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SOME ASPECTS OF THE ECOLOGY OF A COASTAL LAGOON

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SOME ASPECTS OF THE ECOLOGY OF A COASTAL LAGOON

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ABSTRACT

Light penetration, temperature, salinity, oxygen, phosphate, ammonia, silica and plankton were sampled in eight stations, each month, for a year, in Laguna Grande, Fajardo. Seasonal changes were found in most of the physico-chemical parameters, indicating seasonal changes in primary productivity. No seasonal changes were found in species composition of the plankton.

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I appreciate your patience and understanding as I fix the text:

I extend my gratitude for the comments and friendship of Fanny, Lourdes, Manuel, Don Antonio, Don Béez, Néstor, and Pedro for their help.

DEDICATION

To my mother, who has never ceased to encourage me from the day I was born. To my father who had faith in me, but who has ended his journey on earth and is not here to share the results of my labor.

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INTRODUCTION: Puerto

Puerto Rico's coastal natural systems are abundantly rich and productive. The most prolific among these include coral reefs, coastal lagoons, and mangrove forests (C.2.M.P, 1977). The lagoons, which are found on the west, north, and northeast coasts of Puerto Rico, are generally shallow and remain connected to the sea throughout the year via channels, thus they are more or less under tidal influence.

Mangrove forests are found along the perimeters of these coastal lagoons. These forests often feature one or more of the following mangrove species: Rhizophora mangle, Avicennia germinans, Laguncularia racemosa, and Conocarpus erecta. These lagoons have been extensively studied due to their critical ecological roles. They act as buffer zones against natural disasters, protecting surrounding areas from floods and strong winds caused by storms and hurricanes (C.2.M.P., 1977).

By trapping sediments, these lagoons buffer the effects of erosion and build up the coastline (Odum and Johannes, 1975). They also contribute to the development of coral reefs by mitigating the harmful effects of sediments on corals (Mathews, 1967; Connel, 1973; Johannes, 1974). Furthermore, these lagoons are vital as habitats and breeding areas, with 60 to 80% of commercial fishes in tropical areas relying on mangrove lagoons for part of their life cycle (Officer, 1976).

Mangroves contribute significantly to the ecosystem by exporting large amounts of organic matter that is utilized by nearby communities (Lugo and Snedaker, 1974). They also directly utilize nutrients by converting these into organic matter and reducing high nutrient loads in coastal and lagoonal waters (Hobbie, 1976). In addition, they purify water by acting as natural settling basins.

Laguna Grande is a coastal lagoon that is bordered by all four mangrove species. It is separated from the sea by two narrow strips of land and is located on the extreme northeast shore of Puerto Rico at coordinates 18°23.0'N - 65°37.1'W (Fig. 1). It can be divided into three sections (Fig. 2): Main Lagoon, Back Lagoon, and Sorocco Lagoon. These sections have a total area of 872,742 m2, with an average depth of 1.47 m.

The text has a volume of 719,742 m3 (Candelas et al., 1968). The deepest point of the Main Lagoon is 4m, but the average depth is only 2m. It communicates with the Sorocco and Back Lagoons through short, narrow, and shallow channels. At the southeast shore of the Main Lagoon, there is a channel 1.5 km long with an average depth of 0.7 m that connects the Main Lagoon with Las Croabas Bay. At the southwest shore is the channel leading to the Sorocco Lagoon. The channel is 200 m long and 0.5 m deep. At the east is the channel leading to the Back Lagoon. This channel is 100 m long and 0.5 m deep.

Cobezas

FIG. 1

FIG. 2 - *, Main Lagoon ©. Sorocco Lagoon B. Back Lagoon D. Land Sectors and Stations of the Lagoon System

Sorocco Lagoon is 0.5 m deep. The south shore of the Soroceo sector is bordered with houses and small restaurants. The Back Lagoon is 0.5 m deep and is characterized by many Rhizophora mangle islands. Candelas et al. (1968) studied the Laguna Grande complex and concluded that it was a unique area due to its beauty and ecological diversity; he recommended that the area should be conserved. Díaz-Piferrer (1968) did not recognize the value of coastal lagoons in terms of detrital and/or nutrient contribution, nor their role as nurseries for many reef fishes and breeding and feeding area for many birds. This investigator concluded in his study that the lagoon had little ecological value. Subsequently, the Puerto Rico Conservation Trust recognized the high ecological value of this area and acquired the land in 1976. The Trust, in an effort to gain basic information about the lagoon and the land that surrounds it for its management, requested the C.E.E.R. to carry out various studies to characterize the area. This study was performed in part as a result of this commission. The Laguna Grande ecosystem was studied in order to determine its present ecological state. In order to accomplish this, several physico-chemical and biological

parameters were monitored over time.

The current characteristics of the lagoon can be assessed by its flushing rate, the types of species present, and the diversity found in the plankton. The measurement of limiting nutrients such as phosphate, ammonia, and silica is crucial to understanding what is available to the lagoon's phytoplankton. The measurement of dissolved oxygen provides insight into the lagoon's productivity. The gathered data provides a description of the lagoon in terms of its plankton species, diversity, and the studied physicochemical parameters. Some of this data allows for comparison with the findings of Candelas et al. (1968) and Diaz-Piferrer (1968).

MATERIALS AND METHODS

Several parameters were monitored over a period ranging from 6 to 12 months. The physicochemical parameters included light penetration, temperature, salinity, oxygen, phosphate, nitrogen, and silica. The biological parameters were the relative abundance of planktonic species, species percent composition, and diversity.

Eight stations were chosen for the study (Fig. 2). These stations were located at representative sites of the lagoon complex, as determined in a previous study by the author.

Station #1: The surface water of the channel that leads from the open sea to Las Croabas Bay.

Station #2: This is 4m deep and is at the bottom of Station #1.

Station #3: Located on the lagoon side of the channel that connects the Main Lagoon and Las Croabas.

Station #4: Located inside the Sorocco Lagoon.

Station #5: Located at the SW corner of the lagoon at the entrance of the channel leading from the Main to the Sorocco Lagoon.

Station #6: The surface water of the center of the Main Lagoon.

Station #7: This is 4 m deep and is at the bottom of Station #6.

Station #8: Located in the Back Lagoon.

Stations #3, #4, #5, and #7 are 0.5m deep. All physicochemical parameters, except for light penetration, were measured at mid-depth for these stations. Light penetration was measured at the surface and bottom.

Stations: Measurements and samples for all physico-chemical parameters in Station I and VI were taken at the surface and in Stations II and VII at the bottom. Samples for all physico-chemical and biological parameters were taken once a month from January to December, 1978. Samples and measurements of chemical parameters were performed in triplicates.

PHYSICO-CHEMICAL PARAMETERS

a) Light Penetration: Light penetration is one of the fundamental ecological factors in the marine environment (Holmes, 1957). The amount of light that penetrates the lagoon waters will limit the primary productivity and oxygen production. Light penetration was measured at all stations at the surface of the water as well as that reaching the benthos with a Photonatic underwater light meter. The results for light penetration are expressed in terms of extinction coefficient and light penetration.

Extinction coefficient is expressed by: c= (log 1 > Log / 2 any day) where C is the extinction coefficient as measured by the underwater photometer and Log I, is the base ten logarithm of the light intensity at depth Z and Log I (2#1) is the logarithm of the light intensity at depth Z+1, (A.M.S., 1959). Light penetration is the percentage of measured surface light that reaches the benthos of a given station.

b) Temperature: Temperature is an important factor governing the occurrence and behavior of life (Gunther, 1957). Temperature measurement was used as an aid to determine the homogeneity of the water column. If a temperature change is found when a profile is performed, it may indicate temporally stratified water masses or two distinct water masses. Temperature was measured by means of a YST Model 33 salinity and temperature at all stations according to the protocol cited earlier. Before each trip to the lagoon, the thermistor was calibrated against a laboratory-grade thermometer. Temperature results are expressed in terms of °C.

c) Salinity: Salinity is defined as the total amount of solid material in grams contained in one

4) Oxygen: oxygen is essential to most forms of life. It is an important by-product of photosynthesis and is consumed by the respiration of aerobic organisms as represented by the simple reversible equation. Photosynthesis: $CO + H_2O = C_6H_{12}O_6 + O_2$. Respiration: $C_6H_{12}O_6 + O_2 = CO_2 + H_2O$. Dissolved oxygen was measured at all stations according to the protocol cited earlier with a YSI Model 55 dissolved oxygen meter. After each trip, the meter was checked, in a similar way as described for the salinity meter, against the Winkler titration procedure (Strickland and Parsons, 1968). The oxygen measurements obtained in this way will serve as

Indicators of mixing and the degree to which oxygen may be limiting are important. Oxygen results are expressed in ng O_2/l or parts per million.

Nutrients such as phosphorus and nitrogen are necessary and can limit the primary producers, as stated by Barnes (1957) and Hobbie (1976). Silica is required for the formation of cell walls of diatoms, thus becoming limiting (Sadava and Volcan, 1977). These elements are incorporated into the producers when there is enough light for photosynthesis and are returned to the environment through excretion, death, and decay.

Water samples for nutrient analysis were taken at depths specified in our sampling protocol with a horizontal sampler, placed in polyethylene bottles in the dark and in an ice chest. Upon arrival at the laboratory, all samples were filtered through a 0.45 membrane filter and stored at -20°C until the next day for analysis.

Results of all nutrient analysis are expressed in µg/l. Total phosphorus was measured using the method described by Strickland and Parsons (1968). Samples for total phosphorus were collected and treated according to the protocol cited earlier (Cooper, 1933; Collier and Kenneth, 1953; Ketchum et al, 1955).

Samples for ammonia were collected and treated according to the protocol cited earlier. 0.4 gr./ml of phenol were added to the water that was used for this test to minimize the uptake of ammonia by phytoplankton, (Degobiss, 1973; Newell, 1967). Ammonia was determined using Strickland and Parsons' (1968) method.

The form of silicon utilized by diatoms and presumably other silicious algae, is silicic acid (Darley, 1974). Molybdate was added to the sample and if any silicic acid was present, it was transformed into silicate (Strickland and Parsons, 1968). Although all the silicic acid does not react with the molybdate, the measurement of silicate probably gives a meaningful measure of the amount of silica available to the growing of plant cells (Robinson, 1953).

Water samples for silica were collected and treated according to the

"Protocol cited. Biological Parameters:

a) Plankton: Plankton tows were taken with 80” mesh nets once every month at the Main Lagoon and Las Croabas Bay. The tows were taken at one location near Station I and another near Station VI. The samples were preserved in 4% buffered formalin. The organisms were identified under dissecting and/or compound microscope with the aid of taxonomic keys provided by Smith, 1977; Owre and Foyo, 1967; González and Bowman, 1965; Newell and Newell, 1963; and Rose, 1933. After identification of the organisms, they were counted, and the relative abundance of species, species composition, and Shannon-Weaver diversity index were calculated per tow. Plankton was compared within and among sites with the aid of Simpson's similarity index (Amspoker and McIntire, 1978).

Simpson's similarity index (SIMI) is expressed by: 2 8 s 2 SIMI = (1,2) =S 0 Pri p2i 7 CS pri? p2i2y ro. Where SIMI is the degree of similarity between assemblages 1 and 2; P1i and P2i are the proportions of individuals represented in the i-th taxon in assemblages 1 and 2, respectively; and S is the total number of taxa in the sample. Assemblages are considered to be significantly similar when the SIMI value is equal to or greater than 70 percent. Trellis diagrams with SIMI values were constructed for each assemblage.

Data Analysis: All physico-chemical parameters were tested with one-way ANOVA (Sokal and Rohlf, 1969) to detect differences among stations and within stations (differences over time) for each parameter. Where significant differences were found, Duncan's new multiple range test (Steel and Torrie, 1960) was applied to the data. In Duncan's test, the data (of a given parameter) is ranked from the highest value to the lowest. Then the value of the error sum of squares (from ANOVA) is located at the 0.05 level of Duncan's table, where a protection value is obtained. If the difference between the means being compared is greater than the protection value obtained, the means are statistically different and thus, assigned a..."

Different letters, i.e., the results for extinction coefficient yield values: Sorocco Lagoon, 1.94; Back Lagoon, 1.47; Main Lagoon, 0.50; and Crosbas Bay, 0.26. When 1.94 is compared with 1.47, 0.50, and 0.26, the protection level is only exceeded with 0.50 and 0.26. The procedure is repeated with each value from high to low until all values are compared with the ones that follow it. Finished results are as follows:

Page 4
Sorocco Lagoon, 1.94 a
Back Lagoon, 1.47 a
Main Lagoon, 0.30 b
Croabas Bay, 0.26 B

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RESULTS AND DISCUSSION
The results and discussion deal mainly with Stations: I, Surface waters of Las Croabas Bay; II, Bottom waters of Las Croabas Bay; IV, Sorocco Lagoon; VI, Surface waters center Main Lagoon; VII, Bottom waters center Main Lagoon, and VIII, Back Lagoon. To aid in the understanding of figures, Stations III, the channel to Las Croabas, and V, the channel to the Sorocco area, are not included. Stations III and V are intermediate areas, but behave more or less as the other shallow Stations, IV and VIII.

PHYSICO-CHEMICAL PARAMETERS

1) Light penetration
Light penetration was measured for a period of eight months. An extinction coefficient table (Appendix A, Table 1) was constructed from the data obtained during the study. The extinction coefficient values range from 16 found in Station I, Las Croabas, in the month of August, to 2.44 in Station IV, Sorocco, in the month of October. Average values per Station were 1.94 for Sorocco Lagoon; 1.47 for Back Lagoon; 0.30 for Main Lagoon, and 0.26 for Croabas Bay. From Appendix A, Table 1 and Figure 3, we observe no significant differences in extinction coefficient per month (within Stations), but significant among Stations, as confirmed by one-way ANOVA analysis (Appendix A, Table 2). To determine between which Stations there was a significant difference, Duncan's (Appendix A, Table 3) multiple range test was used.

Page 16
(Figure 3 was here)

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The study found no difference between Stations IV (Sorecco Lagoon) and VIII (Back Lagoon), and no difference between Stations IT (Croabas Bay) and VII (Main Lagoon). However, the group of Stations IV and VIII significantly differed from Stations IT and VII. The extinction values were lower for the deeper stations, indicating greater water transparency. The percentage of surface light reaching the benthos (light penetration) is detailed in Appendix A, Table 4 and Figure 4. An increase in light penetration was observed in all stations during the intermediate months of the year, as confirmed by one-way ANOVA and Duncan's test (Appendix A, Tables 2 and 3).

In terms of temperature, water temperature values obtained during the study are included in Appendix A, Table 5 and Figure 5. During the study period, temperatures were higher in the shallow stations, with an average high of 32° for Station IV (Sorocco Lagoon) and 33° for Station VIII (Back Lagoon). The average high for the deeper stations was 29° for Stations I (Croabas surface) and IT (Croabas bottom), and 31° for Stations VI (Lagoon surface) and VII (Lagoon bottom).

The average low temperatures were 25.5° for Stations I, IT, and IV; 25° for Stations VII and VIII; and 26° for Station VI. To determine if there were statistical differences among stations and within them for this parameter, a set of one-way ANOVA was performed (Appendix A, Table 2). The results indicated no statistical differences between stations, but significant differences between months. A Duncan's test was performed to determine which months were statistically different (Appendix A, Table 3). This test indicated, with some degree of overlap, that temperatures were higher in the intermediate months of the year and lower in the first and last months of the year.

As for salinity, values obtained during the study are included in...

in ppm. The highest and lowest values are found in the area of Sorocco with values of 11.1 in July and 1.0 in September. The average O2 values per station were 5.95 for Croabas, 5.25 for Main Lagoon, 4.70 for Sorocco, and 4.20 for the Back Lagoon. When the data is analyzed by one-way ANOVA, no significant difference is found among stations, but a significant difference within stations, (Appendix A, Table 2). Duncan's test was used to find which months are statistically different (Appendix A, Table 3). From Duncan's test, it was found that March is different from all the rest with a D.O. reading of 7.4; and July and May with values of 5.9 and 5.5 are different from September with 3.6. All the rest of the months are similar among themselves.

e) Nutrients

Phosphate data is contained in Appendix A, Table 8 and Figure 8. The values are expressed.

"In 1.0 x 1072 g/1, the lowest phosphate value of 1.0 was found in September at Las Croabas bottom, and in October at Las Croabas surface and Main Lagoon bottom. The highest was 10.0, found in August at Main Lagoon surface, and in December at Las Croabas surface. The average values were 3.95 for Las Croaba, 4.3 for Sorecco, 3.4 for the Main Lagoon, and 4.0 for the Back Lagoon. Upon analyzing the data with one-way ANOVA, no significant difference was found among Stations, but significant differences were found within Stations (Appendix A, Table 2). Duncan's test was used to determine which months were significantly different from each other (Appendix A, Table 3). December and June, with values of 5.7 and 5.4 respectively, are statistically different from October, which had a value of 1.6, but not from each other.

The nitrogen data was measured in terms of ug-at/1 of ammonia and can be found in Appendix A, Table 9 and Figure 9. The highest value was 5.00, found in July and August, at the Sorecco area. The lowest was 1.30, found in June, at the Back Lagoon. The average values were: Sorecco, 3.46; Main Lagoon, 2.0; Back Lagoon, 1.945; and Las Croabas, 1.95. One-way ANOVA was performed to identify significant differences among Stations or within Stations. No significant difference was found within Stations, but significant differences were found among Stations (Appendix A, Table 2). Duncan's test was used to determine which Stations were statistically different from each other. Station IV, Sorocco Lagoon, is statistically different from all other Stations (I, II, Croabas surface and Bottom; VI, VII, Main Lagoon surface and bottom; and VIII, Back Lagoon), while these are not significantly different among themselves.

Silica is expressed in terms of ug-at/A of silicate and can be found in Appendix A, Table 10, and Figure 10. The highest value for silica was 2.71, found in August, at the Back Lagoon. The lowest was 1.41, found in November, at Las Croabas. The average values per Station were: 2.40, Back Lagoon; 2.28,

Soracco: 1.94, Croabas: 1.95, and Main Lagoon. When the data was analyzed through one-way ANOVA, no significant difference was found within the Stations but significant differences among the Stations (Appendix A, Table 2). Duncan's test was used to determine which Stations were significantly different from each other (Appendix A, Table 3). Station IV, Soracco, is similar to VIII, Back Lagoon, and Croabas is similar to the Main Lagoon, but both groups are different from each other.

BIOLOGICAL PARAMETERS

a) Plankton

The zooplankton and phytoplankton expressed in terms of numbers of relative abundance are found in Appendix A, Tables 11, 12, 13, and 14. These tables contain the calculated Shannon-Weaver diversity index on a per-month basis. It is found that the diversity for phytoplankton is higher in Las Croabas and lower in the Main Lagoon. The diversity of the zooplankton is higher in the Nain Lagoon.

In Figures 11 and 12, Trellis diagrams for Las Croabas and Main Lagoon phytoplankton, and the Trellis diagram for Las Croabas vs. Main Lagoon phytoplankton (Fig. 13), show generally no significant similarity in succeeding months. In Figure 14, the Trellis diagram for Las Croabas zooplankton shows significant similarities between January and February, June and July, August and September, and October and November. The Trellis diagram for the Main Lagoon zooplankton (Fig. 15), showed not only significant similarities between succeeding months, but also when any month is compared with any other month; thus indicating that the zooplankton community is homogeneous throughout the year. When Croabas Bay is compared with the Main Lagoon, similarities are found in January vs. January.

FIGURE 11
Trellis diagram for Las Croabas phytoplankton
*Presented data is a set of similarity values.

The text appears to be a report or study with diagrams and figures. However, it's difficult to provide a corrected version as there's a lack of context, and the figures and diagrams are not properly displayed in this format.

Moreover, some parts of the text appear to be distorted or corrupted which makes it difficult to interpret. If possible, please provide additional information or context.

In temperate areas, authors such as Raymond (1963) believed that due to the high levels of solar radiation that prevail throughout the year and the presence of a permanent thermocline, the tropics were only capable of low levels of primary productivity that proceeded at fairly steady levels. However, the work of Beers, Steven and Lewis (1965), Gonzalez (1965), and Cintron (1969) provided evidence of seasonal fluctuations in the primary productivity of the tropics.

When the relative species composition (refer to Appendix A, Tables 15, 16, 17, and 18) is compared with the results of the physico-chemical parameters, no pattern is found between any planktonic organism and a given combination of the physico-chemical parameters. This lack of pattern can be attributed to several reasons:

a) No significant differences were found between the stations sampled for plankton (Las Croabas versus Main Lagoon) in terms of light penetration, temperature, salinity, dissolved oxygen, phosphate, ammonia, and silica.

b) Perhaps the most critical factor that does not contribute to the establishment of a relationship is the inability to perform quantitative sampling of planktonic organisms.

Seasonal changes have been found in light penetration (extinction coefficient), temperature, dissolved oxygen, and phosphate. These changes suggest a seasonality in the planktonic productivity of the lagoon. These can only be attributed to the rain pattern of the area over the past 30 years, where heavy rains occur in Spring and Autumn (NO. AL AL, 1978).

The lack of measurable amount of seasonality in the concentration of nutrient elements such as ammonia and silica is probably due to a steady and high turnover rate of the nutrients from the environment to the organisms, resulting in the residence time of the free element being practically zero.

In terms of light penetration (extinction coefficient), ammonia, and silica, differences exist between stations. The differences in light penetration are between the deeper stations, Las Croabas and the Main Lagoon versus the shallow stations, the Back Lagoon, and Sorocco.

Lagoon. These are due to the nature of the stations. In the shallow stations, the fine sediments are more likely to be stirred up by the turbulence caused by the wind or any other agent.

The differences between stations for ammonia and silica are also due to the nature of the stations. In Station IV, Sorocco Lagoon, the levels of ammonia are higher than the rest of the stations, while these are not different among themselves. This is most likely due to the dumping of raw sewage by several houses that border the south shore of the Sorocco Lagoon. The limited circulation within Sorocco Lagoon and this sector (Sorocco) with the Main Lagoon allows this extra ammonia load to be filtered out in this area for its effects are not observed in the Main Lagoon end of the channel that joins both sectors. High levels of silica are observed in Station VIIT, Back Lagoon. In this sector, the bottom is covered with a bed of diatoms, a high turnover rate in these, and a large and unknown source of silica could explain the high silicate levels.

One of the objectives of this study was to compare the current ecological state of the lagoon with some of the data from Candelas (1968) and Diaz-Piferrer (1968). Candelas found oxygen levels of 9.15 ml/l to 2.6 ml/l and salinity of 30.10 ‰ to 43 ‰. Diaz-Piferrer found salinities of 43 ‰ to 54.4 ‰. In general, taking into consideration differences in instrumentation and error, this study has found about the same data as Candelas (1968) and Diaz-Piferrer (1968) with the addition of a more complete list of phytoplankton and zooplankton (Appendix A, Table 19), and seasonal data for all the physico-chemical parameters studied.

Examination of the earliest photographic record (Plate 1) compared with later and actual photographs (Plate 2) reveal that very little change has occurred over the past 42 years. This photographic evidence indicates that the lagoon system boundaries are more or less stable. If left undisturbed, two factors are considered.

The following text has been corrected for typographical errors and logical organization:

Of utmost importance in order to maintain the equilibrium in the system: The channel that connects to Las Croabas should be maintained open, as the fishermen of the area have done so for at least 40 years or more. No dredging or modifications should be allowed to the channel.

The Sorocco Lagoon, bordered by small houses and restaurants, is suffering the effects of these establishments dumping raw sewage into the area. This practice should be stopped, or at the very least, no further constructions should be allowed on the southern border of the area.

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SUMMARY AND CONCLUSIONS

Light penetration, temperature, salinity, dissolved oxygen, phosphate, ammonia, silica, and plankton were sampled for a period of about a year at the Laguna Grande system. The results indicate that Laguna Grande is a coastal lagoon that supports abundant marine flora and fauna. The system is free from fresh water influences other than precipitation and runoff, and its salinities are quite similar to sea water.

No obvious relationships were found between the plankton and physico-chemical parameters. There was no seasonal variation in species composition. There is a very high similarity of zooplankton in the Main Lagoon within itself, but none with the phytoplankton or with Las Croabas Bay.

Seasonal changes were found in all the physico-chemical parameters except for ammonia and silica. These seasonal changes indicate seasonal changes in planktonic productivity, with peaks in Spring and Autumn. Observed changes are most probably caused by heavy rains in Spring and Autumn.

The lagoon has been highly stable (based on photographic evidence) for many years. It is the belief of the author that in order to maintain this stability, the recommendations stated earlier should be observed. In order to detect the mechanisms that allow a highly stable zooplankton community, while the phytoplankton is not as stable, further research is required.

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Strickland, J. D. H., and Parsons, T. R.

The text appears to be a combination of different book references, page break indicators, and seemingly random alphanumeric strings. Here's an attempt to fix this text by separating the references, removing the page break indicators, and disregarding the random strings:

"1968. Practical Handbook of Sea Water Analysis, 2nd ed. Fisheries Research Board of Canada, Bulletin #167, 310 pp.

Tait, R. V., and De Santo, P. S., 1972. Elements of Marine Ecology. Springer-Verlag, N.Y. 327 pp.

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1970. Nitrogen deficiency in tropical Pacific Ocean phytoplankton. Photosynthetic parameter in poor and rich waters. Limnology and Oceanography, 15:380-385."

Please note that some parts of your text were not clear and could not be fixed.

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