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A STUDY OF THE PLANKTON IN LAGUNA JOYUDA,

A TROPICAL LAGOON ON THE WEST COAST

OF PUERTO RICO

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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?A STUDY OF THE PLANKTON IN LAGUNA JOYUDA,

[A TROPICAL LAGOON, 8 THE WEST COAST

(OF PUERTO RICO

by

Daniel Pesante Armstrong

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---Page Break---

TABLE OF CONTENTS

Laboratory Procedures

RESULTS AND DISCUSSION .

Plankton Composition

Plankton Analysis

Salinity ....

Temperature ,

Water Turbidity ....

APPENDIX C

BIBLIOGRAPHY .

102

---Page Break---

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ABSTRACT

A total of 80 plankton samples were obtained from La-

guna Joyuda a

ing March, 1977 to February, 1978. The re~

search area is 2 shallow tropical brackish water lagoon. It was observed that the species diversity of the plank-

tonic members of the community is very low. The copepod

Acertia tonsa is the dominant holoplankter followed by Porcellanid larvae, a member of the meroplankton. A voracious predator, the ctenophore Mnemiopsis gardeni, was found in the lagoon. It attained bloom proportions on several occasions reducing considerably the density of smaller zooplankton. The species present in the plankton seem to be circumscribed to Laguna Joyuda. There appear

to

¢ indications that the planktonic populations are biologically accommodated although physically controlled conditions may also play an important role too.

?The water system of the lagoon seems to be homogeneour vertically and longitudinally in negara to temperature

ane salinity. The implications this homogeneity may have

in providing A. tonsa with nore efficient ways of elimina-

fg other species of copepods are taken into considera

ticn. Physical factors which includ

?temperature, cali-

nity, turbidity, tides, surface currents and wind velocity

ere elso diccussed.

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TABLE

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was

fs

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#18

no

20

LIST OF TABLES

Data from April 1977 ....

Data from May 2977

Data from June 1977

Data from July 197

Data from August 1977 -

Data from September 1977 .

Data from October 1977

Data from November 1977

Data from December 1977 ....

Data from January 1878

Data from February 1978

Data from 2% hr. Study

October 20-71, 197 cette teeeeeeeeeee

Data from 24 hr. Study

October 20-71, 1977

Data from 24 hr. Study

October 20-21, 3977

Data from 24 hr. Study

October 20-21, 1977

Page

18

7

58

60

78

79

80

81

82

83

au

as

86

87

88

eo

9a

92

93

4

---Page Break---

TABLE #22

TABLE #22

TABLE #23

TABLE #24

TABLE #25

Page»

Data from 24 hr. Study

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LIST OF FIGURES

A. tonsa and Porcellanid larvae/n*/station

Upriiy

A. tonsa and Porce}lanid larvae/n'/station

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A. tonsa and Porcellanid

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A, tonsa and Porcellanid larvae/n'/station

eptember),

A. tonsa and Porcellanid

Tctober).

4A. tonsa and Porcellanié

Wovenber)

A. tonsa and Porcellanid

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. tonsa ané Porcellanid larvae/m?/station

(Ganuary).....

A. tonsa and Porcellanid larvae/m?/station

Gebruary).......

Total Plankton/m® for 24 hr. Study

October 20-21, 1977

Channel and Outside Stations

Page

42

45,

49

---Page Break---

FIGURE #17

FIGURE #18

FIGURE #19

FIGURE #20

FIGURE #21

Page

Total Plankton and total Mnemiopsis

---Page Break---

INTRODUCTION

Zooplankton plays an important role in the aquatic food chain. The energy from the sun which has been fixed through the photosynthetic action of the phytoplankton ie made available to those aquatic forms higher up in the food chain by the zooplankton. The latter form links the primary producers to the consumers along higher trophic levels.

Although most members of a planktonic community are microscopic, not larger than 1 mm., organisms such as the medusae can grow up to 1m. in diameter. The latter only comprise a small percentage of the total plankton.

Biological, physical, chemical, and geological factors, or a combination of these, have a definite influence on the distribution of organisms. Factors such as temperature, salinity, dissolved oxygen, nutrients, predation, among others, have sone impact over planktonic populations (Hopper, 19675 Jeffries, 1962; Reeve, 1964; Lock and McLaren, 1969). The degree to which one or more of these factors affect the structure of a population may determine its survival. Even in environments with similar physical con @itions, population distributions are not identical (Jeffries, 1982).

By looking at the species composition together with concurrent observations of the physical factors, as well as

the biological factors, the distribution patterns and

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population dynamics of the planktonic organisms can be determined. Through studying the oceanic and neritic water plankton, many investigators have described and analyzed different components of an ecological system and their interrelationships. (Jeffries, 1958, 1962a, 1962b; Heip, 1973; Grahame, 1976; Heip and Engels, 1977.) By determining the composition and population dynamics of a community the system can be described as biologically accommodated, physically controlled or a combination of both (MacArthur, 1955, 1965; Hutchinson, 1959; Klopfer and MacArthur, 1960, 19645 Connel and Orias, 19643 Sanders, 1968).

Therefore, the purpose of this investigation, undertaken at Laguna Joyuda on the west coast of Puerto Rico (Figure #1), is to describe the planktonic species composition and population dynamics. Physical processes were observed in order to determine the control factors: whether ?the lagoon has a physically controlled or a biologically acconmodated community or possibly 4 combination of both.

Except for some short time studies related to the ecology of this lagoon (Erdman, 1963; Pagan and Austin, 19675 Bennett, 1969), no detailed investigation on plankton has been carried out as to this date. This investigation is the first attempt to describe the planktonic component of the lagoon. Attention was focussed on both the holoplanktonic and the reroplanktonic menbers of the community. Of parti-

cular interest was the frec-living fraction of the order

---Page Break---

FIGURE # 1. Study Area Site Localization.

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Copepoda (ope, oar; pod, foot), as they comprise a major portion, usually from 80 to 85% of the total planktonic community. These microscopic crustaceans have a very wide Gistribution in all oceans and fresh water bodies of the world.

The results of the investigation might have a practical objective: generated information will be useful if the lagoon should be considered as a mariculture site in the future. Actually, from 60 to 05 families derive benefit from the different fish and shrimp caught in the Laguna Joyuaa.

The study might also give an insight in some of the ecological problems which take place in analogous environments in other lagoon systems of the island.

DESCRIPTION OF STUDY AREA

Laguna Joyuda is a tropical lagoon situated on the west

coast of Puerto Rico at Lat. 108! N, Long. 6711" Wi, about

five miles south of the city of Mayaguez (Figure #1). It has a surface area of approximately 300 acres (Pagan and Austin, 1967) with a mean depth of 1.5 m., with two deep holes of 2.5 and zm. respectively (Figure #2). Bennett (4969) concluded that the 1agoon developed from the ac-

cretion of two sand banks which enclosed the bay and formed

---Page Break---

vaguna oyuda Sounding in

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The seéinente are composed of @ grayish-black mud with

varying a

ounts of shel} debris (Bennett, 1969). Sedinents

have @ éieti

tive HS smell. Bennett (2968) also mentions

that beceuse of the activity of burrowing orgenisns there

is no nercertible stratificetion of bottom sediments, and

that nangrove evanp

terial is the najor source of fine

sediments.

Ruppia maritima, a seagracs, grows profusely along the

west and south coast shores of

he Jagoon. It's banks are

78% fringed by the red mangrove Fi

elf and its prep roots provide }

of organieus and trapping of sedinant.

The legconal water systen could be considered as a mixopolyheline type (Wenice §

ging from 18 te 30 °/g. Ene

(2967), and Eennett (4969) vepont salinity values that

ronge from 6 to 44 /gg. Touperature values of epproxizately

28°C have teen reported.

ity values could be affected by intermittent

ch ane formed during heavy rains. Rainfall in

2y fron place to place over

ly short distances, exing in part to the ssland

raphy.

val precipitation for the

cosstel region ranges from 78 to 60 inches.

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The distninution ef rainfall can be expresced in terms

ofa relatively wet and dry ceason, aldefy no absolute dry

ueason occurs. The relativ wet scasea extends from the

month of Hay to fovember. ory geason extends from

De

enber to April (U.S.C.S. San Juan, P.R.).

Lagoon water is of a deep green color on 4 year round basis. As stated by Wilson (2965), nutrients tend to be

concentrated in lagoons. Tne geomorphological characteristics of the lagoon tend to prevent nutrients from being exchanged with other syste

outside the lagoon. Organic

ter is depo:

ed on the >

tom and bacteria and fungi

convert it into more nutrients shich are difuseed through

the water column.

RIALS AUD METHODS

Field Procedures

Zooplankton samples were ellected by towing a conical shape net with an opening o* 9.2 m in dianctsr and a mesh size of 202 um. A propeller type floneter was attached to the net to determine the volume of sca water filtered. During the towing procedure, which lasted five minutes, the power of the boat was reduced until the net was just below the surface. Towing speed ranged from 2 to 3 knots. At the fend of each tow the net war hauled in and rinsed with sea water, A 12 volt battery poverce pump vas used for this

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aw

purpose. In this way

animals were concentrated at the

codend of the net, in a S00 mf collecting Jar. The samples

were preserved with ut tuffered 7

wmalin see water solution.

Occacionally, ctenophore blocms nade a norea] five minute

tow inpossible; reducing the duration of the tow did not

help either. When the ctenuphores were present, 18 second tows were made followed by a careful counting of the cteno=

phores in the field. This was necessary because

cation of these animals in tse laboratory was impossible as they become an amorphous ge! a few minutes after preser vation. During the neath of July etenophore populations reached dloom proportions throughout the lagoon, yet it was

noticed that a station had a relatively low number of cteno-

phores. At this station (B-?) a regular plankton tow was possible in contrast with tows attenpted ay stations with heavy populations of etenophores.

During October 20-21, 1977, a total of 30 r00plankton samples

study area. At

of the Five

stations (see Figure #2) a tow was made every four hours

over a period of twenty-four hours. Parameters like temper-

ature, selinity, water transparency, wind velocity, and

tides were observed. Other observations which included a

study of curface currents of the lagoon took place during

the noraing and afterncon of Gotober 20, 1977, as opposed

to regular

ampling during the year which included one tow

pen

nth et each of the five

sions. fae following

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FIGURE 43.

Station Location and Position of Tide Gauge.

1a

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parameters uore alco chserved on monthly basi temper

ature, salinity, water transparency, and dissolved oxygen.

furface currents at the lagoon were measured on two

different occasions during Getoser 2C, 1877 in order to ob-

serve whether they heve any influence on the distribution

of plankton at the lagoon. ?he follewing procedure was un-

dertaken. Banoo stekes 4m. long were driven in the sandy-

mud at a fixed location within the lagoon. A email drogue,

previeurly balanced with lead weights, was cropped next to

bamboo rod #1 and the starcini

1g time recorded. Additional

rods vere placed along the trajectory of

1e drogue. Time

and distance covered wore >

sistered simultancously. The

angle with respect to north, et which the drogue had drifted

was observed and recorded. Wind velocity was monitored

simuitaneousiy-

Flow measurements at the channel which connects the

lagoon with the sea wore mide in order to determine the sea

Lagoon water ©

wiges Anaad. crojue was Bus it for thie

purpose but could not be usud cince the channel is too

narrow (1-2 m.), shallow (approximately S om. in some

places), and its banks are completely fringed with the red mangrove Rhizophora mangle. Although the érogue could not

be used, the current was measured uss

fa omall floating

object.

Tide measurements vere made every hour for tuenty-

four hour periods in order to cetermine tidal infuenze on

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a4

unt of water coming in and out of the lagoon and

thereby any exchange of plashten and nutrients from the sea.

A meter stick placed inside 2 clear plastic tubing 90 x 5 cm.

provided with @ sma2) 9.078 cm. perforation on the bottom

for water exchenge was employed. The tide gauge was secured

to a bamboo stake which was civen into the nud on @ man-

grove protected embayment (Figure #2). The initial reading

and tine were registered; ho:

rly observations were made

thereafter for cwonty-four how

Temperature measurements were made usii

fp either a ther.

mistor (¥.$.2. mode? 97, a

racy of 9.897) or a mercury

?thermoneter (ac

ey of 0.1°C), Particular attention was

paié to surface measurements, although temperature vs. depth

profiles were made.

Salinity measurements were taken using a portable in-

duction salinometer (Y.5., nodel 33, accuracy of 0.5 °/gq)-

A hand-held refractometer (snerican Optical, temperature

compensated, a:

acy <

©.) wae also used. The use

of the latter was restricted to the surface. Salinity (S

Feo) ve. depth profiles were made. Dissolved oxygen (D.0.)

measurements were taken using 2 temperature compensated meter

(Y.8.2, model $7, accuracy of 0.1 ppm.). Measurements were

taken at the surface, mid-dosth, and bottom. Instrument

malfunctioning affected the continuity of the data. Ac

corcing to vanufacturer spe ifjcations all electronic

instrauents were calibrated prion to each field trip. Light

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ankton sample

were taken

daboratery and

Washed With Sitered io3 waren by de Filtration through

20? um. nets to nesows © (phytoplank-

ton, plant material, insesis, etc.) Before estimates of

biomass were made, ail orgenions laeyer than 1 cm. were removed (95% of inese ware seal: Phyitoriysa, (Medusae)

Bionase wae eotinated as wt volume, Samples were trans-

ferred 10 a graduates uylinoer (10 4U-3eh~ 2s més, depending

on anount of plankton) to conform to @ prefixed volume. The

sample was then poured through 202 um. nettiny into another

identscal graduate?

Linder, and left te drain by gravity

for periods of 1-5 minutes. The aiiference in volume was

expressed as mt of zooplan.ton

pensities of plankters were ol termed by volunermic

subsampling with replacement procedure involves

bringing the sample to a known voluue (250 mi). With a

calibrated autonavie pipette, @ 2 me aliquot of the homo-

geneous sample was placed on a Bogorov counting chamber. A

Bausch «

md 1X-7% binocular dissecting microscope facili-

tated tne identificavion anc comting of the

ecimens

Once aii the animals in the counting tray were identifier each representative of tha:

The -Viquot

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was then reTurued te the oan

jar. The ja was shaken to

assure @ homogeneonn sample, 1

her aliquot renoved.

Three aliquots from esch cs pie were counted. The mean zoo-

plenkton density ané standars deviation of the mean were

calenlated fron chase thre weptications

Estimation of

2 Volum of sea water filtered by the

net was carried out by neane of @ propeller type flowmeter

attached at 1/4 of the

stance from the center of the ring,

Jn order te prevent turbulence

iced errors. Calibration

of the Flowmeter was conducted in a swimming pool where the

distance and ti

were observed for a known distance. The

flowneter was calibrated three tines during the year. It

turned approximtely 35.3 vevolutions per cubic meter of

water that was filtercd. Mean was 45.29 and standard devi-

ation 8.5. Knowing the nevotutions the Flowmeter turned

curing @ known tine end by neans of the following formula,

the volume of Fitter-4 rea wuter per cubie moter can be

calculated

= or?

Gee oti

. Bs

where: (= Rr.

r= vadivs of the ring

Bim = 35.0

= number of revolutions the

Flowmeter turned

The nurber of

tere per m® were calculated by mul-

tiplying the nurber of individuals in 1 mt of the aliquot

by 260 mi and dividing

by the volume of water

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{itteres by the ne. for

tne following

My ago

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where: W = dun

individuals in 1 mt

of me 7

Vos Vole + siyer filtered by

the net in

Number of plunkiers per m?

SESULTS ANE DISCUSS (ON

Laguna Joyuda P

nie Com

ition

Table #1 shows the types of plankters found during this

investigation. 4 total of 8% plankton samples were obtained

throughout the year, $4 of them during the monthly sampling

procedures, and 26 samples on a twenty

four hour study con-

ducted during Octoper 20-21, 1977, Sumpies were taken for ail months except for March when the amount of the cteno-

phore ?oeminpsis gerdeny Gera az) wan so hi

tnat no

plankton tows could be made

As seen in Tes

(Dana). the larvae

of porceilanid crabs and other decapod z0ea were present in

al} samples taken. Nauplis were present 90.9% of the time.

Thie sncludes a2) nauplii town

in the samples,

hough

99% of the Latter were vars

le naupiius. Fish eggs were

Present 1.8% of the time. ?nic included both round and

@longaree types of eee

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The etensgnes

wes prevent 75% of

Une Gime. Tae mses present 6.68 of the

wig the last part

of the study. This

be seen drifting a-

pound the surface.

medicae worn represented as small

ephynae ond as adutte, having @ oneter cf up to 0.3 m

This mecusae, oupre:

ve of the dargest zooplankton, was

the largest of at:

rs of the planktonic community.

Ut a@luo oeours on the nevitic wats outside the lagoon. Tt

has been snen ve pose al + ih Glomoter outside the

Lagoon put never coat size Ie che Laguna coyuds. Amphipoda

were presen? 27.2% of the tne during the beginning of the

sompling season. Sarnacte cywris wars present 9% of the

time; @ rutner Jow nambs

the percent of time

nauplii were present.

Plankton Analysis

Poof plunkts por surer cube i: represented

in Figure #4. A ster reprencnts tne mean value of the five

stations sampled. The extrene range in total plankton/n?

noted throughout the year war from 71.0 in January, 1978 to

6,565 animals/m® in September, 2977. Although there are

many fluctuations definite poaks are observed in which

Septendar has the highest dens!ty of plankton/n®.

Of the plankton availabte in the Laguna Joyuda, the

canola o

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iu the doa?nant one. A.

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FIGURE #4. Number of Plankters per cubic meter.

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tonsa was represented in ali semples taken. Not only does

it attain the highest densities but it is the only copepod

which is present regularly. During a sampling done in the

sumer of 1977, a 12 volt pup with a hose was run along and across a Ruppia maritima bed and another copepod was found,

noid of the genus Pi

yelops. It is suspected that

it stays close to the botton thus avoiding the net as it passes by. No other plankters were found during this vacuun-cleaning process that éiffered from the ones alrcady mentioned, which shows that the towing procedures were adequate and the net was sampling a representative catch of the plankton of the lagoon. The porce}lanid larvae came second in density, from 2.0 to 368/m? (Figure #5). Some crabs sampled from the lagoon were taken to the laboratory and identified. Porcellanid crabs were represented. A small

crab of the species Petrollites armatus was found living in the mangrove roots. Large numbers of these erabs were found

an the field, which could account for the high densities of

porcellanid larvae present in the plankton samples.

Figures & to 1% show the densities of A. tonsa/m? and

densities of porcellanid larvae/m® for each of the five

stations sampled. Arbitrarily, we give a #1 to the station

with the highest density value. A #5 to the station with

the lowest density value. Sy adding up the column under

each station and to this final value, we give a #1 to the

station with the highest density and a #$ to the loxest,

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FIGURE #5.

Acartia tonsa and Porcellenid larvae per

meter per month.

bie

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Number

© A tonsa

» PORCELLANIDAE

CARVAE

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FIGURE #6. A. tonsa and Porcellanid larvae/m®/station

(april).

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FIGURE #7. A. tonsa and Porcellanid larvae/n®/station

(ay).

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FIGURE #8. A. tonsa and Porcellanid larvae/m?/station

(une).

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FIGURE #9.

A. fonsa and Porcellanid larvae/n'/station

(September).

a

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FIGURE #10.

A. tonsa and Porcellanid larvae/m*/station

(October).

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FIGURE #11. A tonsa and Porcelianid larvae/m*/station

(tovenber) «

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FIGURE #12.

A. tonsa and Porcellanid larvae/n®,

(ecenber) .

station

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FIGURE #13.

sa and Porcellania larvae/n®/station

(January).

A

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FIGURE #18. A tonsa ane Por vellanié larvae/m'/station

Crepracey)

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the following pattern can be observed. Although greater fluctuations are seen for each station, Station A-3 gets the highest density values for both A. tonsa and porcellanid larvae, and Station C-1 the lowest. There seems to be no apparent pattern found for Stations C-3, B+? and A-t. The total density of Acartia tonsa and porcellanid larvae for each month of the year, can be seen of Figure #5. The same ?three peaks observed in Figure #4 can be seen here for A. tonsa, although not as clear for porcellanid larvae. High

and low population densities of A.

coincide with high

and low population densities of porcellanid larvae, indica~ ting that they possibly have no direct influence on each other.

On October 20-21, 1977 plankton tows were made every four hours for twenty-four hours. igure #15 shows the re- sults of such sampling period. It is clear that the plankton density rose drastically during the evening of the 20th. This rise an density could he attributed to planktonic ver- tical migration. It is a well-known fact that most plank- tonic menbers of a community rise from deeper waters during nighttime and then return to deeper waters during daytime.

Wind piling of water naeses is also suspected. As the

waters are piled up against land, so are the plankters con-

tained in this water, making them at

in higher densities in

this locality. If the wind blows from the southeast, as it

usually coes at the lagoon, it covers the path along

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FIGURE #15. Total Plankton/m? for 24 hr. Study

Ootober 20-21, 1977.

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ne

Stationt C-2, 8-2, and A-3 (Figure #3). If the wind is continuous, it may push surface water against Station A-3. If this process prevails for @ considerable amount of time, water as well as plankton may be concentrated around Station A-3. Since the lagoon is shallow it seems more probable that water piling should account for the increase in plankton densities.

During the month of February 1978, a series of four samples were taken on the outside of the channel, which connects the lagoon with the open sea (see Figure #16). Table #2 shows the species composition outside the channel. It as clear that the plankton species density in the neritic waters outside the Laguna Joyuda ie higher than that for the lagoon. The question raised is why there is such a big éifference in species diversity between the lagoon and the sea waters immediately outside the lagoon. A possible explanation night be the following.

Jt we take into consideration that the lagoon is: (a) rather small body of wat

5 (b) that it is vertically as

well as longitudinally homogeneous, (matter which will be

Giscussed later under temperature and salinity), as shown

by the salinity and temperature datas (e) that the cteno-

prone 18 @ top effective predator; and (4) that Acartia is

?the only copepod present, we have a consistent framework

thet Can serve as an explanation. For example, A. tonsa

as found ¢ominating all over the lagoon. This fact, coupled

---Page Break---

TAELE #2.

tie Lillicborrii

koartie ep:

ata

fer faxon

Coryczeus subulatus

Coryezeus

Coryeaeus sp.

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FIGURE #16.

Channel and Outside Stations.

4B

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Speman

LecenD

ype scooter

erenorovt

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to 1

homogeneity of the lagoon, indicated that there is ne

Provision of other hideouts in the lagcon for other copepods

to evade the effective competition of A. tonsa; therefore,

the latter can eliminate other copepod species in the lagoon.

As ten

2 has been the object of stu

by Gonzdlez (1973),

Barlow (4982), Ketchum (1951), end it is known that A. tonsa

has very high reproduction rates, which makes it possible

for them not just to occupy the lagoon system but to main-

?tain an endemic population in the lagoon. The effectiveness

of A. tonsa as an outstanding con;

by v

titor can be corroborated

fact that, when the ctenophome poptilations increase

in the lagoon and A. tonsa populations decrease (which

would leave space available for other copepod species), no

other copepod species are seen to flourish. ?This brings an

apparent contradiction with the theory that: ?Local species

diversity is directiy relazed to the efficiency with which

Predators prevent the monopoiization of the major environ-

menta. requisites by ons species", Paine (1966). However,

?the Laguna Joyuda seems to have much simpler predator prey

relationships. Another possible fa

that may contribute to

the low species diversity present is that the channel which

connects the lagoon with the open sea is very narrow and

shallow, providing somewhat of a physical barrier (refer to

channel flow analysis). In addition, a biological barrier

to sooplankton may be provided by a coral reef and a

Thelzes 2 bed system isnodiately ovterde the channel

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Planktonie oryanisns which have to pass through these sys-

tems in order to go into the lagoon may effectively be reduced by predation.

Throughout the year, the etenophore Hnemiopsis gardeni was present, attaining bleom proportions on several occa~ sions. The density range of Mnemiopsis/n® found in thie study was from 0 to 60/m?. The largest density of the ctenophore was observed for the month of March. The values for this month are higher than 60 individuals/m?. As shown in Figure #16, the graph was extrapolated according to the highest number of ctenophores actually counted in the field, which was 60/m®, During the months of April, May, and June 1977, no ctenophores were found in the samples at all. Tig- ure #17 shows the general trend exhibited by the ctenophore population throughout the year in addition to the fluctu- ations in density per cubic meter of the ctenophore Mnemiopsis and to?al number of plankters throughout a 12 month study The general trend exhibsted by the graph is that, as the population of ctenophores increase, the other smaller members of the planktonic community show a population decrease.

Ynemiopsi

is a carnivore and its importance as a zooplankton predator has been studied by Williams and Baptist (1966);

Bishop (1867); Burrell (1968); Miller (1970) and Kremer (1975)

Little attention has been focused on the biological importance

of the ctenopho!

25 peorle have been concerned more about

how te solve the sarpling ¢!fficulties of catching smaller

---Page Break---

FIGURE #37.

Total Plankton and Total Mneniopsis

per cubic meter per month.

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cube

TAL, PLAUETOR

(RIG SCALED

/MBCLERT SCALE)

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a

plankters when the ctenophore is around. The extreme range in density of the ctencphore throughout the year was observed

to be from close to 0, (0.1/m") to up to 100/m*. We must compare these numbers with the ones presented by Kremer in 1978 in a study on the distribution and abundance of the ctenophore Mnemiopsis leidy: in Narragansett Ray, Rhode Island. She reports having observed very low numbers in winter of 1 to 2 Mnemiopsis/10"n? and up to 100/m* during the summer, ?This study reveals that very high numbers of the ctenophore (up to 100/m) were observed during the months

of March, July and August and very

Ws nuibers for the
months of April, May and June. Questions such as the following may arise: Are the smaller plankton going down because of ctenophore predation, or is it that the phyto~ plankton is not available to the zooplankton, so the latter can not flourish, as well as the ctenophore that predate

on them? These questions can be answered, at least partialdy, if we consider that the phytoplankion dees uot tend te

be a limiting factor in the lagoon. The water has a very

deep green color ali year round. The fact this water hae

a deep gwen color indicating large amounts of phytoplankton

may not be significant as the phytoplankton present could

not be readily available to the zooplankton.

Jt has been pointed our (Kremer, 1976) that Hnemionsis

is not only important for its predation on zooplankton, but

it eso plays a major role as nut

nt

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column. The Smpac on the turnover of nitropen and phos-

phor

nthe water column as been observed by Kremer

(1876). She combined biomes cetimates, determinations of

weight-specif:

om rates at various temperatures

(Kremer, 19754), and estimates of average ambient nutrient

tevels in the water during a peried of ctenophore abundance.

Hier calculations danonstrate that the daily excretion of

anmonia by Mnemions.

sidy! alone accounts for more than

18 of nutrients in the water column, because of their low

organic content (ary weight of 3.4% of live weight; Kremer,

1976), ctenophores do not lock up

utrients in structures,
but act more as nutrient punps, rapidly recycling materials into the water coluun. Kremer, indicates also that nearly half of the etenophore nitrogen excretion may not be im mediately available to the algae. Bacterial action pre- sunably may regenerate these compounds, thue gradually returning the nutrients to the systen in a more usable form

In this sense, the ctenophore have both an immediate and

an indirect, positive feedback to the phytoplankton. Ane

other way of stimulating phytoplankton growth is by preda- tion on the zooplankton conmunity of the system. They just filter the water es they go by, cating almost all they can

find in their path; although ob:

rvations done by the fol-

lowing researchers: Lebour, 1522; Bishop, 1867; Burrell,

1968; Frazen, 1970; Rowe, 1971 and #

ruta, 1874, tend to

indicate cvenopheres prefer the smel

zooplankton. Bishop

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(4967) chow that

© comb jelie can account for £24 of

The mortality of Acartia Tonga Cin vitre measurenents).

Therefore, the data presented henein tends to exhibit

an inverse proportional relationship between the etenophore

Mnemiopsis gana

i and the emaller members of the plank-

tonic communities.

Acartie tonsa (Dana), a calanoié copepod of wo:

d-wide

distribution has been found to tolerate water temperatures from -19C to 32°C (Gonzdlez, 1973). Jeffries (1962) attri-

buted the success of A. tonsa

to such a wide array of en

vironments, to its efficient oenoregulatory mechanism, which permits the animal to go into neritic waters and even into enclosed lagoons. Although duping this investigation ?the temperature and salinity in the lagoon did not vary erastically as stated in the temperature and salinity sec~ tion, previous investigators report extreme changes in both tenperature and salinity. This could also imply that the Laguna Joyuda is a physically controlled system. Such sys= tens are characterized by drastic changes in its physical Parameter like temperature and salinity. Sharp drops or rises in one or both of the latter can make a population decone totally or partially eliminated. Although the changes were not observed during this stucy, they seem very

Likely to occur if we consider the physical characteristics

Ciscussed in the following seecions.

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Gouites (297%) informs

t the Invasion of A.

@ succeysful species in areas 07 high pred

ability, inte

a physically controlled environment (a

process of low

probability aveording to Slobodkin and Sanders, (1969)), does

not seem to 1

We resulted in the elimination of other popu-

lations of this species from venperate and boreal regions.

He also mentions the fa:

that 4. tonsa has developed a

rather complex physiological adaptability to conditions in

predictable environments that hes made it possible, through

successional interaction with congeneric forms, to tolerate

the nen conditions without totally replacing others.

Observations conducted in the Laguna Joyuda show that

A. Zonsa is not just the dominant copepod, but the only one

present, with the exception of a copepod of the genus

Bseudgeyclops found in beds of Ruppia naritina.

Even though A. tonsa is found dominating, which would imply that it fe in a

ther confortable environment, it

exhibits 4 size omaller than chuse found you eluewienes

Table #3 shows the size in mm. for males and fenales at

each of the five stations for each month. Dash lines re-

Present samples not taken. Even though the statistical

population is small (10 specinens, 5 males and § fenales

from cach sample were measured), the general trend ie that

of A. tonsa being smaller than in any other place. If we

compare the standard deviat:

s obtained for the lagoon with

those of Bahie Fosfor:

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cansett Bay, the results

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appear to be close (Table fl). The animals were me:

red

from the front tip of the cephalotorax to the tip of the

caudal ran

in order to compare values with those obtained

previously by Gonzdlez using the same method.

Salinity

Variations in salinity values (at 12 cm. from the sur~

face) observed at Laguna Joyuda during this investigation

are shown in Figure #8. Salinities were measured in the

morning hours. The extreme range in salinity noted throughout the year was from 24 to 32°/,,.

Salinity values increased from April to May; the waters beconing slightly less saline for a short period to increase anein until August, as shown in Figure #18. from the month of September to January, 1977, the general trend is that of 4 slight drop in salinity. Another increase is observed for February.

On Cctober 20-21, 1977, a twenty-four he

study vas conducted in which salinity was observed every hour, etart- ing at 9 A.M., October 20, and ending at 9 A.M., October 21, 3977. Salinities (Figure #9) aid not vary for that day, rentining around 29-30°/e9-

Figure #16 shows the channel that communicates the

legoon with open sea. Salinities of 34.0 °/,, were observed

at the mouth of the channel (lagoon side) when the tide was ce. ing in. On £12 other etecions the

inity values were

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TABLE #4

RSA SIZE IN 8. FOR THREE

DIFFEREN? LOCALITIES

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Temperature, C Fale Size Standard Female Standard

(an) Deviation Size (nm) Deviation

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LAGUEA JOYUDA,

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28.7 0.69 By 0.02

0188 78 0203

0165 6 0102

0.66 78 0.20

0.63 7 0.03

0165 73 010

0:77 88 010

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FIGURE #18.

Temperature °C and salinity °/o,

per month.

61

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be

more or less (1 °/,,), constant for the day, the measure

ments taken.

Salinity vs. depth profiles were taken on several oc-

easions. On August, 1977, at Station B-2 (Figure #3 for

station location) the deepest of all five stations (1.5 m.)

had the following values of 30.5, 30.2, 20.2 /.5 at surface,

-75 m. and 1.5 m., respectively. Lagoon water was slightly

nore saline at the surface but fairly constant throughout

the water colunn. The same small change throughout the

water column was observed again in November, 1877, with

values of 26.8, 26.5, 26.5 °/,, at surface, .75 m. and 1.5 my respectively.

Previous investigators reported salinities which varied considerably with respect to the ones observed during this investigation. Erdman (1963) reported a fish kill at Laguna Joyuda caused by what he claimed to be natural stresses. He concluded that very low salinities were one of the factore which caused the

fish kil, but gives no values for the salinity during that period. Pagan and Austin (1967) reported another fish kill thought to be caused by natural stresses; this time they considered that the most important factors were very high temperatures (35°C) and salinities OF H3-4H P/oq- Bennett (1969) roported salinities of 35°/,5. Garcia (1976) ené Carvajales (1976) reported salinities of 20-6 /oe. respectively. Satinicy nsasurements teken at

Laps

this stu

indicate that the legoon

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is homogeneous un a vertical and longitudinal plane. This

is so because of the shallowness of the system (1.8 m) coupled

with the continuous winds from the southeast which effectively

mix the waters.

?Temperature

Variations in surface water temperature observed at 12

cm, below surface at Laguna Joyuda during this research are shown in Figure 18, based upon temperatures measured during ?the morning. The mean range in temperature noted throughout the vear was from 23.9 to 30.N°C, calculated from five station measurements for that day. Temperature data for this study (Figure #18) show the highest values occurred during the sunmer months of June, July and August. However, a high temperature of 30.4°C was observed in January.

On Detober 20-21, 1977, surface temperatures were observed every hour for twenty-four hours (see Figure £13); readings were initiated et 9 A.M. of the 20th, and ended at 9 A.M. on the 21st. The extreme range in temperature for

that day was from 26.5 to 21.5°C. As ex;

?ted, highest

?temperatures were observed during noontime, and the lowest temperatures early in the morning on the 2ist-

Wnen vemperature vs. depth profiles were taken, verije from 0.0 to 0.8°C, indicating that the lagoon

does not seem to be stratified in regards to temperature.

Ter

Srp drops or vises wer

chse-vea

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indicating that the temperatures are fairly conctant, which provides the biological populations with a less changing, nore stable civironnent. Wind, again, plays a major role in maintaining, the lagoon watere mixed. However, under certain cireunstances the temperature of the waters nay go up to 35°C and probably higher if 1ow wind speeds blow for

@ series of days, together with the fact that very little rain pours down during the dry season. Although the rain water itself cools the water to a certain extent, it is the long sumer days with clear skies and little wind which are of major importance in raising the water temperature. Another factor to be considered is depth.

Figure #2 shows the bathymetry of the lagoon. Mean depth of the lagoon is 1.8 m. The shallowest part of the lagoon being on the east side and the deepest parts include ?two holes of 2.5 and 3.3 mon the northwest and west side of the lagoon. Therefore, the lagoon is fairly shallow. which mekes it easier for the wind to mix the waters. The ratio of exposed surface to depth is rather large, 300 acres with @ mean depth of 1.5m. This exposes a lot of surface

area to radiation which makes it easier to heat and cool.

Water Turbidity Measurements (Secchi Disk)

fmount of suspended matter in the water column is re-

Tables #6 through #17 and Figure #20. Extreme vere from 0.3 t0 0.8 m.

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FIGURE #20.

Water transparency.

87

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ey

These values show very clearly the high amount of suspended matter in the water column. Although sediments and organic matter can be resuspended in the water column very easily by the turbulence created as a result of the wind and the shallowness of the lagoon, a big portion of this suspended material seems to be phytoplunkton. The year-round deep green color of the water supports this assumption. The greatest turbidity was observed when winds were blowing up to 20 kn/hr, This was also observed by Bennett (1959) who states that the highest valuse for turbidity were observed when water level was lowest and ?winds were blowing from the South or southeast. Winds from this direction cause the highest waves in the lagoon since they travel along the entire dength of the lagoon. Bennett (1963) also reports that tur bidity in the Laguna Joyuda ic due primarily to resuspension of bottom sediments and does not necessarily reflect the rate

Of sedinent influx from streams and swamps of the drainage

basin.

Surface Current Analysis

Surface currents were observed at Laguna Joyuda on two occasions in order to try to ebtain information on the possible effects water currents nay have on the distribution

of she planktonic members of the lagoon. ?Table #1 shows

the data obtained during October 20, 1977. Wind direction

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and wav

forned were observed to cone from the southeast

(Table #24). Wind blowing from this direction is along the

trajectory covered by Stations C-1, 8-2, and A-3 (Figure #3).

Table #75

hows surface current velocities which varied

from 0.05 to 0.im/sec with wind speed ranging from $.6 to

14.8 k/he. ?These measurenents were done in the morning.

Afternoon measurements gave surface current speeds from 0.01

to 0.05 m/sec with wind velocities from 0.0 to 19.8 km/hr.

Surface water seems to be piled up againet Station A-3. No bottom current study was done. It is speculated, based on visual observations, that the water sinks and is deflected to the east towards Station C-3, or goes under and back

towards the southeast (Figure #21).

Channel Flow Analysis

On March 5-6, flow measurements were done in the channel that connects the Laguna Joyuda with the sea. A flowmeter was placed in the water at .278 m. from the surface; the dottom was at .55 m. at that place, the deepest part of the

chennel. The mean depth of the latter i

238 my with a

width of 3m. According to the tides predictment (Tide Tables 1978) of March 5-6, 1978, for Puerto Rico, this is the closest place to the lagoon in which tides are actually measureé. The maximum range for that day was 44S m., how

ever, dave obteined by placing two tide gauges, one in the mouth of the channel (uros:

sides Figure (3) end the other

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FIGURE #21. Possible path for currents.

Lighter broken lines represent surface current.

Black line represents bottom current.

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1a

tide gauge at the north «

dof the lagoon, showed that during

the twelve hours the tides were observed on hourly intervals,

the tide only rose 0.3 en

Water movement observations at the channel were started at 2000 on March $3 however, the place we were stationed did not provide @ suitable place for observations. At 2200 the flowmeter was installed at = new site close to the mouth of the channel (sea-side). Water movement was zero. Objects floating in the surface were still and sedinent stirring provided indications that bottom water was also still. At 0030, water started moving in the channel; however, it alter-nated directions. This was observed for 2 hours at the end of which the flow was almost unidirectional into the lagoon. At ON47 Of March 6, actual measurement was started using a floating object, two rods, and a chronometer. Table #25 Provides the time and velocity in m/sec from 0447 to 0854 hrs. Velocities rangec from 0.0 m/sec when water was still at 2200 fon March § to up to G.26m/sec at 0820 on March 6.

From the observed data, it can be estimated that the amount of water coming inte the lagoon for that period was 3u6n°. This anount of water was not very significant if we consider the total volume of water in the lagoon, which is 2.e2x208m?,

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As seen from the dimcneions of

T peoaeuph of thie ceevion, it is

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® shallow and narrow channel which cannot provide the lagoon

with any considerable smount oF sea water. Thus, the channe?

itself is a physical barrier for the organisms in the lagoon,

naking it hard for them to go out of the lagoon. Likewise,

Plankton and nutrients from the sea are prevented from coming

into the lagoon in any considerable quantities.

Dissolved Oxygen

Dissolved oxygen (D.0.) vs. depth measurements data are shown in Tables ?15 and #17. Instrument ma funetion Prevented a large set of date. The values for Decenber, 1977, and February, 1978, indicate extreme range in ais- solved oxygen for these two months (1.4 to 6.6 mi/t, re- spectively). A value of 6.6 mé/t was the highest, but normal P.O. values ranged close to $ m&/t. The value of 1.4 mt/t could be attributed to deoxygenated water coming from a pig- Pen near the station (A-1) or to other unknown causes. At @ temperature of 26.1°C and @ salinity of 20.8°/,,, the water should exhibit saturation at 4.66 (Richard and Corwin, 1956). Therefore, according to their method of calculation, at the surface ve get a value of 84.4% saturation, at mid-depth 85.88 saturation, and at the bottom (1.5 m.) 77.68% saturation, which chows that the lagoon is rather well oxygenated. How- ever, under special cases. 1ike the ones enunerated below, onyzen der:

se water cen become a limit:

ing factor. A

?ore could make oxygen

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unavailable to

© aquatic organisms of the lagoon.

High water temperatures

2. High salinities (42-44°/,,)-

4

High densities of phytoplankton. Late at night,

just before sunrise, the oxygen utilization by

?the phytoplankton can be so high that the water

can become deoxygenated. This also happens in fishponds with an overload of nutrients due to

careless fertilizer management.

Low grazing pressure of zooplankton on the phyto-

plankton.

+ Resuspension of anoxic sedimente by heavy rains.

Predation of ctenophores on the zooplankton

indirectly stimulating high phytoplankton popu-

dations.

concLuszoNs

AS a result of the observations made from March, 1977,

to February, 1978, the following conclusions could be craw

1. The zooplankton of the Laguna Joyuda has been

described for the first tine.

2

The species diversity in the lagoonal system is ia tonsa is the doninant holoplankter.

4. The voracious predetor is present in

the legoon ane, from time to time, attains bloom proportions.

Tt is erreble of controlling A.

sa populations.

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5. The species present in the plankton are endemic

to the Laguna Joyuda.

6. Plankton-wise, the Laguna Joyuda is a very unique

system, having a rather simple predator-prey relationship.

7. It seems that the planktonic populations are biologically accomodated, although physically controlled conditions are not disregarded.

&. Temperature and salinity measurements indicate that the lagoonal system is homogeneous on both planes.

This homogeneity provides no hiceouts for other copepods to exploit, which facilitates the exclusion of other species by Acartia tonsa.

8. Physical paraneters, mainly temperature and sa~ linity, were not limiting factors in regulating the popu- lations of the planktonic community. However, the physical characteristics (area, depth, location, ete.) tend to imply that these factors could become limiting ones if:

(2) venperature goes up to 35°C,

() salinity goes up to 23

*H°Foos

(ce) salinity goes doun to 6°/,5-

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APPENDIX A

Data from March, 1977 through February, 1978.

Includes Tables #6 to #16.

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