PRNC188

G.118, fader,

PRNC - 188

FUATO AICO NUCLEAR CENTER

CABO MALA PASCUA ENVIRONMENTAL STUDIES

Prepared for the Puerto Rico Water Resources Authority

By the Staff of Puerto Rico Nuclear Conter of the

University of Puerto Rico

June 16, 1975

?OPERATED BY UNIVERSITY OF PUERTO RICO UNDER Co!

'NO. AT (40-1)1899 POR UB ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

---Page Break---

---Page Break---

CABO MALA PASCUA ENVIRONMENTAL STUDIES

by

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

and M.J. Canoy

---Page Break---

---Page Break---

1.1 INTRODUCTION

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

One or more of these sites.

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

The sites chosen for study were: Tortuguero Bay, Punta Manati, Punta Higuero, Cabo Rojo Platform, Punta Verraco, and?Cabo Mala Pasctia (see Figure 1.1-Fi).. The Seventh site, Barrio Islote, was studied and reported under @ separate contract.

The reports in order of their dates of completion are:

Tortuguero Bay Environmental Studies April 1, 1975

Punta Manati Environmental Studies April 18, 1975

Punta Higuero Environmental Studies May 1, 1875

(previous studies of Punta Higuero, also referred to as "Rincon" or "the BONUS site? have been reported in Wood et al., 1974),

Cabo Rojo Platform Environmental Studies May 15, 1975

Punta Verraco Environmental Studies June 1) 1975,

Cabo Mala Pascua Environmental Studies June 13, 1975

?The present report on Cabo Mala Pascua concludes this

series of reports. For environmental research study reports

on the Barrio Islote site, see Final Report of Environmental

Research Studies for a North Coast Nuclear Power Plant (June, 1975).

---Page Break---

2a PHYSICAL AND CHEMICAL PARAMETERS

?AT CABO MALA PASCUA

by

B.D. Wood

2.1.1 INTRODUCTION

?The Cabo Mala Pascua site is located on the southeast

corner of the island of Puerto Rico (Figure 2.1-F1). The

Sampling progran has been centered on a valley immediately west of Cabo Mala Pascua. The point at Cabo Mala Pascua rises very steeply within 700 meters from the shore to a height of 323 meters. The only other location suitable for building power plants is in the Maunabo River flood plain on the east ?Side of Cabo Mala Pascua. The sampling zone lies between Fanta Tuna to the east end Punea Viento to the west (Figure

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

2.1.2. TIDES

?The tidal waves that affect the south coast of Puerto Rico have their amphidromic point in the eastern Caribbean Sea. The waves move ina counterclockwise direction (Anikouchine and Sternberg, 1973), that is, from east to west past Cabo

?a Pascua. The south coast?tides are diurnal. Two waves exist, but one is dominant for about ten days, followed by about four days of neap tide conditions as oné wave decré in amplitude and the second wave builds. Then, the seconi wave is dominant for about ten days. Predicted tides for the South coast are shown in Figure 2.1:F2. These predictions were made from the National Oceanic Survey (1972).

ses

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

2.1.3. CURRENTS

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

Rico rarely exceeds 0.5 knots (25 cm/sec).

2

---Page Break---

Sig. 2.4-FL Cabo Mata Pascua site with depth contour Lines and hydrographic

Sampling transects each with three stations

---Page Break---

1972

6

15

fs

<0

Mor!

Cirren

4

NOVEMBER

24

3 3 2 2 ° 2

t ® & 2

F-OW sW>Wws oF

1

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

---Page Break---

The current pattern near Cabo Mala Pascua is affected

by wind, tide, river discharge and the shape of the shoreline.

The wind is predominantly out of the east (Wood, 197Sa) tending to come from the east southeast during the day with nfd-day velocities of about 7.5 m/sec (15 knots). Four out of the six major hurricanes that hit Puerto Rico since 1893 struck at Cabo Mala Pascua. This tends to push surface water onshore toward the west. Back eddies form at times on the lee sides of Punta Tuna and Cabo Mala Pascua.

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

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

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

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

Currents at Cabo Mala Pascua were measured using dye @rops and aerial photography in the morning and again in the afternoon of November 15, 1972. The first drop started shortly before 0900 in the spots? shown in Figure 2.1-F3 which coincided with low tide (Figure 2.1-F2). The currents were very weak,

but most tended to the west. ?The current near the garbage dump at Cabo Mala Pascua (drop #i) started to the cast as did drop #8. Drop #8 turned west slowly as the tide began to rise, but drop #4 continued to the east for about one hour at about 11 cm/sec before turning slightly seaward and then west. Drop #6 started west, then turned shoreward toward drop #3. Drop #2 went into

---Page Break---

---Page Break---

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

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

Table 2.1-T1,

TABLE 2.4-Tt Dye studies at Cabo Mala Pascua, Novenber 15, 1972

NORNINS 0850-1117

Dye Drop Wiocity Direction comments

Nunber 9300-2000)

1 23 en/sce 1 West, then slightly

seaward

2 10 en/a s# Inshore, eplit, offshore

3 5 cm/sec ve Wry slow

6 11 ea/see ENE Nast, then turned west

5 10 en/sec va ?wry slow second hour

é 8 cm/sec ne Little movenent

7 5 enforce cy Slow west

8 1 en/eee W NE, then slow west

AYTERWOON 1325-1550

Dy Drop. Wlocity Direction comments

Number? 1325-1535,

7 @ vo Started west, then

dissipated

2 9 wow Bllowed shoreline

3 18(0) ¥ (started fast, then

4 38010) ® Colowed in the second

(hour

5 5 8 (Mow was slightly shore-

8 e W (ward, but paralleled

7 a wa (the shoreline

8 1308) W Slowed after Firet hour

---Page Break---

---Page Break---

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

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

to be that flood current is to the west while ebb current is to the east.

2.1.4 BATHYMETRY

The Puerto Rico Nuclear Center has undertaken no. detailed bathymetry of the Cabo Mala Pascua site beyond that done during benthic and hydrographic samplings ?The COO Charts 302, and 928 (National Ocean Survey, 1972) are inadequate, especially with regard to the definition of shelf edge and deep Water soundings south of the outer reefs. Alsoy there are Sone discrepancies in the shallow regions caused by coral growth and shifting sediments. The contour lines. shown in Hygure 2,1-F1 and the depth profiles in Figure 21-3 were drawn ysing depths shown? in The above mentioned charts" and sonic depths obtained during hydrographic work

?The shallow region immediately west of Punta Tuna is slightly protected from the dominant wavotrain and receives Sediments from the Maunabo River. This high siltation retards coral growth to Cabo Mala Pascua. Nearshore coral reefs exist westward from Cabo Mala Pascua to the bay just east of Punta Viento. A shallow basin exists seaward of these nearshore reefs bounded on the south by a series of long narrow reefs

about 2 kilometers off and parallel to the shoreline. The

seaward side of these outer reefs mark the shelf edge. The

shelf slope is very steep in this region especially between

Cabo Mala Pascua and Punta Tuna where the bottom drops from

20 meters to over 1000 meters in a distance of 2 kilometers

as shown in Figure 2.1-F5.

2.1.5. TEMPERATURE, SALINITY AND DENSITY

The physical parameters of temperature and salinity

were measured at the Cabo Mala Pascua site on seven cruises

Covering four seasons (Table 2.1-T2).

---Page Break---

Fig. 21-15 Botton profites along the sampling transects of tho Cabo Mala Pascua site

?Gréieal Lines indicate relative positions of the hydrographic stations vertican

EXAGGERATION

25

---Page Break---

TABLE 2.1-T2 Schedule of hydrogrephic cruises to Cabo Mala Pascua,

wrvreR SPR SUMER PALL

PA-088

3972 - Mar 264 : +

Pa-028

1973 Feb 22 May 23 - -

PA-039 PA-042 PA-046 PA-052

1970 Teb 29 ape 23 Aug 22 Nov 14

??????? ae am

Tor Punta Viento, resulta reported by Beck, 1072,

?The hydrographic sampling stations are shown in Figure 2.1-F1, Five transects were sampled on most cruises. The transects are nearly normal to the shoreline, each with three Stations wore most shoreward, the

88 of 125 meters of water, 'and the most seaward stations ("C") were in excoss of 325 meters. Fourteen depths were sampled on each transcct. Temperatures were measured using deep-sea reversing thermometers with readings accurate to +'0.03°C, Salinities were determined with an induction Salinometer to an accuracy of * 0.005°/oo. The values are included in a report of hydrographic data for the south coast of Puerto Rico (Wood and Asencio 1975). These data were con- Verted to standard depths and averaged by season and type of stations. The sampling, analytical and data processing pro cedures are described in "A Manual for llydrographic Cruises (Wood 19756).

Temperature

Temperatures were determined using reversing thermometers in pairs, or in triplicate when possible. Although only one temperature is shown on the computer printout of the data (Wood and Asencio 1975) for each depth, these values are often the average of two or three thermometers. Most temperatures below 50 meters were measured using both ?protected? and ?unprotected? reversing thermometers. A thermometer depth, 12, was then calculated for the sampiing depths and correlated quite well with the calculated depth, CZ, obtained from the amount of hydrowire paid out, WZ, and the cosine of the wire angle, 0. A comparison of some of these depths was made for the Punta Verraco site report (Wood et al., 1975).

"

---Page Break---

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

?The averaging for the depth profiles was done first for all stations by season (Figures 2.1-F7, 9, 11 and 13) then by type of station by season (Figures?2.1-F8, 10, 12 and 14), The tabulated data are in Appendix 2. 1A.

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

Little seasonal change was seen below 150 meters except that the fall temperatures were generally lower than the other

Seasons. There was a general temperature decrease in the 100 to 200 meter depth interval between winter and fall. The

thermocline during spring was 50 meters and in the summer and fall was about 25 meters with a temperature inversion existing in the fall as Surface cooling and land runoff occurred.

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

Very little change in surface temperatures with distance fron shore was seen at Cabo Mala Pascua. Slightly warner nearshore tenperatures existed in spring and sunner and silghtly cooler temperatures in the? fail.? "Nearly uniform surface temperatures were noted in the infrared Scans nade

here, also, (Wood 1975a) except for slightly cooler than ambient températurés in the plume of the Maunabo River.

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

2

---Page Break---

---Page Break---

He.

Shee 34 35 36 37

TC 16 18 20,22 24 26 2B

100.

o

E

Pe

T

H

m

200

300

mo. 1 2 3 4 5 6

POS pa-at.P/I x10 cMP=1

2A TT Averaged hydrographic paraneter (temperature, T°C; salinity, $°/005

density, &; dissolved oxygen, 0p; and reactive phosphate, Fof) vs.

Standard depth in netere for the'winter season of 1979 and 1974 at

Cabo Mais Pascua.

4

---Page Break---

Nig. 2.4-18 Depth profiles of hydrographic parameters averaged by type of stetion

for the winter season of 1973 and 197

Stee 34 35 36 37

Tec 82022 ee

8 Te A

8

- |

504 A eft

}

|

100 i b

0 0 re

? T

Pp

, A i

* if

100

m

\ y 9

200

300

Opmio 2 + 2 300 4 5 6

Ph po-ct PI XI0 cMP-t

---Page Break---

Te 16 18 20. 22 24 26 28K

100

3 ra0mo

200

300

Qmno 2 1 2 3 4 5 6

POR pg-at PN X10 CMP -2

Tg. 24-19 Averaged hydrographic parameter depth profiles for the sprire

Season of 2972 and 1974 at Cabo Mala Pascua.

16

---Page Break---

Fig. 2.1=110 depth profiles of hydrogranhic panane

fon for the spring season of 197%

= averaged by type of

a7,

ae

so}

1004 7

raumo)

100

200

300

4 mill O 1 2

po-at P/IX10

---Page Break---

S%eo 34 35 36 37

TC 16 18 20.222 24 26 28

100

°

E

Pp

H

m

200

300

Qmno 2 4 2 3 4 5 6

PO} pg-at P/1X10 cMP-3

Hg. 2.1-Fit Averaged hydrographic paraneter depth profiles for the sumer

season of 1978,

---Page Break---

Tig. 21-112 Depth profties of hydrographic paraneters averaged by type of station for the eusner season of 1974,

35 36 7

Re

8 20. 22d SCR

srw Te A

10 a T

° 8

501 | x Q

100 l

Do re

E

P

T

H

100

| 5 Nes

200

300

ee

Omid. ft 7 3 a Se

Py po-ot PNxI0 cMP=3

---Page Break---

3 ravmo

200

300

Le nnn Geena

nin O 1 2 3 4 5

ee PQ} pg-at P/IX10 CMP-4

Fig, 24-719 Averaged hydrographic paraneter depth profiles for the falt

20

---Page Break---

Hig, 24-78 Depth profiles of hydrographic paranetere averaged by type of

station for the fa! season of £274,

Ste 34 38 36 37

Teco 82022 BG

? = st = y?7?JA

>

E

.

r

4

m

200

300

mil O

° CMP-4

POH po-ot P/1x10

a

---Page Break---

TEMPERATURE °C

16 8 20 22 24 2628

3 r3avmo

cme

Winter +

Spring 2

Summer 3

Fig. 2.1-F15 Averaged seasonal depth profiles of "C" station temperatures at

Cabo Male Tascua for 297 and 197%,

---Page Break---

Salinity

Salinity, $°/oo, is the total salt content of water

expressed in parts per thousand. It is used along with

temperature to typify ocean water masses. Low salinity

usually occurs at the surface and indicates dilution by pro-

cipitation, runoff, or fresh water intrusions. High salinities

are found in subtropical regions and are the result of high

rates of evaporation. The salinities at Cabo Nala Pascua were

determined using an induction salinoneter with the readings

good to better ?than + 0.005°/oo. The average seasonal sa.

jinity data are shown plotted against depth with the other

hydrographic parameters in Figures 2.1-F? through Fide. In

general, the salinities increased with depth to about 150 meters then decreased slightly, The layer of high salinity water with @ maximum of about 37.08/00 was formed by evaporation in the subtropical North Atlantic Ocean,

A comparison of the averaged "C" station data by season is shown in Figure 2.1-Fl0. The lowest surface salinities are found in the fali season coinciding with the end of the tropical rainy season. The highest surface salinities occur in the spring toward the end of the winter-spring dry season. The salinity depth profiles are very similar, below 75 meters for all seasons except fall. A sharp pycnociine exists at about 50 meters during the fail where the salinity increases fron about, 33.7 to 36.9°/o0 between the depths of 25 and 100 Meters. The Salinity maximum is shallower for the fall season fo. Little Seasonal change was noticed below 150 meters Where the salinity decreased from 36.8 to about 36.4°/00 300 meters except that the winter salinities were slight higher than for other seasons.

It

Little difference was seen in surface salinities with distance from shore for all seasons except fall. The affect

of the sumner-fall wet season is reflected in low salinity

values caused by land runoff.

Density

Water densities were catculated from temperature and

salinity data and included with the other paraneters as

Signa-t, ?t. Signa-t is related to density at the temperature

measured,/t, by the following relationship?

Sts t= 1) x 105 (ny

Changes in sigma-t with depth are an indication of the sta-

bility of the water column. A small sigma-t gradient indicates

a well-mixed or unstable zone, whereas a high gradient is ine

dicative of a very stable portion of the water column. The

surface layer usually has @ very small density gradient because

---Page Break---

SALINITY ?oo

34 35 36 37

°

?

P

T

H

?,

cue

Winter

Spring

Summer

Foti

300

Tig. 2.1-P16 Averaged seasonal depth profiles of "C" station salinities at

Cabo Nala Pascua for 1973 and 1974,

2

---Page Break---

Of wind-induced wave mixing. This 1ayer varies from iess

Sigma-t profiles are shown plotted with other paraneters in

Figures Pvt? eneeuge ata,

surface water density decreases because of dilution and fairly

There was no significant difference in surface density

with distance from shore except during the fall season when

the "A" station densities were lower than for the "B" oF "iC"

Stations (Figure 2,1-F14) due to low salinities

2.2 cHENIsTRY

2.2.1 DISSOLVED oxYGEN

qhe amounts of dissolved oxygen, D.0., in the water off

eegstals Pascua were determined by the Winkler titrariee mohod foracghtand,and Parsons, 1968) with the analyses useeily per-

Thee one iRipboard within a fow hours of sample Counaey (eer

peesbigration Values are generally good to berter cha ee

repay Ge OnyEeR data are included with the hydrogreehis dita

Teported by food and Asencio (1975) in mi/4, mel aan teat

yiv8gn saturation is a function of both temperature and

Teade Liansatee Rether shifts drasticaliyyin ehereraeare,

Averaged ange in Near surface D.O. is expected nor weeras? Seen.

Othe eae orayalues in milliziters per Titer are pieced 2eee

pe seaheaTontaphic parameters in Figures 2<1-FF chedtk ty%

wiageasOR and type oF station. "the highest value eeee El tne

Tison ore deoeureace values were near saturation A cam?

{he ,PAYgeN Minimum occurred at about 200 meters, slightly shai loner

arepte, BFIRE and slightly deeper in the summer. ?ett Sh average oxycen minimum was 4.11 me/t during the spring coccan,

2.2.2, NUTRIENTS

izients are important from two aspects. First, nutrients

Ses Sontnee Yqlow," the tropical Atlantic Ocean and carineens

Sea Surface waters and Limit prinary productivity. Second,

---Page Break---

DENSITY OF

28

20 22 24 26

°

Aq

100: N\

D

E

P

T

H

m

200

cme

Winter 4

spring 2

Summer 3

Fol 4

300 Me

Fig

2

24-717 Averaged water density (signa-t) profiles of "c"

by season for Cabo Mala Pascua, 2973 and 1974, tation data plotted

---Page Break---

DISSOLVED OXYGEN mV

3 4 5 6

o+ ?i

MP

Spring

Summer

soo, Fan

D

E

Pp

T

H

m

200

300:

Fin. 2.2-T1 Averaged dissolved oxygen depth profiles by season at Cabo Mala Pascua

for 1973 and 187%,

---Page Break---

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

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

ive Phosphate

\e concentration of reactive phosphate was generally low (ca 0.05 ug-at. P/t) in the surface waters off Cabo Nala Pascua as'seen by the averaged "C" station seasonal phosphate profiles shown in Figure 2.2-F2, The phosphate values remained tow with depth to nearly 200 meters before increasing to about 230 ugrat. P/t.

Reac

There was very Iittle difference in surface phosphate concentrations with distance fron shore except in the fall- This anomaly coincided with low salinity (runoff) in the fall season

Nitrate

Nitrate was determined by the cadmium-copper reduction method (Wood et al., 1967). A limited number of samples were analyzed for nitrate at Cabo Mala Pascua for the summer and fall seasons of 1974, The transect CMP-4 was sampled for nitrate in beth the Summer and fall of 1974, The "A", "B" and "cv station data were averaged and the resuiting depth profiles for the two seasons are shown plotted in Figure 2.2-F3." The Rearshore nitrate surface values were higher than those at the offshore stations for both summer and fail, Surface nitrate was generally low to 150 meters where a general increase began. The Values at 300 meters appear low in the summer season and high in the fall season, Nitrates were near zero at 30 meters

in both summer and fall.

28

---Page Break---

REACTIVE PHOSPHATE jg-at.P/i

0 43 04 o2 03 04

°.

MP

Winter 1

Spring 2

Summer 3

400 Far 4

o

E

P

r

H

m

200

300

Fig. 2.212 Averaged reactive phosphate depth profiles by season, 1973 and 1974

---Page Break---

NITRATE ?_ pg-at. N/l

0 2 4 6 8B 10 12 14 16 18 20

100

3 I4vmo

200

300

Fig. 2,2-f2 wWitrate depth profiles for the summer and fall seasons of 197%

at Cabo Mala Pascua.

---Page Break---

3a GEOLOGICAL PARAMETERS AT CABO MALA PASCUA

by

E.D. Wood

3.1.1 INTRODUCTION

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

Cabo Mala Pascua itself is located on a wedge of volcanic rock which is very hard and resistant to erosion.

The plant site would most likely be located slightly to the west in a valley which is underlain by quarte-diorites and granite-Like rock. Roth rock types are Cretaceous in?ag

the diorite being considered part of the San Lorenzo batholith,

The Maunabo River flood plain lies to the cast between e Mala Pascua and Punta Tuna, Another flood plain makes up Punta Viento. This alluvium covers dioritie bedrock,

Sediments

The sediment size distribution found at a particular location reflect two factors, supply and transport. Sediment Samples were collected at ali "A? stations and sieved. Plocs of cumulative weight percent and weight percent histograms for the fine sediments are shown in Figures Se1-Fl and fo, The sieving statistics are tabulated in Table 3.1-Tl.

TABLE 3.4-T1 Size analyses statistics for the Cabo Wala Pascus sedinenta.

SaaaaanREREEEmmeeeeeeeeemeee

MEDIAN MEAN STD. DEX

STATIONS Nao Me ?a

6A

The major supply of sediment in the Cabo Mala Pascua

region is the Maunabo River. Some sediments are carried around

Tunta Tuna, also. The scdiments at CMP-GA were very fine

(Mé* 3.4). Fine sand and course silt might be expected here

an

---Page Break---

(wis Bol-=o

some £ 2 1 0 ee

so *

---Page Break---

see!

S66

ind cwnutative wefght poncen:

---Page Break---

since it is very near the mouth of the Maunabo River and the

Jee of Punta Tuna offers a region where fine sediments may

be deposited.

Sediments at the other "A" stations were more coarse (sand) especially on the windward side of points such as

Punta Viento and Cabo Mala Pascua.

---Page Break---

4a ZOOPLANKTON STUDIES 1973 AND 1974

by.

Marsh J. Youngbiuth

4.1.1 INTRODUCTION

The following report provides estimates of the abun-

dance and diversity of zooplankton in the surface waters

along an eastern portion of the south coast of Puerto Rico.

These data form one part of an environmental survey conducted

by the Puerto Rico Nuclear Center, All collections were

gathered in an area adjacent to the recion proposed for the

siting of a future power plant. Samples were gathered on

2 days during 1973 and 1974; 22 February, 23 May, 13 February,

23 April, 22 August, 14 November, and 12'December.

4.1.2 MATERIALS AND METHODS

Field Procedures

Zooplankton were collected with a 1/2 meter diameter cylinder-cone shaped nylon net. This net was designed to reduce clogging error (Smith et al., 1965), Nesh size was

233 microns. The net was towed from a 17 foot skiff ina circular path through the upper 2 meters, The speed of the vessel ranged from 2 and 3 knots (determined with a Sims yacht specdoneter). The duration of a tow was 10 minutes After each tow, before the cod end was removed, the net was washed with sea water with the aid of a battery driven pump (12 volt, Jabsco water-puppy). The catch was preserved in

44 sea water formalin buffered to pl 7.6, All samples were gathered during the daylight hours. The volume of water filtered through a net was estimated with a flowmeter (TSK or General Oceanics Nodel 2030) suspended off-center in the gouth of the net. The volumes usually ranged from 100 to 150 n>. The meters were calibrated every 2 months. Calibration factors fell within 8! of the mean.

At each site three tows were made in the area adjacent to the region where a power station may be located. Single tows were taken at the other stations. The regions sampled

Were chosen in such a way as to collect within and around the

area where thermal alteration is likely to occur (Figure 4.1-F1).

---Page Break---

uoayuetdooz 1a-1"y ?Bid

serys wnaseg BTeK 0geD 9y2 3B suOTIES

---Page Break---

Laboratory Procedures

Within 24 hours after samples were collected the pit

was checked and adjusted, if necessary, to 7.60 If a

sample contained a noticeable conglomerate of phytoplankton

or detritus, the zooplankton were separated from such ma-

terial by gentle filtration through 202 micron mesh netting
Before estimates of biomass or numbers were made all organisns larger than 1 cm, usually hydrozoan medusae, were renoved,

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

The total number of organisms was estimated by Volumetric subsampling with replacenent (Brinton 1962)

Three aliquots from each sample were counted, ?The abundance of major taxonomic groups of holoplankton and meroplankton were determined fron dilutions of 300 to 500 organisms. Copepods, usually the most numerous of the zooplankters, were identified to species.

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

4.1.3 RESULTS

A total of 46 samples was collected fron 5 stations (Figure 4.1-F1). The abundances of several taxonomic groups of Zooplankton at each station have been determined (Tables 41-16 through T17). These data are arranged to facilitate comparisons among Sets of consecutive tows, nearshore tows, and offshore tows.

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

---Page Break---

TABLE TL, Summaty of ratios between the highest and lowest density

values of total zooplankton during each period.

3979 3974

20 Feb 29 May 13 Feb 23 Apr 22 Aug 14 Now 12 Deo

Consecutive Tows 1.30 162 2.2/1 1.4 1.2/0.5 162 4.2

Neavshore Towe 2.00181. 26 0

offshore Tows 1.20.2

Wil Tow Rene a2 26 28 = 2a

?The ratios are similar but generally smaller than

those observed in other coastal regions around Puerto Rico

(Youngbluth 1975). Another way of judging differences be-

tween samples was determined by calculating the variance

between consecutive samples and estimating the number of

tows needed to detect various levels of difference (Table.

401272). ?These data indicate that a large number of replicate

TABLE 61-12, Total zooplankton (logyg transforeed) fron 7 sets of

replicate tows. The number of replicate tows (n) needed

to detect a + 5-308 difference in density is indicated.*

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

stato 2 2 2 2 2 2 2

2.60306 .

2.55630 2.91908 2.08047 260986 p.ounge 9.15229

2.77052

2.suuoT 2.90867 28237 Zage2 2.97589 9.07188

2.6057 2.90098 aigsoue 2.72591 5, 10

a 209s 2.72534 5.03202 3.14299

ash uss? nye ss

ae 3 3 24M 1 1

noob 1 1 4 1 1

Suz t2 ms? Where (1) je Student's ¢ for the 95t confidence level

G2 (dufo2)y s° 46 the sanple variance based on replicate tows

dth of the confidence interval desined

---Page Break---

tows would be necessary to detect density differences at the 5% level. However, on the average, differences of 20% can be noted with only?3 tows. Differences of 30% may be Tevealed with a single tow. Density estimates larger than

304 were found between nearshore and offshore catches. The range of density values during a sampling period was usually two to three-fold. Seasonal changes in the abundance of total zooplankton at any station or among all samples were within the same range (Table 4.1-T6). The highest concen: trations occurred in December. These larger densities, how- ever, probably represent the range of variation among tropical zooplankton communities in the coastal waters around Puerto Rico rather than a recurrent seasonal pulse since the 954 confidence intervals from each station overlap (Table 4.1-T3).

TABLE 43-19 Average density of all zooplankton collected.

Total Zooplankton/ad

ee

173 1974

22 Feb 22 May «19 Feb 25 Apr «22 Aug 24 Nov 12 De

Range 231-654 530-840 $57-6N5 269-812 gou-ess -

Median 320 663 586 619 532 - -

Mean 26 863 600 591 352 - -

58 Cb. 4897 490807 ass a3 - -

?These fluctuations in density refer primarily to

holoplanktonic organisms since they composed, in most cases,

60 t0 90% of the total zooplankton. Meroplankton formed 3.

to 27% and were more numerous during April and August. The

dominant meroplanktonic groups were prosobranch veligers and

caridean larvae.

Fish eggs were abundant in this area forming 2 to 40%

gf thg total zooplankton (Table 4.1-T4), The largest density

229/m3, was observed at Station 5 on 13 February 1974. Fish

eggs were mgre numerous on this date than any other, aver-

aging 177/n® and forming 31% of all zooplankton collected.

Most of the eggs were round and 0.5 to 2 mm in diameter.

Oblong eggs were common. It is not known which groups of

fish are represented by most of the eggs.

---Page Break---

TABLE 4.4-Te Sumary of densities of fish eggs from all stations

sampled at the Cabo Mala Pascua eite.

??

STATION

1 2 3 ® 5

Range 12-96 19-151 197-824-229 23-208,

Median ou 38 25 48 87

Mean a? 52 50 88 at

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

Copepods formed 60 to 85% of the zooplankton community. A total of 39 species was identified. Time did

not aliow a detailed examination of species abundances at all stations, consequently, one sample from Station 2 for

each period was selected for study. The entire sample was

Scanned to form a species list and subsampled for quanti-

tative analysis. Using these data, the species most numerous,

those commonly observed, and others occasionally found are

listed in Table 4.1-T5.

---Page Break---

TABLE 4.2A1-TS, Copepod populations observed at the Cabo Mala Pascua Site.

Species usually most numerous (7% individuals/n®)

Clausocatanus funcatua

Foracalanus spp. (?- aeuleatua, P, erlssivostris, P. parvus)

Ferranuia graciite

Otehona spp. (, plunifera, 0. app.)

earvia spinata -

?Fesoreinbtaata

Galanopia anerfeana,

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

Conyeaeus spp. (C giesbrechti, ¢, pacificus, C, speciosus)

Teenie wlgartse

Talocaianie

Nammocstanis wfaon

os

Candacta

Fisiaews Tonptcomte

ia ighies

Species oscasionaliy present

spp. (0, nedivernanea, 0

Torycacus spp~ (C- susutatas, ©. SPI

Feendodiaptomie soksrt TPP

Galoestants pavoainas

?Scolectthrix. danae

Copia apps

Spain ?spp.

Yonstriiia spp.

Nacrosetela gracilis

Pisema spinifene

a

---Page Break---

4.1.4 DIScUSSTON

?The variety and abundance of zooplankton observed

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

Copepeds always dominated the zooplankton community The larvae of gastropods and decapods were the major mero- planktonic organisms, The largest proportion of meroplenkton Occurred during Aprii and August. Fish eggs were very numerous during February 1974.

Limitations of the Data

?The sampling program was designed to provide quanti- tative 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 hanner of field sampling determined the variety and bionass of organisms encountered. The data in this report are based fon collections made in the surface waters during the daylight hours. The sampling gear and methods were kept uniform, i.e.,

net type, net mesh, towing speed, and depth range sampled.

A-small Aumber of Feplicate tows were gathered at each site

to obtain some measure of the variability between sample:

To obtain a better understanding of the zooplankton community

more sampling with replication should be done at frequent

intervals, at a greater number of stations, at different

depths, during the day and night, and during different seasons

for several years. Information gathered in these ways will

be necessary to interpret fluctuations in standing stock and

diversity in relation to environmental changes and biotic

interactions.

---Page Break---

BATUPHe ?AED TH/ ANE FUE Ty

- seo - oer oett owt wre

- - : ee + one oMettnE

oe ee ses usyecs 6 69/565 nuacee

a9 a8 oe, we oan 999 ere sunoez

95 uss 935 gtz/on9 ons eee Jor coc/ete??emuzort

99 95 eu one os 108 ore exsoee

882, sez 18 ove ee ose oe euzote

* s ? ? : 2 & w see

EAE aS RTS

sx01 8095550 exoy e2oyes09%, cnog exearrdeg ssoyeston

(eu/doquna) uobquvydoos Jo aeqane TOD aire Starr

- 280) - - 60" err 80" wucter

- - - - eer zi cor: onettar

- s1un0" ta" 480°7650" n60°/0S0" 60"/t60" yresoze

c 80° ww fs nunoee

8 ne smo"/610" 9¢0°/260" we0"/980" ?yracoet

neo 0 gor 260 0° exsoez

zo" 010" 90" aro shor exzoze

* = = z T % a oa Ra

wares ToS

sno 2048550 sno saoyssves,

SaTe wioeeg Pity OTD (qa Fe) BONN TIO Jo TG TET Ete ore

43

---Page Break---

2uSrepFMo_ tAepern/aNPTUPTAg

us - 8s - 6 es a err

- - - mer sot sor otutiNy

wo a ees ear erie centr ort/ssyusaxe

3 ? uw we oer 86 ss se senoee.

ze 8 ? ones tren vs aye gnczorr

ose 6s mo ze s6 et exsoee

wo 6 Ea ste z a ° eczoee

* 5 ? = « = ae

wonHS SWS

senoy 99048550 enoy aneopTdeg aogsseey

Tqa/asqana) uortueidoiou Jo sone Ted arte Tee

- ws - amet ster sor over suzret

- - - wee 988 eee om onettar

soz oct ore esn/son ces Tue/ssy?aes/ea?convaue = ytuBore

eur 98s ust 9 ate os, ens 130 sunoce

me oat ase no/zon 26 oreo nB/tn creme uzocr

ose tes oes pes SoH Sse 78 3 ecsoce

ae tet ss wt oss 008 c0e 6 eccove

7 : = z t = « % ae

ROTTS ToaTS woes

nox 92046550 on sxoyezeoy soy s289FTday auoussEON

Tauis PHoseg CUES OD (ga/seGaa) UORIONTACTON Fo aE THO Thre 1a

---Page Break---

SubiCeTHe *eppra/sutruety

= ost ~ ve one th re wazeee

- : - we ten sts Sse ghatter

see store ze sos esi/en b/c pncaorz

cere a ese et oar eee es nunoee

wor 9 tet oe ers crest aynot?stucaee

wore i sce oot 02 ose cd exsoee

or 98 ms aat__teh ae aut 56 exzote

é z ¥ = ve oe

ToS aes saaS

?eno 046359 enoy Bsoyeseey sno, o3e2}tde ascent

(qaoiaeiamay Season jo saga TOL Orr oTeeE

= see - wn eee 6 eer naziet

: - - mS ove 099 £99 ohuttnr

oot oz ceo oewane ers ase/tor ?aen/zon?Lzw/onz?ghusrz

stm ors eer ensue on 36" one sence

wee se ee eayore tan o/eoc ?ox/sne sear ynuzot

son se us ome ess ors os exgoce

est ont een mee ae ea ze exzoez

* 5 ? z + 2 & %

a eS SOAeS

smog, 93095532

ero saogeaeag

ssoy s38oFtdoy ssoyssvo:

Tonys enone] Sten

Faaqruray apoledes go Seqane Twaed

Posed

4s

---Page Break---

ays)

SORTA TUE

~ we - ue oe es

- - - ee = ee vez okatEat

coe cee sue teefenn ue zeta sarees yma0ee

es as sr swe. 60 96" nose

me ase ses gayest eriest ?sayues?taytst greet

cron so uns ter tn 095 exsoee

oe orcs wt on z o exzoee

° s © z t % @ we oe

SiS Topas

mos 92096530 sang 920452898 nog exeoy day ascyszeen

ae /aogana) beavey saRpTen go Fegan ToL ord

~ ew : on my os eee sects

- - - see 1s sm 99 hc teE

seek ext eayocs cor eesoon?cttyore = ttysse?gtueace

nee sor me gaz on er ts sunoez

eras car eevee ne fevers wuyeun?czyuet?gmuzoct

nes e585 tee srt en eect cn wor eusoez

ee ame eee etme ost 6 8 euzore

* 5 © z ¥ = @ % oe

SSS Res SORES

enor asoysis0 sno, osoysce9g ror oveoyTing asoyextoK

?eans mnowed ©T¥4 OWED (quOT/sOqATU) SUEOTEAIeT Zo TOqIMU TA 9 OTE

46

---Page Break---

SWBrpyie tAMpeTA/ SNSUP

> ee ~ = + on we went

- - - see nse % once

ss eet Hein os eur/en ?vez/ne?ynuaee

eon a » . + ze % nenoee

1 te + weet 9 zit en eee wnizoer

eo ee er oer sst zr exsoez

. * st 9 ?© "s % eezoce

© z 7 % « & ort

a ai

nog at04y33:0 eve: esoyetoss smog a3eoFrdeg aloyareon,

{SI eg) Ces RTE Sm TT WET y TL

=e - 98 - o o or mucter

- - - oe oe uaz er oncttn

scree yor oetvoet? ete ont/ner syste seayeet?ynusoze

ome cr 8 ee o 66 sucez

mos + wose we wyser Were era guzoer

ae + oe wor eet 98 zs ost exsoee

ster se ee 65 ° sexo

7 : ? z * = @ we

Fars aS TAS

nog 92098330

?aro. soyseon

nog s28OF Tou esoyeseeK

"Oars erosRa PTeH

ome) (qa01/aeaana)

ft ueepyaes 30 Zoqunu THIOL

Pree

a

---Page Break---

BaStpHis Mepera/ wSRODTKS

~ ee = oF - te ot ee mere

- - - - o eo i omettHe

= oe * sees ot oxen zeyen test ymuaoee

ws et a zs ? o er ?uncee

noe ee us orate wiser wetser wrszoer

eons x se ? a 8 eusoce

eo 6 a 6 8 3 wuzoze

? z r 3 = we oe

aot ss0ueson

snog savoytdeg asoysieey

Gqusqana) Sie Weys go Sogare Twin

- 06 - ? - & om ae mutt

- - - e - 6 ? onto

. 1 + exes te 698 ayn ytusoze

9 + 99 se a ss err sunoce

. . * ws ves was wmzoer

ue Pa ork ner ect exsoce

. es er te 8 + eucoze

> : : z t = % * eae

xox axcuess0 anor as3ees

Tears mnoveg ®TON O@@9 (,a0i/seqna) FFTRPE

Teadpuiys go Soa TSE Srisra ore

ae

---Page Break---

4.2 BENTHIC INVERTEBRATES AND FISH STUDIES

by

Paul Yoshioka

4.2.1 INTRODUCTION

This report gives the results of benthic and fish

studies conducted at the Cabo Mala Pascua site fron February

1973 through August 1974,

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

The qualitative and quantitative descriptions of communities are important aspects of community studies. However, these aspects represent only preliminary levels

of community investigations and are often insufficient

to satisfy the demands of contemporary environmental concerns. It is often necessary to ascertain the direct effect of

a perturbation on populations of specific species and also 3ts secondary and tertiary ecological effects upon the

entire community

The role of such secondary or tertiary ecological

effects should not be underestimated. Several studies have demonstrated that the structure and diversity of ny natural communities are determined by ecological inte:- actions (Dayton 1971; Paine 1966; Paine and Vadas 1969; Kitching and Ebling 1961; Huffaker 1959; Harper 1969).. In Such cases predictions based solely upon the direct effects ?of any physicochemical perturbation on single species populations would be inadequate and misleading if extrapolated to the conmunity level.

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

---Page Break---

seays wndseg PIEN oe Oya 2e suOTAeIS PLOTS sarpnas Dyauog La-z'y ?Sta

50

---Page Break---

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

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

The gorgonian communities were selected as the major object of investigation during the latter phases of this study, ?The gorgonians represent a dopinant feature of the Benthic communities at the Cabo Mala Pascua site. The growth fore! of gorgonians adds a considerable amount of physical structure and heterogeneity to the benthic environment.

Such physical structure greatly influences the remainder of the biological community (Elton 1966). Gorgonians nay be useful indicators of environmental parameters such as wave action, currents, and turbidity, also. (Grigg 1972; Opresko 1975; Goldberg 1573; Kinzie 1973) -

4.2.2 MATERIALS AND METHODS

Field Procedures

Field stations are shown in Figure 4.2-F1 and Appendix

Field procedures were divided into three categorie: surveys, shore fish collections, and station dives.

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

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

sq Station dives. Station dives were made at the various stations to collect quantitative samples and to observe the Presence of macrginvertebrates and fish. Gorgonians were collected in $m? (1 x § m) or 10 m2 (2.x 5m) quadrats depending upon the diversity of gorgonians and limitations of diving bottom time. Gorgonian samples were taken in April, ?August, and December 1974. ?Two replicate samples were usually taken.

st

---Page Break---

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

Quantitative samples of infaunal gnd smaller epi-benthic organisms were taken from 1/4 m¢ quadrats. These samples were placed in a plastic bag held as close to the Sampling site as possible to minimize the loss of organisms. Substrate was renoved with the aid of a hanmer and chisel. Vicente (1974) provides further description of the samp! ing method.

Laboratory Procedures

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

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

4.2.3 RESULTS:

Both rocky shore and sandy beach habitats are found at the Cabo Mala Pascua site. At the shoremost subtidal Stations the bottom consists of rock boulders, ledges, and sandy areas (Stations S11 and $12). At distances of about 500-1500 meters offshore sand dominates the bottom substrate (Stations 3, 2, $9, $10) although boulders wero encountered in the viciiity'of Station CS10./ ?the mos! abundant encrusting organisms appear to be the zoanthid Palythoa. Gorgonian, coral, sponge, and fish species observed if Station 12 are listed in Appendix 4.2C. In general, the diversity (in the number of species) was iess at the inshore stations than at hard-bottomed stations further offshore. For example, four genera of gorgonians were observed at Station S12 versus

nine at Station S8. Shoreline fishes collected at the Cabo Mala Pascua site by rotenone and seining are listed in Appendix 4.2B. Organisms at shore stations S1 and S2 are Listed in Appendix 4.2).

Several plant species were observed growing on the sandy

substrate at Stations $2 and $3. Among these were Caulerpa

Udotea, Halophila, and Halimeda (see Appendix 4. °C), The

dontnant plant at Station So was lialophiia.

---Page Break---

scalty Boulders gt Station S10, harbored many organians

typically associated with hard substrates, including Mont.

gavernosa and other hard corals, and several sponges Cally=

Spongia Vaginalis, Haliclona rubens, Verongia longissina,

and treinte stropiaiaas ~

The reefs, occurring about 2.5 kilometers offshore,

offer the most visually impressive benthic communities

(Stations S1, $5, S4, S6, 57, S8, S13). The rocky substrate

contains relatively fittle topographic relief. No larse

outcrops, ledges, or depressions were encountered. The

major features of the benthic fauna appeared similar in all

offshore reef areas. A list of the larger vrganisms observed at Station S8 is found in Appendix 4.2C. Although the Larger algae are conspicuously scarce, in general the richest diversity of larger benthic and fish life was observed at these offshore reef stations. For instance, three species of fish were observed at (inshore) Station S13 and $0 species at (offshore reef) Station 8.

Quantitative Samples

The epifaunal and infaunal organisms collected in two 1/4 m2 substrate samples at Stations S1 and $7 are listed in Appendix 4.2. The distribution of individua}s among species shows the same characteristics found in 1/4 m* quadrat samples collected from other sites. In particular, there is an equitable distribution of individuals among species. Eighty-two individuals were divided among 38 species at Station S1 (excluding algae) and 66 individuals among 30 species at Station $7. The species were represented by 66 and 674 single individuals, respectively. Of a total of 58 species, only 12 occurred in both samples. The lack of similarity between the samples in terms of species co-occurrences prob: bly cannot be attributed to differences between the stations because samples taken within a few meters of cach other at other sites have also shown a similar amount of disparity.

Gorgonjan colonies were collected on 22 Aprit 1974 fron two $m? quadrats at Statiog $8. Overall colony density was 10.4 and 17.8 colonies per a/ in the tvo subsamples, The Shree fort abundant ?species! {a decreating. order of abundance were Plexaura homonaila, Funices clevigera and Plexaura. flesuosa, These species comprised? about $71 oF the torel_ Ruse et eee nies. The relative abundances shoved a significant correlation (Kendaii-Tau="+0.71, pe0.01) indicating that the relative abundances of the go/gonian conmunity was adequately sanpied,

---Page Break---

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

4.2.4 DISCUSSION

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

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

?The greatest abundance of fish life vas observed at the Cabo Mala Pascua site in rocky areas with moderately

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

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

---Page Break---

43 PLANT ASSOCIATIONS

by

M.J. Canoy

4.3.1 INTRODUCTION

The general aspect of Cabo Mala Pascua is one of an advanced tertiary successional forest. It has a deceptive form in that the difference between wet and dry seasons is

30 pronounced. During the dry season the leaf area index. (LAT) is between 1 and 2 or as high as 3 on the ridges and northwest slopes of the hills. During wet seasons. the LAr changes to

~6 and the apparent dominant species shifts as trees and shrubs that Stood bare previously begin to leat out the

change seems to be fron a xerophytic to a mesophytic forest in two weeks tine.

The trees and shrubs found on the study site range from

Bucida buceras to Trichilia hirta and the vines are predominantly

Acacia riperis, Banisteria purpurea, and Stigmaphyllon lingulatum.

No grasses or forbs were observed on the site; during either

the wet or dry seasons. (See Appendix 4. 3A)

4.3.2 MATERIALS AND METHODS

?The study site was walked twice, once during the winter nonths (dry, season) and again during the sunmer-f411 months wet season).

4.3.3 SUMMARY

Three relevant points should be remembered.

(A) The forest is novel for Puerto Rico.

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

(©) If the large highway now being planned for the area

is built, in view of points (A) and (8), there may be nothing left to protect,

---Page Break---

REFERENCES.

Ahistrom, D.H. and J,R, Thraikill, 1962. Plankton volume loss with tine of preservation. CALCOFI Rept. 9:57-73.

Almy, C.C., Jr, and C. Carrion-Torres, 1963. Shallow-water Stony corais of Puerto Rico, Carib. J. Sci, 3(2§3):133-162.

Anikouchine, WA. and R.W. Sternberg, 1973. The World Ocean: ?An Introduction to Oceanography, Prentice-Hall, Inc., Englewood Cliffs, N.J.

Bailey, R.M. (Chairman), 1970. A List of Common and Scientific janes of Fishes from the United States and Canada (Third Edition Aner. Fish, Soc. Publ.) No. 6:1-149.

Bayer, F.M., 1961. The Shallow-water Octocorallia of the West Thdian Region! Martinus Nijhoff, The Hague, Netherlands.

Beck, B.F., 1972. Preliminary report on the proposed Punta Verraco power plant site, Submitted to PRNRA Feb. 1, 1972. PRNC, Mayaguez.

Bigelow, H.B. and W.C. Schroeder, 1953. Fishes of the Gulf of Maine, Fish and Wildl. Serv. Fish, Bull, 74, Vol. 53, U.S, Dept. of the Interior, GOP, Washington, D.C.

Bohike, J.E. and C.C.G, Chaplin, 1968. Fishes of the Bahanas and Adjacent Tropical Waters. Acad, of Nat, Sci, of Phila., Livingston Publ. Co., Wynnewood, Pa.

Breder, C.M., Jr., 1948. Field Book of Marine Fishes of the Atlantic 'Coast. G.M. Putnam's Sons, New York.

Briggs, R.P. and J.P. Akevs, 1962, Hydrogeologic map of Puerto Rico and adjacent islands. Atlas NA-197, U.S. Geological Society, Washington, D.C.

Briggs, R.P., 1965. Geologic Map of the Barceloneta Quadrangle, Puerto Rico: 17142. U.S. Geological Survey.

Brinton, E., 1962. Variable factors affecting the range and estimated concentration of euphausiids in the North Pacific. Pac. Sci. 16:374-408,

Brock, V-E., 1954. nary report on a method of estimating reef fish populations. J. of Wildl. Mgmt.

28 (3) :297-308.

Brooks, J.L. and $.L. Dodson, 1965. Predation, body size,

?and competition of plankton, Science 150:28-35.

---Page Break---

Carpenter, E.J., S.J. Anderson, and B.B. Pech, 1974. Copepod

and chlorophyli concentrations in receiving waters of a

nuclear power station and problems associated with their

measurement. Estuar. and Coast. Mar, Sci. 2:1-25.

Casey, J.G., 1964, Angler's guide to sharks of the north-

eastern? United States Naine to Chesapeake Bay. Bur. of

Sport Fisheries and Wildlife, Circular 179, Washington, D.C.

Cervigon, F. 1964. Los Corycaeidae del Caribe suroriental

(Copepoda, Cyclopoida). Men. Soc. Science Nat. La Salle.

24:163-204,

Cervigon, F., 1966. Los Peces Marinos de Venezuela, Tonos I y Il, Mohografias Nos. 11 y 12, Fundacion La Salle de Ciencias Naturales, Caracas.

Chace, F.A., 1972. The shrimps of the Smithsonian-Bredin Caribbean Expeditions with a summary of the West Indian shallow-water species (Crustacea: Decapoda: Natantia), Smith Contr. Zo01., No, 98.

Chaplin, C.C.G. and P. Scott, 1972, Fishwatcher's Guide to Mest Atlantic Coral Reefs. Livingston Publ. Co., mnewood, Pa.

Clark, H.L., 1933, Scientific survey of Porto Rico and the Virgin isiands. A handbook of the littoral echinoderns of Porto Rico and the other West Indian islands, N.Y. Acad. of Sci. 16(1).

Connell, J.H., 1961. The influence of interspecific competition and? other? factors on the distribution of the barnacle Chthamalus stellatus. Ecology 42:710-723, Darwin, D., 1854. A monograph on the subclass Cirripedia.

Ray Society, London. Repr. by Johnson Reprint Corp.

(1968), New? York.

Dawson, E.Y., 1956. How to know the Seaweeds. William C.

Brown Co., Dubuque, Iowa.

Day, J.H., 1967. A monograph on the polychaeta of southern

africa, Parts I and IT. British Musou (Natural History),

jondon:

Dayton, P.X., 1971, Competition, disturbance, and community

organization: the provision and subsequent utilization of

space in a rocky intertidal community. Ecol. Mon. 41:351-389.

, 1972, Toward an understanding of community

?FEETTIsRte of the potential effects of enrichments to the

benthos at McMundo Sound Antarctica. Proc. Coll. Conserv.

Prob. in Antarctica, Ed. 8.C, Parker, Allen Press, p. 81-85.

---Page Break---

Dukin, W.J. and A.N. Colefax, 1940, The plankton of the

Australian coastal waters of New South Wales. Univ,

?Sydney Dept. Zool., Monogr. 1.

Elton, C., 1966. Animal Ecology. Sedgwick and Johnson, London.

Fager, E.W., 1972. Diversit)

A sampling study, Am, Nat.

106: 3932310.

Fields, F.K., 1971. Floods in the Guayanilla-Yauco Area,

Puerto Rico: U.S.G.S. Hydrologic Investigations

Atlas HA-414,

Fields, F.I. and D.G. Jordan, 1972. Storm-wave swash along

the north coast of Puerto Rico: HA-430, U.S. Geological

Survey.

Fraser, J.H. and V.K. Hansen (Bds.), Fiches d' Identification

duZooplankton. ?Conseil Permanent International Pour

1" Exploration de la Mer. Andr. Fred. Host & Fils, Copenhague.

Frost, B. and A. Fleminger, 1968. A revision of the genus Clausocalanus (Copepoda: Calanoida) with remarks on Giseributional patterns in diagnostic characters, Bull. Scripps Inst. Oceanogr.

Glynn, P.W., 1964. Common Marine Invertebrate Animals of the Shallow Waters of Puerto Rico. Inst. Mar. Sci., Univ. Puerto Rico, Mayaguez.

Goldberg, W.M., 1973. The ecology of the coral-octocoral conminities off the southeast coast of Florida: geo-morphology, species composition, and zonation. Sul. Mar, Sci. 23:465-488,

Gonzalez, J.G. and T.£. Bowman, 1965. Planktonic copepods from?Bahia Fosforescente, Puerto Rico, and adjacent waters. Proc. U.S. Nat. Mus, 117(3513):241-304,

Grice, G.D., 1960. Copepods of the genus Oithona from the Gulf of Mexico. Bull. Mar, Sci, 10:485-490,

,, 1961. Calanoid copepods from equatorial waters GE tHE Pacific ocean. Fish. Bull, 61:1-246.

, 1963. A revision of the genus Candacia. Zool.

WedeTingen. 38:171-194,

Grigg, R.W., 1972. Orientation and growth forms of sea fans.

nol. and Oceanogr. 17:185-192.

Grossman, 1.6.» 1963. Geology of the Guanica-Guayani1ia Bay

Area, Southwestern Puerto Rico: U.S.G.S. Prof. Paper 475-B,

pp. BIid-BIi6.

---Page Break---

Hall, D.J., W.E, Cooper, and E.E. Werner, 1970, An experimental

Approach to the production dynamics and structure of fresh

water animal communities. Limnol. and Oceanogr. 15:859-929.

Harper, J.L., 1969. The role of predation in

egetational

diversity. Brookhaven Symp. Biol. No, 22:

8-62.

Hartman, W.D., 1955. A collection of sponges from the west coast of the Yucatan Peninsula with descriptions of two new species. Bull, Mar. Sci. Gulf Carib. $(3):161-189 and A color key to the sponges of La Parguera, Puerto Rico, Inst. Mar. Biol., Univ. of Puerto Rico, Mayaguez, No. 1789.

Hedgpeth, J.W., 1973. The impact of, impact studies. Helgol. wiss: Mires, 24:436-445,

Hickenlooper, I.J., 1967. Floods at Barceloneta and Manati, Puerto Rico; #262. "U.S.Geological Survey.

Holmes, Arthur, 1965. Principles of Physical Geology, 2nd Edition: The Ronald Press Co., New York, New York, U.S.A. 1288 pp.

Huffaker, C.B. and C.E. Kenneth, 1959. A ten year study of vegetation changes associated with biological control of

Klamath weed. J, Range Manag. 12:69-82.

Huselman, K., 1966. A revision of the genus Lucicutia. Bull.

Mar.?sci! 16:702-747.

Hutchinson, G.E

1961. The paradox of the plankton. Am,

Nat. 95:137.

Hyman, L-H., 1955. The invertebrates: Echinodermata. The

coelomate Bilateria, Vol. 4.

Janzen, D.H., 1970. Herbivores and the number of tree species

in?tropical forests. An. Nat. 104:80-528.

Kaas, P., 1972, Polypacophora of the Caribbean region. Studies

on the fauna of Curacao and other Caribbean islands,

415137) 11-162.

Kendall, T.R., E.D. Wood, and T. Smith, 1975, Hydrographic data report, north coast of Puerto Rico, 1973-1974, PRNC Report?177,

Kinzie, R.A., III, 1973. The zonation of West Indian gorgonians. Bull. Mat, Sci, 23:93-155.

Kitching, J.A., and F.J. Ebling, 1961. The ecology of Lough Ine X1," The controi of algae by Paracentrotus lividus (Echinoidea). J. Animal Ecol. 30: 373-383.

---Page Break---

Laubenfels, M. de, 1936. A discussion of the sponge fauna ?of the Dry Tortugas in particular and the West Indies in general, with material for a revision of the families and Orders of the Porifera, Publ. Carneg. Inst. 467 (Paps. Tortugas Lab. 30):1-225.

.1949. Sponges of the western Bahamas. An. Mus.

TST Ts.

Little, E.L., F.H. Wadsworth, and J. Marrero, 1967. Arboles Comunes de Puerto Rico y'Las Isias Virgenes, Editorial, Univ, de Puerto Rico.

Manning, R.B., 1938. Key to the genera and species of Western ?Atlantic Stomatopoda. After Schmitt, W.L., The stomatopods fof the west coast of America, based on the collections made by the Allan Hancock Expeditions, 1933-38. Allan Hancock Pac. Exped., 5(4)1129-255.

McLean, R.A., 1951. Scientific survey of Porto Rico and the Vitgin Islands, The Pelecypoda of Porto Rico and the Virgin Islands. N.Y, Acad, Sci. 17(1).

Menzies, R.J., and P.W. Glynn, 1968, The common marine isopod Crustacea of Puerto Rico.? Studies on the Fauna of Curacao and other Caribbean Islands. 27(104) :1-133.

Monroe, W.H., 1971. Geologic map of the Manati Quadrangle, Puerto Rico-Map 1-167, U.S.G.S., Dept of the Interior,

National Ocean Survey, 1971. Tide Tables 1972, East Coast ?of North and South America, NOAA, U.S. Dept. of Commerce.

National Ocean Survey, 19728, Tide Tables 1973, East Coast

?of North and South America, NOAA, U.S. Dept. of Commerce.

, 1972b. North Coast of Puerto Rico,

art Nor $, NOAA, Dept. of Commerce, Nov. 4, 1972.

, 1972c. South Coast of Puerto Rico,

THEFE NG-CROS BUT, NOMA, "U.S. Dept. of Commerce, Washington,

: , 19724. Guayanilla Bay § Tallaboa Bay,

?UNaTE NGS IEWOAA, LS: Dept. of Commerce, Washington, D.C.

National Weather Service, 1973. Raw weather data taken hourly

gE Sani Juan international Airport. NOMA, Dept. of Commerce,

jan Juan.

Nutt, MoE.

1975. Islote Environmental report, 1975. Puerto

Rico

clear Center.

---Page Break---

Oceanographic Program, 1971, Report on oceanographic base line data for neatshore areas along the coasts of Puerto Rico. Dept. of Public Works. Commonwealth of Puerto Rico, San Juan.

Ogden, J.C., R.A. Rrown, ard N, Salesky, 1973, Grazing by the echinoid Diadena antiliarum Philippi. Formation of halos around Nest Indian patch reefs. Science 182:715-717.

Opresko, D.M., 1973, Abundance?and distribution of shallow-water gorjonians in the area of Miami, Florida. Bull. Mar. Sci, 23:535-558.

Owre, J.B, and M. Fayo, 1967. Copepods of the Florida current. Fauna caribaea 1112157.

Paine, R.T., 1966. Food web complexity and species diversity. Am, Nat! 99:97-108.

Paine, R.T, and R.L. Vadas, 1969, The effect of grazing of the sea urchin, Strongrlocentrotus, on benthic alga: populations. Limn. and Ocean, 14:710-791,

Park, T.S., 1970. Calanoid copepods from the Caribbean Sea and Gulf of Mexico, 2, New species and new records from plankton samples. "Bull, Mar. Sci, 20:472-546,

Provenzano, A.J., 1959. The shallow-water hermit crabs of Florida. ?Bull, Mar. Sci. Gulf and Carib, 9(4):349-420,

, 1959. Pagurid crabs (Decapoda, Anomura) from StI Youn, Virgin Istands, with descriptions of three new species.? Crustaceana, 3(2):151-166.

Puerto Rico Department of Public Works, 1972. Oceans baseline

Puerto Rico Nuclear Center, 1972. Preliminary report on the Survey of Tortuguero Bay Site for the installation of

nuclear power plants. Report to Puerto Rico Water Resources Authority, Aug. 23, 1972,

, 1974, PRNC-174. Punta Higuero power plant eaviFormental studies 1975-1974. Report ts P.Ry i Resources Authority. port to PeRs Water

Puerto Rico Water Resources Authority, 1975. North Coast Nuclear Plant No. 1 Environmental? Report.

Rathbun, M.J., 1933. Scientific survey of Porto Rico and the Virgin Islands." Brachyuran crabs of Porto Rico and the Virgin Islands: N.Y. Acad. Sci, 15(1).

Roos, P.J., 1971. The shallow-water stony corals of the Netherlands Antilles. Studies on the fauna of Curacao and other Caribbean islands. 57(130) 1-108.

---Page Break---

Rose, M., 1933. Copepods pelagiques. Faune Fr. 26:1-374.

Schmitt, W.L., 1935. Scientific survey of Porto Rico and the Virgin Islands. Crustacea Mactura and Ancrura of Porto Rico and the Virgin Islands. N.Y. Acad, '$(2,.128-277.

Schultz, G.A., 1969. How to know the Marine Iscpod Crustaceans. William ¢! Brown Co., Dubuque, Iowa.

Shoemaker, C.R., 1935. Scientific survey of Porto Rico and the Virgin islands. The amphipods of Porto Rico and the Virgin Islands,? N.Y, Acad, Sci 15(2):229-262.

Smith, F.G.W,, 1971. Atlantic Reef Corals. Univ. Miami Press, Corai Gables, Fiorida.

Smith, P.E., R.C, Counts, and R.I, Clutter, 1968. Changes in filtering efficiency of plankton nets due tc clogging under tow. J. Cons. perm. int, Explor, Mer. 32:232-248

Smith, S.V., 1973. Factor-analysis of presence-absence data
in Atlas of Kanesha Bay: A Reef Ecosystem under Stress.

Strickland, J.D.H. and T.R. Parsons, 1968. A Pract?cal Hand-
book of Seawater Analysis, Bulletin 167, Fish. Res. Bd.
Canada, Ottawa.

Suarez-Caabro, J.A., 1958. Quetongnatos de los mares Cubanos.
Mem. de 1a Sociedad Cubana de Historia Natural. 22:125-180.

Taylor, W.M., 1960. Marine algae of the eastern tropical
and subtfopicai coasts of the Anericas. Univ. Michigan
Studies Sci, Ser., 21.

Thomas, L.P. 1962. The shallow water amphiurid brittle stars
(Echinodermata, Ophiuroidea) of Florida, Bull. Mar. Sei.
Gulf Carib. 12(4):623-694.

Treadwell, A.L., 1939. Scientific survey of Porto Rico and
?the Virgin fstands. Polychaetous annelids of Porto Rico
and vicinity. N.Y. Acad, Sei, 16(2):151-319.

Van Name, W.G., 1930, Scientific survey of Porto Rico and

the Virgin? Islands. The ascidians of Porto Rico and the

Virgin Islands. N.Y. Acad, Sci, 10(4):405-535.

, 1945. The North and South American ascidians.

TT eF? Muss Nat. Hist., 84,

Vicente, V.P., A key to the sponges of the West Indies. Unpubl.

Warmke, G.L. and R.T, Abbott, 1962, Caribbean Seashells.

Livingston Publ. Co., Wynnewood, Pa.

---Page Break---

Wiebe, P.H. and W.R. Holland, 1308, Plankton patchiness:

Effects of repeated net tows. Limnol. and Oceanogr.

12:316-321.,

Williams, A.B., 1965. Marine decapod crustaceans of the Carolinas. U.S. Fish Wildl. Serv. Fishery Bull. 65(1).

Wood, E.D., F.A.S. Armstrong and F.A. Richards, 1967. Determination of nitrate in sea water by cadnium-copper reduction to nitrate. J. Mar. Biol. Assn., U.K., 47:23-31.

Wood, E.D., 1974. Punta Higuero power plant environmental Studies 1973-1974, PRNC-174,

Wood, E.D., 197Sa. Winds for Puerto Rico with sumnaries- Yol. i! Ponce, 1971-1974, Puerto Rico Nuclear Center, Mayaguez

Wood, E.D., 197Sb. Aerial infrared scanning of discharge fegions of present and alternate power plant sites. Vols. I and II, Puerto Rico Nuclear Center Tech. Report, PRNC-180.

Wood, E.D., 197Sc. A Manual for Hydrographic Cruises. in press.

Wood, E.D., and R. Asencio, 1975. Hydrographic Data Report West Coast of Puerto Rico. in press as a PRNC Technical

Report.

Wood, et al., 1975. Punta Verraco Environmental Studies.

Buerto Rico Nuclear Center - PRNC-188

» MoJ. Youngbluth, M.E. Nutt, P. Yoshioka and

?Wy~tanoy, 1975. Tortuguero Bay?Environmental Studies,

Puerto Rico Nuclear Center, PRNC-181.

Yanaji, I., 1973. I11ustrations of the Marine Plankton of

Japan.? Hoikuska Publishing Co., Ltd., Tokyo.

Youngbluth, M.J., 1973. Results of the plankton survey at

hai de Tortuguero, Punta Manati and Quebrada de Toro.

January and March, 1973. (unpublished).

Youngbluth, M.J., 1974a, Diel changes in the composition of

@ tropicai, coastal zooplankton community. In preparation.

, 1974. Diel changes in the composition of

?Wropical Tooplankton assemblages from coastal waters around

Puerto Rico, Unpublished.

,1975 Survey of zooplankton populations in

Jobers Bay.?in preparation as part of Jobos Bay Environmental

Studies, Puerto Rico Nuclear Center.

---Page Break---

---Page Break---

APPENDIX 2,14,

Tabulated Averaged Hydrographic Data

---Page Break---

---Page Break---

AVERAGE SATA FOR 42339" +

OFPTR Te PEMATLAE 5,

2

---Page Break---

(CABO MALA PASCUA ~ 3

Pugs -NITRUGE?

ae

NITROGEN

8.195

---Page Break---

AVERAGE ATA FOR @2333# THROUGH 7Sob4

DEPTH TEMPeaA Sicha 7

a 25, 25,601

we 25, 351682 23,603,

AVERAGE DATA FOR O25324 THROUGH A59692

DEPTH TEMPERATURE SALI? 8

35

May

623

1 35,743 an

28 35,744 234657

3e 35,765 23,709

3 36 23,928

75 36

320 36,635

AVERAGE ATA FOR @23351 THROUGH 739679

LINITY s.

DEPTH TEMPERATURE Sa

2 25,936

1225.83

22 25 le26

Se 81779

5a Belert

75 251829

32224! 788

152 22,883

2a

25?

sae 171397

CABO MALA FASCUA=14

OXYGEN PHOS NITROGEN

782

973

CABOMALA PASC UA-18

OXYGES PHOS NITROGEN

2,033,387

263

176

407

ayA26 2,796

yess e138

10438484

CABO MALA PRECIA-10

OXYGEN PHOS NITROGEN

4,857 ayer2 2,297

2,248

eye83

043832

3972 5ue

21

230

125,

2,269 2

my3e7 21998

---Page Break---

AVERAGE DATA FOR 829493 THROUGH 042735 CABO MALA PASCUA -28

DEPTH TEMPERATURE SALINITY SIGMA T OXYGEN PHOS NITROGEN

@ 27,258 35,721 23,395 4,738 8039 aaa

18 -27,2388 35,729 B3y208@ «44741 m9 ew

AVERAGE DATA FOR 829502 THROUGH #42734 CABO MALA PASCUA -28

DEPTH TEMPERATURE SALINITY SIGHsA_T OXYGEN PHOS NITROGEN.

a 27879? 35,725 4,795 Po

10271255 35,725 2

28 35.726 e

3e e

52 2

75 e

108 36,580 @

AVERAGE DATA FOR 829583 THROUGH 042735 (CABO MALA PASCUA = 2°

OEPIH YEWPERATURE SALIVITy Sicth 7 OXYGEN PHOS SI TROGEN

27,861 $923,771 44822 BSA BeBe

2 331756 gszex 44842 2,eee

22 35,783, 29a 4)802 eyeue

3 351755 Bi ay 794 a.eue

5a $5,788 24783 a, 202

75 361144 23,946 4) 683 ey2ee

127 36,529 53744575 ayeee

134 >a a6 43785

20a 67 57 ayaa

252 $8 6,394 ANAL

302 $6,413 264517 44305

---Page Break---

AVERAGE DATA FOR 846852 THROUGH A46854

DEPTH TEMPERATURE

9 28,286

1 28,334

SALINITY SiGMA_T

AVERAGE DATA FOR @48849 THROUGH 74484>

DEPTH TEMP

2

18

20

3e

32

75

x08

ERATURE

28,110

28,117

23,324

27,935

28,763

25.228

23,549

SALINITY Sigma T

35,534 22,781

35,535 22,779,

22,778

22,899

23,607

24,426

25,180

AVERAGE OATA FOR 246842 THROUGH 46544

DEPTH Temes

3

rt

2e

30

52

5

sae

159

20>

252

30

ERATURE

28,130

28,132

SALINITY

35,584

351584

35,528

35,592

CAM ALA PASCUA ~ 3A,

OXYGEN PHOS NITROGEN

24026

ase

CABO MALA PASCUA 93

OXYGEN PHOS NITROGEN

4,762 #252

4794 e350

47a 2,239

4y785 2,228

41963 2,239

41922

aaa?

CABO MALA PASCUA ~3C

OxYGES PHOS NITROGEN

4,738 74290

41734 ay 74s

41738 alpen

P1735

Pines

raat

262

03767

yan

Oy x6

208

---Page Break---

AVERAGE DATA FOR 952998 THROUGH 52002 ?CABO MALA PASCUA ~ 4A

DEPTH TEMPERATURE SALINITY SIGMA T OXYGEN PHOS NITROGEN.

© 26,882 «SB, 94e = 25,206 4,884 Byes 8428

12 26,958 33,421 28,566 4,702 BVO Bee

AVERAGE OATA FOR #52995 THROUGH 252991 CARO MALA PASCUA - 4B

erry TEMPERATURE SALINITY SJcHA y OXYGEN PDS MITRUCES

33,738 214794 #030 1138

we 224165 a

2 22,534 @

3° 22,991 a

be 24,275 8

75 24638 2

08 25,231, a

AVERAGE DATA FOR 982996 THROUGH e52998

DEPTH TenPeRaTURE SALINITY S¥nms 7 OHyGEN

27,822 «33,729 244777

fy 22,097

20 22,398

se aes

30 nas

5 667

122 25,245

452 254744

2ar 264199

259 26.448

320 26,576

---Page Break---

APPENDIX 2.18

BATHYTHERMOGRAPHY TRACES

---Page Break---

---Page Break---

2¢-ano

---Page Break---

Ouarz &

st ee ste se

2°530 JUNI HIONIL S20UYL HoUUSONNIHLAWING

---Page Break---

cucKs

99-aNn9

98-aK9

o¥-ano

28-aK9

se ae

sz

Mab SCORYINLAMIYE

---Page Break---

99-aK9

st

ez

28-ano

St ae

3 °930 SuNiwNTaNIL

29-ano Of-eK 92 -4n2

a

52

rest ?e2 ?adv

z¥0 "ON estnag

ey

ee s ez Se ae

S30VHL HovYOONNIML ANUS

---Page Break---

rc6i ?12 *8ny

9¥OVd "ON osyn39

---Page Break---

261 ?PL *AON

Yon asrnag,

zsovd

99-419 98-aN9, Ob-aKo, 8-dWO 92-aK9

athe /MV/ r +

ee st ae se ee se ae

2 °930 aunLuaadWai

SIDUYL Hob4IOHTHLAHLUS

out

ez

gst

aot

---Page Break---

APPENDIX 4.24

Dates of Dives and Locations of Benthic Stations

Station Bt

?Location:

Date:

Investigator:

Station 82

Location:

Date:

Investigator:

Station St

Locat ica:

Date:

Depth:

Invest

Station $2

Lecation:

Date:

Depth:

Investigator:

Station $2

?Location:

Dat

Depth:

Investigator:

Station su

Location:

Data:

Depth:

Investigator:

Station $5

Lacation:

Date:

Depth:

Investigator:

ator:

ft Cabo Mala Pascua

Shore station about one mile west of

Cabo Nala Pascua

22 March 1973

Se Martin

Shore station about two miles west of

Cabo Nala Pascua

22 March 1973

5. vartin

Reef station about 1.5 fles offshore

at Punta Viento

22 Febvuery 1972

16m

3. Martin

Sand station abovt 0.75 miles southeast

of Punta Vento

22 August 1974

dss

P. Yoshioka

Sand station inshore of $2

22 February 2673

20»

S. Mantin

Reef station about 0.5 miles east of S2

23 May 1972

e-em

V. Vicente

Reef station about 1.0 miles east of St

22 February 197%

ism

P. Yorhioka

---Page Break---

APPENDIX 4,2 (continued)

Station $6

Location:

Date:

Depth:

Investigator:

Station s7

Location:

Date:

Depth:

Investigator:

Station $8

?Location:

Dates

Dept!

Investigator:

Station 99

Location:

Date:

Depth:

Investigator:

Station $10

Location

Date:

Depth:

Investigator:

station Sit

Loca:

Date:

Dept

Investigator:

Station $12

?Location:

Investigator

Station $23

Location:

Date

Depth:

Investigator:

Reef station about 2,0 miles east of ot

1,0 wiles offshore

23 May 1973

32 t0 18 m

¥, Vicente

Reef station about 0.5 miles east of $6

22 February 1979,

aim

W, Vicente

Reef statton about 0.5 niles east of 87

2 February 1974, 21 May 197%, 22 August 197%,

32 Decendet 1974" (Permanent station)

P. Yoshiova

Sand station about 0.3 miles {nshore of $7

22 February 1973

2a

S. Martin

Sand boulder station about 0,7 niles

Inshore of $7

22 February 1975

cary

8. Martin

Inshore station

22 February 1972

O- 5m

S. Martin

Inshore station near Sit

22 August 1978

o- sm

S. Martin

Reef station about 1.5 miles east of $7

22 May 1978

retry

V. Vicente

---Page Break---

APPENDIX 4,28,

Shoreline fishes of the Cabo Mala Pascue

FAMILY

Muraenidae

Echidna

Ophichthidae

wyrichthys

Gobuaocidae

Arcos macrophthalmus

?ieoe Bstgenoeae

Tonfeodon acta

Reson artiue

cuninatus

Sconpacna plunien:

corneidae

nelanopterus

Ponacentridae

Abudefduf taurus

Hudefdut saxatis

Magitidae

Mogit Liza

Labeédae

Doratonotus segatepis

Halfshoeies Soceliettna

Searigae

Sparisona rubripinne

Blenniidae

Entonacrodus, nigricans

cLinidae

Dablenariopsis leptocirnis

Dabeieemas eee pense

LBbrlsoms fattTensts

Tabelsoms auchipinnts

cobiiae

Awaous tajasica

Sipe peti seven tneatus

sovenTinentus

Guatholipis thonpson

tontapeltur oleeona

idae

ast

schoepet

27 Feb 73

Fry

27 Feb 73,

Rotenone

2

---Page Break---

APPENDIX 4.20

Macroinvertebrates, algue and fich cbserved at

?selected stations at Cabo Mala Pascua

s2 31 se

22 hug 7 22 Aug 7 22 Aug 7H

Phytun Rhodophyta

whloria op. x

Phylum Chtororiyta

Caulerpa noxicana

founds

Fenietilus capitatus

?doten conglurina

Bates Flabeloun

?Deoten apinatoca,

Phylum Spermatophyta

Lents x

Hauophsta

ava,

FONGDOM

Phylum Poritera

elas

Sathorigneita varians

tallgepongle vag teat hs

rLgepongta vap als

Tinachyra caverncaa

wtlietes ep

Faliclonm rubene

Tpeints

ToereTota birotulate

Wyeate angulosa

Wyeale a.

WeeriSulania nagsa

Difgocerse Reworrages .

Weranria Tacunos

Verongto Longisetna

Terongia op x

Recteepangia muta x

---Page Break---

APPENDIX 4.26 (continued)

s2

22 Aug 74

Phylum Cnidaria

Class Anthozoa

Subclass Octocoralita

Sriareum asbestinun

?Enythropettam eps

Eunfers Landay

Eunleea ay

Sengenta 2p.

Tunfeca 6p.

Sarfoeapeis ap.

Flexaure Flextosa

?Hisaura Ronomafia

?Feeueplexaura sp-

Reeudspeeroamt Eerogorgia ep.

reroergia =p

Subelass Zoantharia

Acropora cervicornis

eae

ieee &

eeiperhplta sp.

BicResoeaTa atokestt

Biptaris TagNIEeE Fon

Diplorta +3.

Eusetiia sastigia

Teghylis ltt fisre

Reandrina ep.

EiElepora sp.

Hentaserea caverncea

Feet betas

Sideraatrea radTans

?Sideraaerea averea

Phylum Chordata

Subphylum Vertebrata

Class Pisces

Family Dasyatidae

Unid. Dasyaria x

2 hug 74

se

22 ang 74

x

x

---Page Break---

APPENDIX 4.2¢ (continued)

s2 $12

8/22 8/22

Phytun Chordata

Family Muraenidae

Gymnothonax noringa

Tarily Holecents

Holocentrus. sp.

Syripristle Jacobus

Fantly Aulostomidae

Aulogtonus maculatus

Family Sphyraenidae

?Sphyracna barracuda

Fanity Serranidae

Cephalepholis fulva

Gea cerrante

Family Granmistiéae

Rypticus sp.

Family Echeneidae

Echeneis

aucrates

Family Carangidae

caranx crysos x

Decapterss #p-

Fanity Lutjanidae

LytJanus ap.

Fanily Ponadasy!éae

aemslon favo ineatun

Family Sciaenidae

Equetus 9p.

Family Sparidae

Calamus bajonade

Family Mullidae

Peeudupeneus acu

ona

se

8/22

ene

---Page Break---

APPENDIX 4,20 (continued)

Phylum Chordata (cont.)

Pam{ly Chaetodontidae

Ponacanchus

Saveodss

Frovnathnes a ales

Family Ponacen

thromis cyanqus

Thromfe mule! Tineatue

Pomacentrus partitus

macenrad 5p.

Ely Labrivae

Noddanes rufus

falfchoeres sp.

Tar

Family Seariéae

Sparisona =p.

thie geeria

Family Acanthuridas

Acanthurus ep.

Panity Balictidae

Balsstes ep.

falletes votula

s2 s12

eee 8/2228

x

x

x x

xX

x

x

x

x

x

x

x

se

6/22

senna

---Page Break---

APPENDIX 8.20,

Cabo Mata Pascua shore collections

Station 82 Station 32

22 Harch 1979 22 March 1979

Puylum Chlorophyta

Cauilerpa racemosa

GhanaotorTs pendeun

faitmeda opuntia

Pontius eapitatus x

Foniortius duretosus:

Uaotea Fiabeltun

Siva Tactucs

Phylum Phacophyta,

Dictyota oitiolata

Ene pcetecim

Phylum Rhodophyta

Sryothasnion triquetrum

Terantun sp.

Talaraura sp.

Tanks captttace

Taurene?a papitiosa

Sclysipionts ep.

Phylum Spermatophyta

Syringodiun ££1iforme x

?Seimedian sp x

Thalassia Tastudinum x x

ARTHAL

EINGDOH,

Prylum NoLdusca

Class Gastropoda

Acnaea anti2iarun x

ieteaes be x x

Salle striata x

---Page Break---

APPENDIX 4.20 (continued)

Phylum Mollusca (continued)

Class Gastropoda

Sertthiun veriabile

Silunberre nereatoria

Diotora welaara

EisauretTs Bas

Fisnmelia ap.

HenTtona Sctoradiata

Class Pelecypeda

Barbatia doainpensis

Codakia orbieutarts

Phylum Arthropoda

Order Decapoda

Suborder Arachyurs

Caltincer,

Werophrys aniliensis

Phylum Echinodermata

Class Fehinoidea

Tripmeustes esou

ensie

Station B2

22 March 1979,

Station 87

22 March 1979

---Page Break---

APPENDIX 8 .2E

Species and individuals per species collected in 1/4 n?

?quadrat at Cabo ala Pascua

PLANT

Eineao

Phylum Phaeophyta

Dictyota sp.

Phylum Rhodophyta

Iaphirea =p.

ayoman

NCTOM

Phylum Sfpuncul ida

Phylum Annelida

Chase Folychoeta

Arabella opatina

Tunfes Fucata

Tunlee ap.

Fermenia verruculoca

Tastmontce Kinbergit

?Papidonotus sp.

Tabrinerets serele. 5p-

Varphysa regalia

Narphysa sp

mens.

Weldon Kingergii

iefaion sp.

Fhyliodoce papitiosa

Family Serpulidae

syle sp.

Pxbale op.

Fanily Terebeliicae

Unid. polychaete

37

2pnes7a

au

Dees

20

---Page Break---

APPENDIX 4.2

37 st

2/ae/7a 23a

Phylum Mollusca

Class Gastropoda

Columbelta nercatoria 1

Tucapina sowersi? 1

Class Pelecyso:

Barbatia doninyensis 2

Ghana sands

Goralifophaga coraltfophaga

foberus. cas taneu 1

thophaza bisuleata 4

Phylum Arthropoda

Onder Stomatopoda

Unie. stonatapeda 2

onder Tadpoca

Ckrolana parva 4

?Spaereca valkert 3

og

order Decapoda

Suborder Natantia

Fanily Alphaeiéa

nid, arphaeia

ee 1

vous nceiendons 1

eus rathbunae 3

Suborder Brechyura

Mithrae pleuracanthus :

Phylun Echinodermata

?Class Echinoides

Euctdarus tribuloides

Class Asteroides

Asteriniges sp 1

class Ophiuroides

Uaid ophiurose 2

---Page Break---

APPENDIX 4,26 (continued)

Family Auphiuridae

ie

eresete agalaa

Baisden

Phylum Chordata

class Ascidacea

styela paretea

37

prez

se

2022/73

---Page Break---

APPENDIX 4.38

TREES AND SHRUBS

fucka buceras

Geers Beets

Teienons grace:

Randle autte a

Ricinel Ti rictnetta

Tabehuls hoteraphyita

FIChiTT

VINES

Acacia riparia

apEStetY purpurea

?Stigmaph) yniba tin Taptlatun

No grasses or forbs were located on the transects.

---Page Break---

NOTICE

---Page Break---