formed patches among the algal mats (Fig. 6). Several observations were made concerning A. varians: 1) they were less abundant than during the summer of 1973; 2) coralline red algae (Rhodophyta) and brown algae (Phaeophyta) were

observed growing within the patches which is unusual; 3) some of the patches were surrounded by a layer of mucous. ‘This could indicate biological interaction within the algal-sponge interface, as many corals and sponges secrete a mucous slime when they are cut, injured, or under stress 3. Coral formations prevailed principally in areas of hard substrate that were unoccupied by algae and sponges. They occurred infrequently, except at some scleractinian corals Diploria labyrinthiformis, Y. columella, Colpophyllia anaranthae and ---Page Break --- The encrusting sponge (Porifera: Demospongiae) Anthosignelia varians was in January 197. The presence of algal patches within them is unusual. ---Page Break --- Dichocronia stokesii formed encrustations and coral heads on the hard bottom. ‘The gorgonian Pseudopterogorgia laxifolia, Eunicea succinea and Pseudopterogorgia sp. were observed on the hard substrate. ---Page Break --- 7 STATION 8 - 25-28 June 1973 The weather conditions were favorable and there was little wave action. Water visibility was approximately 16.5 - 18 m. BENTHOS 80 predominant formations characterized the area, except for possibly the sponges. There were primarily two bottom types: a sandy bottom and a hard bottom. Sandy bottom: ‘the same as that found near the deep communities in station A, except for the absence of ripple marks. Dominant Organisms 1. Algae Portions of this sandy region were covered by algae, Amphiroa rigida and A. fragilissima were two common ones. There were patches of the flowering plant Halophila baillonis growing over the sand. 2 Sponges ‘The only sponge growing here was the basket sponge Xestospongia muta, which was quite common at these depths. ---Page Break --- 6 hard bottom: ‘This area consisted mostly of coral-sponge aggregations. Many sponges occurred including Xestospongia muta, Schaefferia vespertilio, V. longiseta, Y. fistularis, and Callyspongia vaginalis. Many of these were covered by hydrozoans. ‘The predominant coral forms were the gorgonians: Bm RED ALGAL MAT ‘the sandy

bottom was nearly entirely covered by algae. However, there was an underlying hard substrate to which algae and other organisms were attached. Dominant Org: ‘the algal mat forming most of the epibenthos consisted primarily of an entanglement of the red algae (Rhodophyta) Corallina cubensis and Janda adherens; Coelarthrum albertesti was also present. Sponges ‘sponges were common here. Portions of the bottom substrate were covered with large patches of A. varians; some of the other sponges observed were X. muta (very abundant on the deep benthos bordering the site), ‘Sphacelospongia vesparia, Higginsia strigilata and Desmapsamma anchorata, ---Page Break--- ° Corals were not abundant in this region, but a few patches of Diploria spp., Montastraea and Siderastrea siderea could be observed encrusting the bottom. A few gorgonians were observed such as Plerogyra anceps and Plexauridae spp. BOULDERS Boulders were conspicuous. These were spaced between either a sandy bottom or a hard rocky bottom. There are three bottom types at this depth: the boulders themselves, the sandy bottom, and hard bottom between or among the boulders. Substrate A thin layer of organic sediments covered the sand. The ripple marks were pale and arranged in a capillary fashion. Although there were generally unfavorable for fare exceptions this type of substrate is HARD BOTTOM Most boulder surfaces were covered by algal aggregations. A large amount of organic sediment, polychaete tubes, bryozoans and hydrozoans was observed. The sponges present were predominantly X. muta and a few others such as Haliclona rubens and Callyspongia vaginalis, ---Page Break--- dominant Organism: Algae This hard flat bottom among the boulders offered good substrate for algal attachment. A red algal mat composed of entangled Laurencia schwackei and Amphiroa rigida covered most of this substrate. Coelarthrum albertesti was common but less so at 18 m. varians formed wide encrustations among the algal mats. A few basket sponges were also present. RED ~ BROWN ALGAL MAT Most of the hard substrate was covered by an ‘algal aggregation composed primarily of two types: the red algae (Rhodophyte) Bryothamnion triquetrum, and the brown algae (Phaeophyta) Dictyopteris delicatula, less common algae occurring in this area were: Corallina sp., Janinia sp., Valonia ventricosa, Halimeda sp. and a few thallus leaves. Sponges Patches of A. varians on the algal mat were observed. Verongia sp. and the stinging sponge Noctiluca massa were also common at this depth. ---Page Break--- 15-3 two species of gorgonians, Muricea elongata and Bunchesia tournefort, occurred in reduced sizes. Occasional patches of the scleractinian coral Siderastrea radians were seen. This coral seems to be quite resistant to sedimentation, as it repeatedly occurred in shallow turbid water. It has also been observed in tide pools of increased temperatures, with no apparent adverse effects. Tistore commmrrres It is known that the inshore benthos are affected throughout the year by wave action and sediments in suspension; however, detailed observations on this shallow region were not made due to poor visibility. The substrate was sandy, and the portions covered with algal mat were underlined by hard structures. There were two types of algal cover in this range. At 3 m there was a light algal cover of red filaments over portions of the sand. This algae may belong to the phylum cyanophyta, which has red accessory pigments (Phycoerythrin) used in photosynthesis. At 1.5 m a different algal aggregation occurred, consisting primarily of two kinds of red ---Page Break--- algae (Rhodophyta): Corallina cubensis, some green algae (Chlorophyta) were common at these shallow depths. These included Fonicttia capitatus, Halimeda opuntia, Wotes flabelliformis and Cladophora fuliginosa. 2. Corals coral growth is limited in environments heavily affected by siltation thus only a few greatly reduced encrustations of the coral Siderastrea sideras occurred. 3. Sponges only one sponge, a species of Verongia, was near shore. Much of its surface was covered by

bul-ike structures which are probably used in propagation. No patches of A. varians were observed. ---Page Break--- 3 STATION C. June 1973 ‘The weather conditions were favorable and permitted good water visibility (18.2 m). There were no bottom disturbances and no wave action. ‘The biotic aggregations inhabiting this area were characterized by coral growths, unlike the epibenthic communities found at stations A and B. These observations are in agreement with Amant (1973). ‘There was a transitional zone at 3 - 12 m, which culminated in a coral community. The biotic aggregations on the deeper portions of the transect 21-27 m revealed that there was biotic continuity at this depth. Similar to Stations A and B, the deep benthos consisted of sponge and algal formations. ae ALGAL zone: (GREFOROOTN ZomaTz) ‘The above description of the benthos present is descriptive rather than real. It does not mean that this alga covered most of the substrate, but rather characterized the area by its abundance (Fig. 7). The substrate at this depth consisted of a flat hard structure with few sandy pockets. Patches of the brown alga (Phaeophyta) Stypopodium zonale characterized the area. Other algae covered ---Page Break--- Fig. 7. The brown bushes are specimens of Stypopodium zonale, which were abundant at Station C. ---Page Break--- 85 Portions of the hard substrate included Corallina cubensis, Dictyota dentata, Valonia ventricosa. Corals were common despite the reduced size of the specimens at this depth. The hard corals (Scleractinian) occurred as small patches or encrustations on the hard substrate. Similarly, the gorgonians were consistently reduced in size. This was probably due to heavy sedimentation or wave action. The hard corals which formed reduced patches or small heads included Porites astreoides, Siderastrea siderea, Montastraea annularis, and cavernosa. The gorgonians included Muricea sp., Eunicea sp., and Ploresia sp. They were less common than the hard corals at this depth. 3+ sponges Many specimens of

Yerongia sp., described in ‘the inshore communities in station 3, occurred. An occasional patch of

A. varians was observed. [TRANSITIONAL Zone No particular name was assigned to this zone since the epibenthos had a miscellaneous composition. An algal mat consisting of tufts of Jania wrens entangled with other algae (e.g., Cladophora fuliginosa) ---Page Break--- covered portions of the substrate. There were hard corals and patches of A. varians. Gorgonians occurred in larger numbers and sizes than those at 3m (Fig. 8). The substrate was hard, rocky and generally flat, except for a few coral outgrowths. Algal tufts composed of Jania adherens entangled with other algae covered portions of the area. Other algae, including Amphiroa fragilissima and Corallina cubensis, were present. 2. Corals ‘the hard corals formed wider patches and bigger formations at this depth than at 3m. Those corals present included: Siderastrea siderea, Meandrina sp., Diploria sp., Montastraea cavernosa, Millepora sp. (hydrocorallina) and Porites astreoides. 3. Sponges ‘A. varians was the most common sponge, covering much of the substrate. CORAL COMMUNITY ‘the previously discussed transitional zone culminated at 12 m in a coral reef community. The corals attained full size and formed a ---Page Break--- Fig. 8. The pale patches (center) are A. varians, some Gorgonians are also present. ---Page Break--- Lex aggregation of organisms (Fig. 9). Also, many gorgonians occurred, covering most of the algal aggregations. Sponges also proliferated. Most of the substrate had a calcareous composition, probably formed by the many corals present, and in some cases forming boulders (Fig. 9). Dominant Organisms A wide variety of corals, gorgonians, sponges, and other organisms occurred. Corals were the most abundant. Algae also occurred in certain areas around the coral formations. 1. Corals (Scleractinia) ‘there seemed to be no predominant form of coral, yet several types occurred. The corals observed included Montastraea cavernosa, Meandrina sp., Diploria sp., Isophyllia.

simuose, Ieopyiiiea ep.) and Mitiopore ep. corns (Cotocoraiita). Many gorgonians occurred, and they attained greater size than at previous shallower depths. They included Peerogergin sp., Muricen elongata, flavida, N. sulprurea, Gorgonis ventalina, and Bunicea toumefortt. A great variety of sponges occurred on the coral formations, some of them typical of coral reef communities. There were the following: Gelliodes ---Page Break--- 1. 9. A coral community which occurred at ---Page Break--- areolata, Callyepongia vaginalis, Sphinctospensta vesperia, small specimens of Xestospongia muta, and Hizeinis ep. Other less conspicuous forms such as Microcions sp. formed thin encrustations on the underside of corals and over the surface of dead corals, and Clions caribboes and Cliona sp. bored the inner calcareous structures. 28-27 DEEP BENTHOS Sponge aggregations appeared to be the dominant group in this region; however, these deeper regions were difficult to characterize due to the limited bottom diving time. Despite the limited sampling, three different bottom types were observed: 1) sandy flat bottoms 2) boulder-like structures with many gorgonians and a few coral patches; 3) boulder-like structures with few gorgonian or coral formations. Deep sandy bottom, this type of bottom was observed at depths of 27, 28, 29 m, 20 m, and 18 m. In contrast to the sandy formation at station A, there were no ripple marks observed and the formation was flat in structure. Similar to Station A at these depths, there was a thin layer of organic sediments covering most of the sand. These areas were nearly devoid of marine life, except for a thin layer of filamentous green algae covering some of the substrate. There were no starfish, sand dollars, or any of the commonly found sandy bottom organisms. ---Page Break--- Boulder-like structures with gorgonians, (18 m) There was a great variety of organisms attached to the structures. Most common of these were the gorgonians along with a few coral encrustations and sponges (Fig. 10). As found at

Station A, the red algae Laurencia intricata covered many of the sponges and portions of the boulders. Also, an unidentified species of hydroid and a few bryozoans were on these deep boulders. The gorgonians observed included Bunicella laxissima, Diodogorgia notulifera, Plerogorgia anceps, and P. eftrina. Probably the most common sponge at this depth was the basket sponge Xectopongia muta. Boulder-like structures—no gorgonians (27 a). The boulders at 27 m lacked the gorgonian formations found at 18 m. Instead, much of their surface was covered by algae such as Laurencia antiqua, Cladophora albida, and Jania adhaerens (Fig. 21). Only one type of hard coral, Montastraea annularis, was observed growing on portions of these boulders. Many specimens of the sponge Xectopongia muta were also found. Various fish were commonly found in and around the coral formations. The observed species included: 3 specimens of Halichoeres bivittatus (Labroides); 12 specimens of Diplocentrus partitus (Pomacentridae); 5 adult blue head wrasses and 2 juveniles of Thalassoma bifasciatum (Labriidae); 2 queen triggerfish, Balistes vetula (Balistidae); 3 groupers (Serranidae); 5 surgeonfish, Acanthurus bahianus (Acanthuridae); and 3 squirrelfish (Holocentridae). ---Page Break--- Like platforms with several gorgonians ---Page Break--- a platform nearly devoid of gorgonians ---Page Break--- ---Page Break--- 95 FOR TABLE 3 W-16 January 1974 The relative abundance of the algae obtained at 6 m at Station C. The numbers represent the dry weight obtained for each species within the 1/4 m² sample. Species Dry Weight (g) Rhodophyta Auphros (sp.); Jania (sp.); and a Hildenbrandia prototypus; Gelidiella pustulata; Martensia pavonia - Dry Weight (g) Phaeophyta Dictyota (sp.); a lacettanoe ae = 2.8 ---Page Break--- FOR TABLE 4 16 January 1974 The relative abundance of the algae obtained at 18 m at Station C. The numbers represent the dry weight obtained for each species within the 1/4 m² sample. Species Dry Weight (g) Phaeophyta Corallina cubensis; Depressi (sp.) a Dictyurus.

occidentalis 3 Coelarthrum alberteci 2 Gelidium pterocladum Mirtensia pavonia: Phacot Dictyota sp. iyota lineare Dictyota linearis Bctvopteris hoytii Padina pavonica Chlorophyta Total 2.3 ---Page Break--- composed of articulated coralline red algae such as Corallina cubensis, Amphiroa sp., and the brown algae, Dictyota sp. and Dictyopteris sp. were observed living as macroepiphytes and entangled within the dominant coralline red algae. Similar to the findings at station A, generally sparse coral fauna was observed. Gorgonians and encrusting corals were rarely observed on those boulders with available hard substrate, ---Page Break--- various different epibenthic associations were observed throughout the study (Figs 12): 2) 4) 8) 8) 9) 10) sponge communities inhabiting the deep benthos at all three stations. Corals and gorgonians did not occur widely, probably due to the limited light penetration at such depths. Light is essential for the growth of corals since it is required by the symbiotic algae that assist them in calcification and other physiological processes. Red algae communities were usually among the patches of A. varians. This situation was common at all three stations; coral communities encountered at station A at depths of 13.5, and throughout Station C, particularly at 12 m. Boulders at Station B at 12 m and brown algal communities at 6 - 7.5 m at Station B. A Stypopodium zonale zone inshore at Station C; boulder-like structures with gorgonians at 18 m at Station C; boulder-like structures with no gorgonians at station C at 27 m. Sandy bottoms with thin layers of organic sediments, sandy-silty bottoms inshore at stations A and B, harboring miscellaneous biotic aggregations. ---Page Break--- 1 NAUTICAL MILE (ABH FD, BROWN ALGAL MAT AND SPONGES & ZONALE vs SAND CULE LIKE: A VARIANS SS ee HS 2% RED ALGAL MAT ©@ Hard coral Fig. 12, Map illustrating the distribution of the major epibenthic aggregations at Binea Ripueroe A, source LIKE WITH SPONGES = SANDY SILTY ---Page

Break--- 00 ‘There is a tendency towards dominant algal populations north of the Point, while on the south of the Point there is a tendency towards coral formations. However, there are coral reef formations slightly north of the Point (Station b, 16.5 m), although not as extensive as those occurring south of the Point. These observations, made during the summer study, agree in some ways with those made by Semant (1973). Most of the hard substrata occurring in the deep sublittoral zone north of Punta Higuero harbor benthic fauna composed principally of algae and sponges. A major change seemed to occur in the benthos during the winter expedition. The sponge Anthosignela varians formed large patches, sometimes covering several square meters of hard substrate. However, almost all the patches of A. varians observed during the winter sampling were smaller than those observed during the summer sampling. Algal aggregations were observed within the sponge matrix, which is unusual. A mucous slime within the sponge-algal interface on some patches was observed, possibly indicating biological interaction. A transition in which algal communities dominate the sponge formations seemed to be occurring. It is not known if this is a long-term phenomenon, since no previous data are available. One cause of successions within the benthic fauna at Punta Higuero may be the influence of the nearby Añasco River (Fig. 13). The silt, clay, and other terrigenous matter transported to the site would have some effect on the benthic organisms. However, no statement can be made concerning the degree of the river's influence without further research. ---Page Break--- 101 Fig. 13, Aerial photograph of Punta Higuero taken during the winter of 1973, illustrating the sediment transported to the south around Punta Higuero. ---Page Break--- aoe ACKNOWLEDGEMENTS This study was accomplished through a cooperative group effort and I would like to express appreciation to my co-workers: Mr. Roberto Castro, Mr. Jose A. Rivera, Miss Beverly Buchanan, Miss Janet

Pedercen, and Dr. Paul Yoshioka. ---Page Break --- 103 REFERENCES SANDOWSDN, Cull, 1946, Behavior of coral planulae under altered saline and thermal conditions, Occas. pap. Bernice P. Bishop Mus., (18): 283-304. AYER, A.G. 1914, The effects of temperature upon tropical marine animals. Publs. Carnegie Inst. Wash., (183): 1-24. FORSSIER, M.J. and ZIEMAN, J.C. 1969. The effect of thermal additions on the biota of Southern Biscayne Bay, Florida. Proc. Gulf Caribb. Fish Inst., 22: 136-45. SVERDRUP, H.U., MARTIN M. JOHNSON and RICHARD H. FLEMING, 1942. The oceans, their physics, chemistry, and general biology. Prentice Hall, Inc., New York, 1087 p. SUNT, A. 1972. Preliminary observations on the benthic communities of the Punta Higuero site. Quarterly report submitted to Puerto Rico Water Resources Authority. WELLS, J.W. 1952. The coral reefs of Arno Atoll, Marshall Islands. Atoll Res. Bull., (a): 1-1. ZIRWN, J.C. 1970. The effects of a thermal stress on the seagrass macroalgae in the vicinity of Turkey Point, Biscayne Bay, Thesis, University of Miami, ---Page Break --- 04 B.D. Martin & Jie Patus The fishes of the Punta Higuero site have been sampled by a number of methods. They have been taken using dip nets and rotenone and have been identified by swimming through an area and from photographs taken by the benthic team. Table 2 lists the species identified from this area and the method used to sample them. Table 2 lists only those species taken by rotenone and the numbers taken at each station. For locations of these stations see Fig. 1. No samples taken thus far have turned up species which are unusual for this end of the island and all species thus far can be characterized as reef, rocky shoreline, pelagic, or sandy bottom dwelling species. The habitats which these fish prefer are more or less continuous from Cabo Rojo to Aguadilla and all have pelagic larvae except for the blennies. Widespread damage to these species then seems unlikely. Sampling is proceeding on a quarterly basis and will be continuous.

sampling procedures above. ---Page Break--- 105 "Sampling — **Normal, Species Method habitat Echidna catenata - Chain Moray R RE Gymnothorax sp. - Moray (juv.) Harengula clupeola - Palse pilchard Jenkinsia lamprotes - Dwarf Herring Arcos rubrigenosus - Red Clingfish Rk Atherinomorus stipes - Hardhead Silverside P R RE R 8 R R Abudefduf vexillarius - Dusky Squirrelfish R RE, Rk s 8 P 8 8 P Pp Holocentrus ep. - Squirrelfish RE, Re Serranus sp. - Grouper RE, Rk Malacanthus plumieri - Sand Tilefish SB Caranx fuscus - Bluerunner > Caranx ruber - Bar Jack Pp Lutjanus apodus - Schoolmaster 8,8 RE, Rk Haemulon parrai - Sailorschoice R RE Pseudupeneus maculatus - Spotted Goatfish S$ SB Pempheris schomburgki - Copper Sweeper —§ RE Folicanthus arcuatus - Gray Angelfish P RE Abudefduf saxatilis - Sergeantmajor R,DS RE, Rk Abudefduf taurus - Night Sergeant R Rk Eupomacentrus leucostictus - Beaugregory $ RE Eupomacentrus variabilis - Cocoa Damsel § RE Eupomacentrus op. - Damsel fish P RE Mugil liza - Liza > P Mugil sp. - mullet (juvenile) R P Thalassoma bifasciatum - Bluehead DS RE, Rk Unidentified small wrasse R,P RE Scarus sp. - Parrotfish s Rt Sparisoma sp. - Parrotfish s RE Dactyloscopus tridigitatum - Sand Stargazer R SB Blennius cristatus - Molly Miller D Rk Entomacrodus nigricans - Pearl Blenny R Rk ---Page Break--- 106 'sampling **Normal Species Method habitat Ophioblennius gibbosus - Redlip blenny S RE unidentified juvenile blenny R Acanthemblemaria spinosa - Spinyhead blenny D Re coralliozetus gordonae - Twinhorn Blenny PD Rk ° Tagiomus guppyi - Mimic Blenny R Re Tagiomus puchipinnis - Weedy Blenny R RE, Rk Neoclinus caeruleopunctatus - Barfin Blenny R YP Rk Paraclinus fasciatus - Vended Blenny K Rk Unidentified juvenile gobiid R Bathygobius soporator - Trilling Goby R Rk, RE Acanthurus balianus - Ocean Surgeon 8,P RE Acanthurus coeruleus - Blue Tang 8yP RE Acanthurus sp. larval R Balistes vetula - Queen Triggerfish P RE Melichthys niger - Black Durgon P RE Rotenone stations, 15 & 16 January 1973, Re £2

Stinning mostly around "Steps", July 1972. Photographs, benthic team samples, January 1973 for connecting 18 February and 6 May 1972. wert = Coral Reef fishes fk = Rocky shoreline or Rock Reef area fish 'P = Pelagic sb 2 Saray bottom, or sand patch species. ---Page Break--- 17 COLLECTING SITES Beach near Tofito's Place. Phonic Rock - a large rock formation on Punta Gorda. Splash Pools N. of Dome. Rock Groin and protected water at the old Honus outfall. Rocky shore between Dome and Lighthouse. Rocky shore just S. of Lighthouse. Surfer's Beach 'Small channel in the beach rock N. of Steps. Funnel behind a beach rock outcropping N. of Steps. Steps ---Page Break--- EXCNE SAMPLES 2 = Re: "ALLE Umi) enuoaan ths Sram awSy Fereredos enTqoNee | TH Sw eP Fae) Se SSSTOR UST SOOTT fae Fram onsooraaar | mse poss riuoptay i pexzrpuoprun sis TOA a pees cores Farmer smpyapeay |} ret eae oft es ™ Ea - ro aa tape aapate snievaet pe ears 'Surman BupaTg Boe agouaFrgrs S05 arate Sy ovae ra so ce a 7 amie swore | 7 Sauer veer Tome Place =f il 'Dome ant Lientnouet Fock Share ust Sy of Lighthouse Surfer's Beach Bot Stepe. Tunnel gut We oF Steps Teepe © at least some specimens were juvenile 'Splash Fools W oF Ta Teck GFoin wt Pome Focky Shore beiweer Teel] Channel TF Bem FIeRTe Rocke ---Page Break--- APPENDIX A ---Page Break--- ---Page Break--- 129 would cut the beach at the dock area so there would be a "north beach" accessible from Agusda and "south beach" accessible from near the gate to the PRVRA site. With ready access, adequate of1 ep{21 guards, and planting to screen the area from the public there should be no loss to recreational or aesthetic values. ---Page Break--- ---Page Break--- Fauna observed in Pinta Kiguero was restricted. This was partially due to a natural paucity in local fauna. Alto transect observations did not get many of the more shy or rare birds or animals. These require trapping and covert observation. Macrofauna consisted mainly of pelicans, Pete, mongoose, cats, and dogs. All, except pelicans, are introduced.

pest species. FAUNA Ls? Reptiles and Amphibians Leptodactylia frog 'Anolis cristatellus 'Anolis sp. aves Crotophaga ant 'Tyrannus dominicensis Mimus polyglottos Guiraca caerulea MAMMALS (native) Hoctttonta bat ---Page Break--- [PROBABLE UNAVOIDABLE ADVERSE EFFECTS 'The most probable adverse effects are those physical effects relating to the removal of the vegetation for development and disruption of run-off patterns. Nothing can be done about the former. A partial compensation can be made by planting fringe areas (Possible Remedial Actions). This action, plus care in grading, should help in avoiding the bad effects of disrupting run-off patterns. POSSIBLE

REMEDIAL ACTIONS Designed Successional Forests: Many attractive and useful plant species are normal members of the secondary successional forest. ‘These include coconuts, almendras, mangos, royal palms, tamarind, cocoloba, casuarina, sapodilla (manilkara), Flamboyant, gumbo limbo, etc. ‘These hardy species can be planted along roads and the perimeters of developed areas. This would serve to (a) promote natural succession, (b) provide a screen against noise, dust, ambient heat, etc., (c) cover the plant from public view. In Front, Parks: ‘The beach areas of Puerto Rico are considered public domain. Therefore, any unsightly, hazardous, or prohibitive developments are undesirable. By ‘and large, the beach front areas (depicted in Fig.3) are not planned for extensive development. Much of the scenic beauty and community value could be preserved by leaving existing natural areas, planting trees along roads (or the fences) and between the beach and the plant and waterfront (dock) area. Exclusion fences for the PRWRA facilities would be essential, tho ---Page Break--- TABLE 3. Species list for the secondary successional forest on the Limestone Hills at Punta Higuero. ‘TREES IN THE SECONDARY FOREST TREE IN THE SECONDARY FOREST Artocarpus altilis Buxus buceras Symphonia globulifera Cocos nucifera Hibiscus tiliaceus Guarea trichilioides Mangifera indica Piper aduncum

stones Borinquénia SEES Sate ‘Temainatia catappa Zanthoxylum martinicense soups Daggene hireuta Tantans Tavolocrata ‘canara ‘Sovanug tGrvum Urenw ep. vies Abrue abrus sa ep. iis ‘Eucadalupensis Faseiflore sp. 3 Lon tonentoeum teen ee Hees Adiantum ertetutun Folypodium ep. Camphyloneurum =p, Tectaria heracleifolia 125 ---Page Break--- ‘TABLE 3. (cont.) HERBS Anthurium Sessa op Tabetin robueve fite tes me sta, jamaicence crass Digitaria sanguinalis Fleas ope ‘Sporobolus sp. 126 ---Page Break--- Figure | = Collecting Sites ---Page Break--- no Additions to the Fish Species Lists for the Punta Higuero Site by F. D. Martin (12 March 1974 two shoreline rotenone stations were done. One was at the station designated as Picnic Rock in the 1973 first quarter report and the other was at a beach rock outcropping between stations 7 and 8 of that report. Species taken are as follows: Previously Picnic Station Species Reported _Rock 5 Echidna catenata-Chain Moray x Grmothorax sp.-Moray (Suv.) x Grmothorax vicinus-Purplemouth Moray x x Harengula clupeola-False Pilchard x Harengula hueratis-Redear Sardine x Jonkinsia lamprotaenia-Dwarf Herring x x jachoa lamprotaenia-Bigeye Anchovy ‘Arcos rubrigenosus-Red Clingfish x Opsibia sp. Parophidion schneideri-Dusky Gulp-eel Atherinomorus stipes-Hardhead Silverside x Adionyx vex Scorpaena plumieri-Spotted Scorpionfish x x Epinephelus adscensionis-Rock Hind x x Dusky Squirrelfish x x Serranus sp.-Grouper x ---Page Break--- Pseudogramma gregoryi-Reef Bass Rypticus subbifrenatus-Spotted Soapfish ‘Agnus maculatus-Flamefish Nalacanthus plumieri-Sand Tilefish Caranx fuscus-Blue Runner Caranx ruber-Bar Jack Trachynotus goodei-Palometas Lutjanus apodus-Schoolmaster Haemulon carbonarium-Caesar Grunt Haemulon parrai-Sailors Choice Pseudupeneus maculatus-Spotted Goatfish Rhamphicentrus schonburgkii-Copper Sweeper Chaetodon striatus-Banded Butterflyfish Pomacanthus arcuatus-Gray Angelfish Abudefduf saxatilis-Sergeant Major ‘Abudefduf taurus-Night Sergeant Epinephelus fuscus-Dusky Damsel fish Expenacentrus

Leucostictus - Beaugregory
Euponacentrus rariabilis - Cocoa Damsel fish
Mugit Liza - Liza Mugil sp. (juveniles)
Doratonotus megalepis - Dwarf Wrasse
Halichoeres bivittatus - Slippery Dick
Halichoeres maculipinnis - Clown Wrasse
Halichoeres poeyi - Blackear Wrasse
Thalassoma bifasciatum - Bluehead

Scaridae sp. - Parrot fish

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Sparisoma chrysopterum - Redtail Parrotfish
Sparisoma radians - Bucktooth Parrotfish
Sparisoma rubripinne - Redfin Parrotfish
Tuctyloscopus crossotus - Bigeye Stargazer
Dactyloscopus tridigitatus - Sand Stargazer
Gittellus rubrocinetus - Saddled Stargazer
Blennius cristatus - Yolly Miller
Entonacrodus nigricans - Pearl Blenny
Ophioblennius atlanticus - Redlip Blenny
Acanthostracion spinosa - Spinyhand
Coralliozetus cardonae - Twinhorn Blenny
Labrisomus bucciferus - Puffcheek Blenny
Labrisomus guppyi - Minic Blenny
Labrisomus nuchipinnis - Hairy Blenny

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13 6,144.3 Ecological Parameters
TERRESTRIAL SURVEY
By Md. Canoy Burnopuerron

The terrestrial ecology of the Punta Higuero proposed power site is divided into three broad community regions: (A) coastal beach and limestone communities, (B) successional plains, and (C) dry limestone. These are sub-provinces of the dry coastal (Little & Wadsworth, 1946) province. The Punta Higuero site and bordering area was surveyed in February 1973 and 1974. For this purpose, three transects were walked (Fig. 1) from east to west and three north to south. From these samples, species lists and locale of plant communities were established. From color aerial photos of the site, and referring to the surface transect data, a map of plant communities was drawn. Three spot checks were made in anomalous areas (marked, Fig. 1) to verify local conditions. Faunal lists and region of occurrence were compiled by observation. Avifauna includes the seabirds as well as terrestrial species. The structure and appearance of any ecological association depend primarily on the species present and the relative numbers of each. In a normal tropical assemblage, the number of species might

be very high. Puerto Rico, however, is a densely populated and severely disturbed area. Also, it is a localized place in terms of zoogeography. Practically all remnants of the original forests are gone. In most cases, the “nature” forests are secondary or tertiary forests. ---Page Break--- ---Page Break--- Much of the island is kept in a permanent state of succession due to constant interference by man. The Punta Higuero site is no exception to this. To determine the present and possible future trends of succession, we followed well-established ecological techniques. The accuracy and completeness of the work is more or less dependent on the activities of man, both locally and "upwind." The general area is a more or less xerophytic coastal regime on land of limestone with a narrow coastal plain of heavy clay. Two hundred years ago it was forested with dry country hardwoods. When these were cut for timber and fuel, a secondary forest began. This was cleared off the plain area for sugar cane and off the hills for fuel. Sugar cane culture continued until shortly before MRA acquired the land for the Bonus Reactor Project (approximately 1958). The area between Incon and Punta Higuero is still in agricultural use for cane and for pasturage. When MRA bought the Bonus Reactor, all the land not used in construction returned to a tropical old field succession. A few large breadfruit (Artocarpus altilis) remained, but the major vegetation was Australian pine (Casuarina) and royal palms, and herbs. This grew to cover most of the plain and the lower hills. However, most of it was bulldozed away in January and February, 1974. (Fig. 2). ---Page Break--- vom ---Page Break--- AND comments The Beach Association (Map, Fig. 3) at the site is quite typical (Fig. 1). The dominant trees are the almond (Terminalia catappa), sea-grape (Coccoloba uvifera), and coconuts (Cocos nucifera). Numerous small shrubs, herbs, and vines form a ground cover under the trees. Germon

Among these are mother-in-law tongues (Sansevieria), Tantana involucrata, Awana wp., and Solanum sp. Other species included are Scaevola plumieri, Crotalaria retusa, Bidens pilosa, Erythrina sp., and Bougainvillea sp. The beach community serves to hold the sand against wind and water, to anchor dunes, and provide a basis for successional forests to follow. Also on a densely populated, tourist-oriented island, such as Puerto Rico, it serves to hide less aesthetic aspects of farms, barrios, and industry from public view at the beaches. For these reasons, it should be preserved. On a small rocky point south of the Bonus plant, there are a few Agave and Plumeria and beach rock conglomerate. Most outcrop is sand and clay over limestone. A list of the major species observed in the beach community is seen in Table 1. Clay plains at the foot of the hills represent the most disturbed sector of the site. This area was cut over for timber many years ago, then cultivated, and finally left undisturbed when FRNA put in the Bonus Plant experiment. It was covered with old sugar cane and cancilia (Leucaena glauca) (Fig. 5). Well over 90% of the biomass was in these two species. During the winter of 1973-74, this area was burned and bulldozed by PEVRA in preparation for construction (Fig. 2). ---Page Break--- A8 Pigs 3+ Community map of Punta Higuero site showing approximate boundaries ---Page Break--- Ayyonmins qnse Bu AOE Pe ---Page Break--- ssypmums umd vere speed ous 2 sumvodans Tenge sofas ogy AORN WORRSENT “5 “PL ---Page Break--- TABLE 1. Beach community species list. TREES and shrubs: Cocos mucifera, Cocos nucifera, Schizolobium parahyba, Tantana involucrata, Plumeria alba, Terminalia catappa, Erythrina fusca, Sideroxylon fruticosum, Scaevola plumieri, Tantana camara, Solanum forme. HERBS and VINES: Hibiscus tiliaceus, Hymenocallis littoralis ---Page Break--- The few large trees left on the plain are casuarina (Casuarina equisetifolia), papaya (Carica papaya), almendra (Terminalia catappa), and palma real (Roystonea).

boringuefa). The species list for plants is found in Table 2. ---Page Break--- TABLE 2. Species List for the plant community on the coastal plain at Pinta Higueros TREES and SEEDS: Aantana involuerata, Tautaena glauca, Artocarpus altilis, Sasauring: equiestritolie, Terminalis catappa, Handia aculeata, Bleue thorn HERBS and vines: Tepewes exp, Hmmeltia fetreptyiia, Crotalaria fetus, Indigofera suffruticosa, Bignoniaceae jamaicense, Hymenocallis littoralis GRASSES: Louoratus, Setaria indicus, Digitaria sanguinalis, Setaria geniculata 123 ---Page Break--- SECONDARY SUCCESSIONAL FOREST The Limestone Hills plant association ranges from the dry communities on the western slopes of the hills to moist forest stands in low areas of the eastern slopes. This association has not been seriously disturbed for 15-30 years. It may serve as a propagation source for re-population of the undeveloped portions of the plain area. Near the base of the hills are Jacaranda glauca, Bursera cinaruba, and Zanthoxylum martinicensis. These are over an understory of Piper spp., Dieffenbachia, Pothomorphe, Randia, Urena, and Jatropha. Young mangos (Mangifera indica) and Royal Palm (Roystonea borinquena) are appearing on the slopes from a few mature individuals up the hills. The grass and sugarcane from the flat area grad into shrubs and scrubby trees. No true demarcation can be made. A return to the mature forest would take a long period of time. A species list appears in Table 3. The drier areas of forest do not have a large ground flora but they are difficult to walk through due to the numerous tree trunks, interlocking branches, and thorns. Prominent trees are the gumbo limbo (Bursera simaruba), quebracho (Schinopsis balansae), and guanacaste (Enterolobium cyclocarpum). On the east of the properties, there are two moist valleys. Here are found mangos (Mangifera indica), papaya (Carica papaya), some of the climbing grasses, Lasiacis and Abrus, also occur here. ---Page Break--- (canow) sxe a worn sonia 3a wo = Tener pra, ---Page Break---

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shelf surrounding the Punta Higuero site. Unlike flashes and scale of the plankton, the benthic organisms, in most cases, cannot relocate themselves permanently or even temporarily if they are being adversely affected by the increased temperature. It is therefore important to determine what benthic assemblages are present, their areal extent, their sensitivity to increased temperatures, and their economic importance to the nearby human communities. The insular shelf surrounding Punta Higuero is very narrow, ranging in width from approximately one to four kilometers. It is an open unprotected area, influenced by the large North Atlantic swell north of the Point and by the Caribbean Sea and Mona Passage currents south of the Point, resulting in a complex current pattern most of the year. The majority of the coastline in this area consists of rocky outcrops and unprotected beaches and there are few protected areas. Also, although no large rivers discharge into the area, it may be influenced somewhat by the Añasco River south of the Point and the Culebrinas River of the Point. ---Page Break--- Initial observations in the area (Puerto Rico Nuclear Center, 1972) suggested that the benthic communities north of the Point might be different from those south of the Point. Therefore, our group first swam transects perpendicular to shore in areas north and due west of the Point, and also surveyed areas south of the Point, to determine the community types present and specifically the areas that would be sampled in detail. Observations from these and subsequent dives seem to confirm that there is a transition from a predominantly benthic algal community north of the Point to a predominantly coral-sponge community south of the Point. As will be further discussed later, this may be an important consideration in the design and location of the plant. Benthic communities in the near and offshore vicinity of Punta Higuero were observed and sampled from January 16-19, 1973. Preliminary observations began with visual and photographic observations.

approximately one nautical mile northeast of Punta Higuero, utilizing SCUBA apparatus and swimming transect perpendicular to the shoreline from 60 to 15 foot depths, covering a bottom area of approximately 4,000 square meters (m²). Similar bottom observations were obtained adjacent to Punta Higuero (20 to 40 foot depths) covering an area of approximately 2,000 m², and also approximately one nautical mile south of Punta Higuero (35 to 45 foot depths) observing an approximate 500 m² area (Figure 1). Divers recorded basic information relative to benthic community types, dominant organisms, bottom composition, and physical observations, including current strength and direction, and visibility on plexiglass plates. Also, the area was photographed and represented for laboratory study. 302 ---Page Break--- 1 mile) Figure 1. Location of shore and offshore sampling stations at Punta Higuero. Shore stations are listed as PS-1, RS-2, and RS-3, while offshore stations are numbered R-1 through R-5. Observation dives are shown as O. to O. Dashed lines represent 30 and 60 foot contour lines. 303 ---Page Break--- Station selection Based on these observations and on other previous preliminary observations conducted by Puerto Rico Nuclear Center biologists (PRI, 1972) five offshore stations were established for more detailed study: Stations R-1 (25 feet depth) and R-2 (15 feet depth) approximately one nautical mile northeast of Punta Higuero; Stations R-3 (35 feet depth) and R-4 (65 feet depth) directly adjacent to Punta Higuero; and station R-5 (25 feet depth) approximately one nautical mile southeast of Punta Higuero. Also, three shore stations were established, one at Punta Higuero, RG-1, and two others, located one nautical mile northeast and southeast of this point, RG-2 and RS-3, respectively (Fig. 1). Station sampling: The sampling techniques at Stations R-1, R-2, R-4, and R-5 were conducted as follows: three divers recorded to the area and assembled the two meter-square quadrat sampling apparatus, consisting

of four metal rods, each two meters in length, and six nylon lines connected to the rod at one-half meter intervals, establishing 16 quarter-meter square areas. While one diver photographed each small (2/4 m²) quadrat in sequence and then the immediate surrounding area, the others recorded observations of benthic organisms on plexiglass tablets and collected representative organisms from the immediate area. Then all divers reassembled and removed the benthic assemblage free. To recover the quadrats, after using a hammer to remove sections containing encrusting and/or boring organisms that were impossible to remove otherwise, the samples were immediately placed in large plastic bags, held next to the collecting site by one diver, in order to ensure that small free-living forms such as crabs and brittle stars could not escape. As the bottom area at Station R-3 was composed almost entirely of sand, with little biomass, quadrat samples were not obtained but rather three 400 cm^3 samples were taken with a standard Beckman dredge. These samples were sieved through a series of screens, mesh sizes 1/8 inch to 1/2 inch, and the retained organisms placed in small plastic vials. As for the shore stations, benthic organisms were observed and/or collected from a variety of habitats, including tide pools, attached to rocky substrata, and burrowed in sand. Also, organisms washed up on the beach were collected, usually from the upper sandy beach zone. Laboratory analysis: All samples were returned to the laboratory, sorted into phylogenetic groups, weighed, and preserved in 70% ethanol for later identification. Corals were weighed, subjected to Clorox digestion, dried, and weighed again to estimate the amount of living animal and plant material present. Also, large pieces of rock were split apart and various creatures removed for identification. Finally, pieces of rubble that remained after most encrusting and boring organisms had been removed were weighed and the weights multiplied by a factor obtained.

from previous work (Seman', 5:72) 20 examined the organisms left in the ibe ---Page Break--- ALL major groups of benthic organisms, including sponges, corals, gorgonians, molluscs, annelids, crustaceans, and echinoderms, were classified to genus and species when possible. However, due mainly to time limitations, the classification of sponges and other minor phyla was not attempted. Therefore, information was obtained on species composition and total biomass for each 2/4 n? quadrat sample collected. D. Photographic analysis: To augment the laboratory studies, photographs obtained from the transect observations and from station areas surrounding each quadrat were studied, and those with representative communities were selected for inclusion in the report. In addition, photographs from the station quadrats were projected onto specially prepared graph paper, and cores, sponges, and algal cover outlined. Then the percentage bottom areas accounted by these groups were calculated and reported as percent quadrat cover. A total of 27 man-diving hours were spent observing and collecting the benthic communities, two transects, one spot check, and five quantitative samples were obtained. In addition, six man hours were spent observing and collecting organisms from the beaches and rocky shore areas. The results will be divided into descriptions of the communities observed and an evaluation of the quantitative data gathered. Description of Benthic Communities 1. Sandy Bottom: Very few organisms were found in or on this benthic ---Page Break--- type. No sand dollars, sea pansies, sea pens, or other usual sandy bottom organisms were observed. This bottom type was found near shore, out to 15-20 feet in depth, and interspersed with higher and harder bottom types farther offshore (20 to 40 foot depths) in other areas. In the future, aerial photographs will be used in determining the areal extent of the sandy areas. 2. Shallow algal (soft bottom): This bottom type was observed in the shallow (15-25 feet) near shore area north of the Point,

Figure 2: Photograph of a section from this area. A tuft of benthic algae on a sandy bottom characterizes the community types, only an occasional sponge or gorgonian interrupting the fairly homogeneous substrate.

3. Shadow aged (hard bottom): This bottom type extends outward from the previous one, from approximately 20 to 35 feet in depth. Less sand is present, which permits gorgonians and sponges to become much more abundant. In addition, loose cobbles provide many invertebrates (brittle

stars, crabs, etc.) with shelter. Only occasional encrusting coral colonies were present. This type of bottom was observed both north and due west of the Point in the above-mentioned depth range. Most areas where this community type was found had fairly regular bottom topographies.

4. Deep algal (tar? potter): Sponges become increasingly more important with depths. Many of the algae in this zone are axial. Gorgonians also increase in importance. Occasional heads of Montastraea cavernosa and Siderastrea siderea emerge from a gently sloping bottom, and many fish were observed swimming in the area, utilizing the corals for food and protection. The transition between the three algal zones is, of course, gradual, and the relative extent of each zone depends on the bathymetry and on the wave pattern affecting each particular area.

5. Deep gorgonian-sponge-coral: This bottom type was found only west of Punta Higuero, at a depth of approximately 65 feet, and was characterized by a sparse overall bottom cover. The area was different from other coral communities observed because of a much lower density of covering organisms. Most of the encrusting corals, such as M. cavernosa, Diploria spp., Agaricia agaricites, Pavia fragilis, Isophyllia spp., Mussismilia angulosa, Porites astreoides, and Yongea lasavciana were among gorgonians (many Pseudopterogorgia and Gorgonia) and several large basket sponges. The bottom profile was also very irregular with up to 10-foot variations in depth. The deeper areas.

were covered with soft silty sediment only a few gorgonians and pores. Figure 3 shows a section of the bottom in the Sariow coral sponge: this bottom type was encountered south of the Point approximately 20 feet to 35 feet, not known how far the covanted shore may go. ---Page Break--- The area is interspersed with occasional rubble and hard sandy Photograph by A.S. Froelich. ---Page Break--- FIGURE 1, Photograph of large sponges, (Kestosper ---Page Break--- The deep large bases of the encrusting coral M. cavernosa, Piploria cLivoss, the octocoral Briareum asbestinum, the hydrocoral Millepora alcicornis and the sea urchin Diadema antillarum are some of the more abundant organisms present. Small encrusting algae and sponges covered much of the bottom between the larger corals and sponges. In addition, many encrusting organisms, such as bryozoans, sponges, tubificid polychaetes, and crustaceans live under large, semi-loose boulders. Feet were much more common here than around the algal area and several large lobsters were also sighted. Coral: This type of coral community probably extends from found 35 to 40 feet to the edge of the shelf. The area we examined was 45-55 feet deep, with a few deeper holes. Figures 5, 6, and 7 show typical scenes from this area. The bottom is heavily encrusted with M. cavernosa, Diploria clivosa, Porites asteroides, and gorgonians, and encrusting algae were observed growing among the colonies. Coral coverage here was approximately 50 percent of the bottom area and is similar to coral communities found on the outer shelf south of Puerto Rico. Fishes were very abundant, especially large parrotfish, snappers, surgeonfish, and grunts (Table II). Bottom depressions or holes contained many large schools of the above. A map of the possible distribution of the above bottom types is presented in Figure 8. There are 312 ---Page Break--- 33 FIGURE 5. Photograph of coral formation mainly of Montastraea Photograph by A.S. Froelich, observed at Sargasso Reef, cavernosa and

gorgoniana. ---Page Break--- sub ---Page Break--- ae ayiw je21yneu eu SU ene uo Ax>05 pa le10> doops reu0> moneys FEA fes02-<Bu0ds- F106 doap'tebie prey tug morese6ie peu Ba 1e6te yos snuogs 8 ayuNdla ---Page Break--- 36 mixture of rocky shores and sandy beaches. The observed rocky shore communities were similar to those of other rocky shores around the north and eastern coasts of Puerto Rico. A good description of rocky shore biota, which applies as well to the rocky

outer slope at Punta Iguero, is that of Glynn (1964). No large tide pools were found on the rocks, but tide pool type organisms were found in the pool behind the breakwater of the old meters from shore along much of the beach near the Roms plant. It was not possible to adequately sample this shelf due to high wave action. It was noticed, however, that much of the algal cover on the shelf consisted of Padina sp. Some invertebrates from this area were collected by Dr. F-D. Martin (FRUC) while rotenone collecting for fish. They are included in Table 2 under the heading, "Tide Pool". Finally, a few samples of beach sand from the swash zone were sieved for beach organisms; however, only a few individuals of Hippa eubenele were found. We were not able to examine the sandy area just offshore due to rough weather conditions. Table II is a compendium of organisms that were sighted at various times during the dives or shore work, although they were not collected and sent to the laboratory. They are included here for convenience ---Page Break--- as Table 1 Organisms collected at various sampling stations, for station locations). i-1, Re2y A-dand Has Stations; 3 is from a gokmin dredge haul on "Miscellaneous" are specimens collected from sites; "Tide Pool" included by rotenone "65 ft. Transect" Made 65) Hot M2 3 Red RS Misc, Pool Transect Mene Chlorophyta x x x x x x x x x x x x x x x x x Phaeophyta x x x x x Hhicante x Histiote ans x x x x x x x x x x x x x a x

Exjethaanfot “triquetrun ---Page Break--- a8 le 1 (cont.) tide 65+ Rel 2 R3 Rt RS Mec. Pool transect Rhodophyta Ceranium op. x Coraline 5 xt x x x roralling Sibensis Galeraure x xox x x x x x x x x x x x x x x Thalassia testudinum x Foraminifera ate x Seine es, fone eras compressa x x Porifera Geliyepongi= sp. x Grote Rei x x ‘Gitona sp x Granta x. x x x x x x xox x x x x x Covtenterata Hyérozoa ‘Ghidoseyphus marginatus x x ‘Hiphsete wigs tere x ---Page Break--- 39 Table 1 (cont.) mde 65" R45 Mise, Pool Transect x Anthozoa, Actinieria x x x x x x x x Farices * Sea atlantica x Birieeopeie Tame x * fexaura TTexu6 x x x x x x x x * x x x x x x x x x x x x x x eae ep, |X x x ‘Wicidion Kinvergis, ‘Gaaphis sb x Yentogente x ---Page Break--- 320 exe 2 (cont) Tide 65" Rel Re2 Be} Red BS Mie. Pool transect cigar cae Tefeberie ap; x one Moet oe Sipunculada. Mollusca, Amphineura Acanthonleure granulate ‘Chiten squamosus Gastropoda ‘Reston enttLiarus moe MOM HHO Mo Mane ned ne eee ---Page Break--- Table 1 (cont.) mee 65! Rel Re2 Be} Red RS Misc. Pool Transect cnet ie semngone . Hetierub breticet x ne ee oping #iczac MoM MMM fe ee : Sores fereetite Nodoltttorina tuberculata ‘Sdostouta Teevigate Sacetoats sectnada Mo MO Pinta ae ee on Pignasis nucleus Folinices Tacteus MMH AO MRDOOO BGS Sewanee ---Page Break--- Table 1 (cont.) Ra Gastropoda eCRyCeFETGS muricatus meee, iseieote iguecute goers Eye Bea tive fortes ‘THivis qisdFipunctate tome ateivog pieetTe spe Varateniare mors mollusca, peaacypoca S18 sennm fhorisana x Fapyrides seateuteata X Eater Arthropoda Crustacea Teopoda eoratians leorn ‘Cirolana perve Re2 Re} Red RS Mise. x x x x x x x x x x x x x x x x x x x x x x x x x x x kr x x x OK x x x x x x x x x x x Ey 3ee Bde 65" Pool Transect x ---Page Break--- Table 1 (cont) Rl R2 Ry Teopoda : Paracereie 9 eerste oRidate x ‘Stonapos Gonodactylus ceretedss Decapoda, Reptantia ‘Alpheus erietulafrons Periclimenseus schai tti Anomura ‘Albunes gibbeois Tosnobt te clypentue

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at Stations Rel and Be + The category "scattered algae" includes all areas where encrusting or foliose algae were growing ---Page Break--- Le 111 - Percentages of bottom cover for the Rincon 2x2 m quadrats on Station Number R1 PORES #4 - scattered algae 50.3365% Sponge 03 1 9 7 cavernosa 2 2 16 scleractinia 3 a treed 4 Siderastrea siderea 4 Diploria strigosa 5 Diploria clivosa 2 2 variate 2 Dichocoenia stokesii 3 Leptophyllia strephos 3 Ysophyllia gibbiflora 2 Thalassia sinuosa 1 Willepora alcicornis 2 Briareum asbestinum 2 2 Gorgonians 4 2 total coverage --- Le eS Total 99.3 993 998 1000 as This includes areas where the algal tufts were too little or too difficult to distinguish and outline these. Amount of algae/area varies in this category, but it would be very difficult to quantify. ---Page Break--- in very small patches so that it was not possible to distinguish the actual areas covered by algae and the areas where nothing was growing. Most of this area had around a 30-50% algal coverage on it. Therefore, around two-thirds to one-half of the category "scattered algae” could be added to "no coverage”. Although Station R-2 had a few corals, Rel and R65 had much more variety in the corals present there. Although the existing data are insufficient for an in-depth analysis of the situation, it is apparent that the benthic communities north of the Point are mostly algae; while in those south of the Point corals predominate. Algae are usually considered fairly resistant to thermal alterations, while corals have been shown not to be. Also, siltation can usually be overcome more easily by algae than by corals. Since the major possible detrimental effects to the environment by the plants would be 1) sediment disturbance during construction of the plant, 2) sediment disturbance and suspension at the discharge channel of the plant, and 3) discharge of heated seawater into the environment, care should be taken that the heat and sediment-laden waters do not affect the coral areas which

are of more economic importance to the nearby inhabitants as fishing grounds. Therefore, it is recommended that the discharge channel be well to the north of the Point where it will have to 1) cool off through mixing, and 2) drop its sediment load before crossing the highly productive coral-sponge communities. ---Page Break--- 330 REFERENCES SLUM, Psi. 1964. Common marine invertebrate animals of the shallow waters of Puerto Rico. Institute of Marine Sciences, University of Puerto Rico, Mayagüez, 53 pp. PUERTO RICO NUCLEAR CENTER, 1972. Site selection survey. Studies for the period of July, 1978 through October, 1972, submitted to Puerto Rico Water Resources Authority, 32 pp. SUMANT, A. v12. The zonation and ecology of Jobos Bay coral reefs. Aguirre Power Project Environmental Studies, 19/2 Annual Report, 50 pp. ---Page Break--- ---Page Break--- ---Page Break---