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PUERTO RICO NUCLEAR CENTER

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Envi ronmental Studies 1972

Annual Report

APPENDIX.

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PRNC - 162

PUERTO RICO NUCLEAR CENTER

AGUIRRE POWER PROJECT

ENVIRONMENTAL STUDIES 1972

ANNUAL REPORT

Prepared for Puerto Rico ater Resources Authority

By the Staff of Puerto Rico Nuclesr Center of the

University of Puerto Rico - March 1973

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APPENDIX A

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MACROZOOPLANKTON OF JOROS AND GUAYANILLA BAYS,

SOUTHERN PUERTO RICO, AND ITS FLUCTUATIONS

UNDER SPECIAL CONDITIONS

by

bro and Fdward A, Shearls

fico Nuclear Center

José A, Suarez-C:

Puerto

INTRODUCTION

This paper deals with the species diversity, abundance and distribution of marine macrozooplankton in Jobos and Guayanilla Pays, southern Puerto Rico. It is part of the environmental studies undertaken by the Puerto Rico Nuclear Center at the proposed Jobos Bay thermoelectric power plant site and at the Guayanilla Ray power plant site where a fossil fuel power plant has heen generating 300 mesawatts from 1957 to 1972 and 710 megawatts since 1972.

Information about the plankton of tropical estuaries and bays is limited and scattered, especially in the Caribhean area and adjacent waters. One of the first research of forts on zooplankton of Puerto Rico was conducted by Duran (1957), who worked on tintinnids of the island. later, Coker and Gonzalez (1960) and Gonzalez and Rowran (1965) studied copepods Fron Bahia Fosforescente, southern Puerto co.

In the Caribbean area and adjacent waters there have boon several zooplankton studies reported, including those of

Noore (1948), Suarez-Caabro (1959), Suarez-Caabro and Madruga (1964), Legare (1961), Zoppi (1961), Cuzen du est (1968), Reeve (1964, 1970), Suarer-Caabro and Gone: Aguirre (1965), Noryakova and Campos (1966), Cwre and Foy (1967) and Bowman and McCain (1971). An extensive bibli~ography on general plankton and the main groups of the area can be found in Rjdrnhers (1971).

?The main objectives of this study were to establish the main components of the macrozooplankton in Jobos and fuavanilla Rays, and their abundance and distribution over a relatively short period of tine as a baseline for understanding their future fluctuations with environmental changes.

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Since the number of sampling stations and the tire were limited, and the sampling procedures and the net sizes were variable, this research is restricted mainly to the identi. Fication?and distribution of the most abundant and common species of the macrozooplankton of Jobos and Cuayanilla Rays during November and Decenber 1971 and January,

February and March 1972. An extensive, scheduled study of the ecology of plankton in hoth bays and other areas around Muerto Rico is being continued by the Radioecology Division of the Puerto Rico Nuclear Center. Nevertheless, it is felt that the paucity of literature dealing with Planktonic communities in Puerto Rico justifies this pre-liminary paper.

STUDY AREA

Johes Kay

Jobos Bay is located in the southeastern part of Puerto Rico (Tig. 1) 20 nautical miles westward of Punta Tune Light (approximately 17° $5" 00" = 17° $7" 3" Nand 66°10" 0" = 66°17" 29" WN). Johos Ray is one of the few natural harbors in the southern coast of Puerto Rico. !¢ is formed by a conplex of tropical marine cormunities: manprove swamps, turtle grass (Thalassia testudinum) beds, muddy and silty hottons, sandy beaches, and coral reefs. the toval length of Jobos Ray, from the eastern tip of Cayos Ratones fo the castern-nost ?part at Puerto Jobosy is approximately

7 nautical miles (Fig. 2). The widest area is 2-2 nautical niles from Central Aguirre to Roca del Infierno.? The bay is divided into three different zones: Inner hay, Mid fay and Aguirre Navipational Channel.

The Inner Ray is the castern-nost end of the bay separated from the Mid Bay by the line betwcen Punta Rodeo and Central Aguirre Dock (Fig. 2). The Inner Bay is a shallow end of Jobos Bay surrounded hy a narrow zone of mangroves on the shores. average depth is about $= 4'm, but there are also a few shallow turtle grass beds at the nouth of the Inner Bay. A 6 m deep dredged channel is found nese the southern shore. The Inner Bay has a silty bottom which gets stirred up during the normal t0-knot trade winds. the Surface currents move the turbid water westward to the Min Pay. There is an upwelling along the entire Inner Bay Jue

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to trade winds. The deep current enters the Inner Ray from the Aguirre Navigational Channel and the Mid Bay (Puerto Rico Water Resources Authority, 1972).

The Mid Day is bordered by Punta Rodeo on the east, Cayos Caribes on the south, and Punta Colchones on the west. The Mid Bay has mangroves growing on the eastern and western shores, while the southern side has mangrove-covored keys and a protecting fringing coral reef separating it from the Caribbean, There are turtle grass beds along the castern and western shores. The central part of the Mid Ray is about 8m deep.

The Aguirre Navigational Channel is open to the Caribbean on the west between Cayos de Ratones, Cayo Vorrillo ane Cayos de Pajaros, which channels are?about 15m deep. On the east there is a 4-reter deep channel called Roca del Infierno. The northern side of the Aguirre Navigational Channel has extensive mangrove areas and on the southern side there are keys with mangroves and fringing reefs. Along the shores of the keys and along the entire shoreline in the north there are extensive turtle grass beds. The depth in the central part of the Aguirre Navigational Channel is hetween 10 and 12m, The surface currents are

moving to the west generated hy the trade winds, the North Fouatorial current entering through Moca del Infierno and the hydrostatic head that pushes waves over the fringing reef and through the rangrove channels between the keys in Cayos de Rarea and Cayos Caribes. A deep current brings water through the entrances in the west into the Aguirre Navigational Channel during the flood tide. This water. moves toward the east into the Mar Negro area, the Mid. hay and the Inner Pay. During the ebb tide water moves out of the bay in the entire water column (Puerto Kico Water Resources Authority, 1972).

Tides in Johos Nay are primarily diurnal with a complex pattern composed of two tidal waves, one with a daily cycle and another with a cycle of 13.3 days (Puerto Rico Kater Resources Authority, 1972). The extreme tides of 30 c/m occur when these two cycles are in phase.

Surface tenperatures in January varied fron 28° C. te 29° C. in the Inner Bay, from 29° C. to 30° C, in the Mid Bay and from 25° C, to 26° C. in the Aguirre Navigational Channel. In August the tenperatures were from 30° C. to 31° C, in

the Inner Ray, from 31" C. to 32°C. in the Nid Tay and from 29° C. t0 30° C. in the Aguirre Navigational Channel (Puerto Rico Water Resources Authority, 1972).

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Guayanilia Bay

This hay (Fig. 1) is located 25 nautical miles eastward of Cabo Rojo Light (approximately 17° 57" 30" - 18° 00° DO" N, and 66% 45" G0" = 66° 48" 30"), It is both the largest and one of the best hurricane harbors in Puerto Rico. The reefs and islands to the southeast break the sea, but not the wind. The harbor, between low and denuded Punta Guayanitla (Fig. 3) on the east and bluff-faced Punta Verraco on the west, is protected at its entrance by extensive reefs which extend a mile or more offshore. The entire bay is 4 nautical miles in length with a maximum width of 2 nautical miles.

This study is concerned with the arca of the bay innedi-
ately adjacent to the power plant (Fig. 3). Cooling vater
ig taken from an enbayment to the west of the plant, and
effluonts are released into a cove to the southeast. The
embayment from which water is taken is approximately a
unitorm 500 meters wide and 1050 meters long. Tenperature
Fanges fron 25.5? C. in winter to 30.5° C. in summer. The
recciving cove is approximately 900 meters in length, the
Pajor part being about 389 neters wide and constricting to
tout 30 meters wide at its mouth. Cooling water was Wise
Chargod into the cove at 10°C. above ambient, i.e. ahove
the inlet hay terperatures. This temperature dropped to
+ f° C. at within 109 m fron the mouth of the discharge
canal with a further decrease to + 5° C. ét toward the
Routh of the cove. There was a 0.1 - 0.5 knot steady. sur-
face current flowing out of the cove anda Nel O02? knot
deep current flowing into the cove at its moths

Hepth in the enhayment varied from 2 to 5 m, dropping to
as much as 20 m at its mouth. An average depth was about
45. The discharge cove is nore uniform, varving from

2-"5 m, averaging about 4m veep.

METHODS AND MATERTALS

Thirty-two surface stations were sampled in ten differont areas during Novenber and Decenher 1571, and January, February and March 1972, at Johos and Guayanilia Bays (Fig. 1). All wore surface plankton samples taken with three pesh size 0.5 m # nets that were provided with small flow= Reters. Most of the samples were collected with a

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macroplankton net of mesh opening size 380 mu, ten stations were Sampled using a net of mesh opening size of 60 my and three samples were obtained with a net of mesh opening size of 300 mu.

The length of the tows ranged between 5 and 20 ninutes. Samples were preserved in 4% buffered formalin. Tempera-

ture, salinity and dissolved oxygen concentrations were also?measured at the station during the towing.

For counting organisms, aliquots of each sanple were re~moved from a well-shaken container by means of 5 cc, 10 cc or 20 ce spoons and diluted into a squared Petri dish.

All zooplankters in the subsamples were counted,

COMPOSITION OF MACROZOOPLANKTON

Jobos Bay

As in Guayanilla Bay, copepods were the most numerous holo-planktonic forms in Jobos Bay. Among the calanoids

Acartia tonsa Dana was found in every area sampled (Fig. 2). E Weltjeborgii Gicshrecht occurred in areas 2, 3, 4, and 5 Mirch were Te ch were Tocated in the Mid? fay and close? to? shore in the Aguirre Navigational Channel. Acartia spinata Fsterly was present in areas 2, 3, and , and -Aeartia Tongiremis (Litljeborg) in area 5?only.

Tenora turbinata (Nana) was the second most conmon calanoid.

Te war recorded for all areas except number 3.

Psoudodiaptonus cokeri Gonzalez and Rowman occurred in areas S; Sami cin the western part of the bay.

Other calanoid species which appeared less common were Calanopia americana F. Nahi, Clausocalanus furcatus irady), aracalanus crassifostris Fe Dahl, TaracaTanus aculeatus Gfesbrecht, Paracalanus spp., Lahidocera scotti Glesbrecht and Labidocera spp.

The Cyelopoid copenous Oithone hehes Geshrecht, O- nana

Giesbrecht and the harpacticoid Futerpina acutifrons (Dana) also occurred in the bay.

ALL those species of copepods except genus Labidocera men- Honed ahove have been Feported in Puerto? Rice Aye enzales

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and Bowman (1965). In Puerto Rico L. scotti Giesbrecht is recorded hy Coker and Gonzalez (1960) only in Bahia Montalva, southwestern Puerto Rico, This species also occurs in South Miseayne Ray, Florida (Reeve, 197 Noodmansee, 19S; and Mavis, 1950), A. longirenis is not Previously reported in Puerto Rico, hat it 1s recorded in Cuban waters by Suarez-Caahro (1955).

lucifer faxoni was present in all areas of Jobos Bay. Juventies oP this ?species are Teported in area #y_tocated at the nouth of the hay. Anong the larvaceans Ofkopleura (exiliaria) dioica Tol, Oiteploura (Vexillaria) payee Lohmann, Fkopleura (Cogeariay Tonpicauda (Vea) nant Sikoptenra (Caecarta) fusiforais Pe cormitopectea Chia) were present in Tohos Rav,

Immature specinens of chaetognaths as Sagitta spp. were present in all areas except in the Inner Tay (area 1) where 5. hispida Conant was identified. S. enflata Grassi and krOhnites sMeilis (Grassi) were. aiso fount Se ghee Bay.

A cladocer, fvadne spp., was recorded in areas 4, 5 and 6, which were'located in the entrances and in the midckannel of the hay. No identified species of pteropods and Siphonophors were present in those entrances.

Two species of mysids wore identified. Siriella chierchiae (Cos feann) was taken in areas fants at Hee anes

area 6 duting the day.? ?ysidopsis sp. (identified by Br. Arattegard a: a now species TeeTifst? found In Colunbion coastal waters in 107} and called ?ysidopsis () was taken ting a'daytine tow in aren 4. Among the Nyperiid amphl= yous the genus lirachyscelus was identified inarea 2.

WWso a garnarid Ss, was Fenorted In area 3.

Guayaniija bay

Copepeds were the most abundant holoplanktonic group found in the areas sampled at Cuayanilla May (Fig, }). Acartia tonsa was the most cornon species of copepod reported ant appeared in ali areas. Acartia 1illjehorgii ant Oithona hehes were present in areas ¥ and-t ant Tenora? turh nays iW areas 2 and 4. Other less common species were Juterpina acutifrons, ?icrosetelia norvepica (Pocck) and jiventies oF Taeutadiaptanas: Corer Seser tons ene Fhe

harpacticoid copepods were alse present.

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All those species were previously reported for Bahia Fosforescente ant adjacont waters, southern Puerto Rico, either by Gonzalez and Rowman (1965) or Coker and Gonzalez (1860). ?fost of the specics mentioned above are recorded for similar areas by Davis (1950), Davis and Wiltians (1950), Noodmansee (1958), Suarez-Caabro (1959) and Peeve (1964, 197).

A sergesti?, Lucifer faxoni Torradsite, and insature

specimens of Sagitea spp. occurred in All-arcas. Sagitta tenuis Conant wae Vtentifiel in area 4. Le faxoni Tes

Been reported as abundant near the coast and specifically in Fiscayne Yay, Florida (Rowman and ?eCain, 1967; and Noodmansee, 1968). S. tenuis is a typical neritic species (Suarez -Caabro, 1958; and AMIvarifio, 1965).

Unidentified isopods were also found in different areas of the bay. Some ganrarid anplipods, Podocerus spp. (probably P. brasitionsis) and Corophiun spp., were also identi fied?in- tuayantiTa tay.

Anong the larvaceans, Dikopleura (Vexillaria) dieica, 0. (Cocearia) longicauda, 0 (extTiaria) rufescons Tol, Fritillaria (iryeera\ eereis) petealis T. sargasst (Cehnatn) and'F.~ (hurycereus) peTiucids (hisch) were recorded. in the hay. ?AI these species of larvaceans are reported for Puerto Rico for the first time, to the author's bnow-ledge. They were found in Cuban waters by Tokioka and

Suareg-Caahro (1956) and in Trinidad Island, brazil, by bjSrnberg and Forneris (1955). Also, Flores (1965) re~ ported these species of the senus Oikepteura for the coastal waters of Veracruz, ?lexicos

The mysid Mysidium colunbiae (Zinmer) was taken during May in area T. A large school was taken with a band act

at the surface near a mangrove stand.

DISTRIBUTION OF THE MACROZOOPLANKTON

Jobos Kay

Jobos Ray has been divided arbitrarily into six sampling areas (Figs. 1 and 2). The Inner Bay, area 1, has heen given little emphasis as the predicted current patterns caused by the proposed power plants should have little

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effect there. Most of the sampling effort has gone into area 2 (the intake area) and area § (the outfall area), Area 4, fioca del Infierno and the area sheltered hy Cayos Carihe?and Cayos Rarca should he indicative of recrulencat potential provided to the coastal arcas directly adjacent fo the power plant conplex, Area 3 was sampled only in Novenber 1971, and then oniy hecause it is a break point for surface waters coming through ?oca del Infierno, This area is probably the most unstable environment, hut at che Same tine the richest jn the hay. Area 6 was sampled to determine a possible trend tovard seaward drift from area § and to estimate recruitment problems associated with wetrinental effects the heated effluent might have. Table 1 is a complete tabulation of plankton hauls analyzed to

gate. It shows the location, date, tine and other paran-
eters of the sampling. Tables 2 through > list plankton
concentrations according toz (A) number taken per cubic
meter of water sampled (¥/m3) and (B) percentage of total
catch that cach plankter category constitutes (1 total
cateh).

As stated before, the Inner Bay (area 1) has heen sampled
scantily, Wotoplanktonic forms caught in this area
Feached 30.4% in Necenber 1971 (Table 2). The main
groups were copepods (43.81), fish eggs (2.0% ~~ anchovy
ehes 0.5%), siphonophors (0.43) and appendicularia (003%) .
lucifer faxoni accounted for 4.0% in this area. siphono.
Dhors were not connon in these inshore waters, Specivens
foun) in area 1 Kore probally taken there by deen water
currents which enter fron the onen sea during Flood tide
and flow easterly atonn the bottom of the Aguirre Ship
Channel in through the mouth of the hay and eastward abong

the hottor of Johos tay (Puerta Rico Vater Resonvees Authority, 1972). The percentage of rieroplankten (49.64) in mid December was slightly lower than that of holepienk= ton. The major erouns were brachyuran zocas (28/02) cirripede nauplii (8.4) and penaeid larvae (4.19),

Copenais were the most abundant group among al} plankters iy area 2 (Table 3), From mid Mecesher 1971 to the end oF

nuaty and early February 1972, accounting for Meet, 74-41 and 64.54 respectively. Permanent mantton ig wid hecenber incinded, in addition te conepats, appendicuracia (0.27) and 4. faxeni (1.24). chactopnathe (ee), aprendicularia (8.47), medusac (lait) and very foe

L faxoni (0.1%) were present at the ent of January. Chaetopnaths decreased to 0.93; apnendicularia increased to F.1%; medusac decreased to 6.2%; and L. faxoni

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disappeared, but nemertineans (0.24) were reported for the first time in area 2. It is interesting to note that gorepods decreased, but cirripede nauplii increased to

Area 3 (Table 4) in early Novenber was predominately holo-planktonic. Copepods, 86.4% during the night and 49.8%

In the day, were the fost abundant group. Other permanent plankters were chactopnaths (1.8%, 1.9%); appendicularia (3.6%) 0.55); and L. faxoni (913%) 1143). Nauplius larvae (0126), pluteus larvae (0.71) and? porcelianié larvae (1.6%) were present only during the day station.

Area 4 (Table 5) in early November was also holoplanktonic (56.45), but appendicularia (19.24), chaetognaths (8.0%), cladecers (9.0%), medusae (1.0%) and siphonophors (2.08) Eopether accounted for more than copepods (16.2%). Medusae, pluteus larvae and polychaete larvae were not present in early Decenber, but L, faxoni (0.4%) appeared at that time.

Area 5 (Table 6, station JR-7, JB-8 and JR-10) in early Decenher was typically meroplanktonic. Rrachyuran larvae (161), decapod larvae (163), fish eggs (20%), fish larvae (0.88), nauplius larvac (124), polychacte larvae (0.14) and porcellanid larvae (0.i%)?accounted for a total of about 49%. Almost two months later (station JB-26, JB-27 and JB-29) the same area had become strongly holopiank-Tonic. Copepods, amphipods, appendicularia, chaetognaths,

and L. faxoni reached a total of 821 in area 5.

Area 6 (Table 7), same as areas 5 and 4, was predominately holoplanktonic in early November. ?Copepods (54.50) 5 chactognaths (29-24), appendicularia (3.3%), cladocers (118) and siphonophors. (0-8) reached a total of GA.9%

of the whole plankton conminity.. Meroplankton accounted for 41.1%, consisting of hrachyaran larvae (10.3%), decapod Larvae (12.34), fish engs (3.04) and others (4.64). In early Deconber and February copepod peaks of 67.3% and 934 were found, respectively. In February larvae fad decreased to a? total of only 3.5%.

ayanilla Bay

?The area of sapling in Cuayanilla Bay was located in the northeastern side of the hay (Fig. 3). General character~ istics of stations are shown in Table 8. Tables 9 through 12 Lise plankton concentrations as: (A) number per cubic

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meter of water sampled (#/m3) and (R) percentage of total catch that each plankter category constituted (1 total catch).

Area 1 (Table 9) in early Neconber was predominately holo- planktonic (99.5% of all plankters captured). Copepods and their nauplii accounted for 76.7% and 7.i% respec tively, polychaetes for 6.4%, chactognaths for 1.34. The only major meroplankters were cirripede nauplii (5.28),

In nid Decenher (GR-A, GN-B) holoplankton had decreased to 691 of the plankton community (66.8% copepods, 2.1%

chactognaths, f.1% polychactes). Of the meroplankton 4% were brachyuran larvae (2/3 of which were porcellanid zoeas), caridean larvac accounted for 3.2%, penaeid larvae for 2.3%, and cirripede nauplii for 2%. It ls interesting to note that copepod nauplii had disappeared and that fish eps and larvae had renained relatively unimportant during this period. Nrachiopods and bivalves were present in early December in minute quantities, but were absent later. Note that penaeid larvae appeared in mid Necenber (2.2%).

In area 2 (Table 10), 90.211 of the community was holo-lanktonic during Novenher, a figure that dropped to 68.9% in December, and further to 30.8% in March. The prinary Teason scened to be the increasing numbers of amphipods? 10% in Decomber, 30.8% in March; fish eggs: 7.6% in December, 19.3%?in March; fish larvae: 0.54 in December, 5.4% in March; isopods: "1.8% in December, 6% in March; cirripede nauplii: 4.6% in December, 1% in March; and brachyurans: 2.8% in'Decenber, 4% in March. None of these latter groups occurred ih Significant numbers in November. (November samples were taken with 60 mu nets, lator samples with 380 and 390 mu nets; therefore, the

decrease in the number of copepods may have been due to smaller copepods nat heing caupht.)

In carly March, bivalves occurred (St) as well as smal] bursts of foraminifers (0.3%), ostracods (0.2%), and tintinnids (1.4%), none of which were found at other times. Gastropod larvae constituted 3.8 of the carly Moreh sam ples hut were present in insignificant munhers (0.038) during Novenher. Nenerteans occurred in hoth November and March (0.03% and 9.2% respectively). Te is interesting that brachyura hecane important only during December (2.81) and late Narch (41), and that polychaetes were abundant (2.71) only in March." Carideans appeared only in March (8142). Copepod nauplii peaied in Novenber (where they Pade up most of the ?.61), and carly ?larch (21.4%),

and disappeared (for all practical purposes) in

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late March. Cirripede nauplii vere also more abundant
(3%) in early than late March (2%), hut also peaked in
ecemher (4.68).

In area 3 (Table 11) holoplankton accounted for 61.6% of
the community during Novenher, 84.91 in Decenher, and 60.5$
in March. A high meroplankton percentage in ovenher was
primarily a function of fish eee production (16.2%) 5
Bastropod reproduction (1.8%), and appearance of tintinnids
(5.78) and foraminifers (3.54}. The latter two were
absent in other periods. it should be noted

was also the only tine appendicularia (0.6%)
chaetes (0.3%) appeared ih area 3.

het November
d poly=

The 59.58 nereplankton concentration in March was a fune-
tion of a brachyuran breeding period (37c4t). a nurse oe
Citripede nauplii (4.04), ant «healthy concentration of
caridean larvae (4.55) ahd penacid Targas, (etd) dhe
Iatter two appeared in areas only Inarehs Rate that
the concentration of hrachyuran. zocas was greater. than
the combined total for conepat adults and hauphit foe 94) «
Apparently eirrinede reproduction occurred noth in
Novenber (114) and Mlorch, preceding the eopepod. nauplii
onthurst in March by a day? Ys Decenhers. Fish: Taevee
Outnunbered Tish ergs, the only tine this cecurred,
chactognaths peaked durine Seecnher (4054) and Merch
(7.18), L- faxonk, ahsent in Sovenbor, way found in smal]
quantities tn Decenher and arche. hecenber was the. oniy
Period plutcus larvae (9.6%) and hivalve larvae (0.6%)
Were found in area 3: Shalt concentrations of myside and
Siphonephors oceurret solely in sisres

In area 4 (Table 12) holoplankton constituted 83.8% of the planktonic community. Xo copepod nauplii occurred while 77.7% of the community was copepod adults and inmatures. Mrachyuran larvae nade up as mich as 1.8) (6.7% porcellanid and as little as 3.64 within a 2 Period toward the end of the month). Cirripede na Gonstituted 5.8%, peracid larvae 2.1%. Caridean larvae dropped fron 3.44 to 1,24 within a matter of hours.

pIscussioN

The plankton at Johos and Cuayanilla Pays was fundamentally neritic. However, it could le that some oceanic forms entered occasionally intn the hays with tides

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and oceanic surface currents.

The neritic plankton tented to have a far higher proportion of meroplanktonic forms. Crustaceans were easily predominant, both in minhers and species. The copepods Fepresented the najor group of crustacea in the rooplankton. ?ost of the species in this group belonged to Caliinoida.

Acartia tonsa was the most abundant and connon of Cata rola. TE Wis present in alt areas of both bays. ?A. Lilljeborgii was also very conmon. A. spinata was Timited fo areas 4 sand. 5 in Johos hay. Another eatanoid, Tenora turhinata, was relatively casy to identify in Jobos and Guayanilla Tays. Psoulodiaptomus cokeri, a calanoid ?lich gees to the surface durin? the night, was reported in night stations at sone Johos and Guayanilla Nay Similarly to A. tonsa, a sersestid, Lucifer faxon

present in all sohos and Guayanilla Tay area?

Aone the chaetoenaths, immature specimens of the genus gagitea were reported in most of, the aroas of hothbays. Scifapids, S. tenuis and S. enflate wore iienetficd. wien Bature specircns anpenred.? 2° Few appendicularians® such as Oikoploura (Vexitlaria) dioica and 0. (Coccariay Jongicanda were aten TWentifiettn Jobs and taayand La Tays.

Decenler distributions for the two study areas were repre-sentative of zooplankton concentrations in general. ?The larger copepods occurred in at least twice a2 preat a number in every aren in Cuayanilla than at Jobose Hrachyuran larvae were comparable on the intake side and the effluent hay at Guayanilla te the most productive

Jobos area, two and a half tines greater at the mouth of the hay. Area 5 at Johos ha! an appreciably greater fish ene concentration than anyrhere else in Guayanilla or Jobos, but again Guayanilia had a hetter overall production, Fohos"area Twas comparable to Guayanilla area 1 for chactoenaths, but Guayanilla 2 and 3 ere much richer

than any other Jobos area, the mouth of Guayanilla (area

4) three and a half tires ?herter than Johgs 1. For total Pacrozooplankton, area S at Johos (12.4/m>) had the richest concentration recorded, still only about 1/4 that of the Guayanilla input hay (area 1), The Guayanilla effluent

hay had almost twice as ereat a concentration and almost ten times as many plankters at its mouth as the nost Productive area in Joho:

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The month of the effluent cove, even though the water tenperature there is 5° C. above anhient, has three tines es any copepods anc fish eggs, tuo and a half times as hany brachyurar larvae, three and a half tires the chactoanath concentration and, in fact, approximately three tines the total plankters than the embayment near the cooling water intake.

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LITERATURE CITED

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?TABLE 2

SUI@ARY OF ZOOPLANKTON DATA FOR AREA I

JOROS BAY

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Bivalve larvae

Brachyuran roe 13.0

caridean larvae 6.3

Chaetognathe

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Deeapod larvae

Buphausids

Fish eggs (total)

Anchovy egge

Fish larvae

Forasinifers

Gastropod Larvae

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Nauplit (total)

?Copepods

Cirripedes

Ostracods

Penaeid larvae 2.0 3a

Pluteus larvae

Polychaete larvae

Porcellanide

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Totals 55.8 100.0

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TABLE 4

SIMGARY OF ZOOPLANKTON DATA FOR AREA 3

JOROS BAY

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Bivalve Larvae

Brachyuran Lary: 16 1s 60.6 366

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copepods 1 86.4 86.3 49:8

Decapod Larvae 37 4 146 a

Fish eggs (total) 07 o8 16 09

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Copepods

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Report No. 2

Introduction

The purpose of this study is to report the foraminiferal

assemblages of sediment samples taken in Guayanilla Bay and to indicate their possible relationships to pollution.

Samples of Stations G-3A to G-9A were taken on May 16, 1972 and samples of Stations G-22 to G-20 were taken on June 10, 1972.

Samples were taken with a Phieger corer of ahout 10 cm? inside diameter. The upper centimeter section of each core was taken from a11 samples. The sections from 1 to 2 cr and from 2 to 3 cm from the top of the core were taken from some of the samples. The sections were preserved in 30% ethyl alcohol in the field. The protoplasm of the foramini-fers was stained in the laboratory with Bengal rose.

The foraminifers and other organisms of about the same size were counted per sample.

The map of Text - figure 1 shows the position of stations in Guayanilla Ray.

?Temperatures and Salinities

Table No. 2 shows temperatures and salinities. The highest temperature, 36.2°C., is at Station G-3k in the Eastern Central Lagoon and the closest to the outfall of hot water

of the electric plant.

Salinities are in the normal range in most of the bay.

Tables 3, 3A and 38 show the organisms comparable in size to foraminifers in Guayanilla, ?ayaguer and Jobos Bay, respectively.

Nematodes are the most abundant organisms of Mayaguez and Jobos Bays, Generally they are several times more abundant than foraminifers. The largest number of nematodes per

sample, 3580 individuals, is from Station 16, Jobos fay, and. they are about 30 times more abundant than foraminifers (119 individuals) .

The total number of foraminifers per sample is similar in the three bays. The total number of the other organisms is proportionally smaller in Guayanilla Bay than in Mayaguez

and Jobos Rays. The number of nematodes is not only small in Guayanilla Bay, hut also the foraminifers are several times more abundant than nematodes.

?The pollution of Guayanilla Bay is influenced mainly by industrial chemicals, while the pollution of Mayaguez and Jobos Bays is mostly organic. Marszaleck et al. (1969) Suggested that the test of the foraminifers is a defense against environmental changes. The nematodes do not have any shell to protect their hodies, which are exposed to chemical pollution, while the test of foraminifers appears to constitute a protection against this type of pollution. This may be the explanation of their abundance in relation to other organisms. in Guayanilla Ray.

Foraniniferal Biofacies

?The most abundant foraminifer in the bay is Ammonia

catesbyana tepida. This species, associated with two other Groups of foraminifers, constitutes the two biofacies den termined in Guayanilla?Bay. The biofacies are:

Ammonia-Quingueloculina-Anmobaculities and Anmonia-Fursenkoin

THETe No "Shows the distribution of orantnt feral popetas

tions per station on which the division in biofacies was

nade.

The Amponia populations of Guayanitla Bay are mostly consti-

tuted by one subspecies, A. catesbyana tepida (Cushman) -

Sone specinens nay be incladed-ss-t- "advena?(Cushnan"y but

the small individuals are difficult to distinguish from A.

catesbyana tepida. Only a few individuals are large and

Sell developed and may be included as A. catesbyans

catesbyana.

nia-Quinqueloculina-Ammonbaculites Biofacies

?This biofacies covers the shallowest part of the study area

(the stations range from 1m to 4.5 m of water depth).

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Most of the stations are in Eastern Central Lagoon: Stations G-3A, G-SA, G-6A and G-9A. The Station G-7A is close to the éntrance to the lagoon

The dominant species is Ammonia catesbyana tepida large population was found ti the Sample of CSE 4 temperature of 36.2°C. This value is above the maximum growth temperature (34°C.) and the maxinum temperature

for reproduction (30°C.) found by Bradshaw (1961) for specimens of this species from Southern California and Baja California. The abundance of this species in Station G-3A shows its high resistance to thermal pollution.

yingueloculina rhodiensis is the most abundant species Sp tietgens in Station G9, ?The specimens oF ehis species in this bay are larger and with thicker costae dl

?an the ones reported for the polluted waters from Jobos Bay (Seiglie).

Ammonia Fursenkoina Biofacies

This biofacies includes the stations from 8.5 to 17.0

eters of water depth, Stations 6-24 to -29, The domi:

nant species is Ammonia catesbyana tepida and the secon:

in abundance is Fursenkoina pontoni.

Fursenkoin:

Armonia Biofacies

This biofacies corresponds to water depths from 17.5 to

18.5 meters (Stations G-22 to G-23).

catesbyana tepida

F. pontoni is the dominant species and A

?The?Second species in number,

nPyritized" Living Foraminifers

Table No. 5 shows the living specimens of foraminifers with pyrite inside the test, and the stations in which they have een found. Ammonia catesbyana forma tepida is the most connon pyritized foramintfer and constitute the 10% as mean Walue of the total population of this species. in the st tions in which it occurs. Fursenkoina pontoni is the second in nunber, but the percentage of "pyritized? specimens is only the??.St as mean value of the total living populations of this species.

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Species Diversity

Species diversity was determined per station by the formula of the information function, Its values are shown in Table No. 6 and in Text - figure 2. The formula of information function is used by the communication to predict the name of the next letter in a message. It is considered a good Reasure of species diversity (NcArthur and McArthur, 1969, McArthur, 1965). It is expressed by?

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Where N is the total number of species in the sample and Pi, the proportion hetween the number of specimens of the ith species and the total number of specimens.

The values of Table No. 6 are not very different from the ones determined for Mayaguez Bay (Seiglie, 1972) and for Jobos Bay (Seiglie, Manuscript). The values are lower, generally, in the shallower stations than in the deeper ones. The lowest values are in the western central lagoon. Species diversity is lower in polluted water than in unpolluted waters, but the values determined in Guayanilla Bay cannot be directly related to pollution, because the values before pollution are not known. The species diversity was also determined for the top centimeter (0-1 en), for the second (1-2 cm) and for the third centimeter (2-5 cm). Distortion of the surface may increase the num-

x of foraminifers and the species diversity in the second and third centimeters. fowever, despite this possibility, the species diversity is the lowest in the second and third centineters (see Table No. 6).

Conclusions and Summary

The low ratio between the number of nematodes and the number of foraminifers and the small number of nematodes per Sample are the most important relationships between the microfauna and the pollution. These relationships suggest that the foraminiferal test is an effective protection against pollution.

The Anmonia populations of Cuayanilla Bay and Mayaguez Bay are constituted mostly by A. cateshyana tepida, while most

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of Jobos Bay populatiore are conetitutes by A. catesbyane cate: byana. Sone faunas of Joboo Say are deformed amt TE

is difficult to include them ina suoepecies. ?The Factern Certral Lagoor. aire containe large populatiore of A. cateobyana tepiea under coreitions of the:mai pollution.

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Figure 1

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Figure 2

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[FORAMIVEFERAL POPULATIONS PER SAMPLE TH GUAYANELLA BAY

GG ok CS Om GM om

mir fe yoo art a

Amobaculites dtrectus

seal 4 2 2

Aamcatcue op.

?Ammovarginul ina fot ac % 2 2 4

fsmvosicatesbyian teptde (2) 83-248

?epalogertoa ef, anguton

olivine ef-infiata

Bs peeudopticate

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Bi vertapaade 1

Betzaline dowmank 1

Bs etetacule

Bilinina sarginges

Bullmineria eleganciseine 1

Ceibroeiphtdtu dace dale

Gs poeyam 2 2 1

Ch tee 2

Gjelogyra. snvorver

Discorbinelia floridenete 1

Eggerella ct, advena

Fissurina peituetaa 1

Florttan gesteloupit 1 5 2

urvenkotha posto

Globocassidelina nincta

Glomepire goreicelie 1

Gases 8

Noplinaina attteees

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Nonfoneila? fragile

Parvigenerioa tps

Prcadonodonsra enhiaha

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Fettocalina sp.

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?FFochaaaina ef. advent

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---Page Break---

TARE & (Cont) a

FORAMINLFERAL POPUIATIONS PER SAMPLE IN GUAYANILLA BAY

9 58 cate

or i on

?aewodtscus sp.

Aemauesinulina foliacea ?

Somats eatestytana tepida (1) 7

Bolivins cf, inélece

1 preadopl cave 1

2! thonbosaal te

Pe

3. variabitts

Brssetina Loving a

B. steiseula 1

Bitinine margioaea

Boldainetia elegantterion

Cetbroetphidtus discosdele

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Bee 1

Sjelogyes tavotve

Discorbinelia Aloridenets

igerella cf, advent

Pissurioa peiigedde

Elobecasstdut ine stnuca

Miielsnetie Labsoas

Wonionelia? fragilis

parvigenerins tp.

woe eoeeda

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shodiansis? (sapoth vee,

phan car oensie

Aoealina floctdana

Sageine cuban

Sign tlopsts arenaca

Frliscalina pe

4. eelgonuta?

Trochammina cf, advena

Ti stecorbte

(1) four ateornal specimen

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302

TARE 4 (COM) »

FORAMTNIFERAL POPULATIONS PER SAMPLE TX GUAYANILIA BAY

25 O26 G26 o27 oe one

or oor fe oi et ot

Aamodtscus 4

fAmomrpinul ia fol ace

Mrontalcaterbytane tepida 2) 361019535

?Angalogerina cf, angulosa aoa

olivina cfs indlace

3 Frowettis! ?

3. Strung

Be etristula

Bolimineria sleganetseion

Crtbroetphtatun discoldale 1

we 8

Sjelogyea tnvovens

Dlacorbined in Cloridenets

Rggecelin cfs advent

Flocilut_geateloupit 4 2 1

Pursenkotan pontont v2 ne

Clotecasetdulina miata 3 1

Gloasepire poedtaite 2

Ge tpe a 1

Nipkideina mtuteees 3

Tages tacvte 1 toa

Miltotiet ia: Labioze 1

elemiey fastte 5 1

Parvigenering sp. 2

fr brovoetpnidtinn

Poe, torviaa

Gisnqueleculina ef. candesans roa

Qo ces pocyans a

9: shsatenete

Q. thodtensts? (swooth ver.2)

@ sep o 6 a 5 6

Bi ceotet i

Tellocetiee 4

Fe trigonal

Otro

eS tm

(2) Zour abnorent spectnens

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omHlisie safe,

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Table No. 5, "Pyritized" Living foramtnifers

at che stations of Guayanilia Bay

303

6-23 Ge2e G26 GPS G27 G29

OL Ol M2 OL Onl

Amonia catesbyana f. tepida 4 99 4&3

Fursenkoina pontont 12 1

Globocassidelina minuta 2

Nonfonelia cf. fragitis 1

Brizalina of, inflata 1

Table Wo. 6, Speckfie diversity by

Aoformition function, #.

Station Station

GA, Oe em, 1.26 6-23, O61 em. 2.07

GM, leew. 113 6-24, OL em. 1.86

GHA, 2-3 cm, 0.68, 6-26, 162 em. 1.37

GBA, Ont em, 1.26 25, Ont cm, 1.99

6A, Oot em. 1.31 6-26, Ont cm. 1.36

Goh, OL em. 1.56 6-26, 1-2 em, 0.76

GTA, 1-2 om, 0,93 0-27, Ort em. 1.58

GOA, OL em, 1.45 6-28, Onl em. 1.60

6-29, O-1 em, 2,03

n22, Olea, 1.72

1

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304

Study of the uffvet of Heated Water on Turtle Grass,

?Thalassia testudinum Xonig, in Guayanilla Bay

by Peter Schroeder

---Page Break---

Guayanilla Bay has a number of turtle grass beds, most of which appear to be dense, healthy and relatively unstressed by man's activities. Those beds of marine grasses found on either side of the mouth of the cove receiving heated effluence from the fossil fuel thermoelectric plant appear to be thinner, stressed and mixed with red-brown algal complexes.

Five stations have been established in the various turtle grass flats at Guayanilla, Station 1 is located immediately fo the south of the entrance to the thermally affected cove; Station 2 is located to the north of the cove's entrance

and Station 3 is located some distance to the west of the entrance. Stations 4 and S are control stations located in a different part of Guayanilla Bay near the intake to the

power plant and are not subjected to thermal stress form the power plant.

Stations 1 and 2 show possible stress from current and/or the heated water leaving the cove. Station 3 is farther

from the entrance of the cove and is an extremely thick, large bed of Thalassig evidently nearly unaffected by the power plant. This bed of grass compares in biomass with the

control Stations 4 and 5.

Periodic samples have been taken with a specially constructed sampler (see diagram) from all five Thalassia Stations and biomass figures for Thalassia from each sample have been ascertained, Dry weights of Various parts of the Thalassia plant (according to Tomlinson and Vargo, 1966) Wave been recorded as well as total weight of plant material.

After dry weight was recorded, the plant material was ground with mortar and pestle and stored in anticipation of chemical analyses, (In Florida elemental ratios go through annual fluctuation; see Walsh and Grow, 1972).

In order to determine the effect of the thermal discharge on Thalassia plants in Guayanilla Bay, a turtle grass transplant experiment is envisioned. ?Floating plant boxes have constructed from wood which are designed to hold e sampies taken, fron thick, healthy Thalassia flats in Guayanilla Bay. These boxes will hold the plants approx-imately fifteen inches below the surface and can be anchored wherever convenient. Once anchored, they can rise and fall with the tide and maintain the plants under nearly equiva-lent light conditions, In every sample certain blades will be marked (according to the technique of Zieman, 1968) in

---Page Break---

order to determine growth rates. At intervals of two to four weeks one sample will be replaced in each box and examined for chemical analyses. Concurrent examination of associated organisms can be made to determine the effects of thermal water on the species diversity within the turtle grass community.

The plant boxes will hold Taylor maxinun-minimum theraon-
eters and will be anchored at three points within the
thermally affected cove. Two boxes will be located outside
the cove in Guayanilla Bay to serve as controls, These will
be located near existing apparently healthy grass beds.

It is hoped that this experiment will lead to a determination
of maximum temperature at which Thalassia communities can
exist in Puerto Rico. It may also indicate what form
thermal stress first affects the plant itself,

---Page Break---

THALASSIA SAMPLER

0203 METER?

---Page Break---

PLANT BOX FOR GROWING

THALASSIA

(# waT6® LeveL

---Page Break---

Station Date collected

Br Ws/ie

Growing tips 3

ioote

shizomes

vertical (short) shoots

new leaves

old leaves

old sheathing leaves

Total

Grams per meter square

3a

Growing tape 8

soote

Rhizones:

vertical (short) shoots

new leaves

02d leaves

old sheathing leaves

Total

Gras per meter square

309

Wet weight Dry weight(grans)

5a +7596

8.8 2.9433

14 +3379

2.1901

342343

Te +7890

66.5 8.254

3,276 406.6

39.4952 3.8410

27.8235 5.5819

8.6453 2.0720

28.9616 346130

32.4598 3.5705

--- 2.8814

157.4558 21.5658

1,756 1062.4

---Page Break---

Station Date collected

4a Ws/te

Growing tips 19

Roots

?hizones

vertical (short) shoots

old sheathing leaves

?Total

Grams per meter square

BA 5/12

Growing tips 8

ieoots

Ahizpmes

vertical (short) shoots

new Leavi

old leaves

old sheathing leaves

Total

Grams per meter square

Wet weight

52.5

25.6

2.5

11.6

49.7

30.0

172.9

8468.

310

Dry weight (grams)

6.3063

6.9540

2.2959

2.3040

4.9123

2.4976

25.2701

1244.8

4.3672

+4340

+3395

1.7307

546310

2.5356

25.0979

143.7

---Page Break---

an

Station Date collected wet weight Dry weight (grane)

38 Use

Growing tips 0

xoote 6.0252

snizone 346636

Vertical ~ Shoat +3313

Kew leaves 2.6558

01d leaves 4.7482

Sheathing 2.4386

Totel 37.8423,

Grams per meter squere 878.3

?3 sire

Growing tips 5

roots 92.1 9.7106

Hnizome no 10.2325

Vertical snoote 36 +4382

ew leaves 23.7 2.4897

014 leaves 70.6 6.7504

Sheathing 50.3 4.8225

Totel 302.0 33.5038

Grans per meter square 14.832 2650.2

3B Use

Hoots 69.3 6.0076

shizone 27.8 3.9867

Vertical shoote ana 2.3280

New leeves 16.0 1.9849

old leaves 43.7 440320

Sheathing 35-4 2.1054

Total 203.3 20,5036

Grams per meter square 10310. 1009.8

---Page Break---

Station Date collected

aA Ts/re

Growing tips 3

Hoots

Rhizome

ertical shoots

New leaves

014 leaves

Sheathing

Total

Grams per meter square

2a Ws/T2

Growing tips 6

Roots

ahizome

Vertical shoots

New leaves

01d leaves

Sheathing

otal

Grans per meter square

3 Tas/Te

Growing tips 3

kote

ahizone

Verticel shoots

New lesves

Olé leaves

Sheathings

sotal

Grams per meter square

32

t weight Dry Weight (grams)

+5384

2.1910

=3226

1652

+8012

1.0447

420320

198.6

42.9 4.6713

26.0 4.7439

10.0 12.2880

we 2.2577

45.3 444390

14.2 2.3285,

150, 27.7284

7399. 873.4

3964 3.9966

47.4 7.6478

20.2 1.5865

21.3 2.6354

63.5 6.5108

22.2 2.2224

204.0 24.5999

10049 1222.8

---Page Break---

Station Date collected

8 1/s/Te

Growing tips 12

Hoots

Rhizome

Vertical shoots

New leaves

014 leaves

vheathing

Total

Grems per meter square

13 1/9/12

Growing tips ©

Hoots

Vertical Shoots

New leaves:

014 Leaves

Sheathing

cetel

Grans per meter square

ea 1/3/12

Growing tips 4

voote

Verticn2 Shoote

Hew Leavee

014 Leaves

Sheathing,

Grems per meter square

Wet weight

30.0

17.3

63.9

23.9

46.7

127

206.2

10253

33.20

22.10

3.20

1.7

88

14.2

82.9

4084

33

Dry weight (grams)

4.8821

4.6692

7.6637

444300

4.7482

2.2363

28.3295

2395.5,

+9686

1.7347

1.0090

+4902,

6.6416

141680

212.0120

591.7

3.2841

1.9203

+3530

2.5469

+8289

2.4334

10. 3666

510.7

---Page Break---

Station Date collected

3B ans/ie

Growing tips 4

Hoots

Rhizome

Vertical Shoots

w leaves

Old leaves

Sheathing

?Total

Grams per meter square

4B 1as/T2

Growing tips 5

uoots

Hhizone

Vertical shoots

New leaves

014 leaves

Sheathing

Total

Grams per

ter square

5B 1ls/le

Growing tips 3

Roots

Rhizome

Vertical shoots

Wow leaves

014 leaves

Sheathing

Total

Grame per neter square

Wet weight

53.6

45.2

3.9

ws

50.5

40.2

210.8

10384

49.00

18.0

2.

21.3

63.5

21.3

178.2

e778.

219.4

33.9

15.0

32.0

79.8

66.0

34542

17043

314

Dry weight (grams)

5.0299

7.2897

1.4022

2.1856

8.8149

3.7725

27.4937

1396.4

5.6480

3.3848

+8900

2.6417

6.0376

1.9040

20.5662

1013.1

12.2036

5.3456

2.5230

3.9680

7.9486

6.2230

3362338

1637.1

---Page Break---

Station Date collected

a asta

Growing tipe 0

roots

izone

Vertical Shoots

New leaves

Olé leaves

Sheathing

?Total

Grams per meter square

2a, ea/Te

Gromng tips 6

xoote

Vertical shoots

Kew leaves

014 leaves

Shesthing

Total

Grams per meter square

3a 8/3/72

Roots

ahizone

Vertical shoots

New Leaves

02a leaves

Sheathing

Total

Grams per eter square

Wet weignt

1.0

42

2.0

6.0

3.4

3.0

18.6

96

45.3

3064

25.8

9.6

22.2

26.0

199.2

7842

216

20.2

21.0

as

375

50.0

167.8

8266

35

Dry weight (grams)

+0572

+5827

+1329

+4680

+2597

+2165

1.7260

84.5

4.6880

547043

4.3285

2.0026

2.0432

2.3293

20.0959

983.9

2.8075

3.8406

2.0002

2.4467

542826

5.0420

22.4186

1055.1

---Page Break---

Station Date collected

4h 8/9/72

Growing tips 3

Hoots

Rhizome

Vertical shoots

New leaves

01d leaves

Sheathing

Total

Gren per meter square

1B 89/72

Growing tips 0

Roots

Rhizome

Vertical shoots

New leaves:

old leaves

Sheathing

?Total

Grans per meter square

2B 8/9/72

Growing tips 2

Hoots

Rhizome

Vertical shoote

New leaves

old leaves.

Sheathing

Total

Grams per meter square

Wet weight

59.0

25.0

17.0

23.0

63.4

35.7

223.1

10390

2.7

5.0

22

2.0

9.2.

1.0

21.9

1374

21.3

13.2

15.7

9.0

21.7

12

210.2

5424

Dry weight (grams)

5.7621,

3.9234

2.5309

2.4296

6.5342

344082.

24.5782

1210.7

2780

+8426

+3334

+1638

+9355

No

2.5523

125.7

2.9340

243580

2.1389

+6617

2.1294

2.4950

22.7170

626.5

316

---Page Break---

Station Date collected

33 a/a/te

Growing tips 0

Roots

Hhizome

Vertical shoots

New leaves

018 leaves

Sheathing

Total

Grams per meter square

45 a/s/72

Growing tips 3

Hoots

ienizone

Vertical shoots

Now leaves

old leaves

Sheathing

Tota

Grams per meter square

5B ea/re

Growing tips 3

Hoots

Vertical shoots

New leaves

026 leaves

Sheathing

Total

Grane per meter square

Wet weight

35.2

28.4

10.0

12.6

36.0

22.6

143.8

7084

1563

28.1

16.5

a3

61.0

45.0

245.2

12079.

223.0

25.4

18.0

29.2

13.2

61.2

342.0

16847

Dry weight (grams)

3.2940

543607

1.5805

1.4264

4.2980

4.9496

19. 3892

995-2

744103

4.8020

1.7390

2.4201

6.0315

4.1425

26.5456

1307.7

11.3560

4.5698

344536

3.0232

6.8974

5.7636

5.7636

2726.8

7

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318

Station Date collected Wet weight Dry weight (grams)

a 6/20/72

Growing tips 4

Roots 22.2 2.4209

xhizone 22.2 345903,

Vertical shoots 24 1.6339

New leaves 21.5 2.3455

014 leaves 40.5 3.6655,

Sheathing 16.5 1.7134

Total 131.3 15.3695

Grane per meter square 6468 111

MZAN WSIGHTS (GRAMS PER METER SQUARE)

Station Wet Weient bry Weight

1 2638 g/n® 360.7 g/n?

2 6187 @/n? 15061 @/n®

3 8440 e/a? 1086.2 @/n®

4 22277 @/a? 1285.3 @/a?

12565 ¢/n 2130246 g/m?

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Tomlinson, P.3. and 7. 2. Vargo (1966). On the Morphology
and Anatomy of Turtle Grass Thalassia Testudinun
(Hyérocharitaceae). Vegetative Morphology, Sul.
lar, Sei, 16(4).

Grow (1972), Composition of

i wudinug and juppia Waritima, Pla, Acad.

iat

Zieman, J.C. (1968

of the Sea-grass, Thalassia Testudinum, Thesis, Univ.

A Study of the Growth and Decomposition

Wiama. Coral Gabli Orids.

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320

MANGROVE. ROOT COMMUNITIES IN A

THERMALLY ALTERED AREA IN GUAYANILLA BAY

by

Seppo Kolehmainen,

Thomas Morgan

and Roberto Castro

INTRONUCTIO!

Thermal tolerance of tropical ecosystems and marine organ-

isms have beon studied very little and much of the available information in this respect comes from subtropics where the annual mean temperature is lower and the seasonal variation greater than in the tropics. Most of the thermal studies with tropical marine organisms in the Caribbean have been made in Biscayne Bay, Florida (Sader et al., 1970; Zieman, 1970; Thorhaug, 1970; Roessler and Zlenan, 1970; Singletary, 1971). Sone old?studies (Mayer, 1914, 1918) are still the only existing data for the Caribbean corals. Only some intertidal species have been studied in this respect in the West Indies (Southward, 1962).

To get applicable data on the thermal tolerance of the Species in Jobos Bay, studies were started in Guayanilla, fifty miles west of Johos Bay, at the fossil fuel? power plant site in October, 1971.? The power plant has been Sperating on the eastern shore of Guayanilia Bay since 1B87." net the spring of 1992 the cutput of the plant was 310 iw. "Now the plant produces 710 iiW.? The ecosystems around? the discharge area of the cooling water resembles those. in the Aguirfe Navigational channels viz; mangrove Swamps, turtle grass beds'and mud Sotton commnities,

?The effects of elevated temperatures upon plankton, benthic organisms, turtle grass beds, mangrove root communities

and fish are studied in Guayanilla Bay in their natural environment. ?The results of these studies show the effect of long-term exposures of living populations to elevated temperatures. This section presents the data on the mangrove root communities over a period of one year. Some preliminary data have been given earlier (Kolehmainen and Morgan, 1972). Data on plankton, turtle grass and fish are given Clsewhere in this report.

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?The power plant in Guayanilla takes cooling water from an embayment on the west side of the plant and discharges the water 10° C, above the ambient through a 190 m long canal into a 900 m long seni-enclosed cove on the southeastern

side of the plant (Figure 1). Until March, 1972, the out~ put of cooling water was 750 m3/min, (188,000 gai./min and after a new 400 MW unit was added the output was raised £0 1510 m8/min, (398,000 gal./min.), the at being the sane as before.

In addition to the heated water, Guayanilla Bay receives chemical and carbohydrate pollutants from the nearby oil refineries and chemical plants. Oil slicks appear periodically and the concentration of heavy metals, including Hg, Cd, Cr, Ni, Pb and V, is high in sea water and the resident marine organisms. the power plant uses chlorine treatment against fouling organisms in the condensers and chromates as an anti-corrodant. Free chlorine disappears quite fast, however, in the discharge canal. Part of free chlorine?could have been associated with dissolved organic compounds of which many have been known to be toxic in a chlorinated form.

Fish kills have been reported occasionally around and downwind from the oi1 docks of Commonwealth Oil-refining Company (CORCO) and near the effluent discharge of Pittsburg Plat Glass, Inc. (PPG). These fish kills are attributed to dumping of toxic chemicals. No fish kills have ever heen reported in the cove that receives cooling water from the power plant. Since the cooling water is taken from the bay per se, it is polluted by chemicals and hydrocarbons. It

is therefore inpossible to separate entirely the effects of elevated temperatures from other pollution. By using the intake area of the cooling water as a control area, the additional effect of elevated temperatures can be seen, however. The combination of chemical pollutants and heat nay produce synergism, but if it exists, it only means that the effects of elevated temperatures are seen more pronounced, Therefore, it is safe to assume that whatever predictions on the éffects of elevated tenperatures are made with the data obtained in Guayanilla Bay, they will be conservative,

METHONS

Temperatures were recorded at several mangrove stations and turtle grass beds with recording thermographs. In addition

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Figure 1. Bast oide of Quayantlia Bay shoving the location of the pover Plant and the sampling stations

---Page Break---

to this continuous monitoring of water temperatures, temperatures were measured with a calibrated thermometer whenever samples were taken. The horizontal and vertical (istribution of temperature in the heated area was measured three times -- 9 October 1971, 18 January 1972, and 20 October 1972, Currents were measured in the cove with recording current meters and with flow meters.

Mangrove roots with organisms were collected periodically at eight stations (Figure 1) and, in addition, spot checks Were made in twelve other stations. The species present, their biomass and vertical zonation were determined with three to six randomly sampled roots at each of the eight stations. The randomness was achieved by selecting every third root of every third tree if the root was over 0.5 m long. ?These roots ere cut at mean water level and surrounded with a 0.5 mm mesh net hefore lifting into the boat.

Crustaceans and fish were collected from the net and preserved with 704 alcohol while the roots with sessile organisms were put into polyethylene bags and kept in an Teehox before they were taken to the laboratory. In the laboratory the roots were cut to 10 em sections and the species present, the number of individuals (when applicable) and the hionass?of each species as wet weight were determined in each section. The wet weight of species included the shells of mollusks and cirripedes, tubes of polychaetes and tests of ascidians, hut only those of living. specimens. Net weight - dry weight ratios of the species are being determined presently. Resides sampling of roots, collect~ing of species and visual observations were made at each station to establish a list of species present at cach tenperature zone.

Temperature of Water

Ambient surface temperatures near the intake varied from 25°C. in winter to 31° C. in summer (Figure 2) and the temperature of the effluent varied from 35 to 40° C. When only the old generating units were operating two thermal

plumes could he seen, one at the mouth of the discharge

?anal and one at the mouth of the cove to Guayanilla Bay

(Figures 3, 4 and Plates I \ - £). At the mouth of the

discharge Canal a rapid entrainnent was observed. The

temperature decreased over 2.5" C, within a distance of

100m. From this distance toward the mouth of the cove

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MAS ARTO S Wort s SOTO AHO Ss RoZIAs BEES

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sce temperature on Jan '3, 1972. Soundings ae in feet.

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Z

Figure 4 . Surface temperatures on October 9, 1972

Distribution of mangroves also shown.

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Power Plont

S JN

oO \

Discharge Canal

\ \

PLATE IA, Water temperature on the surface - October 20, 1972

---Page Break---

PLATE IB, Water temperature at one meter!s depth.

October 20, 1972

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---Page Break---

PLATE IC. Water temperature at 2 meters depth ,

October 20, 1972

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Po Power Plant

OB,

wis ?A\

\ Discharge Canal

y \

PLATE ID. Water temperature at 3 meters depth,

October 20, 1972,

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PLATE IE.

Power Plant

? /\

ischorge Canal

Water temperature at 4 meters depth,

October 20, 1972,

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332

the temperature decreased an additional 1.5° C. At the mouth of the cove the water was still 5.S° C. above the ambient. Inside the cove there was a thermocline at the depth of 2.5 - 3m. Below this depth the temperature of water was about 0.5° C. above the ambient (Figure 5). At the mouth of the cove the heated water rose to the surface and dissipated within 600 m (Figure 6). At the mouth of the cove there was a narrow deep channel coming toward the cove from the west. Outside this channel water here is very shallow (Figure 3) and, consequently, there is a limited supply of ontrainnent water.

Testing of the cooling system for the new generating unit

was started in the middle of February by pumping water
Occasionally at ambient temperature through the system.
This lowered the tenperature of the effluent about 5° C.
This testing continued, on and off, until May, after which
time test firing of the gencrating unit was started. While
the new unit has been operating the tenperature at the
mouth of the cove has been 7.5" C. above the ambient. The
daily mean temperature and the maximum and minimum at the
mouth of the cove are given in Figure 7. The diurnal
fluctuation of anbient temperature was about 1° C. while
the diurnal fluctuation at the mouth of the cove was about
2c.

Currents

?The water was discharged from the old units at the mouth of
the canal 0.75 m/sec. and the current at the nearest man-
groves was 0.1 = 0.2'm/sec. At the mouth of the cove below
the thermocline water was flowing into the cove at a
velocity of 0.1 = 0.2 n/sec.. The water going in was 0.5°C.
above the ambient, and thus 345 m3/min. was needed to en.
train 750 m3/min. of heated water that came out of the dis-
charge canal at i0* C. above the ambient to lower the
temperature down to 5.5° C. ahove the ambient in the cove.

Subsequent to the operation of the new unit the currents have increased considerably. Earlier the current was laminal and flowed toward the mouth of the cove on the surface. Now there is a large eddy inside the cove circulating counterclockwise (Figure 8). Current velocities for the present situation are not yet studied, but according to the calculations 395 m3/min, entrainment water was needed to lower 1510 m3/min. from?1n to 7.5° C. above the ambient within the cove. ?This means that there was about the same volume of entrainnent water going into the cove as hefore.

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Figure 8. Surface water currents in
the cove in summer 1972.

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The turbulances in the discharge canal saturate the cooling water with oxygen and, consequently, oxygen readings in the thermal plume area?were between § and ? mg 02/1,

Tides

Tides in this area resembled those in Jobos Bay. The difference between the high and low tide was about 30 cm.

Mangroves

Guayanilla Bay was once surrounded by mangroves on all sides, but the construction of industrial plants, piers, jetties and landfills have decreased the area of mangroves to a small proportion of the original cover. The area of the mangroves adjacent to the power plant covered 19.6 hectares. At the waterline about 954 of the mangroves were red mangroves (Rhizophora mangle), the rest being

Black mangroves. Cavscenaiy nitiaay ?ane white mangroves (Laguncularia racemosa). In the cove there were mangroves growing along the entire length of the east shore. The Water temperature in the warmest place around the nan: grove roots varied before fron 33° C. in winter to 38° C. in summer. Now with the new unit in line the temperature in the summer of 1972 was 39.5" C.. ?The mangroves were reproducing in the cove even though the temperature was

9° °C. above the ambient. Earlier there were a few dead trees at station 7 (Figure 1) and at the mouth of the cove at station $, but this was not due to the temperature, but rather to the current which was eroding the sediment from around the roots of mangroves in such a degree that the trees were uprooted and fell down, Now with increased water currents more trees were failing and dying. The man-groves in other parts of the cove still appeared to be

Mangrove Root Communities

Species composition: Mangrove root communities in the sie Shacoutsiae verioct the effects of elevated venpera tures. The number of species on the mangrove roots and the

temperature of water on'9 October 1971 at eight stations

(Figure 1) are given below:

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STATIONS.

Control _1

Temp. °C. 30.0 31.2

Spp. Algae 6 5 5 Rk 7 4 5 5

Spp. Invertebrates 90 45 69 67 58 25 21 10

Total ¥ Spp. 96 «48 74 75 65 29 2815

The number of invertebrate species at control station are

very high, This station had more species than any station

in Jobos Bay, an area that does not have chemical pollution

like Guayaniila Bay. There appeared to be some unknown

ecological factors that nade this station so favorable for

Sessile organisms. The natural variation of the number of

species is great in the mangrove root conmunities (see the

section on mangrove root communities in Johos Bay1972 Annual

Feport) and no two areas are exactly alike. A trtest was made between the different stations comparing the number of Species in cach phylum. This showed that station 1 differed significantly from stations Control, 2, 3 and 4." Station 1 had only one row of poor-looking mangrove trees along the shoreline which may have been the reason for the snail num-her of species living on the roots. Stations Control, "2. 3 and 4 did not differ from each other significantly, but Stations 5, 6 and 7 did differ significantly fron ail the other stations (P = 0.05). At 35°C. all the sensitive species were climinated while above that temperature a few Species dominated the root communities. The importance of this tenperature was seen clearly in the winter when the effluent was coming from the discharge canal at 35°- 36°C, Then many of the organisms that in sumer were found only gutside the cove immigrated into the cove and established fast-growing populations. This was especially noticeable among ascidians, polychaetes and crabs. They followed the reduction of the 35° C. isotherm into the cove all the way fo station 7, when the water temperature increased in the spring these species gradually died and disappeared from the cove.

The number of species in different phyla is given in Table syoiltGteaigae were not as numerous in Guayanilia as in Jobos Bay. ?Molluses had the most species at Control

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TABLE 1

san@ER OF SPECIES TH DIFFERENT PHYTA ON THE MANGROVE ROOTS On

(OK OCTOBER 9, 1971

PRY

cyanophyta

cntorophyta

Phaeophyta

Rhodophyta

Porifera

coctenterata

Annelida

Stpuncul ida

Yollusce

Arehropoda

aryoz0a

Eehinoderaata

Chordata

(Aseidiacea)

algae

Invertebrates

Total

Control

27

25

45

48

203

4 6

1

13

14

aoa

w 7

,oa

wow

2 6

o3

12

te 46

5 8

7 67

BOS

10

18

38

65

25

29

2

a

26

10

1s

339

station and at station 3, but arthropods were the most numerous at most stations. "At station 1 ascidians had most species of all phyla. Annelids, molluscs, arthropods and ascidians were the nost important groups at all stations. The list of species found at different stations is given in Table 2.

The species composition in the cove and at station 4 changed during the winter. When the temperature decreased larvae that were coming into the cove with the counter-current on the bottom settled on the mangrove roots and established colonies and populations. The number of species of macroorganisms in winter, 1972, at different stations is given helow.

STATIONS

Control 34

Temperature °C 25.5 26.0 26.4 27.2 28.9 31.5 33.0 34.5

Species 94 45 74 7H NSH a8

The most pronounced increase in the number of species happened at stations 5, 6 and 7, Stations 4 and Control also showed a slight increase. The increase in the species diversity was due to the additional species of sponges polychaetes, crustaceans and ascidians. These changes all occurred in?a four-month period which showed that a thermally altered area can recover rapidly. In this respect, thermal pollution is different from some other types of pollution. There are no residues left from thermal addition.

When the ambient temperature and, consequently, the temperature in the cove rose in the spring, the populations of the nore sensitive species gradually disappeared. khen the more sensitive species such as ascidians died, the surface area that became available was quickly utilized by the hardy species. Dluegreen algae, an encrusting sponge (llalisarca sp.), a calcareous tube dwelling polychacte

(Tonafastepus jtelzatua), etree oyster, ((tognanan seus),

a periwinkte (Littorina angul fers), two faTanus. species

and two crabs (Kratus pisonii and Pachygrapsus t: ns rsus)

were the more hardy species. Nacroalgae, coelenterates,

echinoderms and ascidians were the most sensitive species.

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Stations

?TABLE 2 (cont 'd.)

Rhodophyta

Loventeria sp.

Polyeiphonta howe!

Polysiphoaia #p.

[INVERTEBRATES

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343

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Gastropoda

Bivalvia

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Stato

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Bionass,

?The biomass of organisms living on mangrove roots was also affected by the tenperature and by water currents. The Towest biomass, in October 1971, was at the warmest area of the mangroves at station 7 (Figure 9). In this area the water current cane from the discharge canal directly {nto the mangroves at high velocity. About 30 meters further behind a small point where the current velocity was very slow the biomass was more than an order of magnitude greater than at station 7, even though the temperature was only 0-1 - 0.2" C, lower than at station 7. Station 6 is about 100 m from station 7. Temperature there was 0.4° C, lower than at station 7 and the current was very weak. The bionass at this station was the high-Gst of all stations, but it was made up mainly of two Species, the tree oyster and Balanus amplitrite var.

rege ene eeeon shad a lower FYomass than the station Biveach side of it. The reason for this is not known, but the low bionass may have been the result of the strong Current at this station. All the stations outside the cove had biomasses between 200 and 300 grams.

At stations Control, 5 and 6 molluscs were the Goninant group, while at station 2 ascidians, at station 4 Qigae and-at station 7 cirripeds were the most important greups (Table 3). In general, algae, molluscs, cirripeds Gnd ascidians contributed most to the biomass.

In the winter the bionass of sponges, polychaetes, crustaceans and ascidians increased in the cove, but no Visible change was seen at the station outside the cove.

After the new power generating unit was fired the biomass fon the Toots at station 5 increased because of the in

Erease in the nunber of tree oysters and Balanus spp. It appeared that tree oysters and cirripeds could conpete better at higher tenperatures. These species were also able to withstand stronger water currents than other Species living on mangrove roots, The other stations in-sfie the cove did not change their bionass, but bluegreen algae increased their proportion of the total biomass from the summer of 1971. Stations outside the cove ex-hibited only small changes in the bionass or species Hiversity except station 4 where the nunber of species of ascidian decreased. The biomass and the tenperatures of five stations on 20 September 1972 are given below.

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Figure 9.. Biomass of organo

Figure 9. Biomass of organisms living on mangrove roots on October 9, 1971 at different stations as grams wet weight Per root.? The isotherms at the same date are given too,

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ANNEDILIA

Polychaeta

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Teopode

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TABLE 4

Vertical Distribution of the Number of Species

and the Biomass (Wet Meight) Calculated

for All Stations on 9 October 1971

4 of Species	Bionass
Depth, cm	sof Total	tof Total
o-9	3	0.8
19	10	8.6
20 - 29	20	22.2
30 = 39	22.5	21.9
40 - 49	20	16.5
so - 59	n	12.2
60 - 69	7	10.5
70 - 79	3.5	5.6
an - 89		1.6

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below the mean water level. In Jobos Ray most of the bio-
mass was somewhat deeper because the biomass of ascidians
in Jobos Bay was much higher than in Guayanilla Ray.

THERMAL EFFECTS IN MANGROVE ROOT ci

The mangrove trees in Guayanilla Bay were living in temper-
atures up to 40° C. until May 1972 the maximum temperacure
in the mangroves there was up to 38° C. and even at this
high temperature the mangroves constituted a reproducing
population. In the summer of 1972 the temperature increased
to 40° C. for the first time due to a new generating unit
that more than doubled the volune of cooling water, During
Summer 1972 the mangroves in the heated cove appeared still
to be surviving, but whether this high temperature will
eventually have?adverse effects on the mangroves will be
seen in the future.

Mangrove root conmunities were much more sensitive to ele-

vated tenperatures than mangrove trees. Species composi=
tion and biomass of organisms living on the mangrove roots
in Guayanilla Bay reflected the long-term effects of the
elevated temperatures, These effects showed in the popula-
tion dynanics, growth? rates, competition between species
and in the seasonal migration of species.

The situation in Guayanitla was convenient for thernal
effect studies because the cooling water was discharged
into, a seni-enclosed area where the surface area beteeen
Isotherns was large enough and constant enough to ilies
trate the horizontal zonation of organisms agcording. vo
the temperature, Since the clevaved temperatures here
were produced by a power plant, the data are difect iy. ap-
Plicable to other power plant? plane? atesy wih Simtage
populations of organisms: A low number of macroalgae in
Guayanitla Bay compared to that of Jobos. fay may be an
indication of stress by chenical pollution in Guayani]La
Bay. lowever, nore invertebrates were found in Cuayaniila
Bay?than in Jobos Bay on mangrove roots. Nine species of
algae and eighty-five Specios of invertebrates ere. Found
in'connon in hoth bays

The post hardy sessile species were intertidal, cirripeds,

Balanus amphitrite var. pallidus and Balanus eburneus, but

sInost as tolerant was the tree oyster Tene Stee

which Lives in the lower part of the intertidaT rors eae

deeper, A polychaete, Pomatostegus stellatus, that lives

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TABLE 5

Maximum Daily Teaperatures chat the Following Spectes have

?been found in Coayanilia Bay.

PLANTS

cyanophyta woe

40

40

40

Chlorophyta Enterosorpha sp. »

Gaulerpa verticiliata 36

C. fastigiaca 35

©. sertulariotdes 35

C._zacemoss 35

Phacophyta Dictyota givarte 34

Rhodophyta Acanthophora sptetfera 35

Hucheusa acanthocladus 4

?Teacheophyte Rnizophors mangle 40

Avicennia nit 40

Laguncularia racenoss 40

AMIMALS

Portfera 2»

36

35

35

34

3a

cue 33

Annelida Pomatostegus stellatus 38

Syllie 3

Phyllochaetopsus claparedit %

?eodtce rub 36

Sabelia welanostigna 3

S. alge 35

Nereis dupertiit 35

Limbrinereie maculata 35

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below the mean water level. In Jobos Ray most of the bio-
mass was somewhat deeper because the biomass of ascidians
in Jobos Bay was much higher than in Guayanilla Bay.

THERMAL EFFECTS IN MANGROVE ROOT COMMUNITIES

The mangrove trees in Guayanilla Bay were living in temper-
atures up to 40° C. tmtil May 1972/the maximum temperature

in the mangroves there was up to 38° C. and even at this, high temperature the mangroves constituted a reproducing population. In the summer of 1972 the temperature increased to 40° C. for the first time due to a new generating unit that more than doubled the volume of cooling water. During Summer 1972 the mangroves in the heated cove appeared still to be surviving, but whether this high temperature will eventually have? adverse effects on the mangroves will be seen in the future.

Mangrove root conmunities were much more sensitive to elevated temperatures than mangrove trees. Species composition and bionass of organisms living on the mangrove roots in Guayanilla Bay reflected the long-term effects of the elevated temperatures. These effects showed in the population dynamics, growth rates, competition between species and in the seasonal migration of species

?The situation in Guayanilla was convenient for thermal effect studies because the cooling water was discharged into a semi-enclosed area where the surface area between isotherms was large enough and constant enough to ilius-trate the horizontal zonation of organisms according to the temperature. Since the elevated temperatures here were produced by a power plant, the data are directly ap-Plicable to other power plant * plume areas with sini

Populations of organisms. A low number of macroalgae in Guayanilla nay compared to that of Jobos Bay may be an indication of stress by chemical pollution in Guayanilla Bay. llowever, more invertebrates were found in Guayanilla Bay than in Jobos Bay on mangrove roots. Nine species of algae and eighty-five species of invertebrates were found n-conmon in both bays.

The most hardy sessile species were intertidal cirripeds, Balanus amphitrite var. pallidus and Balanus eburneus, bat aTnost a5 tolerant was the tree oysters Teosnseee status Which lives in the lower part of the intertédal fone ant deeper. A polychaete, Ponatostegus stellatus, that lives

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TABLE 5

Maximus Detly Temperatures that che Following Spectes have

een found in Goayaniila Bay.

puants

cyanophyta Vlothetx sp. 40 ¢

?Tyngbye op. 40

Osctliatoria ap. 40

ius 6p. 40

Chlorophyta Enteronorpha sp. 39

Caulerpa verticillaca 36

E. fastigiata 35

E. sertulariotser 35

C._zacemosa 33

Phaeophyta Dictyots divartea %

Rhodophyta Acanthophora sptetfera 35

Eucheupa acanthocladus Es

?Teacheophyta Rhizophora mangle 40

?Avicennia nltide 40

Laguncularia racemoee 40

ANIMALS

Porifera Maliserce ep. 2

Gallysponia sp. 36

Myeale sp. 35

Halichondria 35

Tedanta Sgnie 34

Coelenterata etholomaea angulata 34

Erythropodiua ceribeorue 3

?anneliaa Pomatostegus stellatus 28

Syllie sp. 37

Phyllochsecopave claparedts 36

[eodice rubri 36

Sabella selanostigns 36

alga 35

35

35

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Annelida

mn

Arthropods

Bryozoa

Echinodermata

Chordata

?TexebelJa annulicilis

atulus sp.

?Sabellastarte nagnitice

Ltorine angulttere

Brachidontes ex

Nassarius vibex

Crassostrea rhizophorae

Great ise veppaceus

Ostres equestrian

Betaloconchos seginty:

Hainoea elegans

Pododeamus rudis

Balanus snphitrite v. pallidus

rachygrapeus Cransversus

?Hratus plsonit

Gontopets cruentaca

CLibanarius cube

Hexapmopeur car ibbacus

Panopeus bermidensia

Eanopeus RarecAt

cross polite

Excorstians suedticornis

Ghthansiae Failte

Eorophiae sp.

Synuipheue Frtzmitterts

Wetopheys Sicornstue

crisia sp.

Qpbiocreza 1istoralie

Ophioehrie angulaca

Rotryllotées nigcun

Distaphia bermudenste

Polyclinus constellatug

Piplosons sicdonalat

Perophors virid

Seyela pare:

setéie aigrs

33

3

RORERRRESS

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Chordata

Clavelina picte

Polyeitor olive:

4

3%

3

33

33

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in the intertidal zone and below the intertidal zone was

associated with the former species in temperatures up to 38°C. (Table S). All these species have adapted for living in extreme conditions, not only in high temperatures, but also in varying salinities, low dissolved oxygen concentrations and polluted conditions. In these extreme conditions these species occupied all depths os {he mangrove roots. These sessile species were poor competitors and in optimal conditions for mangrove roots Organisms in the middie and lower parts of the Toot these species were covered by macroalgae, encrusting sponges and (haliagsetscidians untit they died ?An encrusting sponge {liglisarea sp.) was also found in temperatures up to? 39°C,

is species grew as a thin layer around the roots in the heated cove, but outside the cove it was uncommon,

Free moving animals were in a better position to avoid too high temperatures. Once species of snail, periwinkle (Littorina angulifera) and two species of crabs (Aratus pisonti ana Pachygrapsus transversuay wore. Fao AE Station 7'as well aein-the disehstes coped along with Balanus amphitrite var. pallidus. Periwinkle and the two Erabs were capable of ciimbing above the surface to aver water that was too hot. Bluegreen algae were found asa think layer covering the bottom in shallow banks and also fon the mangrove roots at station 7. In September 1972 when

the temperature in the cove was between 37°8 and 39.7" C. biomass of bluegreen algae was increased greatly from the situation in the previous summer. While bluegreen algae were found covering parts of mangrove roots only at's

7in 1971, now bluegreen algac were seen on all mangrove foots in the cove, and there were large areas in the cove yhore the surface'of water had flakes of Mluegreen algae floating.

FRteromorpha and Ulothrix were the only algae besides Eluegreens found inthe Gove in oetongy 143° Three other polychaetes (Syllis sp., Leodice sp. and Narphysa regalis) pesides Ponatostegus vote Tound in ine cove above 7 Two molluscs (Erachidontes exustus and Sovcatvos vibex) UGig dying, in the cove Tn summer, too. Two sopods (Sphacrosona walkeri and Cirolana parva) and several crabs (iibsnarvas Sinensts pe eSergeays Parva) Goniopsis gtuentata, Vanopeus bernudensis, Cailinectes savetestus)) wore found In the cove in Cetsber Tories eee MaTeIDaEUE) Bryozoa (Crisia sp.) lived in temperatures up to 38° C. Five species oF ascidians (Distaplia bermudensis,

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Polyclinum constellatum, Didennum candidum, Diplosona
BolyeL ine cons eae eaeay were fount Living. in tompera-
eee eo sort. pst of the other species did not

occur above 35° C, (Table 5).

ahout 3/4 of all species were found living in temperatures
Shove 38° ?, The rest may very well be able to live at
those high temperatures, but there may have been sone other
ological factors preventing their living in the area
Ghere the temperature was this high in Guayanilla. The
Tiversity of species on mangrove roots varies normally
Greatly and the factors affecting this are still mostly
Ehknows (see the section on the mangrove root communities
in Jobos Bay 1972 Annual Report).

The results of this study show that both the species compo-
Sition and biomass of mangrove root communities were not
affected adversely in temperatures below 34° C. Between
Sd and 35° C. the number of species dropped abruptly and

above this temperature the number of species was inversely Telated to the temperature of water

All the temperatures given in this paper are long-term mean Cenperatures, thus there were short times, a few hours, Ghee daa while when the temperature at the stations col- Yected exceeded the mean temperature by one to ty degrees.

The 1ach of information on the thernal tolerance of tropi- fal marine organisms sakes it inpossible to compare the Silstun thermal Limics of the most important species found Shccuayanilia bay.? A population of the snail, Nassarius tibexy was found at 36" C. in Guayanilla Bay shite Tkorhaug SESE Gort)" Feported 3715.7 40.29". ?as the upper thermal Fiat cor this species in?a 72-hour laboratory experinent. sesame authors. found the upper thermal Limit of 36.1) - syle C, fora sitimp, Poriclimenes americanus, while in Ghayaniiia the sane species hat a Tiving population at S47C. On the pasis of these two limited examples it appeared that the popolations were living about two to iffee degrees helow their upper short-term thermal Limits. Aetually? the poptlations in Cuayanilla were sometimes ex- posed to temperatures up to 2° C, above the reported mean Waperatures This means that even the most, sensitive life Stunes of these species were able to take these short-term heat maxima. Fast inmigration of larval forms that

eStantished populations in the cove during the winter months Showed that the reproduction and the larval stages were not adversely affected by temperatures below 34°C.

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APPENDIX B

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INVESTICATIONS OF PRINARY PRODUCTION

The few preliminary measurements made to date suggest that the hionass and production of nhytoplankton in Jobes Ray are substantial. Nutrient level measurements are consistent with high productivity where light intensity is adequate in the upper water colunn and on shallow hettome containing sea grasses and benthic algae. The magnizade of primary production in the major compartments of the systen is of interest both for estimating the total primary Rroduction of the Ray and for establishing hase line pros ductivity data for comnarison with later values in the altered system.

Major sources of nrimary production are (1) nhytoplankton in the water column, (2) rooted sea grasses (primarily

Thalassia) and their alpal epiphytes, (3) benthic algae,

?aTTocthonous material enterine the Ray waters, pris marily from mangrove areas. The mangrove studies in Progress should supply information to estimate the input from the trees. The input of allocthonous organic maverial (other than sugar mill wastes) from shore run-off nay he minor, since there are no permanent streams. There are in= puts, especially to the Central Ray and ship Channel, from the ocean. Fxcent for water entering the Pay through the Boca del Infierno and between the outer cayos, these inputs are at depth and may thus he less significant to the total productivity, Coastal marine values of hionass. and produc tivity (e.g. tlargraves et al., 1970; Rurkholder et ale, 1967) may he useful for estinatine this conponent of-tnput Production. Jf water transport into the Ray fron the Southeast is quantitatively significant, messurerent of Productivity on the fringing reefs and shallow grass beds of the cayos may he indicated.

Studies in similar shallow marine situations (e.g. Poneroy, 1960) suggest that where depths are greater than about 2 a, the bulk of primary production is hy phytoplankton, even where ambient light levels at the hottor are hipher than

those that occur in parts of the Ray. Although much of the Inner Bay is shallower than 2m (Tir. 1), the low anhient Might level at the bottom (< 2% of surface intensity at 1 m depth in many places) and the scarcity of Thalassia deeper than 1m suggest that henthic productivity may he-Tow ip

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much of the Inner Pay, In view of this and of the limited exchange with ocean water (probably lower in productivity), an estimate of production in the Inner Pay hased on local phytoplankton alone nay he sufficiently accurate.

The sampling program should undertake productivity heasurenents at a few locations within the Inner Ray near the surface and a set of measurements at one or more locations to get a vertical profile of productivity vs. qight and depth (App. 1)._ The vertical profile data could heextrapolated to much of the Inner Ray, and the produc~

tivity vs. light data could be used to estimate sub-surface productivity in other areas, based on light measurements and surface productivity measurements. Productivity for the entire water column could he obtained by integrating the productivity vs. depth curves so obtained (e.g. Burkholder et al-, 1967).

It seers unlikely that the small area of sea grasses in the Inner Nay (Fig. 2) could contribute significantly to the total production, These heds are not expected to ex-perience heating due to power plant effluent. If grass Nistribution and abundance change significantly due to power plant operation (e.g. hecause of reduced turbidity fn the Inner Ray), repeated surveys of the type already conducted (see "Feolopy of Turtleprass . . .? section, this Feport) should detect the chanves.

The distribution of significant quantities of macroalpac

in the Nay is poorly known. The henthic microalgae have not been studied, but they may he presumed to occur wherever light levels are adequate. Their productivity

is sisnificant in some similar shallow marine situations (e.g. Pomeroy, 1989, 1960; Jones, 1968). It is difficult to puess their importance in the extensive shallows of the Inner Ray (< 1m depth). Information ahout the compensa~ tion depth of phytoplankton from the vertical profile work discussed ahove should he helpful in estimating their distribution. In addition, sone productivity measurements Should be made of bare mud?hottom in situ. Macroalgae, if present, would be included in the measurenents (App. 2}.

In hoth the Central Bay and the Ship Channel, shallows make a much smaller fraction of the total area than in the

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Inner Ray (Fig. 1). Although the water is less turbid, Probably 1Mt or less of the area is shallow enough for Significant benthic production (Fig. 2). There are, how- ever, a number of acres of Thalassia present, which should

be unaffected by power plant operations and which might provide a useful control site. Morcover, much of shallow area occurring in the Central Pay does contain Thalassia.

A station should he sampled for prinary productivity and leaf growth (App. 3). Probably either station 6 or 7

(see Fig. 2) should he used so as to permit correlation with existing and planned hiomass data. \ few measurenents of bare hottom area at successively preater depths near

the same station should he made to estimate benthic algal productivity (App. 2).

In the Ship Channel, the hottom area divides rather abruptly

into a najor area that is much too deep for significant

benthic production and a much snaller area of shallows,

most of which has a considerable cover of Thalassia (Fig. 1).

Only in parts of the Bahia de Cayo Puerea and Var Vepro are

there extensive shallows without Thalassia. Much of the

area will experience sone temperature elevation from power

plant operation, and major chances in currents will occur

locally. Phytoplankton productivity should he measured in

a few locations in the open Channel and in the Pabia de

Cayo Puerca/Mar Nearo area (App. 1). Productivity an? leaf

growth of Thalassia should he measured (App. 3) in

Thalassia feds on Roth sides of the Channel, e.g, stations

and S (Fig. 2). In at least one case, an adjacent hare

bottom area should be measured (App. 2)! A hare hottom

area in the Rahia de Cayo Puerca/"ar Negro area should also

he measured.

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widep wnwyeow eur so 18K fo UROUS 840 Ai

tuojiois Suyduioe yo won0201 eu, ?ko@ sogor

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APPENDIX I

MEASUREMENT OF BIOMASS AND PRODUCTIVITY OF PHYTOPLANKTON

Phytoplankton biomass would be measured directly by weighing the quantity of cells filtered froma large volume of water. It can be estimated indirectly from measurement of chlorophyll a extracted from cells filtered from the water. | The measurement of chlorophyll a also provides a Peasurenent of "photosynthetic potential? from which, at known light intensity, productivity and efficiency can be gstinated. Productivity would also be measured by changes in dissolved oxygen caused by photosynthesis and respiretion. Light and dark bottles would be suspended in the Bay at various depths, and oxygen changes would be determined initially by Winkler analysis. After development of the polarographic ?oxygen electrode? equipment (see Appendix 2), it may be feasible and preferable to adapt this equipment

to plankton productivity measurements also.

The following steps would be involved in making the above Reasurenents, using the Winkler analysis for oxygen. initially, ?step I-A vould be repeated successively at a Station throughout the daylight hours (e.g. once every

Zhours). From these results, a method would be derived for estimating daily production from a single measurement (e.g. Doty et al., 1967).

1. Sampling Pian

A. Take a sample of about 1 gallon from just below

the surface (avoiding the surface film) at each of the specified stations. Use a clean glass or

| For further details and discussion of analytical procedures, see Strickland and Parsons (1968),

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plastic container.? Weasure surface irradiance and irradiance at the depth of the center of the sample.

Measure temperature and oxygen concentration of the Bay water using the surface oxygen meter.

Measure salinity using the AO Refraction Salinometer.

Fill a clean 2-1/2 gallon cubitainer with water from just below the surface.?

At specified "Profile" stations, take a sample as in A? (above) and an identical sample at each 1/2 meter depth to within a few centimeters of the bottom.

Treat samples immediately in the boat as follows:

A. Pour the 1 gallon surface sample through a piece of 0.3 mm clean nylon netting. Deoxygenate this filtered sample per detailed instructions. Fill 4 clear 300 ml BOD bottles and 2 opaque 300 ml POD bottles completely full with the filtered sample water. (Insert stoppers if necessary while handling).

Label 2 clear bottles "IB", To each, add 1.0 mi of manganous sulphate by putting the tip of the automatic pipette just below the surface of the water in the bottle. Then add 1.0 ml of alkaline iodide solution in the same way, using its own automatic Pipette. Stopper the bottles tightly immediately without including air space, and shake the bottles

a

Initially an additional sample or two would be taken within a few tens of meters of the location to evaluate Patchiness of phytoplankton.

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thoroughly until the precipitate is evenly dispersed. Store the bottles out of the sun (do not Tefrigerate). After a few minutes, shake then again and return then to storage.

Innediately stopper the other 2 clear hotties

after filling, without including air space, and label "LAY. fo the same with the 2 opaque bottles and label them "DR". Wire stoppers on tight using Stainless steel or chrome-nickel wire and put all LB and DR bottles back at the depth from which they were taken (use an anchor weight and a float just sufficient to keep the bottle up). Note the time the ROD hotties are put back in the Ray-

After the specified time, X, recover the LB and

DR bottles from the Ray, remove stoppers and add manganous sulphate and alkaline iodide in the same way as for the IB hotties. Shake well twice and store with the IB bottles. Record incubation time,

Ne

D. To the remainder of the 1 gal. surface sample add about § drops of well-shaken magnesium carhonate Suspension using an eye dropper, label the con= tainer "Pigments", shake well and store in the dark on ice.

III, At the shore base, within several hours, treat samples as follows:

A, Store IB, LB and DR hottles out of the sun (do not refrigerate).

B. Pour the water from the 2-1/2 gallon cubitainer through a piece of 0.3 mm clean nylon netting. Measure and record the amount of water filtered. Filter this water again through a 47 mm diameter, 0.45u Millipore filter. As soon as all water ha: been filtered}, sprinkie a few drops of lit! on the

If phytoplankton are sufficiently numerous, an ade- quate sample for weighing nay he obtained without iltering the full volune of water.

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filter paper.4 Drain the filter thoroughly dry under suction, Weigh and record the weight of the paper with phytoplankton.

C. Filter the "Pigments" sample through a 47 mm diameter, 0.45 (HA) Millipore filter. Record the quantity of water filtered, Vy. Shake vie-orously in the hottle hefore filtering. Drain the filter paper thoroughly dry under suction, remove it from the filtration equipment, and trim avay as much excess paper around the periph-ery as possible with clean scissors. keep only the part containing plankton.

Place the filter paper in a $0 ml stoppered graduated centrifuge tube. Add approximately 40 m1 of 90% acetone using a polyethylene wash hottle, stopper the tube, and dissolve the Filtor?paner by shaking the tube vigorously. Place the tube under refrigeration in complete darkness. ?shake the tne once more after about Tto 2 hours under refriperation.

IV, At the Nuclear Center laboratory, treat the samples as follows:

A. Within a few days after collection of the samples, perforn the following analysis on all IR, DB and TR hoteles:

Take bottle fron storage without shaking and remove stopper. Add 1.0 81 of concentrated (specific gravity 1.84) sulphuric acid to

the sample, placing the tip of the pipette just below the surface of the water. Re-Stopner and shake thoroughly until the pre-cipitate dissolves fully. Do not permit

air to hecome trapped in the bottle. Keep out of direct sunlight.

A few tests will be run initially weighing papers be-fore and after adding HCI to get an estinate of Carhonate sediment in the sarples. A tare weight for filter papers will also he established.

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Within a few hours, transfer 50.0 mi of the solution into a painted conical flask using a volumetric pipette. Titrate at once with standard 0.01 N thiosulphate solution until-a-very pale straw color remains. Add § ml of starch indicator and finish the titration, adding thiosulphate carefully until the biue solution just clears.

Use this first "end point"; do not wait for the Solution to color again. Record the number o: BOF thosulphate solution used. ?Ira "plan value has been supplied when the reagents? were Prepared, subtract it from this number of ml. The Fesult 48 called V, i.e. Vj Vpg oF Vig. Obtain

the value of £ supplied with the reagents.5

?

fs

Calculate the dissolved oxygen, 0, in the bottle

and recor

0 =1,6096 xf xv

where 0 is in mg 0,/liter

Calculate the productivity values for the sample

as follows, and record:

Gross photosynthesis, mg carbon/n® - hr =

sosstx zy ~ vps]

Nee

Net photosynthesis, mg carbon/m? - hr «

sosxex [Wy - V,

Nx 1.2

S Manganous sulfate and altatine iodide.

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Respiration, mg carhon/m3 - hr =

eos x x [Vie - Von]

N

C. At least 20 hours but not more than 2 days after filtering from the water, analyze the "Pigments" samples as follows:

Remove centrifuge tubes fron refrigeration and let then warm to room temperature. Add 90% acetone using a polyethylene wash bottle to make the liquid up to exactly 40.0 mi. Replace the glass tube stoppers with plastic stoppers and centrifuge for ahout 10 nin. at about 3000 - 4000 rpr.

Pour the clear liquid from the tube carefully to fill a Beclman Dil spectrophotoneter sample cell having a path length of 10 cm and Volume of ahout 30 ml. Immediately measure the extinction, T, of the solution in the

spectrophotoneter apainst a reference cell

Filled with 90% acetone only. Measure at

wave lengths: 7500, 6650, 6450, 6300 and

4800 A. Record valiies to'the nearest 0.001

unit in the range 0 - 9.4 and to the nearest

0.005 unit for extinctions greater than ahout

0.4. Then fi11 hoth cells with 90% acetone

(Sample cell and reference cell) and measure

extinction at each of the above wave lengths.

This gives a cell-to-cell blank correction,

Fee. Calculate the corrected extinctions at

each wave length as follows:

Fe650 * B6es0 (aS measured) - F750 (as measured)

+k

= "ce 66s0

---Page Break---

E6450 * Feaso (a8 measured) - E7so9 (as measured)

+ Bee gaso

T6300 = Fesno (as measured) - F759 (as measured)

+ Fecgsoo

E4goo * Eagoo (a8 measured) - 3 x Eysop (as measured)

+ Feegano

The sign for Ecc depends on the relative readings for the 2 cells when they were compared with both containing 90% acetone. Calculate the concentration ratios, C, of chlorophyll a as follows:6

1 6450 - 0.14 F6300

Vw

where Vy is the volume, in liters, of water passed through?the Millipore filter. ¢ is in mg pigment/ nd water.

Or get C value from nomograph supplied, using the corrected F values.

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Doty, M.S., J. Newhouse and R.T. Tsuda. 1967. Daily phytoplankton primary productivity relative to hourly fates: Ini. Improvement and Application of Benthic Algal Isotope Productivity Measuring Methods. Hawaii Botanical Science Paper No. 3. University of Hawaii.

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APPENDIX 2

MEASUREMENT OF PRODUCTIVITY OF BENTHIC ALGAE

The details of this method are yet to be developed. It is Planned to enclose an area of bottom mud and a smail amount of overlying water in situ by placing the open side of a clear or opaque plastic chamber on the bottom. (A clear chamber would be used for measurement of net photosynthesis; an opaque chanber would measure respiration). It is desirable to provide stirring, e.g. by including a magnetic stirrer driven by battery power or compressed air. Piastic hags can be used as disposable test chanbers to scal on very uneven bottons.

An initial oxygen concentration measurement would be made immediately and one or more made subsequently after sufficient ?incubation? tine in situ to produce changes in oxygen sufficient for productivity computations. Initially the oxygen would be monitored frequently and tests run sequentially throughout most of the daylight hours. From these results, a method would be devised for estimating daily production fron a single measurement (e.g. Doty et al., 1967). A light intensity measurement would be made with each oxygen measurement.

Oxygen could be measured by any method available, but the use of a polarographic ?oxygen electrode? is much preferred for ease Of frequent (or continuous) monitoring, ninimun contamination (dilution) of samples and accuracy unaffected by oxygen saturation of water. The polarographic techniques and submersible equipment of Wells. (cog, Welie and Wer iss 1971) appear applicable alnost unchanged, and equipment Of this sort would be assenbled for the purposes

The routine test procedure would involve (1) placing a clear and an opaque chanber on an appropriate bottom area with minimum disturbance of sediments, (2) connecting the stirrer power supply (battery or ait), (3) taking an initial dissolved oxygen reading for ¢ach chamber, (4) taking a submerged and a surface irradiance reading, (5) marking the location, and (6) returning after the proper interval to take further readings. The oxygen electrode calibration should be checked cecasionally (e.g. in water -

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saturated air). A calibration sheet would be used to convert current readings to oxygen concentrations.

Gross photosynthesis, net photosynthesis and respiration would be computed from oxygen concentration measurements Tn'the same general manner as in Appendix 1, section IV.A. The productivity estimates so obtained would include the effects of the phytoplankton in the volume of water en Closed within the chamber. Values for phytoplankton produc- {ivity measured at the sane light intensity either con- iNiehely or at some similar station would be used, together With the known volume of water enclosed, to correct the Chamber measurements so as to yield benthic productivity values.

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Doty, M. S., J. Newhouse and R. T. Tsuda, 1967. Daily Phytoplankton primary productivity relative to hourly Fates. Ini Improvement and Application of Renthic Algal ?Isotope Productivity Measuring Methods. Hawaii Botanical Science Paper No. 3. tiniversity of Hawaii.

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APPENDIX 3

MEASUREMENT OF PRODUCTIVITY OF SEA GRASSES

The method for measurement of productivity of the entire plant is basically the same as that used for measurenent

bf benthic algal productivity (Appendix 2). The same or very Similar equipment would be used. Bottom chambers would be Sized so as to contain the height of sea grass leaves without excessive crowding and to cover an area containing a humber of "short-shoots? (clumps of green leaves) in a Roderately thick growth of Thalassia. Measurements of oxygen and light intensity Would be taken in the same way. The measured oxygen concentrations would be converted to productivity and respiration values in the same way for the Enclosed systen. Phytoplankton productivity would be sub-

tracted out in the same way to give a total benthic pro-
Guctivity value, For sparse growths of Thalassia, benthic
algal productivity and respiration should also be subtracted
out to obtain estimates of values for Thalassia alone

(see Jones, 1968). Benthic algal productivity per unit
area from an adjacent parcel of bare bottom, measured as

fn Appendix 2, would be used, together with the area of

the chamber, to compute the correction. For dense growth
of Thalassia, the shading of the bottom is probably such
that the benthic algal correction would be negligible

{see Pomeroy, 1960). In any case, for estimation of
primary productivity of the bay, it is the total benthic
Yalue-benthic algae plus sea grasses, as measured-that is
Of major interest, Although the productivity of algae
epiphytic on Thalassia may be considerable (Jones, 1968),
for purposes of this study, it seems unnecessary to
separate this component from the productivity of the
Thalassia plants.

Much of the photosynthetic production of Thalassia goes into growth of roots, rhizomes and the basal portion of NShort-shoots?, which cannot be conveniently marked and subsequently harvested to measure growth. However, a Substantial fraction of net photosynthesis results in growth of visible green leaf blades (Jones, 1968). Measurement

Of growth rate of these leaves gives an estimate of productivity that is at least useful for comparative purposes. Tt provides some check on the estimate obtained by oxygen neasurement. The leaves constitute the portion of the plant

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which has most rapid turnover and is passed along the food chain most quickly and conspicuously (Wood et al., 1967). Measurement of green leaves gives information on the amount of plant material available to participate in photosynthesis.

Measurement of leaf growth would be included in future ecological Thalassia studies. The present sampling procedures include biomass measurements of leaves and other plant parts (see "Ecology of Turtle grass...? section, this report), Additional information to be recorded would include number of green leaves, width of blade and length of blade, since the work of Thor haug and Stearns (unpublished manuscript) suggests that elevated water temperatures produce different effects on these different plant characteristics. AS a means of monitoring effects of elevated temperatures and seasonal effects, at some stations, semi-permanent quadrats should be defined, and a blade count Should be made at each biomass sampling occasion.

In addition to the biomass measurements, leaf growth should be measured in the fietd by marking a group of leaves at the Station and subsequently harvesting the leaves to measure the elongation. A marking method similar to that of Zienan (1970) could be used (also see "Studies of the Effect of Heated Water on Turtle Grass ..." section, this report). Leaves should be marked initially at the point of transition from sheath to biad feman's results (fieman, 1970, Fig.3) could be used to estimate total leaf elongation from élon~ gation at the blade base. The sum of this new material plus Ehe total length of any new leaves produced comprises the

growth for the tine interval. It would be convenient to hark a group of leaves in this way at each Station sampling Occasion and harvest all or a portion of these leaves as a routine biomass sample at the next occasion. The length, width and weight of new leaf growth would then be taken Along with present biomass data. Leaves should be cleaned of epiphytes before weighing by washing in dilute acid in order to produce accurate and meaningful Thalassia biomass values.

The blade density and blade growth data would be especially effective for sinple estimation of production in many areas having widely different grass coverage. The work of Thorhaug and Stearns (unpublished manuscript) indicates very similar growth per blade over a wide range of blade densities in Card Sound and good agreement between increase in blade area and increase in blade weight.

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PHYSICAL OCEANOGRAPHIC

METHODS

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CURRENT STUDIES

by

E. D. woop

1, Meters - Hydro products Model 503

Calibrated in a swimming pool, the neters were

Suspended by floats and towed?the length of the pool at constant speed. Tows up and down the Length of the pool were averaged for velocity calculations. The pools circulating punps were off for several hours before and during calibra tion. Calibration was done at velocities of: +2, 15, and .8kt. The velocities shown by the

ters'were a11 lower than measured and the corr: tion factors determined were

Meter # Factor

S

2

9

?The meters are checked periodically in the elec- tronics shop; and adjustments to the read-out circuitry made as required.

Current meter placenent.

The current meters have been installed by two different methods.

(4) Individually anchored meter installation is Sed where the meters are to be in different locations. The moter is attached to a weight (lead or cement) by a line measured to give the desired depth for the sensors, A Danforth anchor is attached to the weight by a 3m section of chain. The meter is suspended by a float which displaces about 20 liters. The float depth is adjusted so that it is about one meter below the surface. This puts the system out of sight of those who may molest, the equipment and deep enough so that it will not interfere with small craft operation. The meters are located by triangulation sites on shore or occassionally marked with a small bouy anchored separately.

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(ii) Group anchored meters are suspended from a path

(ii)

fatform, either a raft, bouy, or ship. Surface meters are tethered and Suspended by floats and actually measure currents at_a depth of about 0.5 m rather than Om. The other meters are suspended from the platform fn such a fashion as not to interfere with one another. Usual depths for our measurements have been 0 (018), 2, 4, 6 m measured from the sea surface to?a point mid-way between the Savonius rotor and the direction vane of the meter.

The platform is usually secured with two anchors to reduce swinging caused by current meandering. Most measurements are for at

Teast 24 hours to take into account tidal and wind effects. The current neters are periodic-

ally checked by dives to insure that they are functioning properly.

« Interpretation of the data.

The-corvent data is recorded by a Rustrak recorder on pressure sensitive paper tape. The settings are such that the paper moves approximately 2.5 cm hr-l. The exact rate iS determined on individual recordings from the "in" and ?out? times marked on the tapes. The data are transcribed onto graph paper manually with meter error correcting and some smoothing.

?The velocities and directions for each meter are averaged over convenient time periods and correlated usually with tide and wind data.

When calculating the flow through a channel, the cross-section is determined either from the charts or by direct measurement. The

cross-section is then divided into appropriate
Sub-sections to correspond to the meter, ¢.8.,
if current meter depths are 0, 2, 4, & 6m
then the depths of the sections are?O-1, 1-3,
5-5, and S-bottom (in meters). From this
information, flow can be determined by summing
average vector velocity through the sub-section
on a daily basis or on an hourly basis. Thus
net flow can be determined as well as total
flow in each direction. The data is usually
reported as the average flow rate

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Drogue studies.

Brogues have been used to determine flow over @
distance. The drogues were made of crossed sheets
of plywood in some cases and parachutes in others.
The main part of the drogue was placed at varying
depths. A pole was mounted on the float of the
drogue and equiped with a radar reflector for track-
ing. The drogues were tested both with and without

structures above the water to determine the effect of wind drag. It was found to be on the order of 20% for a 12 mph wind and all drogue velocities Were corrected accordingly.

Dye Studies

Pe Spot Feieases of rhodamine-B dye are used to

letermine rates of flow over a distance and degree of mixing. The dye is dissolved in acetic acid and mixed with fresh water in the ratio of about 75 g/l. The resultant mixture is nearly the same density as sea water. A study usually entails 8-12 releases of 10 liters each either from a small boat or dropped from an airplane. The dye spots are then photographed over a period of several hours to deliniate the surface current patterns of a particular region. Releases are Tepeated for various sets of conditions. Since the photography is limited to daylight hours,

a release is made early in the day to measure the effects of low wind velocity usually experienced during the night. Late afternoon releases then give results for windy conditions. This usually takes the tides into account as Puerto

Rico has essentially one tide a day.

Photography is often compticated by poor Light, low clouds, or lack of landmarks. These problems have been partially solved by using high speed film, taking angle shots normal to the shore-line?and placing float markers for reference points.

Dye studies are correlated with current meter measurements when practical.

Continuous Dye Releases.

Soluble rhodomine-B was released into the study region from an anchored raft at the rate of

7 kg/day for a three day period. The continuous dye release allowed visual and instrumental tracking of the surface currents of @ period of

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(3d) time. The dye plume was photographed from the air at three different tines a day. Transects fo the dye plune were made to map the extent surface spreading of the plume. Equipment was loaded in a 17" boat equipped with a portable generator. The concentration of dye in the Pluae was measured with a flourometer equipped with a "flow-thru" cell, The water was pumped through a tube 3 in. long at a fast rate. The cell was fed through by-pass which gave nearly an instantaneous response to the water near the boat. The depth of the intake could be adjusted

ron surface to 3m,

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COLLHCTION AND PREPARATIVE METHODS

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COLLECTING METHODS FOR FISHES

F. D, MARTIN

shes are collected for our studies by a nunber of nethods including, gill nets, seines, cast nets, dip nets, hand Tines, £2h toxins, Spear guns and traps. The methods most congoiay usedvare gill nets, selnes! ang, fish triage? tach Bethod has its special uses and limitations and outlines of these three methods will be given here.

Gill nets are nets which depend on fish trying to force their way through the mesh of the net and becoming entangled therein by their gill coverings and/or fins. The nets ve use are constructed of monofilament nylon which is virtually invisible in water. A lead line is used to hold the bottom down and a float line holds the net vertical, Normally we wish the net to remain stationary so that it does not tangle up or become lost while left in place. To accomplish this,

5 pound lead weights are attached to the lead lines at each end of the net. If currents in the area are strong, additional weights are attached as needed. Marker buoys

are attached to the float lines at both ends of the

net by enough heavy cord (200 1b. test minimum) so that

the buoy floats with some slack in the line. Since the nets we have are rigged to be set on the bottom, in the event that floating nets are desired, ompty plastic jugs (1/2 gallon or larger) are attached every 8-10 meters along the float line as the net is played out.

When setting nets near shorelines, we normally set the net perpendicular to the shoreline because, on the average, fish Rove more often parallel to the shoreline than to or from it, Occasionally it is desirable to attach the net to an object on shore. In this event, attach only the float line

go that the lead line can have énough slack to renain on the ottom.

The gill nets we use are normally stored in plastic garbage cans and when being set are fed directly from these over the side of the boat, In order to facilitate this, the net is usually fed over the bow or one of the sides well away from the motor and any cleats or other potential snags As it is fed out, any tangles or kinks in the lines are

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straightened out as these are potential tearing or breaking points when pressure is put on the net to pull it in.

Normally the net is set in a straight line and with enough slack to keep the net from being pulled tight. Tight nets do not entangle fish as effectively as loose nets.

If wind direction allows it is generally easiest to feed the net out at about the speed the wind drifts the boat and

to have the motor off, (Remember: gill nets do bad things

to outboard motors when wrapped around a prop and vice versa). Otherwise one or two people play the net out while another backs the boat in the direction the gill net should run and at a very slow speed.

The net is then left for a period of time (never less than 30 minutes) and is then pulled back in starting from the down wind end or the end away from shore. All attachments are removed as the net is pulled over the side and the net is fed directly back into its garbage can. Fish are renoved as they are pulled over the side and are placed in properly labled containers. Techniques of removal depend on the fish, the mesh size of the net and degree of entanglement. Experience is the only effective teacher in this area.

Gill nets are seldom left more than 2-4 hours because: 1.) of the danger of it drifting and becoming fouled on coral heads or other snags; 2.) crabs congregate and dine on the trapped fish thus eliminating much of your catch; and 3.) untended nets are temptations to persons who chance upon them.

Nets are rinsed with fresh water as soon as possible upon return to PRNC and then dried with as little exposure to digect supLighe as possible. Sun tight Breaks down nylon and must be avoided as much as possible.

Gill nets are ineffective in catching eels of any kind and seldom catch territorial fish as they do not normally mo enough to take them in the area of the net. They are quite selective in size, as fish below a certain size go through the mesh and do not become entangled.

Another method of fish capture is the seine. This is a flat net which is pulled through the water (some are not flat but have bags in the center, but these are not used here), Te 48 equipped with a lead?line to keep the bottom down, a

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float line to keep the top on the surface and poles at each end to make pulling both lines at the same time possible. The net is pulled by two or more people through the water and then either pulled up on the beach or lifted by getting the lead line well in advance of the float line and picking it up so that the fish are picked up on the surface of the net. The most common reasons for ineffectiveness ar

1.) failure to keep the lead line on the bottom; 2.) snagging the net so that progress stops while the net is undone

3.) allowing the net to roll up while being pulled through grassy areas and, 4.) persons walking in front of the net and frightening the fish away before the net gets there.

Seines are ineffective in collecting: 1.) fish which are strong swimmers and can move faster than the seine; 2.) fish which bury in the bottom or hide among snags when

jumping fish which can go over the net and
can force their way through the mesh (e.g.
's and needlefish)

The other common method used in collecting fish is fish toxins. The toxin we use is Pro-Noxfisi® which is a solution of rotenone in xylene with emulsifiers and synergists. The toxic effect is upon the gills of the fish so that they come to the surface for oxygen where they can be dipped up with long handled dip nets. When we do a poison station we are interested in establishing the biomass of fish for a given surface area. For this reason we fence off an area

th a fine meshed net before introducing the toxin. If the Station is to be near a convenient shore, we use the shore as one side of the fenced in area. We use a 100 foot net as the fence and if the station is using a shore as one Side, two poles are driven into the bottom 33 feet from the shore and 33 feet apart and the net is pulled around then to make a 33" by 33' square. Otherwise four poles are driven into the bottom so as to make a 25' x 25" square and the net is pulled around then. Also before introducing the poison, the lead line of the net is checked to make sure it is snug against the bottom, About 300 ml of the toxin are poured into a 2 gallon bucket containing 1 1/2 gallons of sea water.

This is introduced into the enclosure in the following manner. About 1/2 is put in on the upcurrent side so that it will wash through the whole enclosure and the rest is spread over the surface of the enclosure as evenly as is feasable, Then the poison is mixed by swimming or wading through the area! (Note: If you get any of the concentrated poison on your skin, rinse it off immediately; if you contact some of the diluted toxin while swimming in the area, it will not do any

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permanent damage but may irritate your eyes or produce hausea if ingested), Within 5-10 minutes, fish should Start surfacing and should be dipped up immediately as they will not stay on the surface once they die. If no fish Come up within 10 minutes, a second treatment using 500 - 700 ml of concentrate is applied in the same manner as the first dose. In any case, when action slacks off (after 30-45 minutes) another dose similar to the first effective dose should be applied.

For obvious reasons fish from the enclosure must be kept separate from any fish captured outside the enclosure. Fish Seen to enter the enclosure from the outside are to be Counted as off station fish and the reverse situation will be Counted as on station fish. If you are not sure where it cane from, it is an off station fish.

Collecting is terminated when fish are no longer coming up regularly and periods of 4 or S$ minutes occur between catches. The procedure at this point is to pull up all corner poles and to purse the fencing net by pulling lead Lines together so that the enclosure has a bottom of net. This is done by dragging the net along the bottom - the iead Line should never be lifted from the bottom. The easiest

way to do this is by pulling the net slowly onto the shore or into the boat by the lead line, The fishes which died and did not come to the surface will be picked up in this way.

Poison stations are less selective than most but, certain Species are not taken by this method. Strong winners Hequentiy eave the area during the setting up process and for'this feason the set up should be accomplished as quick) and with as Little wading? and splashing as possible and wid So wading in the area to'be enclosed until after the fencing Bperation ig complete. Many anali fishes which Live in crevices ani anong the plants die in place and are not seen. The other group not. taken by toxins are the sharks and rays. They are net sensitive to this toxin and on occassion sharks cone, Into the general. area to feed on the incapacitated fish. Sarthe event that. this happens (and ehis partically never happens) get out of the waver with all due haste but with as Tittie spfasning a5 possible.

?The other methods of collecting are methods widely known and I will not discuss them here,

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?The one remaining point of discussion is the criteria for deciding on sanpling areas. First priority is placed on establishing base lines for areas which should be directly effected by whatever 1s to happen in the areas. In the case of Jobos this is the intake area, the outfall area and the areas down current from the outfall which could receive effects directly from the thermal plume or which might be exposed to chemical effluents. A? few areas which should receive no effects are sampled Fegularly as control stations.

Within each major area under consideration, subareas are established based on habitat type (mangrove root areas,

turtle grass beds, open bottom areas, etc.) and each area is sampled by means appropriate for the habitat and ai intervals so that seasonal variations can be established.

Normally the general area and the habitat types to be Sampled are predetermined, but the suitability of a specific site for sampling on any given day is determined by the Sampling technique to be used and conditions of tide, wind, etc. Seine stations cannot be deeper than 1 to 1 1/3 meters and must be relatively free of snags. Poison stations cannot be deeper than about 2 1/2 meters if they are to be quantitative and if they are deeper than about, 1 meter, the visibility should be such that the bottom can be seen easily, Fast currents or heavy wave action limit the effectiveness of poison stations. Beyond this, there are no simple guidelines and experience is the only teacher.

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THE THALASSIA BEDS

Sampling Wethods:

The sampling bionass of plants and benthic invertebrates was done with a special fore sampler that was designed by ME Peter Schroeder. This sampler consists of a stainless steel pipe (16,1. mn @ with a-crank. (Figure 1 in the Section on Thalassia bede in Guayanilla Bay). It samples an area of 20S-ent-~ The upper end of the pipe is covered Sich's ?sereen of 0.8 mm mesh to prevent free moving, Sninals from escaping. A rubber flap seals. the upper end and prevents the core from dropping off when the sampler is alfted from the bottom. This sampler has proved £0 be very fast and quantitative both for the plants and the Invertebrates. Two cores were sampled at six stations at adepth between 0.5 to 1 meter.

Plants and animals were separated from sediments in a standard set of geological sieves. Thalassia was Separated to six different parts: old Teaves, new 1 sheathing, rhizomes, vertical shoots and roots (see Tomlinson?and Vargo, 1966), Thalassia leaves were weighed after cleaning off all the sediments and filamentous algae. No effort was made to remove attached microorganisms from eld leaves. These microorganisms include: diatoms, filamentous algae, foraminiferans and small polychaetes dvelling in calcareous tubes. Their bionass is only a fraction of one percent of the biomass of Thalassia and usually proportional to the biomass of old Ieaves. The

wet weight of plants and invertebrates and the number of specimens of different invertebrates were recorded. Dry weight was measured only for the biomass of plants.

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THALASSIA SAMPLER

0203 METER?

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CORAL REEFS

erials and Methods

Sampling methods were geared to collect descriptive and quantitative data. Three methods were used, all involving the use of scuba diving:

Transects: A nylon line marked at 1 m intervals was used to make transects extending from as Close to the reef flat as safe swimming allowed, tothe beginning of the reef fore-siope. The transect usually covered a distance of 7S to 125 meters. Data from the first few transects were Fecorded on plexiglass plates, on which all corals and major cover ofganisns (such as sponges and gorgonians) along each meter interval were noted And recorded. Later transects were Tecorded Photographically, but only every third meter was Photographed. |The transect data vas used to jescribe the reef zonation and structure and to determine species dominance anong the main cover organisns.

Measured Quadrats: Two meter by two meter areas were marked off with heavy stakes and nylon lines

or with a metal rod frane. The plots were then divided into 1/4 n? grids, The areas covered by each species of coral and other important organisns were recorded on a plexiglass plate or on film. The resulting diagrans or photographs Were used to calculate percentages of bottom coverage, and dominance and species diversity among thé major encrusting organisms.

Collected Quadrats: 1/4 n? areas of the above quadrats were collected in their entirety. Crow-Bars and knives were used to remove sections of the reef rock which contained encrusting and boring organisms. The samples were immediately placed into large plastic bags, held next to the collecting site by a second diver, in order to

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ensure that none of the small free-living organisms such as crabs and brittle stars could escape. The Samples were stored in plastic buckets and refrig~ erated on their way back to the laboratory where they were sorted into phylogenetic groups, weighed and preserved for later identification. Corals were weighed and their surface area estimated. Pieces of pre-weighed and measured coral were dried at 110°C., reweighed, subjected to Clorox digestion, dried and'weighed again to estimate the amount of living animal and plant material present. The pieces of coral rubble which remained after most

of the encrusting and boring organisms had been renoved were similarly treated to estimate the anount of non-removable material (some bryozoans, boring sponges, calcareous algae, and boring worms) still remaining. A factor was calculated from this and used to calculate the amount of organics in the total rubble sample. This total is listed in the biomass estimates as "miscellaneous."

In the case of station 10, three clumps of material were collected and labeled samples 10A, 108 and

10C. The narrowness and relief of the reef there made it very difficult to collect quadrat samples. for this reason, no transect data was collected for this area.

Total biomass estimates were derived by tracing the area covered by coral reefs from a standard WOSS map, cutting out and weighing the tracings and multiplying the estimated area by the average of the bionass estimates computed from the collected quadrats data.

Only the corals, gorgonians, mollusks, crustaceans and echinoderms ?were classified to genus and

species level. The classification of the sponges, annelids (present in very large numbers), sipunculids and other worm-like organisms was not attempted. I wish to acknowledge and thank Mr. Carlos Carrera, Department of Marine Sciences, thiversity of

Puerto Rico for his help in classifying the brittle stars.

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PREPARATION OP CUBITAINERS

Jaw #1 Label everything with date and station number.

1.

2

3.

4

Rinse with tap water.

Kings with 4 N Nitric acid.

Ringe with distilled water.

Put on cap and put @ piece of masking tape labeled

"Prep." on the oubiteiner eo it won't be confused

with dirty ones,

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COLLMOTION OF Sua Wa!

On station rinse the cubiteiner with @ little of the

sea water you will be sampling.

F221 cubs teint

to avoid paint

current from the boat and motor

Bas, and oil.

Add 10 ml (cc) of concentrated HCL (hydrochloric acid).

Filter within 8 houre to get rid of bacteria and alges

If this can't be done add 1 ml chloroform and keep cool,

or freeze the whole thing. Save filter in plastic bag.

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METHODS MANGROVE ROOTS

Sampling. and

?The mangrove root communities in Jobos Bay show enormous

variations in the species composition and biomass. The

reasons for this are by in large unknown, but it seens

like, salinity, temperature, food availability, wave

action, depth and pollution? are important factors controlling

?the mangrove root communities in Puerto Rico.

Eight sampling stations were selected to represent different types of mangrove root communities around the proposed intake and discharge areas of the cooling water for the power plants. Station #1 was north of Cayo Puerca at the end of a cove that has received effluents from the settling ponds of Central Aguirre (Figure 7), This area used to be badly polluted with dissolved organic compounds that utilized all oxygen fron water. Part of the mangroves in this area were killed by the poliution and all of th showed signs of stress which could be seen from an unusually large number of aerial roots, Since spring 1972, this area has not been receiving waste from the sugar mill. Even months after the dumping of sugar mill effluents were stopped this area was anoxic on the bottom and producing HS and was well saturated with oxygen and currents were méderate. Sediments at this station were silt and fine sand, Water was shallow, between 0.3 and 0.5 meters. Temperatures up to 31 c were observed on the surface in the summer.

Station #7 was on the south side of Aguirre Navigational Channel at Cayos de Barca, This station was exposed to the wave action and the swells in the Navigational Channel. Water was well saturated with oxygen and clear. Sunmer temperatures up to 31 c were measured on the surface. Currents were noderate and flowing to the west. Water was shallow between 0.2 and 0.5 meters deep. Sedinents were

Station #3 was located on the east shore of Punta Colchionas inthe Midbay. This station was exposed to the wave action and swells, but it was somewhat protected by a wide shallow turtle grass bed in front of it. Water at this station

was light brown, well oxygenized. There was a weak southerly

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current passing by the station. At times of strong winds water was silty. Water temperatures rose up to 31-S-c in summer. Water at this station was 0.7 meters deep and the sediments mud.

Samples were collected twice. The first time in September, 1971 and the second time in July - August, 1972, The first collecting involved cutting a 30 cm section of ten roots

from the Roan sea level down- The species, genera or phyla Mere identified and the biomass of each of then measured. The results are given in the Aguirre Nuclear Plant Annuai Report 1971 pp. 34-43. This study uncovered so many interesting aspects of the mangrove root communities that @ more thorough investigation was undertaken.

In the second sampling whole mangrove roots were collected by cutting then at the mean high water level, which coincides with the uppermost sessile organisms on the roots. The roots were carefully surrounded with a 0.5 mm mesh net before lifting up. This way all the free swimming crusta-ceans and fish were also recovered. Three to six randomly chosen roots were collected at each station.

The roots were placed into large poyethylene bags and transported into the laboratory in an ice chest. In the laboratory the roots were cut to 10 cm sections from the upper tide level down. The organisms in each section were separated, identified and the wet weight of each species

was recorded. Because of the vertical zonation of organisms

the biomass is given per root instead of per unit length

of root.

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PREPARATION OF SAMPLES

FOR ANALYSIS

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PREPARATION OF BIOLOGICAL SAMPLES FOR AAS

Grind the dried sample to a fine powder.

Neigh out about 2 g sample in 125 ml erlennayer.

Add drop hy drop about 25 ml of aqui

regia.

Place on the hot plate, digest about 20 minutes at very

low heat.

Bring to near dryness.

Dissolve with double distilled water (DDK).

Filter through pre-washed glass filters.

Dilute with MDW to SO ml, Put in screw cap plastic

bottles.

Pipette out three 17 ml aliquats into small plastic

bottles.

Add proper standards of different concentrations of

each element to cach one. (Standard addition technique)

Run at AAS,

Sy plotting each sample on the graph, find out concen-

trations of the samples.

Report the result

milligram per gran,

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BIOLOGICAL SAMPLE COLLECTION AND PREPARATION FOR

?TRACE ELEMENT, NUTRIENT AND CHIN ANALYSIS

Five or_six organisms were collected at each sampling sta-

tion. The species to be collected were selected: (1) to

Fepresent the various trophic levels (primary producers,

herbivores and carnivores) and (2) because they made up 'a

major part of the biomass.

collected from three habitats: the coral reef,

sia beds, and the mangrove root communities.

Inmediately after Collecting, the samples were placed on ice until they could be frozen back in the laboratory. The following collecting procedure was used:

A. Coral Reef Samples:

Divers, using SCUBA equipment and, where possible, wearing plastic gloves, collected? the chosen organisms and placed then in clean, unused plastic bags. Encrusting organisms were collected by hand, when possible, but more usually with the aid of a stainless Eteel knife or spatula. Care was taken to pour out all the sea water from the sample bags before the bags jere closed and stored on ice.

B. ?Thalassia Bed Samples:

Organisms from this habitat were also collected and cleaned underwater. Cleaning involved removing sediment and extraneous encrusting material from the sample organisms. Once collected, samples were treated as

C. Mangrove Root Community Samples:

Organisms growing on the mangrove roots were collected

by hand or with the aid of a stainless steel knife in
the case of the oysters, Sediment accumulated in the
algae was washed out before the sample was collected.
?The mangrove and tree oyster were not cleaned of
epiphytes since only the meat is used in the analysis.
As before, sample bags were closed and stored on ice.

It was found that the chosen organisms were not equally
present at all the sample stations. Substitutions were

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made where necessary, but enphasis was placed on trying to
collect the sane organisms at all stations of the same
habitat type.

The Sample Preparation Procedure Is The Following:

The samples were defrosted, placed into acid-cleaned beakers, and weighed together with any fluids which may have been in the sample bag. Since all the sea water had heen removed from the bags soon after collection, all fluids in the bags, after defrosting, were considered vital fluids which had been lost by the organisms during the freezing-thawing process. The heakers were then covered and dried to constant weight at 110° C. The dried samples were ground to a fine powder with a porcelain mortar and pestle and reweiphed. Two grans subsamples were dissolved for trace element analysis and one gram Subsamples were used for CIN and nutrient analysis:

Mollusks were renoved from their shells before obtaining the wet weight. Sea urchins were ground shell and all. Coral samples wore not ground, but the coral tissues were dissolved off the skeleton vith a strong base instead of an acid.

Care was taken during all steps of the sample collection and preparation to try to avoid contamination from glass~ ware, metal utensils, and human hands.

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TREATMENT OF WATLP AND BIOLOGICAL SAMPLES FOR TRACE ELEMENT AND NUTRIENT ANALYSIS

Water:

Water samples should be filtered with 0.45 m filters as Soon as possible after the collecting. After the filtering the samples should be acidified with concentrated lICl, 1 ml per liter of water.

For phosphate, nitrate and nitrite analysis 4 L of water is needed. Trace element analysis required 10 L.

Soluble orthophosphates are collected from 2 L of water by an anion exchange column and total soluble phosphates from 1'L of water, also with an anion exchange colunn, after all Phosphates have been oxidized with a potassium persulfate digestion, The analysis of phosphates is carried out with an Autotechnicon autoanalyzer. Nitrate and nitrite are

also run by the autoanalyzer.

Eight liters of water are scavenged with Fe(0ll)s to pre-concentrate Nn, Mg, Co, Cu, Ni, Pb, Zn, Cd, Cr, Ca, and Sr for analysis by atomic absorption spectroscopy.

Biologi ples

After the collecting all specimens are cleaned of silt and dirt, specimens of the same species put into a plastic bag, labeled, and frozen. In the laboratory the specimens are dissected, weighed, and dried at 105° C.. Part of the frozen sample 1s saved for pesticide and lig analysis.

Dried samples are cooled in a dessicator, weighed, and ground. Dried samples are analyzed for Carbon, hydrogen,

and nitrogen content with a gas chronatograpl

For phosphate and trace element analysis 2 g of dried sample are digested by aqua regia wet digestiong method.

Phosphates are analyzed with the autoanalyzer and trace elements (Fe, Mn, Mg, Co, Cu, Pb, Ni, 2n, Cd, Cr, Ca, and Sr) are analyzed with atomic? absorption spectrophotmetry

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LABORATORY METHODS

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CLEANING GLASSWARE

Rinse out all biological or chemical matter with tap

water.

Wash using cleaner provided.

Rinse in tap water.

If biological material adheres to glassware, soak in

NaOH solution. Rinse.

Rinse glassware with 6N. HCl.

Rinse two times with distilled water.

Dry glassware in low - heat oven.

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LAB PREPARATION OF WATER SAMPLES

If the water has not been pre-filtered, do so. Save

for counting.

Ferric Hydroxide Precipitation:

a, Lower the pli of the sea water to 2.0.

b, Add 10 mi of Ferric Chloride and mix well.

?. Add slowly, 6N NH,0H to raise the pH to 9.0.

4, Add 10 mi of separan after § minutes of precipitation.

e. Allow sample to sit for 24 hours.

£. Filter the water.

Put the precipitate in 250 mi plastic bottles.

Centrifuge

i. Put the precipitate in 150 ml beakers and boil

until nearly dry.

Put pre-cut filters into 1N HCI and leave for
20 minutes. Wash filters with distilled water
and let sit for 15 minutes.

Filter what is left of precipitate and put into
25 ml plastic bottles for Atomic Absorption.

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NAA for TRACE METALS IN SUSPENDED
PARTICLES IN SEA WATER

Cut to pieces a known weight of the filter and place the
pieces in a 25 ml beaker,

Add $ m1 conc. HyS04 and approximately 3 drops HNO,
cover beaker loosely.

Heat slowly to a boil. Evaporate to dryness

Wash beaker out 3 times with 3 ml aliquots of distilled

Water. Place washings in a 10 ml polyethylene vial,

Place?in a vacuum desicator and evaporate to dryness.

Heat-seal vials under vacuum.

Irradiate for 5 minutes and allow 3 minutes for decay.

Count 400 seconds line-tine (Al, S, Ca, Ti, V, Cu) then

Count 1000 seconds line-tine starting {5 minutes after

(Na, Mg, Cl, Mn, Br, In, I)

?The same sample, or another portion of the sane air

filter, processed as above, should be then irradiated

for 2-3 hours in the reactor core as was suggested in

Air Tape Analysis (please see Annual Report 1972)~

a.) Allow to cool 20-30 hours and count 2000 sec.

b.) Allow to cool 20-30 days and count 4000 seconds.

Run blanks using "clean" filters and standard reagents.

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DETERMINATION OF REACTIVE PHOSPHORUS

Introduction:

All methods for phosphate in sea water rely on the formation of a phosphonolybdate complex and its subsequent reduction to highly colored blue compounds. Methods using stannous chloride as a reductant at room temperature have been favoured as they are most sensitive and give less interference from easily hydrolysable organic compounds than

do other techniques. There are complexities in these Rethods due to interference fron arsenic and to concealed blanks arising from the reduction of molybdate in sea water in the absence of phosphate. An excellent program of Comparative tests has been described by Jones and Spenser (J. Marine Biol. Assoc. U.K., 43:251, 1963).

The procedure given below is taken from the recent publication of Murphy and Riley (Anal. Chim. Acta, 27:31, 1962) and is so superior to other methods in terms of the Tapidity and ease of analysis that it probably represents

the ultimate in sea-going techniques.

Method:

A. Capabilities

Range:0.03-5 ug-at/liter

1, Precision at the 3 uG-AT/LITER LEVEL

The correct value lies in the range:

-03/nl/2yug-at/liter.

Mean of n determinations +

2. Precision at the 0.3 uG-AT/LITER LEVEL

The correct value lies in the range:

Mean of n determinations +0.02/n!/2ug-at/liter.

3. Limit of Detection

The smallest amount of phosphate that can be

detected with certainty is about 0.03 ug-at P/liter.

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Reject duplicate determinations if extinction values differ by more than 0.02 in the extinction Fange 0.5-1.0 or more than 0,01 in the extinction range 0.1-0.5,

If the duplicate extinction values differ by less than the above limits, take a mean value.

Outline of Method

The seawater sample is allowed to react with a composite reagent containing molybdic acid, ascorbic acid, and trivalent antimony. The resulting complex heteropoly acid is reduced in situ to give a blue solutign the extinction oF Which is measured at 8850 A-

Special Apparatus and Equipment

130-1 capacity screw-capped polyethylene bottles
marked on the side at 100ml (+2 ml) with a band
of black tape

Neutron Activation Techniques:

Handling of the samples was done in a clean room equipped
with @ laminar-flow clean hood. Approximately 1g of the
Gried material as sealed in either quartz ampules or in
medical grade polyethylene tubing. (A number (10-20) of
Samples With appropriate standards were packaged poly:
ethylene container and irradiated in a TRIGA. TIT reactor.
An integrated flux of about 1018 n.cn"? was received by
each package of samples. The sampics were cooled for 4
Period of 2-4 weeks before counting.

A portion of each irradiated sample was placed in a tared
Snap-top capsule, the weight determined and then couneed? on
4 31 Ge (Li) detector.? The analyzer was calibrated using
Fadioactive standards. Three absorber's Cas Clana bet
each about 1 an in thickness, were placed bétwees the
Sample and the detector to reduce the low enereyCerpton

and Bremstralien. The ganna-ray spectrum of e&ch seepie was analyzed and the ?concentrations calculated by a computes.

Standards of Ni-Co wire were placed in each package of samples tg,monitor the flux. ?The fast flux was eeiculated fron the 28Ni (n,p) ¢8co reaction and the thermal flux

from the 59Co (n,y) 60co reaction. Inorganic standards were

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included: Fe-2n, Co-Cs and Hg packaged both dried on Plastic tape and?as liquid in quartz vials.

The blanks run were of the plastic tape on which inorganic standards were irradiated,

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PLANKTON: METHODS AND MATERIALS

Methods and Materials

Plankton samples were obtained in several ways, The majority were taken using plankton nets of mesh sizes 380u, 300u, 202u, and 60u, pulled behind 13 to 17 feet dories for?s to 30 minutes. For uniformity, the nets were pulled at speeds to keep them 1 to 3 feet below the water Surface. The samples were then preserved in #4 buffered formalin and taken back to the laboratory for analysis.

A small flowmeter was suspended in the mouth of each 380y mesh net, volunes of water sanpled estimated for the remaining nets used.

For counting organisms, aliquots of each sample were removed from a well-shaken container by means of Scc, 10cc, oF 20cc spoons and diluted into a squared Petri dish?or a counting tray. All zooplankton in the sub-samples were counted under? 10 to 30 power magnification. Phytoplankton and zooplankton were identified using 30 to 400 power magnification.

A few plankton samples wore obtained using a 2-quart bucket to pour surface water through a 60 net sieve (primarily for phytoplankton and microzooplankton). One sample, JB-25, was taken utilizing a hand held concentrator over the side of a boat as it journeyed through a shallow canal between heavily mangroved cays

Biomass estimates were obtained in the following manner. Zooplankton was sampled using 2 202u mesh net, animals

(and incidental trash, phyto- and mannoplankton) transferred to bottles that were placed, without preservative, into an ice chest. Wet weights were determined as, explained in the following. Phytoplankton and manno-Plankton were sampled by using 2-quart buckets to fill

45 gallon cubitainer. This was then first filtered through 2 60u mesh sieve, with frequent washing off of captured iaterial to eliminate clogging, to separate phytoplankton and then filtered through 0.45) membrane filters to separate mannoplankton. All samples were finally filtered through membrane filters that had been HCL treated. Initially the filters were wet with fresh water, a Slight vacuum placed

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on them, then the sample poured through. Ten filters were weighed? wet (following 15 seconds of vacuum) and their average used as the weight of a standard filter. The filtered samples were subjugated to an additional 20 seconds of vacuum following apparent dryness, then were weighed on a Mettler balance accurate to 0.01 gram.

Future studies of zooplankton in Jobos Bay will emphasize seasonal and areal variability in the total standing stock and the more numerous species. Triplicate tows will be made at several stations with two 1/2 meter plankton nets (65u and 200y mesh size) to provide reliable estimates of the zooplankton community.

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PROCEDURE FOR COLLECTION OF PLANKTON AND PREPARATION
(OF PLANKTON FOR NEUTRON ACTIVATION
ANALYSIS AND ATOMIC ABSORPTION

1.) Sample should be collected off the front or sides of

the boat to avoid contamination from boat oil and gasoline.

2.) Avoid smoking, eating or coughing close to plankton sample.

3.) Collected plankton should be put into a large plastic container. Then add 2'L. fresh sea water (Take {Fesh?? Sea water from the front or sides of boat).

4.) Filter plankton through a funnel fixed with same mesh size filter as tow, using low vacuum suction. (To avoid breaking cells of plankton).

5.) After filtering, put plankton sample into small piastic bags and heat Seal? to avoid contamination.

Put plastic bag filled with plankton sample in plastic Jars. Opening of jars should be the same size as the rest of the container.

7.) Freeze sample inmediately.

4g

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NITRATE AND NITRITE IN SEA WATER

The procedure used for the analysis of nitrate plus nitrite in sea water is described in Industrial Method 43-69W, Technicon Instruments Corporation, Tarrytown, New York 10591. Millipore filtered aged sea water, in place of synthetic sea water, was used in the preparation of

standard

were not

Complete

is to be

supplied

solutions and as a systen wash. Air scrubbers

used in the color reagent line.

instructions for the operation of the Auto Analyzer

found in the General Operating Instruction manual

with the instrument.

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THERMAL NEUTRON ACTIVATION ANALYSIS

OF AIRBORNE PARTICULATE MATTER

IN THE SOUTH COASTAL AREA

(OF PUERTO RICO

By

Tin Mo

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INTRODUCTION

In the past several years there hac been mounting awaren and concern over the addition into our atmosphere and water bodies of waste byproducts by modern industry which might be injurious to the public's health. The presence of ?smoke?, sulfates, and fallout in air is being routinely monitored by the U.S, Public Health Service, pollution control agencies of large cities, and many other ecientific ?teams. The practice of burning coal, oil, and refuse, in addition to their combustion product: continually injecting many trace elements into the atmosphe:

At present, on the island of Puerto Rico, no large-scale program is?conducted which is directed toward the detection of trace metals, even though air filter tapes are collected and are available for detection. Data and information on ?the levelo or concentrations of these pollutante in the air are necessary before they can be judged ae hazardou:

In addition to this, a knowledge of these data, and the variation of the clemental distributions as a function of Location and time is of importance in understanding the ?transport mechanisms for geochemical studies and for solv-ing general problens of air pollution and pollution control. Correlations with public health problems can give an idea of the magnitude of potential problems.

?The concentration of trace elenerts in air can be meaoured by many techniques. Thermal neutron activation ansiysie Sb relatively simple and is also nondestructive, if ene study ie limited to ganmn-ray eaitting nuclides and with ?the application of high resolution gasma-ray spectroscopy by meano of lithium ~ drifted germanium [Ge(Li] detectors The object of this study is to the conditions and procedures for ele

borne particulate matter by means of neutron activation anelyets ani Ge(ii) techniques (Dans et aly 1971, Dam et al, 1970, Tuttle, Vogt, Parkinson, 1971). Computer teckniques for miti-niclide gamma-ray opectrometry will be applied for data reduction (Dane et al, 1570). The Beasurenent sensitivity for many induced fuclides should Selmore than adequate when the Puerto fyco Mucgenr Center high flux Triga Pip reactor (1-3'x 10m. eares sect)

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is used in conjunction with the 40 cc Canberra [Ge(1i)] detector (of about 3.5 kev energy resolution) coupled to @ Packard 1024 channel analyzer.

Dust is usually collected on a filter by drawing air through a vacuum pump. This resulte in the filter becomirg @ part of the sample. Hence, the choice of filter material i important and'the proper filter should be free of high thermal neutron cross section elements. The commonly used asbestos and glass base filtere which have a high collec~ tion efficiency for small particles, are not suitable for thermal neutron activation analysis es they contain large amounts of Na, Cl, and other elements. In this study, a cellulose ~ base filter paper (furnished by the Environ?

mental Science Division of Bendix Corporation, Baltimore, Maryland) which exhibits a low gamma-ray background after fan exposure to thermal neutrons wil: be used.

EXPERIMENTAL PROCEDURES

pling

Air particulate samples are presently collected bi- and simultaneously at ten aifferent locations along the south coast of the island of Puerto Tico. (The locations are described in the PRNC Aguirre Power Project Environ mental Studies 1971 Annual Report and are shown in Figure 1.) These locations range from low population to high population density areas, areas which are in the immediate vicinity of industrial plante and those at varying dis- ?tances from then.

Each air pump (manufactured by Environmental Science Division of Bendix Corporation) sampled approximately 12,260 cubic meters of air through 1.27 om® area of filter paper during a period of two meeke. The exposed filter tape after removal from the pump is sealed inside a polyethylene bag. One centimeter square of the exposed tape is cut out to be irradiated each time. Each eample to be irradiated contains the dust from approximately 9,670 cubic meters of air.

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PREPARATION FOR IRRADIATION

The procedure to be followed for development of a non: destructive thermal neutron activation analysis system for routine determination of heavy metals such as Cd, Ni, V,

Se and Hg in the paper tape samples are given below.

1

Using plastic gloves and a clean glass slide (or a sharp Teflon or polyethylene knife) tear off

4 piece of paper of 1 cm¢ area corresponding to every fourth spot of dust collected on the tape. Place in a small Petri dish. Dry under an infrared lamp. Cool in a dessicator and weigh, Roll up and put inside a 1 cc polyethylene snaptop irradiation vial, Heat seal in vacuum with a Teflon coated soldering iron tip so as to minimize contamination of the sample. (A reduced line voltage for the soldering iron is to be used for a satisfactory heat seal.) This sample is ready for irradiation,

Cut off five 1 cm? pieces of clean paper tape. Dry and weigh each one as done in 1.

3. To two of them, add known amounts of standard solutions of Ni, V, Hg, Zn and Se (1.0 pL of each with a concentration of 0.1 to i.d gm/L or 0.1 to 1.0 wg/spot). Dry under the infrared lamp. To the third piece of paper tape, add Cd carrier and repeat as above. Leave the remaining two paper pieces clean. Dry these under the infrared lamp too.

Put all in a dessicator.

4, Heat seal under vacuum each sample inside a 1 cc polyethylene snaptop irradiation vessel.

IRRADIATION AND COUNTING PROCEDURES

Since some of the induced nuclides like 52V have "short" half Lives, the samples would be irradjated for a period

of 1-2 minutes in 1.5 x 1013 em-2 sec-l Flux of the PRNC Teactor's fast transfer rabbit facility. Because

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?the neutron flux from one irradiation to the next cannot .

be assumed to be constant, an accurately weighed Co or lin

standard wire will be used as a flux monitor. Th

will be taped to the side of the small polyethylene
irradiation vials before they are encapsulated inside the
outer irradiation rabbit.

?The short lived gamma-ray nuclide
about 3 minute
means of the Canberra (Ge(li)] detector couple
ard 1024 channel analyzer by Counting for 400 si
time. ?The flux monitors will be counted for 20 seconds
each. ?Then the samples will be counted again for 1000
seconde live time at 15 minutes after the end of irradiation.

will be detected in the

Later, the samples will be reirradiated for a period of

2- 4"nours and counted at decay times of one and two days

for 2000 seconde live time and then for 4000 seconds live

?time after 20 ~ 30 days of cooling to determine the contents

long = lived nuclides. or the long irradiation all

sd in @ polyethy-

4-om in diameter, and lowered into the reactor

pool. Sample cooling during irradiation will be accomplished :

by @ilowing the pool water to circulate through several

holes punched in the container bottle. The samples will be

confined to a single horizontal layer of vertically ori-

ented tubes at the bottom of the bottle and the bottle will.

be roteted 180° at half of the irradiation time to effect

normalization of flux. Fast neutron flux gradients are

usually about twice as large as thermal gradients, but the

only fast neutron reaction that wiljgbe used in,ghie study

is in the determination of nickel, "Ni (n, p) °C

?The ratio of thermal to fast neutron flux will be deter-

ned at boyy irradigtion eiteg using the reactions

He ay) Sep and 99S (ny p) 2P. Entergerences by thresh-

old reactions will be checked experimentally.

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AUTOMATED DATA REDUCTION

For the procedure of nondestructive neutron activation analysis to be practical and efficient when applied to large numbers of samples, such as in routine monitoring,

an automatic date reduction system is necessary (Dams et al 1970). An automatic instrumental data reduction system fast and accurate and many human errore are eliminate However, human judgement thould still be in the examihation of the data and in devising procedures for checking the quality of the data.

In the present study a computer program wil: be developed

to perform the following taske:

1+ qualitative determination of the presence of iso-

topes,

2. calculation of net peak arese

3. conversion of peak areas to weights of trace

elenente

subtraction of analytical blanke due to filter

materials

5. calculation of the concentrations of trace elements

in the originally sampled air

---Page Break---

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TABA.

?SCOR/UNESCO PROCEDURE FOR CHLOROPHYLLS

INTRODUCTION

?The following procedure was agreed to by a SCOR/UNESCO Working group and has been published by UNESCO in Monographs ?on Oceanographic Methodology.

METHOD:

Concentration of Sample:

Use a volume (Note a) of sea water which contains about 1 ug chlorophyll a. Filter (Note b) through a filter (Note c) covered by a layer of MgC0; (Note d).

Storage:

The filter can be stored in the dark over silica gel at 1C or less for 2 months but it is preferable to extract the damp filter immediately and make the spectrophotonetric measurement without delay.

Extraction:

Fold the filter (plankton inside) and place it in a small

(5-15 ml) glass, pestle-type honogenizer. "Add 2-3/mi 908

acetone. Grind?1 min at about $00 pa. Transfer to a

centrifuge tube and wash the pestle and homogenizer 2 or

5 times with 90% acetone so that the total volume is 5-10 ml.

Keep 10 min in the dark at room temperature. Centrifuge

(Note e) for 10 min at 4000-8000 g (Note £). Carefully,

Rour into a graduated tube so the precipitate is not

disturbed and if necessary dilute (Note g) to a convenient

volume (Note h).

For Thi

sia Leaves

A weighed quantity of fresh Thalassia leaves ground in

ceramic mortar and pestle with some quantity of distilled water. Wash motor and pestile with acetone so final solution 80% acetone. Keep 10 min in dark at room temperature than centrifuge for 10 min. Pour off supernate and ead absorption or Beckman DU spectrophotoneter.. Re-extract precipitate with acetone to determine efficiency

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of first extraction. Maximum absorption for chlorophyll a in acetone reported at 663 nanometers. Chlorophyll b absorption maximum around 640 nanometers.

Measurement:

Use a spectrophotometer with a band-width of 30 A or less,

and cells with a light path of 4-10 cm (Note i). Read

the extinction (opticg] density, absorbance) at 7500 (Note j), 6630, 6450, and 6300 A against a 90% acetone blank.

Calculation

Subtract the extinctjon at 7500 from the extinctions at 6630, 6450 and 6300 A. Divide the answors by the light path? of the celig in ogeinecers,/ TE these corrected extinctions are Fes ?and Egzo9 the concentrations ct ehiorophylis. 189882 96?5Scetone $50eact as ugsal ate given by, ime SCOR/UNESCO equations (refer te section IV.3.1). ff the values are multiplied by the volune of extract in milliliters and divided by the volume of the seawater in Liters) the concentration of ?the chigrephylis in the sea water is obtained a ug/liter (mg/m)

NOTES.

(a) The amount of chlorophy11 a should be less than 10 ug, otherwise a second extraction with 90% acetone might be necessary. With ocean water about 4-5 liters of sample should be used; with coastal and bay waters, sometimes one tenth of this amount is sufficient.

(6) Use no more than two thirds of full vacuum.

(c) Satisfactory filters include paper (Albet), cellulose (Cella "grob"), and cellulose ester (0.45-0.65 u pore-size);'the filter should be 30-60 mm in diameter. If these filters clog with inorganic detritus, use Schleicher § Schull 575.

(4) Add about 10 mg MgCOs/en? filter surface, either as 2 powder or'as'a Suspension in filtered sea

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(e) A swing-out centrifuge gives better separation than an angle centrifuge.

(8) If stoppered, graduated centrifuge tube is used,

the extract can be made up to volume and the Supernatant carefully poured or pipetted into the spectrophotoneter cell:

(g) If turbid, try to clear by adding a little 100% acetone of distilled water or by centrifuging

gain.

(h) This depends on the spectrophotoneter cell used,

The volume should be read to 0.1 ml.

(4) Dilute with 904 acetone if the extinction is greater

than 0.8,

(3) If the 7500 A reading is sreater than 0.005/em

Light path, reduce the turbidity as in Note g.

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TRACE METALS AND MAJOR CATIONS IX BIOLOGICAL MARINE

SAMPLES BY ATOMIC ABSORPTION SPECTROPHIOTONETRY

In the last decade trace inorganics in the marine environ-

ment haye been getting attention as much as organics such

as pesticides, etc.

Neutron activation and atomic absorption spectronetry are two common and sensitive methods in this field. We have been using a Jarrel Ash AAS and a Perkin Elmer burner.

We receive our samples in coarsely-ground form, Sometines out of necessity, due to the coarseness and resulting prolonged and possible incomplete digestion, we find it appropriate to pulverize the samples. This is preferable for All samples, but considering the length of tine involved has not been performed on all samples up to now.

Using various weights of samples (0.25 - 1.0 g), we found the 1.0 g weight to be the most suitable since Some elements are not detectable using smaller weights.

To standardize techniques and to ascertain the most suitable one, i.e. giving the highest peaks, two sets of experiments were undertaken: the first to determine the best technique for dissolving and the second to determine the length of tine for dissolving.

Table 1 shows the average readings for the various dissolving techniques. Methods using nitric acid, in general, were better thai sulfuric acid methods, Loss of the sample with sulfuric acid methods may have contributed to the low Feadings because of the splattering when hydrogen peroxide was added. Aqua regia, by way of best and second best Toadings, was concluded to be the best method for getting the greatest peaks. Consequently, aqua regia is now the preparative method used in this 14h.

In the second set of experiments samples were refluxed from tire varying 15 minutes to 24 hours. No significant reading differences were noted. Therefore, we only reflux samples for approximately an hour, or possibly two, until dissolving appears to be complete:

Following is a step-by-step account of the method in use:

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1, Grind to.a fine powder.

Weigh out a one gram sample, record weight

to the nearest ten-thousandth place.

Dissolve in a 50 mi beaker containing aqua

region (11 ml/g), place on a hot plate.

4. Filter after two-hour refluxing.

5. Dilute with distilled water to 15 ml.

?The following table shows the sensitivity of our readings

and the per cent standard deviation of identically prepared

samples:

Element Detection Linit -d_Deviation

ca 0.026 ppm 5 ppm level

cu 0208 50 ppm lever

Fe 0.4 300. ppm level

Ni 023 20 ppm level

Zn 0:02 300: ppm level

co 0118

10 ppm level

Mathematical Calculation:

Our calculations are reported in parts per thousand (ppt, mg/g). The samples are concurrently run with two blanks, treated in the same manner in the preparation steps as the samples. Sets of standards are run through AAS at least before and after samples. The graph heights are read and recorded. Fron the standards we construct a curve from which the sample and blank concentrations are read. lank values are then subtracted from sample values

to account for inpurities which may occur during prepara-tion.

?The final concentrations are calculated fron the formula

given below:

(eR = m/er. (ppt)

P = Readings from standard curve

B = Blank

V = Volume of the dissolved

we= Weight of sanple

ple

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?The standards are currently made from inorganic salts.

a comparison it might be worthwhile to use organic trace

metal standards, preparing them in the same manner as the

samples since the biotic material we receive is organic.

For

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PROCEDURE. FOR ESTINATING DISSOLVED OXYGEN

5 ML WINKLER METHOD

Introductios

?The method to be described here is a modification of Fox and Wingfield (1938). It is convenient in that it allows one to measure the sample of water and run the Winkler reaction in the same syringe. It is also useful since small, but manageable samples may be analyzed. Finally, with sufficient precaution the method is accurate enough for many research purposes.

?The Winkler reaction may be summarized as follow:

1 + 2Hn(OH) 2

2Mn (OH) 2 + 0 + 1/2 02 = 2Mn (OH)

2MnCl2 + 4NaOH = 4Ni

2Mn (OH) + 2KI + GUICL = 212 + 2KCL + 6H20 + 1

?Thus the introduction of manganous chloride in the presence of alkali results in the formation of a manganous hydroxide

precipitate, ?The manganous hydroxide is oxidized by the oxygen of the sample to manganic hydroxide. Acidification of the sample then results in the oxidation of the Ki to iodine by the manganic ions. Fach molecule of oxygen 1ib-erates two molecules of iodine. The extent of the iodine released depends upon the amount of manganic ion formed, One then titrates the iodine with sodium thiosulfate using starch as the indicator. The reduction of the iodine to iodide by thiosulfate results in a loss of color following the disappearance of the starch-iodine complex.

In the following procedure there are two steps which must be done carefully. These include the volume measurement of the water sampie and the standardization and titration with the sodium thiosulfate. The remainder of the reagents are generally added in excess of that required for the reaction.

\ipnent_and Reagents

Reaction sygringe - These are constructed from 10 ml syringes which have glass needle fittings. A capillary tube, which is drawn out toa fine tip, is attached to the

needle fitting with a piece of stiff plastic tubing. The capillary is fitted to the syringe in such a manner that there is a minimum of space between them. The fine capillary tip allows the reaction to proceed without dif~ fusion of gases into or out of the syringe. For extrenely accurate results the syringe volune should be calibrated by weighing with distilled water. For less accurate re- sults, the volume of the sample can be measured using the syringe calibrations.

Burette - The burette is important, but need not be elab- orate unless very accurate results are sought. For our purposes a1 ml burette or a 1 ml tuberculin syringe with E capillary tip is adequate.

?Titration Equipment - The most convenient arrangement is to make the determinations in a 25 nl beaker or Erlenmeyer flask which is stirred by a magnetic stirrer. The ?flea? can be easily constructed by cutting a small piece of wire, Such as a paper clip, into 1 cm lengths and cover with a piece of capillary giass. The titration should be done on

a white background with fluorescent lighting.

Reagents -

i

thiosulfate - Weigh out 24.82 g of sodium thio-
te and dissolve in 1 liter of boiled and cooled
distilled water. Dilute 1:9 for standardization,
Weigh out exactiy 0.8917 g K103 and dissolve in i liter
of distilled water to make 0.035N solution for stan-
Gardizing the thiosulfate. Fill a 10 ml burette with
the diluted thiosulfate. Pipette accurately 2.0 ml of
Kis into the titration vessel and add 1.0 ml of 1% KI.
Add°5 drops of concentrated fisP04 and 2 drops of
starch and titrate. Repeat tlree tines. Calculate
the normality of the thiosulfate as foliows:

xv = xv

KIOs KIO5 na28203 Na2$203

0.05 = Nx ¥

Note: N/100 Sodium thiosulfate is now commercially

available as a standard.

2, MnClz - 40 g/100 wl distilled tio

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3. Alkaline Todide = 32 g NaOH and 10 g KI to 100 mt

distilled 1120,

4. KI-- 1,0 g to 100 mi distilled 11,0.

5. Starch indicator - 1g is added to 100 mi distilled

water and heated stowly to 190° C. Cool and add 0-1 g

of salicylic acid.

6. IlsP0q - Concentrated reagent.

?Titration of Sample:

1, Using the 10 m1 syringe with nozzle, fill the dead

space carefully with MnCl;. Be sure to remove all air bubbles. {

2. Fill the syringe to the 5 m1 mark with the water sample. Again, be sure to exclude all bubbles.

Take in two times the dead space volume of alkaline iodide.

4, Rotate the syringe to mix the manganous hydroxide thoroughly.

5. Allow the syringe to set three minutes for oxygen absorption.

6. Draw in three to four times the dead space volume of concentrated 1i3P0q. Rotate the syringe until the precipitate is thoroughly dissolved. The reaction has now stopped, and exposure of the solution to air does not result? in error.

7. Eject the solution into a titration vessel, such as a

25 mi beaker, and wash the syringe twice with 2 ni aliquots of distilled water. Add the wash to the titration vessel.

8. Add two drops of starch indicator and titrate the sam-ple with the standard thiosulfate. For this purpose, use a 1 ml tuberculin syringe or a 1 mi burette,

Rince the 10 mi syringe thoroughly in tap water and distilled water, When the syringe is again rinsed with MnClp it is ready to use.

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Opmi/1 (STP) = _n.A,5600

2A, 5600

n= ml thiosulfate used in the titration

A= normality of thiosulfate

V = volune of the water sample titrated

A correction should be applied for the dissolved oxygen tn

the reagents (MnCl and the Alkaline iodide). It is assumed to be about 3.4 ml/02/1.

tice of the Technique

1, Place a sample of distilled water in a beaker and stir vigorously for about 1 hour using a small stirring motor. Take the temperature of the water and read the barometer. Remove three samples of the water and Getermine the oxygen content, Compare your values with those obtained from the Handbook of Physics and Chemistry.

Bar. x 0.209 (1000 «) = ml0,/1
760

where Bar. is the barometric pressure and « is the ml Of oxygen which will dissolve in 1 ml of water at the Specified temperature if the sample is in equilibrium with an atmosphere of oxygen. Estimate the reagent

Yolume and make the correction for the reagent oxygen.

2. Try determining the oxygen content of a sample from

Mhich mest of the oxygen has been removed by nitrogen

washing or boiling.

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aay

STRONTIUM 89 AND 90 IN MILK

AND

TODINE - 151 IN MILK

by

Giiser G. Wood

IODINE - 131 in Milk

Apparatus:

1, 2,5 liter polyethylene annular counter containers.

1. 248 Trichloroacetic acid.

2. 124 Trichloroacetic acid,

3. 28 NaI Solution (20g AgN0s/1iter water).

4. 24 AgNO solution (20g AgN0s/Liter water).

Determinatio

1. Put 2 Liters of the whole milk sample to a 5 liter

beaker.

2, Add 2 ml of 40% formaldehyde solution.

3. Stir for § minutes and let stand at room temperature

for 1 hour.

4. Transfer 1 liter of sample into annular counter container, Addl liter water; mix and ganna count (C)).

S. To remaining sample, add with stirring, 900 ml of 24% trichloroacetic acid solution, and?l ml of 24 NaI and then I ml of 2 AgNO, solution.

6. Stir for 30 minutes. Allow the precipitate to settle.

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4a

7, Filter by suction through a 15 cm WHATMAN #42 filter paper.

8. Wash with two $0 ml portions of 12% frichloroacetic acid solution. Discard the precipitate.

Transfer the liquid (filtrate and washings) to

annular counter container. Mix well, Gamna

count (C2)-

Calculation:

The net counting rate of 11 = c, -

The counter effigiency is determined by adding « known

Standard to a 13i] free milk. Decay constant is

0.086 day. Half life is 8.05 days.

Acct

A= Age!

Reference:

Harley, John H. 1967. Manual of Standard Procedures

U.S.A.E.C. New York.

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STRONTIUM 89 AND 90 IN MILK:

A, By Ion Exchange

Presery:

Imnediately after the collection of a milk sample, a preservative, formaldehyde (about 3 m1 37% formaldehyde Solution per'liter of milk) must be added. Sample must be refrigerated (at 32° - 34° F.) for at least two weeks to allow the Yttrium 90 daughter of Strontium 90 to reach into equilibrium with its parent.

Reagents

Cation - Exchange resin: Dowex SOX-X8 (Na* form, { 50-100 mesh), analytical grade (the chemical

grade can be'used for this purpose after

Purified by a method given by Harley, G-04-

01).

Carrier Solution: Sr°as Sr(NO5), : 20 mg Sr*? per

al.

Citrate Solution: 3N (pH 6.5).

Apparatus

Ton-exchange column:

Dimensions are shown at Fig.1.

Put § ml of distilled water in the 30 ml column,

pour 170 m1 Dowex 50 W resin into it.

Procedure.

1, Put 1 liter of milk into the reservoir.

2, Put 1 m1 strontium carrier into 10 ml of citrate

solution, mix until dissolved. Put this solution

into the milk with 5 ml distilled water, mix

well.

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443,

3. Open stopcock control flow rate at 1 ml/min.

4. Stop flow when just enough milk remains in column

to cover resin.

Discard effluent milk.

6. Put 300 mi of warm distilled water through the

column (about 10 ml/min).

7, Discard the effluent water.

Push the resin out of column in a very small

beaker or vial. Dry and gamma count.

aslen

Fritted

Glass disk

B. By Ashing:

Apparatu:

Analytical oven

Corningware dish

Muffle furnace

Procedure:

1, Put 2.5 kg evaporated on S kg fresh milk into

corningware dish.

---Page Break---

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2. Dry in oven at 100°C. for 48 hours.

Transfer the sample to a muffle furnace and raise

fhe temperature slowly to S$0°C. Ash at S50°C.

for 24 hours.

Cool, weigh, and grind the ash to a fine powder.

5. Ganma count or

6, Dissolve in 1 m1 of 6 N HNO,

7. Dilute to a 25 ml in volumetric flask.

8. Run at Atomic Absorption.

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APPENDIX

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MATHEMATICAL SIMULATION OF THERVAL PLUMES

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Introductioi

The material in Appendix C, consisting of two parts,

Tepresents a teoranination section 11{-0-1"b. (Phe Blane.

EfEisent?SyScong-Heat environsentai influences, pp. 64-68)

of the Aguirre Power Plant Complex Environmental? Report

?The first part is a detailed check (including data, equations used and references) of the values listed in Tables 111-2 and 111-3 of the Report, nade at the request of the Puerto Rico Water Resources Authority, In addition, the distortion of the plume centerline by an anbient current of 0.5 ft/sec at 45° is computed by superposition of jet and ambient velocities.

The second part contains calculations, parametric studies and a modification of the basic Pritchard model intended

to provide a quantitative basis for the evaluation of the applicability of the model to conditions existing in the Aguirre Ship Channel, and to examine the effect of re-entrainment on the predicted plume extent. Specifically, this part consists of an outline of the basic model equations, a comparison of required entrainment flow to ambient flow, the effect of entrainment of heated water on the size of the 4°F isotherm and the effect of deflection and subsequent Fecentrainnent of heated water, inpinging on the Cayos on its temperature. All calculations are for the case of two fossil plants.

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CALCULATIONS FOR TABLES ITT-2 AND III-3

of

AGUIRRE POWER PLANT COMPLEX ENVIRONMENTAL REPORT

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Basic Dat

ind Unit Conversio:

a) From p. 62, Ref. [1

Flow Condenser Excess Temp. Power

Fossil: Qe = 226,000gpm eg = 18.74°F Pg = a60Mne

Nuclear: Qy * 555,000gpm en = 14.80°F Py = GoOHNE

b) From pp 3204 § 3209, Ref. [6]:

1US gal. = 0.13368 Ft3

Tacre = 4.3560 x 104 fe2

©) Converted Flow Data and Approximation

Fossi:

Q = 226,000gmp = 503.528 Ft 3/sec ~ Soscts

Nuclear: Qn = 555,000gpm = 1256.54 ft 3/sec ~ 1250c¢s

Equations for Computation of Table II

Let Ng = Number of Fossil Plants

Ny * Sumber of Nuclear Plants

4) Power Production

Prot "Pe Ne # Py?

b) Flow Rate

Qrot = Oe Ne + Qn +

©) Condenser Excess Temperature

Pctor? (ce = Of + NF * Cen = Qy +

4) Discharge Nozzle Dimensions (Triangular)

lo * exit velocity

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hg = exit depth

bg * exit width

cc) "Normalized" Nozzle

For equal area and centroid, equivalent rectangle defined

by

Recomputed Values for Table I1I-2:

a) Data

Qe = S0Scfs Pp = 460NNe cg = 18. 74°F

Qn = 1250cfs Py * GOONKe = Ocg = 14.80°F

Ug = 6£t/sec

b) Table Values:

Ne| xn] Peot | Qtr | Sector | Triangle | Normalized

uve} cfs] cr [bo [bo | bs | hg

i re fee foe | te

1 | 0 | 400 | sos | 18.74 | 16.83 | 10 | 12.62 | 6.67

920 | roto | 18.74 | 33.67 | 10 | 25.25 | 6.67

2 | 1 |1s20 | 2260 | 16.56 | 37.67 | 20 | 28.25 | 13.33

|

(2 [2 fave [sie | 15.98 | sesso [20 | essa 13.33

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Equations for Computation of Table 111-3:

From Ref. (1], [2], [S]:

ley oe

Golty) = (0/0,)"2 by = 6 be

- 2

Ax 0.215 62

NOTE + Excess temperature at discharge orifice.

Recomputed Values for Table I11-3:

NOTE: Assumption of no cooling in discharge canal

9 = Octot, is made. For cooling in canal and

resulting changes in Table III-3, see items 6,

and 8.

Proe| 460 Mite 920 Mie 1520 MWe 2120 Mie

0g | 18. 74°F 18.78°F 16.56°F 15.93°F

bs | 12.62 ¢e 25.25 ft 28.25 ft 43.88 fe

e [co | ae fo | Ao co | Ae Re

ce | ee | acres

12] as [0.17] soo] 0.07 | 323] 0-31] eos] 1.06

to | 266 | 0.35] 532] 1.40] 465] 1.07] 668] 2.20

8 | ais | oes] ss] s.ar] 726] 2.60] 1944] 5.38

© | 739 | 2.69] 1478] 10.78 | 1291 | 8.23 | 1856] 17.00

4 | 1602 | 13.63 | 3325] s4.se | 2905 | 41,66 | 4176] 86.06

Equations and Parameters for Surface Cooling in

---Page Break---

a)

»)

°

a

482

Equation for temperature change - Ref. [2]:

no = uae Por Oe - 80

canal Area A - Ref. [1], pp 62, 63:

L= 7900 ft, w= 156.5 ft, A= 1.24 x 108 ft?

Surface Heat Loss Coefficient w

i Fron Ref. [4]

for wind = 12 mph

dew pt. = 70°F

water surface temp. = 80°F

3 __ Btw.

vy 2 2.1991 x 1073 Eze See

ii From nef. [5]

for wind = 10 mph

water surface temp. = 80°F

excess temperature = 18°F

uz © 2.5361 x 1073 Btu

2° 2 Fer see

iii For computations use average value

elope ue x 1073 3 a Bt

we E(uy + ug) # 2.3676 x 10°32 2.4 x 10S FEE GES

leat capacity of water - Ref. [4]:

» 6a BE

ccs 64 FeveR

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Surface Cooling in Car

Xen Prot Qtot = etoe =n 8

1 0 460 sos, t878@ tao

20 920101878 ot

2 1 1520 2260 16.56 0.38 16,22

2 2 21205510 t5.93 ott t5.72

Modified Values for Table 111-5:

Prot ?tne 460 920 1520 220

oF 1.01 17.88 16.22 1s.72

bg tt 12.62 25.25 28.25 43.08

le tortt |Agracres| co | Ao | to | Ae | to do

loa tsz_ | 0.11 | 366] 0.56! st0| 0.47] 452) 1.01

| 0 219 | o.2¢ | ase] 1.16) eas | 0.98] 651] 2.09

5 sz | ose | 757] 2.83, 697] 2.40 1017] 5.10

6 609 1.83 1345 | 8.93 1239 | 7.57 | 1807 | 16.12

loa taco | 9.35 | sner [asses a7er | ae.se | anes | arse

i L

Equations for Plume Distortion - Ref. [3;

fect ge a4

Frere t Ben q

wet). BER

m-yORery

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10. Plume Distortion:

bata: Exit velocity u, = 6 ft/sec

current: 0.5 ft/sec at 45°, consequently

b= 0.5 cos ase = gt

U = 0.5 cos 45° = hy

Vv = 0.5 sin ast =

. WE

Values of bf and £g correspond to those given in

items 5 and 8.

3) Values corresponding to item $ (no canal cooling)

|Feoe| 460 xwe | 920 wwe | 1520 wwe} 2120 Me

fos | taser | 25.25 | e.2s | 43.88

|g | 1.74 18.78 16.56 | 15.93

o feel ael e [a] ela} ela

jaz! ae] 1s | sos] 26 | sea] 21] 493] 29

| 8) ase) an oro | 79] 788] 62] 1131] 87

92/1662 | 184 | 1434) 143 | 2055 | 199

so7 3040 | 615 | 5380! 476 | 4835 | 659

---Page Break---

b) Values corresponding to item 8 (with canal surface

cooling)

Prot| 460 Me 920 MWe | 1520 MWe | 2120 MWe

bs 12.62 25.25 28.25 43.88

& 17.01 17.88 16.56 15.72

2 ela & a = a ela

12} 162] 10} 359} 23] 330 | 20 | aso] 28

to | 235} 16] sar} sz] 47a | 32 | 696] 45

8) 372] 30} 826 | 69} 756 | so | i101) 84

6 | 678} 69] 1505 | 160| 1374] 135 | 1998 | 191

4 | 1599} 230} ssez | 535 | 3234 | 447 | 4699 | 633 |

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Page No. 26¢ (1971)

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I. Basic Jet Model:

The basicy tNo-dinensional jet model is defined by Bq. (16

ofrete hfe Y Fae Ge)

debs (Eley) » Ev = 6b, 3 Bbey a)

This variation of width leads to the velocity distribution

um uy (Ey/E)1/2 @

Lf Qo 48 the discharge rate from the orifice and Q(t) the

flow°across a section of the jet, then

@= a CEE)? ©

and the entrainment flow is

Ge = 2- =a [erp] ro)

Finally, defining

05 = orifice excess temperature

%@ = entrained water excess tenperature

© = excess temperature in the jet at £9

one obtains

Fol e9f 2)

6.

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11, Rate of Entrainment - Two Fossil Plants

Assune that entrainment occurs over the entire length of the plume (approximately $500 ft) until it exits from the favos.. For two fossil plants with a discharge rate

&, = 1010. £t3/sec and a triangular exit orifice of width

= 6bg = 6(3bo)e isi. ft

we no)

le (e/ey)!/2-1] = 1010 [7sso0 y1/2

ae = gfiereo¥ a] 200 (geese

so7s £t8/sec.

Thie compares well with the natural flow of approximately

0 fr8/sec across a section of the Aguirre Canal (Note
that only one half of the entrained water comes from one
side, so that the comparison is between 2538 ft3/sec and
3100).

More to the point, the momentum jet model does not depend on
ambient cross flow for entraigment, The question is rather
nough water (i.e, 2538 £t4/sec) can be withdrawn from
the area east of the plume. If it is assumed that all
Sherainment water must be drawn in between the cayos and
rough the Boca del Infierno, then the induced velocity is

indicator of the availability of entrainment water. The
stetional flow area of the cayos is approximately 1250 ni

ui af the Boca del Infierno 1100 m2 giving a total area of

?proximately 25300 ft¢, The induced velocity is therefore

u = 1/299 = 2538 -0.1 ft/sec

A 25300

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III, Effect of Entrained Excess Temperatures:

If the entrained water is not at ambient temperature, but has an excess temperature of 9, the centerline isotherm distance is given by Eq. (5).

For the case of the two fossil plants and the 4°F. excess temperature isother

bys 151.5 ft, 6, = 17.9°F,, oe aR,

the effect of 6, is illustrated below:

ba Ay

ft acres

3034 45

3745, 68

4808 a4

6520 210

9576 453

15970 1258

35657 5585

125673 77953

NOTE: The values given above are computed on the basis of momentum jet only. Surface cooling and diffusion are neglected.

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IV, Modification for Reentrainnen

To obtain a first estimate of the effect of reentrainment,

the model shown schematically in Fig. 1 is assumed,

The portion of the plume Eyct<ts only is of interest, At

Peet the fiow rate? Qo is partially feentrained,, the

Feontrained porition Being? dz, Reentrainnent is" assumed

tg?occur snip over the section Eicest aad complece

St Rho" Toontyained water with anbione?is alse Easuned

If the parameter @is defined as

B6y/ by (6)

then Q, and Q, are obtained from E9.(3).

Oy = ACE MEyII/2 = Qo 81/2 CE,/E D4 Vp = Qo (EQ/E,I!?

a)

Since there is no reentrainment on ¢,sCs ,, the excess

temperature 6; becomes 1

oy, eye = (by/E,)1/2 (8)

®1y2

For total mixing in the jet

28) = 8] + e282 (9)

and for total mixing of reentrained water

er%e7 ~ 28292 1 F (yz) = 0092 ao)

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Substitution of Eq. (10) into (9) gives

an

and finally, use of (7) and (8) yields

= 8 (ey\W/2 az |

27 8

3)

Note that the temperature @ is independent of the parameter

8, that is of the ratio £,/2,. This is a natural consequence

of the assumed total mixihg.* The temperature distribution is

the plume is, however, dependent on By The parameters a and

gare not independent, since for steady state it is necessary

that

992 £ oz = 9-0) as)

which gives the restriction

as 1-8l/2 aay

and II summarize results for the case of two fossil

?t Aguirre with the following values of the parameters

by + 151.5 ft.

&, = 5500 ee.

6, = 17.90 *F,

Table I show the variation of fj, 6, and a max with 6

Table IT gives the variation of @) with a .

It should be noted that the present approximation does not

include surface cooling and will necessarily overestimate

a.

2

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Cooling Systems."

26c (1971)

Siting Criteria for Once-Through

Chesapeake Bay Institute Paper No.

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TABLE -

1

TABLE - IT

= VSS v

2 *Fli7.o7 | iiss | s.94 | 3.96 | 3.30 | 2.97

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Notice

?Th repr wa prepare as en account of work aporora by the Unie Stan

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