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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.

ACKNOWLEDGMENTS:

The author is grateful most particularly to Richard G. Clements who made comments at all stages of the work, revised the proposal, the final draft, and helped with the statistical analysis, and to Edmond Bonneau without whose help the proposal and the actual setting up of the work, and the identification of the phytoplankton would not have been possible; his aid and criticism were invaluable, and to Juan González without whose training, work with the zooplankton would have been too difficult, and to Damaris Viera; without her help in the field, the work would have been tedious and intolerable, and to Arthur McB. Block who permitted the use of his laboratory facilities for the chemical analysis which was so critical to this project.

The help and comments of the graduate committe; Manuel Vélez, Richard Thomas, Gustavo Candelas, and Gilberto Cintrón was invaluable. My special gratitude to Gustavo for his understanding and for accepting the role of Thesis Director; to Gilberto for his great help and for his comments at all stages and final form of this document.

My gratitude to all the personnel of the C.E.E.R., most particularly to Iván Rosas for his comments and friendship; and to Fanny, Lourdes, Manuel, Don Antonio, Don Báez, Néstor, and Pedro for their help.

D E D I C A T O R Y

To my mother because she has not ceased to encourage me from the day I was born to this day, and to my father who had faith in me, but because his journey on earth ended is not here to share the results of my labor.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION:

Puerto Rico's coastline natural systems are very rich and productive. Among the most productive: coral reefs, coastal lagoons and mangrove forests are found, (C.Z.M.P, 1977).

The lagoons found in the west, north and northeast coasts of Puerto Rico are in general shallow and are connected during all the year to the sea via channels and thus are more or less under tidal influence.

Along the perimeter of these coastal lagoons are found mangrove forests. In most of these we can find one or more of the mangrove species: *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa* and *Conocarpus erecta*.

These lagoons have been studied because of their ecological roles as: buffer zones against natural disasters, they protect the areas that surround it against the floods and strong winds caused by storms and hurricanes (C.Z.M.P., 1977); by trapping sediments they buffer the effects of erosion and build up the coast line (Odum and Johannes, 1975), and aid in the development of coral reefs by stopping the harmful effects of the sediments on the corals (Mathews, 1967; Connel, 1973; Johannes, 1974); are also important as habitats and breeding areas, 60 to 80% of commercial fishes in tropical areas depend on mangrove lagoons for part of their life cycle (Officer, 1976); mangroves export large amounts of organic matter that is utilized by nearby communities (Lugo and Snedaker, 1974); mangroves also directly utilize nutrients by fixing these into organic matter and reducing high nutrient loads in coastal and lagoonal waters (Hobbie, 1976); they also act as natural filters for the purification of waters by acting as natural settling basins.

Laguna Grande is a coastal lagoon bordered by the four mangrove species, and separated from the sea by two narrow strips of land, located at the extreme northeast shore of Puerto Rico 18°23.0'N - 65°37.1'W (Fig. 1). It can be divided in three sections (Fig. 2): Main Lagoon, Back Lagoon and Sorocco Lagoon. They have a total area of 872,742 m^2, an average depth of 1.47 m and a volume of 719,742 m^3 (Candelas et al, 1968).

The deepest point of the Main Lagoon is 4 m, but the average depth is only 2 m. It communicates with the Sorocco and Back Lagoons by means of short, narrow and shallow channels.

At the SE 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 SW 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

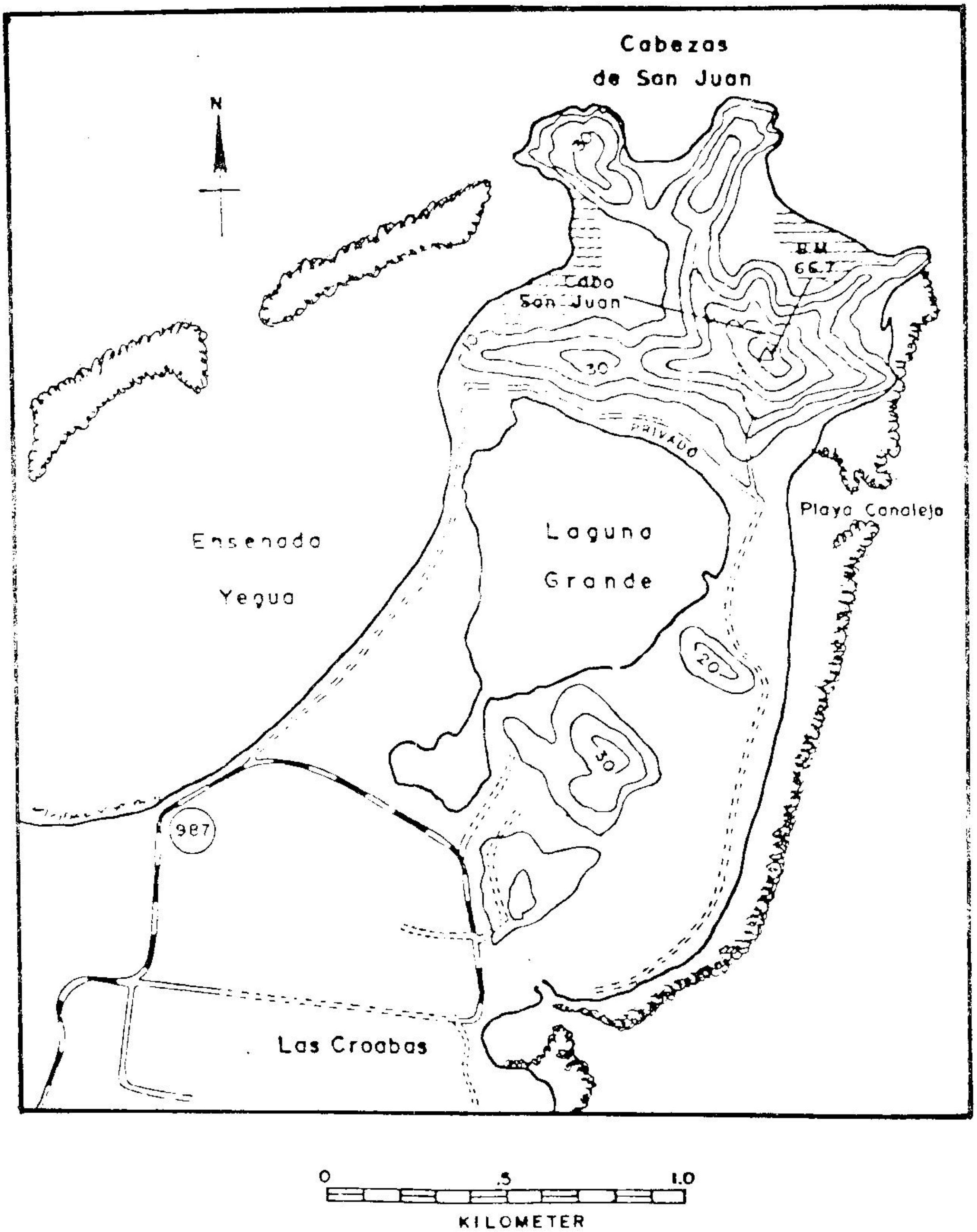
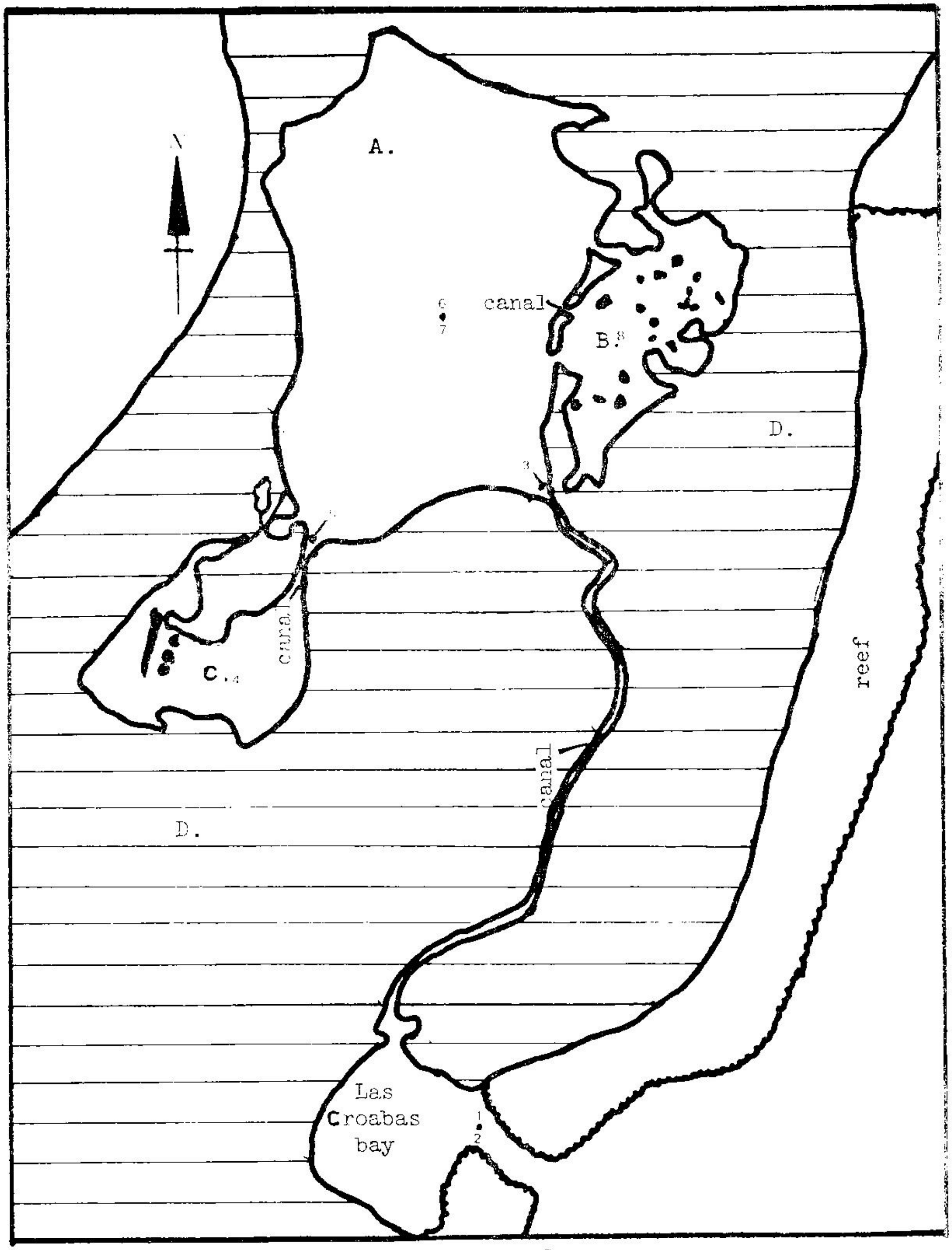


FIG. I Map of Las Cabezas de San Juan showing position of Laguna Grande



A. Main Lagoon C. Sorocco Lagoon

B. Back Lagoon D. Land

FIG. 2 - Sectors and Stations of the Lagoon System

and 0.5 m deep.

Sorocco Lagoon is 0.5 m deep. The south shore of the Sorocco 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 present characteristics of the lagoon may be judged by its flushing rate and by the types of species and by the diversity found in the plankton. The measurement of limiting nutrients such as: phosphate, ammonia and silica are important in order to have an idea of what is available to the phytoplankton of the system. The measurement of dissolved oxygen gives an indication of the productivity of the lagoon.

The data obtained describes the lagoon in terms of its plankton species and diversity and the physico-chemical parameters studied. Some of this data allows comparison with the data of Candelas et al (1968) and Díaz-Piferrer (1968).

MATERIALS AND METHODS

Several parameters were monitored for a period of 6 to 12 months. The physico-chemical parameters were: light penetration, temperature, salinity, oxygen, phosphate, nitrogen and silica. The biological parameters were: planktonic species relative abundance, species percent composition and diversity.

Sampling:

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

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

Station # II: Is 4 m deep and is the bottom of Station # 1.

Station # III: Is located on the lagoon side of the channel that joins the Main Lagoon and Las Croabas.

Station # IV: Is located inside the Sorocco Lagoon.

Station # V: Is located at the SW corner of the lagoon in the entrance of the channel that leads from the Main to the Sorocco Lagoon.

Station # VI: Is the surface water of the center of the Main Lagoon.

Station # VII: Is 4 m deep and is the bottom of Station VI.

Station # VIII: Is located in the Back Lagoon.

Stations III, IV, V and VIII are 0.5 deep and the measurements and samples for all physico-chemical parameters except for light penetration, were taken at mid-depth. Light penetration was measured at the surface and bottom in these 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 Photomatic underwater light meter.

The results for light penetration are expressed in terms of extinction coefficient and % light penetration.

Extinction coefficient is expressed by:

$$C = (\text{Log } I_Z - \text{Log } I_{(Z+1)}) \;/\; Z-(Z+1)$$

Where C is the extinction coefficient as measured by the underwater photometer and Log I_Z is the base ten logarithm of the light intensity at depth Z and Log I (Z+1) is the logarithm of the light intensity at depth Z+1, (A.M.S., 1959).

% light penetration is the % 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 YSI 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 kilogram of sea water when all the carbonate has been converted to oxide, the bromine and iodine replaced by chlorine, and all the organic matter completely oxidized, (Pearse and Gunther, 1957; Baker, 1966).

Salinity is used to characterize water masses in the same way as temperature measurements. If the salinity is the same throughout the water column, the body of water is mixed; but if salinity yields different values it indicates different masses of water column. If the change in salinity is gradual with depth, the water masses mix somewhat in their borderlines; but if the salinity change is abrupt, we have two stratified bodies of water (masses of water which do not mix with one another).

Salinity was measured with a YSI Model 33 salinity and temperature meter at all Stations according to the protocol cited earlier. A water sampler was used to take samples at least in two of the Stations. The samples were fixed in the field placed in tighly stoppered polyethylene bottles taken to the laboratory and analyzed with Strickland and Parsons (1968) low precision salinity titration procedure. The values obtained were compared with those of the salinometer in the field, and a correction factor was introduced where necessary for the measurements with the salinometer.

Salinity results are expressed in grams of dissolved salts / kilogram, parts per thousand or 0/00.

d) 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.

$$CO_2 + H_2O \underset{\text{Respiration}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} CH_2O + O_2$$

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. Oxygen results are expressed in $\mu g\ O_2$ /l or parts per million.

e) Nutrients

Phosphorus and nitrogen are needed and are limiting to the primary producers, (Barnes, 1957 and Hobbie, 1976). Silica is needed for the formation of cell walls of diatoms, thus becoming limiting (Sadava and Volcan, 1977). These are incorporated into the producers when there is enough light for photosynthesis and are returned to the environment thru excretion, death, and by decay.

Water samples for nutrient analysis were taken at depths specified in our sampling protocol with an horizontal sampler, placed in polyethylene bottles in the dark and in an ice chest. Upon arrival to the laboratory, all samples were filtered through a 0.45μ membrane filter and stored at -20°C until next day for analysis. Results of all nutrient analysis are expressed in μg-at /1.

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, 1935; 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 μ mesh nets once every month at the Main Lagoon and Las Croabas Bay.

The tows were taken: one nearby Station I and the other nearby 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 by Smith, 1977; Owre and Foyo, 1967; González and Bowman, 1965; Newell and Newell, 1963; and Rose, 1933. After identification of the organisms, these were counted, relative abundance of species, % species composition and Shannon-Weaver diversity index was 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:

$$SIMI = (1,2) = \sum_{i=1}^{S} P1i \quad P2i \; / \; (\sum_{i=1}^{S} P1i^2 \; P2i^2)^{1/2}$$

Where SIMI is the degree of similarity between assemblages 1 and 2; P1i and P2i are the proportions of individuals represented i-th taxon in assemblages 1 and 2, respectively; and S is the total number of taxa in the sample. When the SIMI value is equal or greater than 70 percent, the assemblages are considered to significantly similar. 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 in 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 error sum of squares (from ANOVA) is located in the 0.05 level of Duncan's table. Here a protection value is obtained. If the difference between the means that are compared is greater than the protection value obtained, the means are statistically different, and thus, assigned a different letter, i.e., the results for extinction coefficient yield values: Sorocco Laggon, 1.94; Back Lagoon, 1.47; Main Lagoon, 0.30 and Croabas Bay, 0.26.

When 1.94 is compared with 1.47, 0.30, and 0.26, the protection level is only exceeded with 0.30 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:

Sorocco Lagoon	1.94 a
Back Lagoon	1.47 a
Main Lagoon	0.30 b
Croabas Bay	0.26 b

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, channel to Las Croabas and V, 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

a) Light penetration

Light penetration was measured for a period of eight months. An extinction coefficient table (Appendix A, Table I) was constructed from the data obtained during the study. The extinction coefficient values are from 0.16 found in Station II, 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 Sorocco Lagoon; 1.47 Back Lagoon; 0.30 Main Lagoon, and 0.26 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

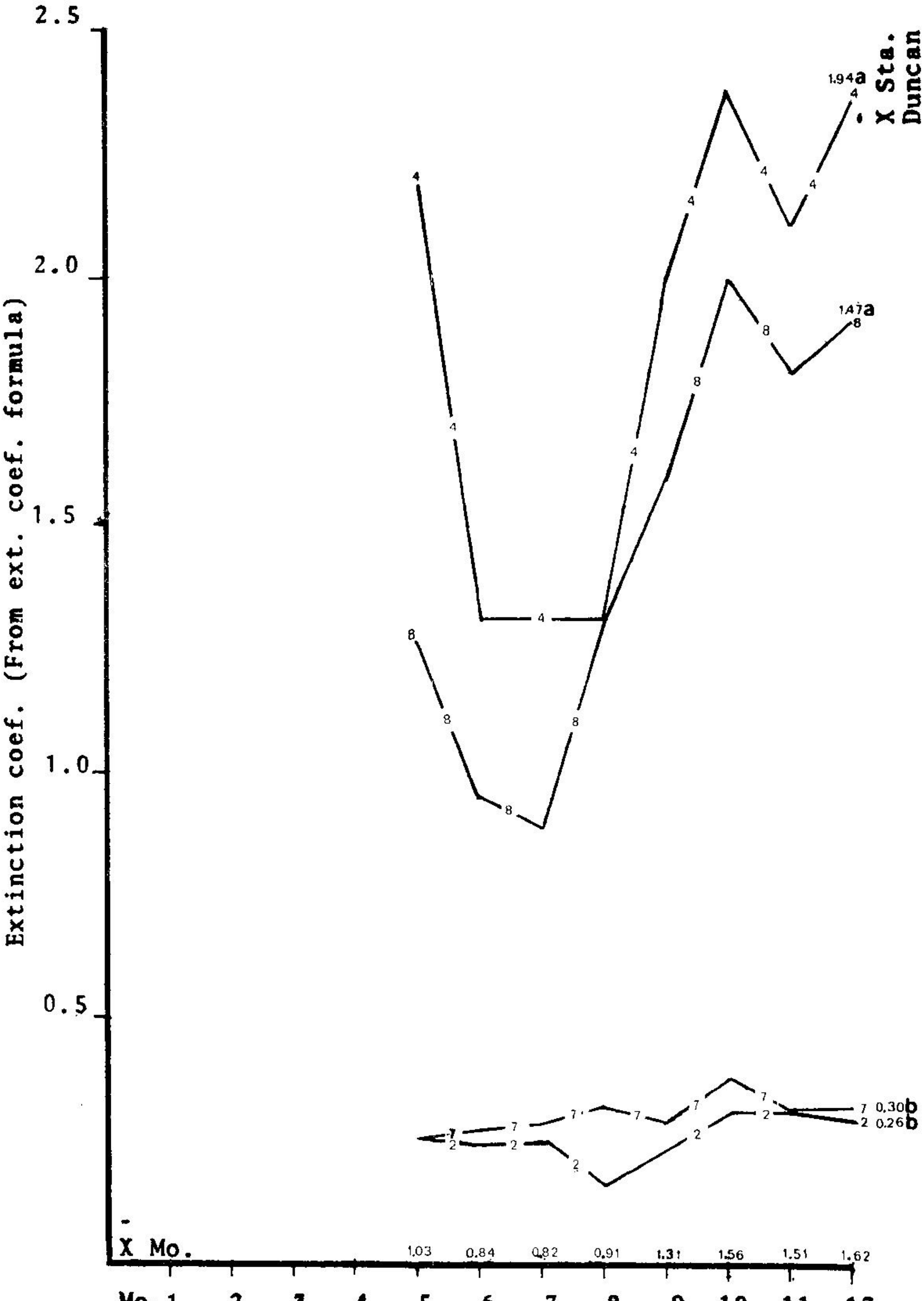


Fig. 3 Extinction coef. per Month and Station

significant difference Duncan's (Appendix A, Table 3) multiple range test was used. It was found that there is no difference between Stations IV, Sorocco Lagoon, and VIII, Back Lagoon; and no difference between Stations II, Croabas Bay, and VII, Main Lagoon; but the group of Stations IV and VIII are significantly different from that of Stations II and VII. The extinction values are lower for the deeper Stations; thus indicating that the water is more transparent in these Stations.

The percent of surface light that reaches the benthos (% light penetration) is found in Appendix A, Table 4 and Figure 4. From this Table and Figure, it can be observed an increase in light penetration in all Stations during the intermediate months of the year. This is confirmed by one way ANOVA and Duncan's test (Appendix A, Tables 2 and 3).

b) Temperature

Water temperature values obtained during the study are included in Appendix A, Table 5 and Figure 5; and are expressed in °C.

During the study period the temperatures were higher in the shallow Stations, with a high average of 32° for Station IV, Sorocco Lagoon, and 33° for Station VIII, Back Lagoon. The average high for the deeper Stations is 29° for Stations I, Croabas surface; and II, Croabas bottom; and 31° for Stations VI, Lagoon surface and VII, Lagoon bottom.

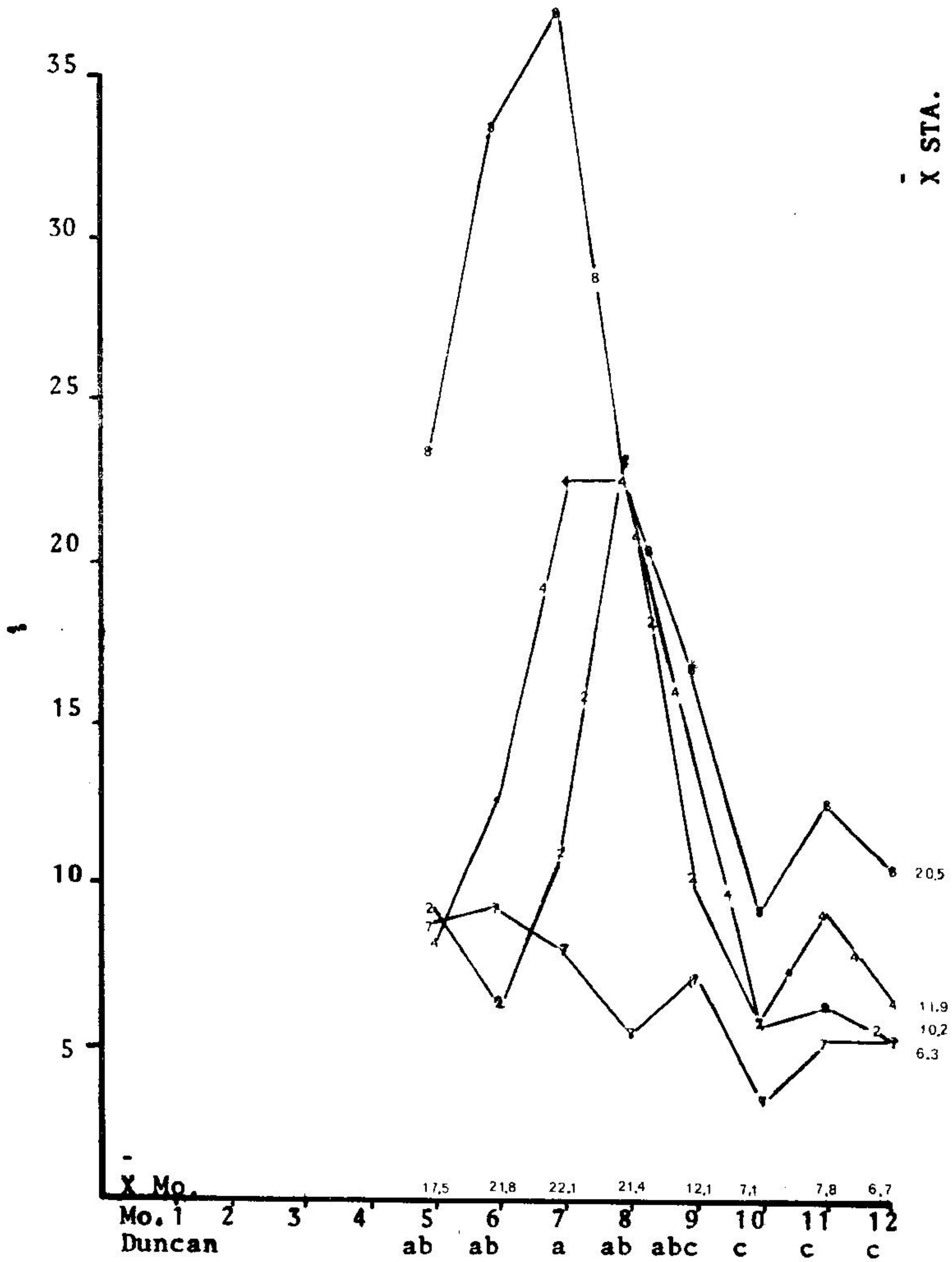


Fig. 4 % light that reaches the benthos per Mo. and Sta.

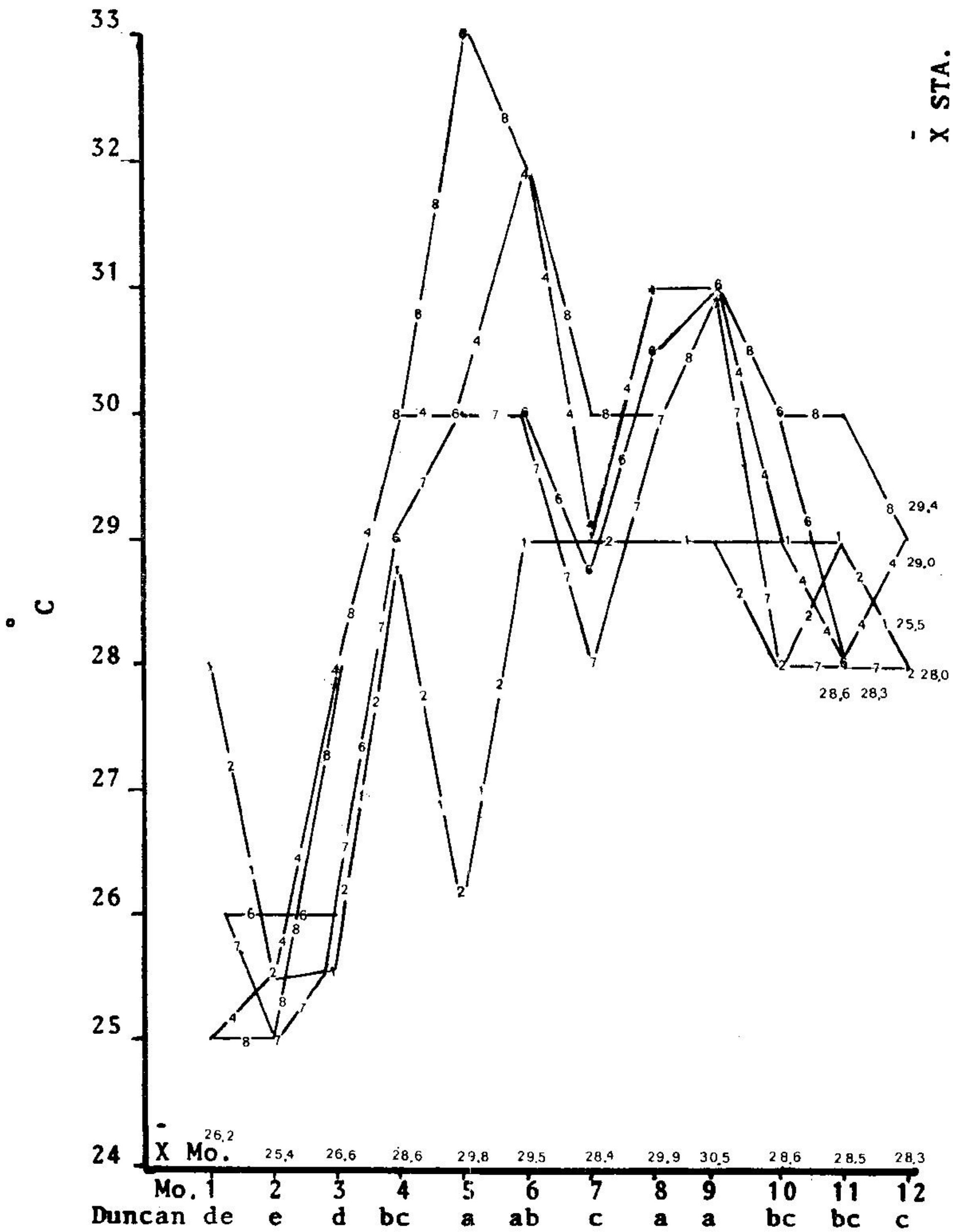


Fig. 5 Temperature per Mo. and Sta.

The average low temperatures were 25.5° for Stations I, II, and IV, 25° for Stations VII and VIII; and 26° for Station VI.

To find if there were statistical differences among Stations and within them for this parameter, a set of one way ANOVA were performed (Appendix A, Table 2). These indicate that there are no statistical differences between Stations. They also indicate statistical differences between months. To determine which months were statistically different a Duncan's test was performed (Appendix A, Table 3). The test indicates with some degree of overlap, that the temperature is higher in the intermediate months of the year and lower in the first and last months of the year.

c) Salinity

Salinity values obtained during the study are included in Appendix A, Table 6, and Figure 6; and are expressed in °/00.

The salinity values obtained are from a high of 40.3 in the area of Sorocco during the month of July to a low of 19.6 in the Back Lagoon during the month of October. Average salinities per Station are 31.85 for Las Croabas; 32.70, Main Lagoon; 34.00, Back Lagoon; and 33.90 for Sorocco Lagoon.

One way ANOVA was used to detect any significant difference between Stations, and within Stations, (Appendix A, Table 2). The test found no significant

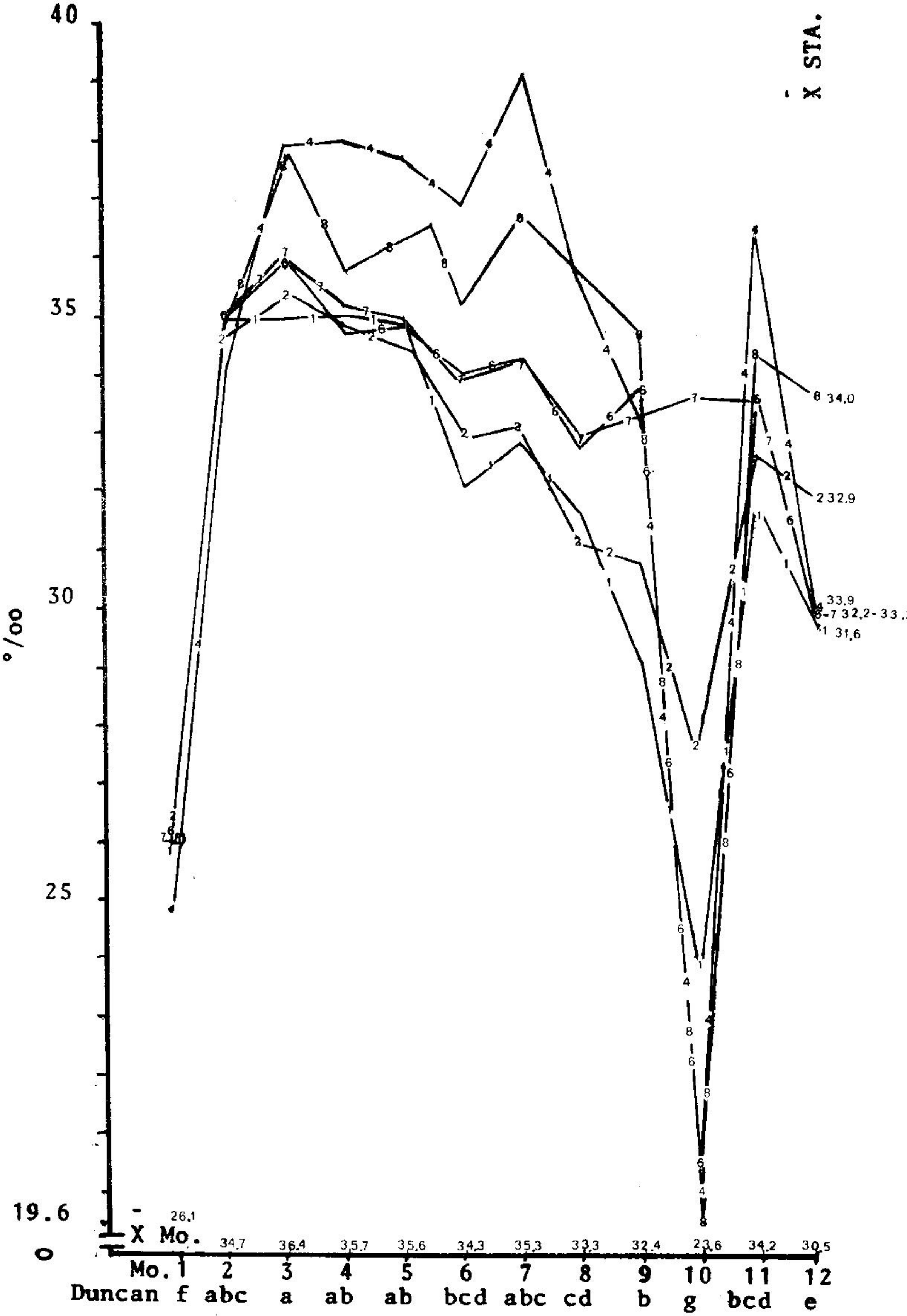


Fig. 6 Salinity per Mo. and Sta.

difference between Stations, but significant within them.

Duncan's multiple range test to determine between which months a significant difference is found (Appendix A, Table 3) was used. From Duncan's test, it is found that January, October and December are significantly different from themselves and from all the rest. Their average salinity values are 26.1, 23.6, and 30.5. The lowest salinity value is 23.6, for October. This coincides with the highest monthly average peak for rainfall for each year from 1941 to 1970, (N.O.A.A., 1978).

d) <u>Oxygen</u>

Oxygen data is contained in Appendix A, Table 7, and Figure 7; and is expressed 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. On the average O_2 values per Station were 5.95 Croabas, 5.25 Main Lagoon, 4.70 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 significant 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 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

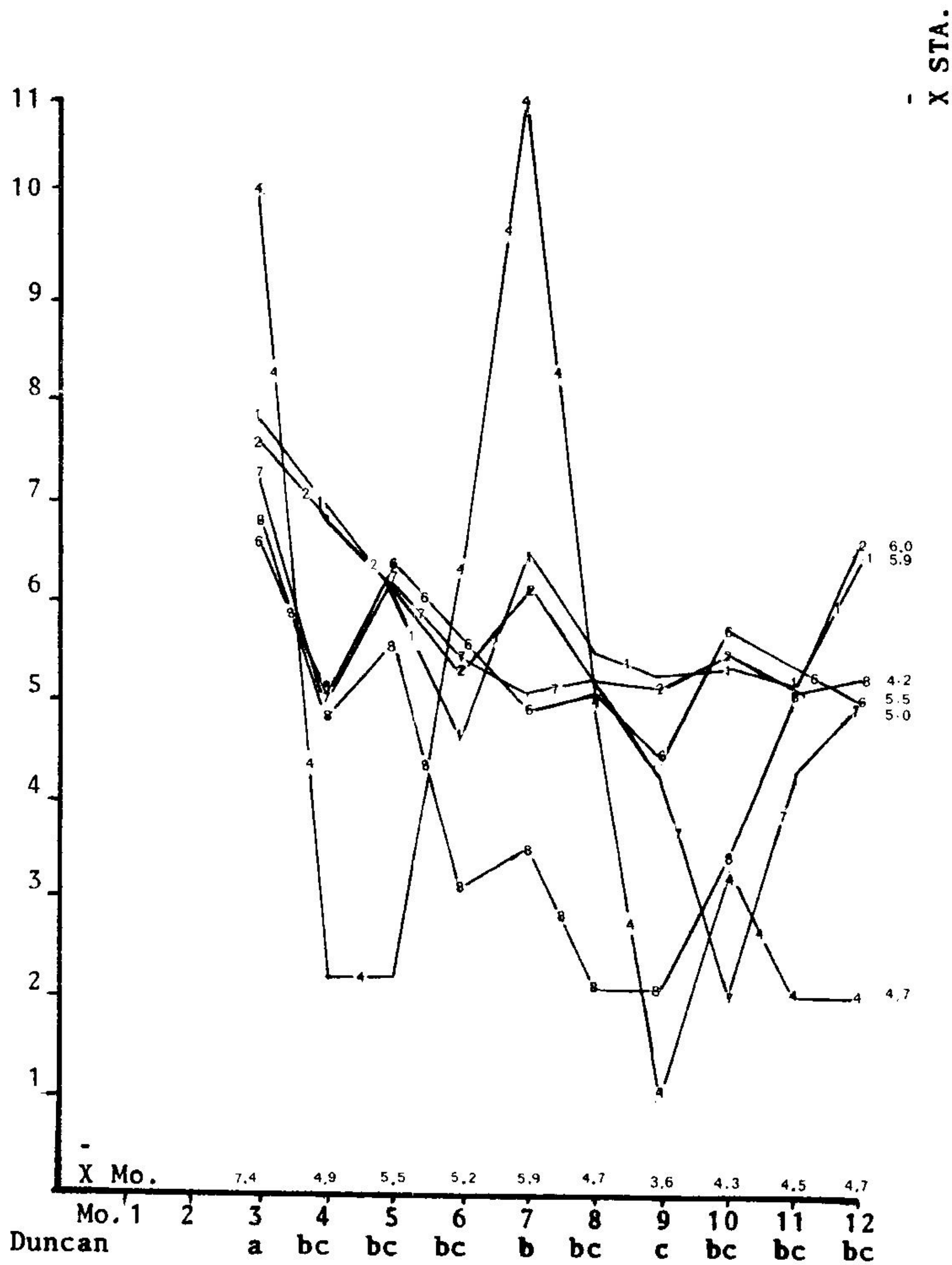


Fig. 7 Oxygen per Mo. and Station

themselves.

e) Nutrients

Phosphate

Phosphate data is contained in Appendix A, Table 8 and Figure 8; values are expressed in 1.0×10^{-2} μg-at /l.

The lowest phosphate value was 1.0 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 Croabas; 4.3, for Sorocco; 3.4 for the Main Lagoon and 4.0, for the Back Lagoon. When the data was analyzed with one way ANOVA no significant difference was found among Stations, but significant within Stations, (Appendix A, Table 2). Duncan's test was used to find which months were different from each other (Appendix A, Table 3). December and June with values of 5.7 and 5.4 are statistically different from October, with a value of 1.6, but not among themselves.

Nitrogen

The nitrogen data was measured in terms of μg -at /l of ammonia and it is contained in Appendix A, Table 9 and Figure 9. The highest value was 5.00 in July and August, at the area of Sorocco, and the lowest 1.30 in June, at the Back Lagoon. The average values were: Sorocco, 3.46; Main Lagoon, 2.09: Back Lagoon, 1:94;

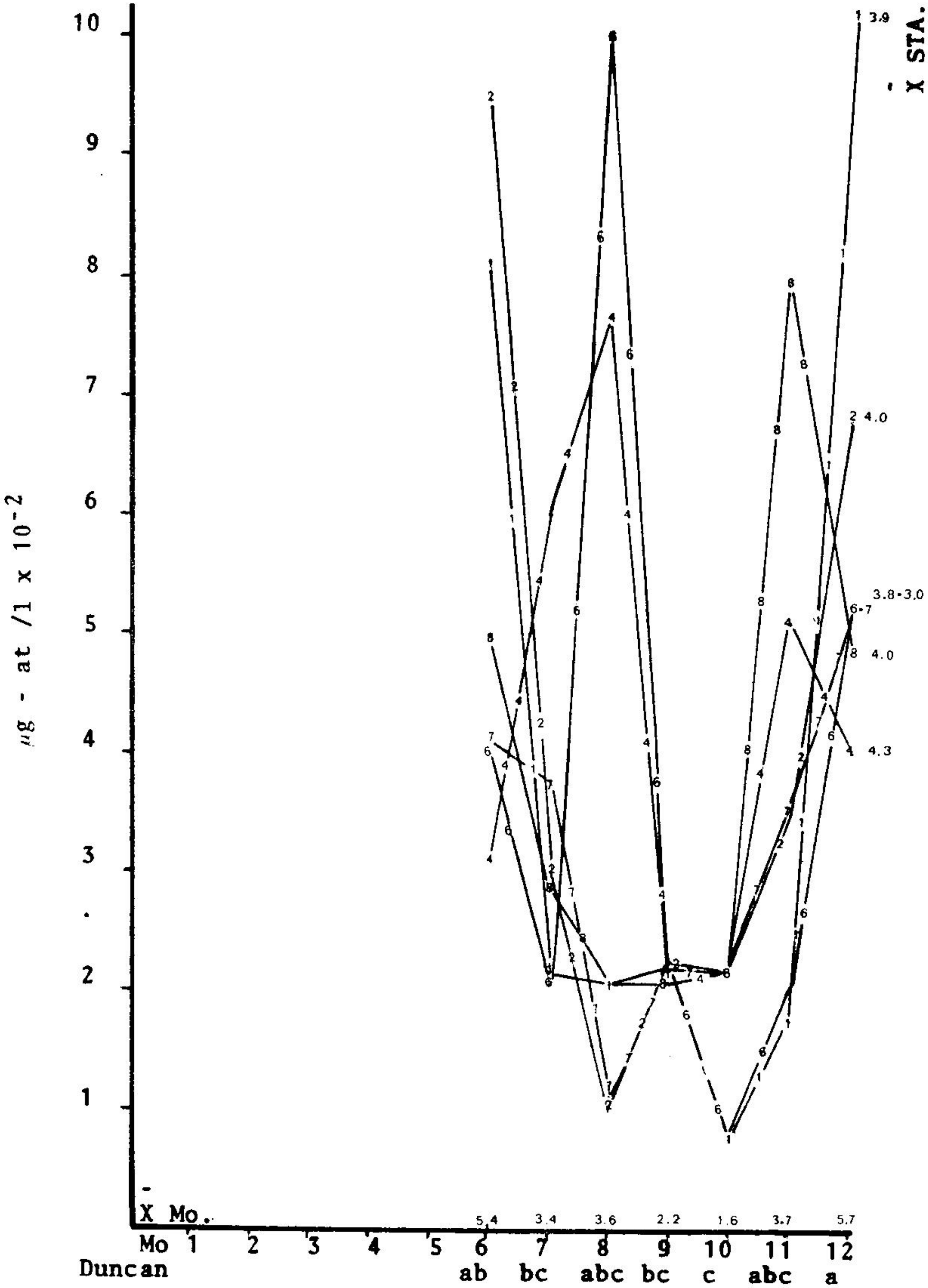


Fig. 8 Phosphate per Mo. and Sta.

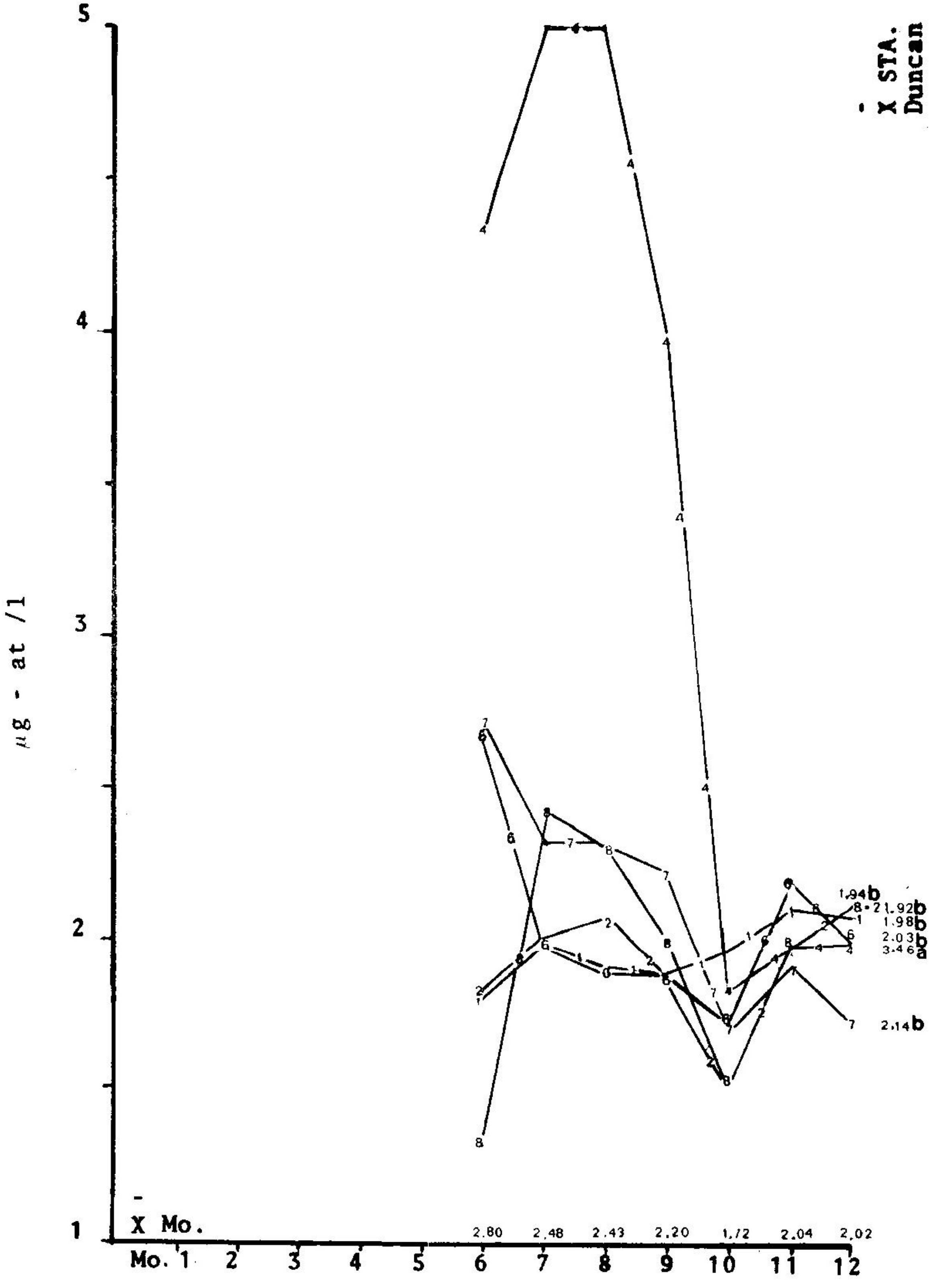


Fig. 9 Ammonia per Mo. and Sta.

and Las Croabas with 1.95

One way ANOVA was performed to find significant difference among Stations or within Stations. No significant difference was found within Stations, but significant difference was 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 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.

<u>Silica</u>

Silica is expressed in terms of μg-at /l silicate and is found in Appendix A, Table 10, and Figure 10. The highest value for silica was 2.71, in August, found at the Back Lagoon. The lowest was 1.41, in November, at Las Croabas. The average values per Station were: 2.40, Back Lagoon; 2.28, Sorocco; 1.94, Croabas; and 1.95, for the Main Lagoon. When the data was analyzed by means of one way ANOVA, no significant difference was found within Stations, but significant among Stations, (Appendix A, Table 2). Duncan's test was used to find which Stations were significantly different from each other, (Appendix A, Table 3). Station IV, Sorocco, is similar to VIII, Back Lagoon, and Croabas similar to the Main Lagoon, but both groups are different from

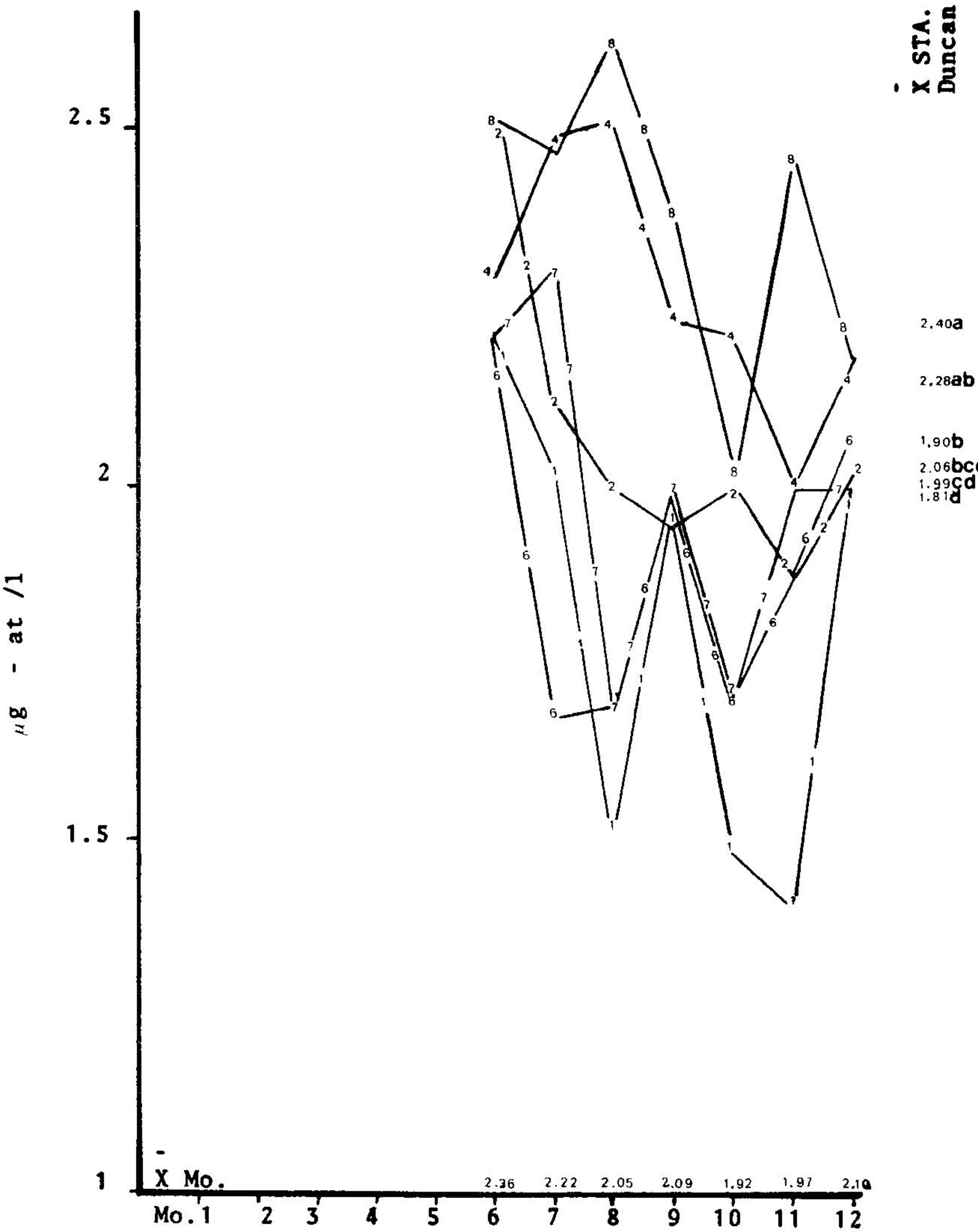


Fig. 10 Silica per Mo. and Sta.

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. In these Tables we can find the calculated Shannon-Weaver diversity index calculated in a per month basis. From these 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 Main 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 in general no significant similarity in suceeding 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 suceeding months, but also when any month is compared with any other month; thus indicating that the zooplankton community is homogeneous during all the year. When the Croabas Bay is compared with the Main Lagoon, similarities are found in January vs. January;

FIGURE 11 Trellis diagram for Las Croabas phytoplankton *

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1		0	-	24	-	4	4	0	2	2	10	14
2			-	27	-	25	6	12	30	66	47	7
3				-	-	-	-	-	-	-	-	-
4					-	2	4	52	2	32	9	5
5						-	-	-	-	-	-	-
6							14	4	96	33	87	4
7								71	38	45	30	1
8									24	13	21	2
9										36	90	4
10											60	7
11												8

* Presented data is % of similarity values obtained between intersecting months.

FIGURE 12 Trellis diagram for Main Lagoon phytoplankton *

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1		1	-	60	78	0	18	79	17	35	7	61
2			-	4	9	5	7	11	2	5	12	5
3				-	-	-	-	-	-	-	-	-
4					0	3	14	1	18	49	5	97
5						0	6	97	0	0	0	01
6							14	4	4	6	27	3
7								13	57	72	62	25
8									6	5	10	2
9										73	40	29
10											41	58
11												21

* Presented data is % of similarity values obtained between intersecting months.

FIGURE 13 Trellis diagram for Las Croabas vs. Main Lagoon phytoplankton *

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1	97											
2		4										
3			-									
4				31								
5					-							
6						28						
7							31					
8								0				
9									11			
10										20		
11											81	
12												10

* Presented data is % of similarity values obtained between intersecting months.

FIGURE 14 Trellis diagram for Las Croabas zooplankton *

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1		69	48	27	36	39	44	22	46	22	28	55
2			54	52	33	62	76	27	41	31	40	59
3				55	41	19	65	85	96	61	86	33
4					32	36	27	49	57	36	50	12
5						26	40	44	41	44	44	36
6							71	38	14	61	46	40
7								58	56	67	71	48
8									80	91	96	26
9										58	82	27
10											89	24
11												27

* Presented data is % of similarity values obtained between intersecting months.

FIGURE 15 Trellis diagram for Main Lagoon zooplankton *

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1		93	85	85	90	90	95	89	85	94	90	86
2			85	93	92	95	95	92	89	96	97	88
3				91	91	74	81	74	94	88	75	92
4					92	81	83	83	93	89	85	94
5						79	83	78	93	91	83	98
6							97	98	81	99	93	74
7								97	85	97	97	79
8									82	91	94	74
9										93	84	91
10											94	90
11												79

* Presented data is % of similarity values obtained between intersecting months.

FIGURE 16 Trellis diagram for Las Croabas vs. the Main Lagoon zooplankton *

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1	84											
2		85										
3			65									
4				50								
5					36							
6						24						
7							72					
8								41				
9									89			
10										36		
11											37	
12												42

* Presented data is % of similarity values obtained between intersecting months.

February vs. February; July vs. July and September vs. September. A complete species list of the planktonic organisms in the study can be found in Appendix A, Table 19.

In temperate seas the marked seasonal variations in temperature, illumination and availability of nutrients in the surface waters give rise to marked fluctuations in the density, diversity and productivity of the plankton, (Tait and DeSanto), 1972).

In the tropics, the seasonal changes are less than those of the temperate areas. Authors like Raymond (1963), thought that with the high levels of solar radiation that prevail during the year and with the presence of a permanent thermocline, the tropics were capable only of low levels of primary productivity that proceeded at fairly steady levels. The work of Beers, Steven and Lewis, 1965; González, 1965; and Cintrón, 1969, provided evidence of seasonal fluctuations in the primary productivity of the tropics.

When the % of relative species composition (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.

The lack of pattern is due to:

a) No significant differences are found between the Stations sampled for plankton (Las Croabas vs. Main Lagoon) in light penetration, temperature, salinity, dissolved oxygen, phosphate, ammonia and silica.

b) Perhaps the most critical factor that does not contribute in the establishment of a relationship is that no quantitative sampling of planktonic organisms could be made.

Seasonal changes have been found in % light penetration (extinction coefficient), temperature, dissolved oxygen and phosphate. These changes indicate a seasonality in the planktonic productivity of the lagoon. These can only be attributed to the rain pattern of the area for the past 30 years, where heavy rains occur in Spring and Autumn, (N. O. A. A., 1978).

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

In % light penetration (extinction coefficient), Ammonia and Silica differences between Stations. The % light penetration diferences are between the deeper Stations, Las Croabas amd the Main Lagoon vs. 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 apt to be stirred up by the turbulence caused by the wind or any other agent.

The difference 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 due most probable 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 VIII, 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 present ecological state of the lagoon with some of the data of Candelas (1968) and Díaz-Piferrer (1968). Candelas found oxygen levels of 9.15 ml/l to 2.6 ml/l and salinity of 30.10 °/00 to 43 °/00. Díaz-Piferrer found salinities of 43 °/00 to 54.4 °/00. In general, taking into consideration differences in instrumentation and error, this study has found about the same data as Candelas (1968) and Díaz-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 of utmost importance in order to maintain the equilibrium in the system:

a) The channel that connects to Las Croabas should be maintained open as the fishermen of the are have maintained it for at least 40 years or more (no dredging or modifications should be allowed to the channel).

b) The Sorocco Lagoon is bordered by small houses and restaurants; these dump raw sewage into the area. It seems the lagoon is absorbing the effects of this sewage. This practice should be stopped or at least, no other constructions shoudl be allowed on the southern borderline of area.

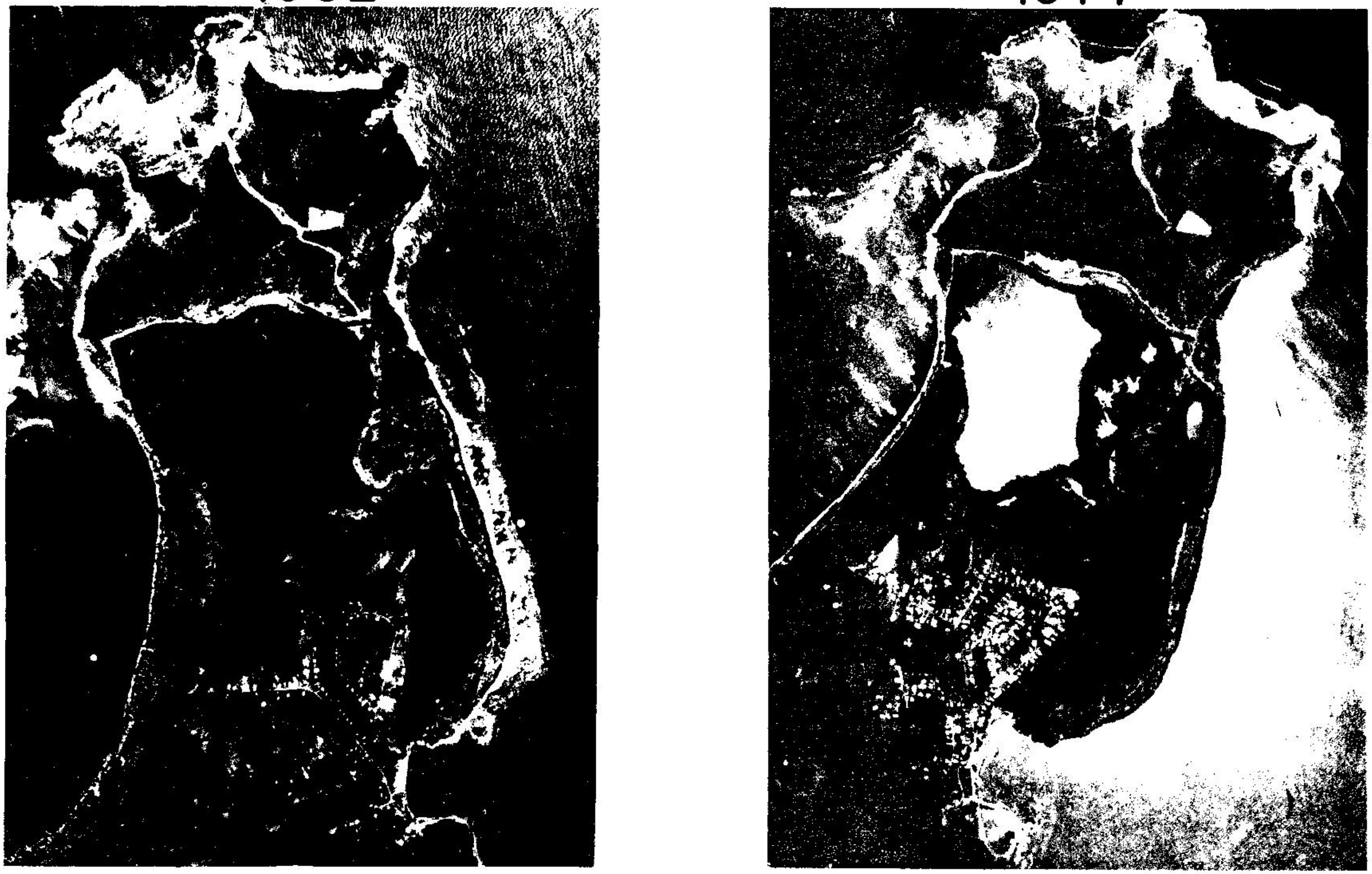
1936

1950

AERIAL PHOTOGRAPH OF EL FARO 1936 AND 1950

PLATE 1

1962 1977



AERIAL PHOTOGRAPH OF EL FARO 1962 AND 1977

Plate 2

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 run off, and its salinities are quite similar to sea water.

No obvious relationship 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 highly stable zooplankton community, while the phytoplankton changes in a great degree from month to month and the physico-chemical parameters change seasonally, more discriminatory techniques should be employed for all parameters; the sampling should be performed at more frequent intervals than monthly, and the plankton should be surveyed qualitatively and quantitatively not only at the surface, but also at mid-depths and near the bottom.

From the data obtained we can conclude:

- Increased nutrients and D.O. lvels in Spring and Autumn indicate seasonal changes caused by increased rain.
- The surface and bottom waters of the system are aerobic during all the year. The variation in D. O. is not wide except in the two shallow Stations, Sorocco and Back Lagoon.
- Temperature and salinity measurements indicate that the water column is well mixed in Las Croabas and in the Main Lagoon center water. The main mixing agent for borth areas is the wind.
- The light levels in all areas during the year are enough for benthic productivity, but the bottom of the Main Lagoon is bare below the 6 (six) feet level.
- In general, the temperature in the lagoonal waters is higher than in Las Croabas; this is due to the limited circulation in the lagoon

(compared to Las Croabas) and to its shallowness.

. The lagoonal zooplankton composition is highly stable.

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APPENDIX A

App. A, Table 1 Extinction coefficient per month and Station.

STA.	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
II	-	-	-	-	0.26	0.25	0.25	0.16	0.23	0.31	0.31	0.30	0.26	0.02
III	-	-	-	-	1.20	0.95	1.10	1.51	1.75	1.86	2.22	2.60	1.65	0.20
IV	-	-	-	-	2.19	1.78	1.31	1.31	2.00	2.44	2.10	2.41	1.94	0.16
V	-	-	-	-	1.01	0.87	1.09	0.85	2.00	2.35	2.31	2.21	1.59	0.24
VII	-	-	-	-	0.26	0.26	0.28	0.32	0.29	0.38	0.31	0.31	0.30	0.01
VIII	-	-	-	-	1.26	0.95	0.89	1.31	1.60	2.00	1.81	1.91	1.47	0.15
$\bar{X}$	-	-	-	-	1.03	0.84	0.82	0.91	1.31	1.56	1.51	1.62		
$S_{\bar{X}}$	-	-	-	-	0.30	0.23	0.18	0.23	0.34	0.39	0.39	0.43		

App. A, Table 2 One way analysis of variance for average concentration of:

Extinction coefficient: among Stations

	SS	DF	MS	F
Treatment	21.33	5	4.27	21.61
Error	8.29	42	0.20	S.
Total	29.62	47		

% Light penetration: within Stations

	SS	DF	MS	F
Treatment	2002.84	7	286.12	4.00
Error	2857.96	40	71.45	S.
Total	4860.80	47		

Temperature: within Stations

	SS	DF	MS	F
Treatment	216.84	11	19.71	17.74
Error	93.34	84	1.11	S.
Total	310.18	95		

Salinity: within Stations

	SS	DF	MS	F
Treatment	1488.37	12	124.03	34.55
Error	326.68	91	3.59	S.
Total	1815.05	103		

Dissolved oxygen: within Stations

	SS	DF	MS	F
Treatment	79.48	10	7.95	3.68
Error	166.25	77	2.16	S.
Total	245.73	87		

Phosphate: within Stations

	SS	DF	MS	F
Treatment	107.03	6	17.84	4.39
Error	199.31	49	4.07	S.
Total	306.35	55		

Ammonia: among Stations

	SS	DF	MS	F
Treatment	14.46	8	1.81	5.84
Error	16.70	54	0.31	S.
Total	31.15	62		

Silica: among Stations

	SS	DF	MS	F
Treatment	1.92	7	0.27	5.33
Error	2.47	48	0.05	S.
Total	4.39	55		

App. A, Table 3 Duncan's new multiple range test applied to the average concentration

	PER MONTH:					PER STATION:			
MO.	% Light	Temp. °C	Salinity °/00	D. O. PPM	Phosphate µg-at/1	STA.	Ex. Coef.	Ammonia µg-at/1	Silica µg-at/1
1	-	26.2 de	26.1 f	-	-	1	-	1.98 b	1.81 d
2	-	25.4 e	34.7 abc	-	-	2	0.30 b	1.92 b	2.06 bcd
3	-	26.6 d	36.4 a	7.4 a	-	3	1.65 a	1.82 b	2.16 abc
4	-	28.6 bc	35.7 ab	4.9 bc	-	4	1.94 a	3.46 a	2.28 ab
5	17.5 ab	29.8 a	35.6 ab	5.5 b	-	5	1.59 a	1.93 b	2.20 abc
6	21.8 ab	29.5 ab	34.3 bcd	5.2 bc	5.4 ab	6	-	2.03 b	1.90 b
7	22.1 a	28.4 c	35.3 abc	5.9 b	3.4 bc	7	0.26 b	2.14 b	1.99 cd
8	21.4 ab	29.9 a	33.3 cd	4.7 bc	3.6 abc	8	1.47 a	1.94 b	1.40 a
9	12.1 abc	30.5 a	32.4 b	3.6 c	2.2. bc				
10	7.1 c	28.6 bc	23.6 g	4.3 bc	1.6 c				
11	7.8 c	28.5 bc	34.2 bcd	4.5 bc	3.7 abc				
12	6.7 c	28.3 c	30.5 e	4.7 bc	5.7 a				

* Numbers followed by the same letters are not statistically different.

App. A, Table 4 % Light that reaches the bottom per month and Station.

STA.	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
II	-	-	-	-	9.0	6.1	10.0	23.5	16.7	5.5	5.8	5.0	10.2	2.34
III	-	-	-	-	25.0	33.3	28.3	17.6	13.3	11.7	7.7	5.0	17.7	3.60
IV	-	-	-	-	8.0	12.4	22.2	22.2	10.0	5.5	8.8	6.2	11.9	2.37
V	-	-	-	-	31.2	36.8	28.5	37.5	10.0	6.6	7.0	7.8	20.7	4.96
VII	-	-	-	-	8.7	8.8	7.7	5.2	7.0	3.0	5.0	5.0	6.3	0.73
VIII	-	-	-	-	23.3	33.3	35.7	22.2	15.7	10.0	12.5	11.1	20.5	3.51
$\bar{X}$	-	-	-	-	17.5	21.8	22.1	21.4	12.1	7.1	7.8	6.7		
$S_{\bar{X}}$	-	-	-	-	4.15	5.75	4.54	4.25	1.53	1.31	1.09	0.99		

App. A, Table 5   Temperature in °C per month and Station

STA.	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	28.0	25.5	25.6	27.0	29.0	26.0	28.0	29.0	29.0	29.0	29.0	28.0	25.5	0.79
II	28.0	25.5	25.8	27.0	29.0	26.0	28.0	29.0	29.0	28.0	29.0	28.0	28.0	0.33
III	25.5	25.5	26.6	28.0	29.0	30.0	28.0	30.0	31.0	28.0	28.0	28.0	28.1	0.38
IV	25.0	25.5	28.0	30.0	30.0	32.0	29.0	31.0	31.0	29.0	28.0	29.0	29.0	0.42
V	26.0	25.0	27.0	29.0	31.0	30.0	28.0	30.0	31.0	28.0	28.0	29.0	28.5	0.40
VI	26.0	26.0	26.0	29.0	30.0	30.0	28.5	30.5	31.0	30.0	28.0	28.0	28.6	0.39
VII	26.0	25.0	26.0	29.0	30.0	30.0	28.0	30.0	31.0	28.0	28.0	28.0	28.3	0.39
VIII	25.0	25.0	28.0	30.0	33.0	32.0	30.0	30.0	31.0	30.0	30.0	29.0	29.4	0.45
$\bar{X}$	26.2	25.4	26.6	28.6	29.8	29.5	28.4	29.9	30.5	28.6	28.5	28.3		
$S_{\bar{X}}$	0.39	0.21	0.35	0.39	0.30	0.54	0.30	0.29	0.34	0.34	0.31	0.25		

App. A, Table 6 Average salinity concentration in PPT per month and Station.

STA.	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	25.9	35.1	35.1	35.2	35.0	32.2	33.2	31.8	29.8	23.8	32.1	29.8	31.6	1.07
II	26.5	35.0	35.5	35.0	35.0	33.0	33.1	31.2	30.0	27.6	32.9	30.2	32.1	0.87
III	25.9	33.1	36.1	35.3	35.3	34.1	34.9	32.9	31.2	24.1	33.9	30.0	32.2	1.10
IV	24.9	34.1	38.0	38.1	37.9	37.1	40.3	35.9	33.2	20.0	36.8	30.1	33.9	1.75
V	27.2	35.0	36.4	36.1	35.0	35.0	35.6	33.1	33.0	19.8	34.9	32.1	32.8	1.38
VI	26.2	35.1	36.1	34.9	35.0	34.0	34.2	32.9	33.9	20.5	33.9	30.0	32.2	1.32
VII	26.1	35.1	36.2	35.3	35.1	33.9	34.2	33.0	33.3	33.6	34.0	30.0	33.2	0.80
VIII	26.1	35.0	37.9	35.9	36.7	35.1	36.9	35.8	34.8	19.6	34.9	32.0	34.0	1.53
$\bar{X}$	26.1	34.7	36.4	35.7	35.6	34.3	35.3	33.3	32.4	23.6	34.2	30.5		
$S_{\bar{X}}$	0.23	0.26	0.37	0.37	0.38	0.52	0.84	0.60	0.65	1.74	0.50	0.34		

App. A, Table 7 Average oxygen concentration in PPM per month and Station.

STA.	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	7.7	6.8	6.0	4.5	6.5	5.5	5.3	5.3	5.2	6.4	5.9	0.30
II	-	-	7.5	6.7	6.1	5.9	6.1	5.2	5.3	5.6	5.1	6.3	6.0	0.23
III	-	-	6.3	3.8	5.2	4.1	4.7	4.4	2.1	4.0	4.0	3.2	4.2	0.36
IV	-	-	10.2	2.2	2.2	7.7	11.1	5.0	1.0	3.6	2.0	2.0	4.7	1.17
V	-	-	6.9	4.8	5.8	4.9	5.3	5.0	4.0	4.6	4.7	4.2	5.0	0.26
VI	-	-	6.7	5.1	6.4	5.8	5.0	5.1	4.8	5.9	5.0	5.0	5.5	0.21
VII	-	-	7.2	5.0	6.4	5.6	5.1	5.2	4.3	2.0	4.5	5.0	5.0	0.43
VIII	-	-	6.8	4.8	5.6	3.0	3.4	2.1	2.1	3.4	5.1	5.2	4.2	0.50
$\bar{X}$	-	-	7.4	4.9	5.5	5.2	5.9	4.7	3.6	4.3	4.5	4.7		
$S_{\bar{X}}$	-	-	0.43	0.52	0.49	0.50	0.81	0.39	0.58	0.46	0.38	0.53		

App. A, Table 8 Average phosphate concentration in 1 x 10^{-2} μg at /1 per month and Station.

STA.	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	8.1	2.1	2.0	2.1	1.0	2.0	10.0	3.9	1.35
II	-	-	-	-	-	9.4	3.0	1.0	2.2	2.1	3.1	7.0	4.0	1.15
III	-	-	-	-	-	4.0	2.1	1.0	3.0	1.1	2.0	3.0	2.3	0.41
IV	-	-	-	-	-	3.1	6.0	8.0	2.0	2.1	5.1	4.0	4.3	0.83
V	-	-	-	-	-	5.1	4.9	4.0	2.1	1.1	4.0	6.1	3.9	0.66
VI	-	-	-	-	-	4.0	2.0	10.0	2.1	1.0	2.1	5.1	3.8	1.17
VII	-	-	-	-	-	4.1	3.9	1.1	2.1	2.1	3.0	5.0	3.0	0.35
VIII	-	-	-	-	-	5.0	2.9.	2,0	2.0	2.1	8.0	5.0	4.0	0.85
$\bar{X}$	-	-	-	-	-	5.4	3.4	3.6	2.2	1.6	3.7	5.7		
$S_{\bar{X}}$	-	-	-	-	-	0.78	0.52	1.23	0.12	0.20	0.73	0.75		

App. A, Table 9 Average ammonia concentration in μg at /1 per month and Station.

STA.	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	1.80	2.01	1.91	1.90	2.00	2.11	2.10	1.98	0.04
II	-	-	-	-	-	1.81	2.02	2.10	1.90	1.50	2.00	2.11	1.92	0.08
III	-	-	-	-	-	1.51	2.00	1.82	1.61	1.70	2.10	2.00	1.82	0.08
IV	-	-	-	-	-	4.31	5.00	5.01	4.10	1.80	2.00	2.01	3.46	0.55
V	-	-	-	-	-	1.31	2.07	2.10	2.01	1.71	2.20	2.10	1.93	0.12
VI	-	-	-	-	-	2.69	2.00	1.90	1.90	1.71	2.02	2.01	2.03	0.12
VII	-	-	-	-	-	2.71	2.31	2.30	2.21	1.81	1.90	1.71	2.14	0.13
VIII	-	-	-	-	-	1.30	2.40	2.30	2.00	1.50	2.00	2.11	1.94	0.15
$\bar{X}$	-	-	-	-	-	2.18	2.48	2.43	2.20	1.72	2.04	2.02		
$S_{\bar{X}}$	-	-	-	-	-	0.36	0.36	0.37	0.28	0.06	0.03	0.05		

App. A, Table 10 Average silica concentration in μg at /l per month and Station.

STA.	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	-	-	-	2.21	2.02	1.52	1.99	1.51	1.41	2.00	1.81	0.12
II	-	-	-	-	-	2.50	2.00	2.01	1.99	2.00	1.89	2.02	2.06	0.08
III	-	-	-	-	-	2.28	2.21	2.21	2.13	2.21	2.01	2.09	2.16	0.03
IV	-	-	-	-	-	2.31	2.50	2.51	2.21	2.20	2.01	2.20	2.28	0.07
V	-	-	-	-	-	2.68	2.51	2.01	1.98	2.02	2.02	2.19	2.20	0.11
VI	-	-	-	-	-	2.21	1.69	1.70	2.02	1.70	1.89	2.09	1.90	0.08
VII	-	-	-	-	-	2.21	2.31	1.70	2.02	1.71	2.00	2.00	1.99	0.09
VIII	-	-	-	-	-	2.51	2.48	2.71	2.40	2.01	2.49	2.20	2.40	0.09
$\bar{X}$	-	-	-	-	-	2.36	2.22	2.05	2.09	1.92	1.97	2.10		
$S_{\bar{X}}$	-	-	-	-	-	0.06	0.10	0.15	0.05	0.09	0.10	0.03		

App. A, Table 11 **Las Croabas** : Phytoplankton relative abundance of organisms.

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Ceratium longirostris	98	0	-	17	-	0	4	0	2	3	0	10
Ceratium furca	8	0	0	0	-	0	42	0	5	0	0	0
Ceratium macroceros	2	0	-	0	-	0	0	0	2	6	2	7
Chaoteceros sp.	82	0	-	0	-	11	0	0	0	0	5	9
Cosinodiscus sp.	0	18	-	0	-	148	21	2	110	29	28	3
Nitzchia longissima	0	40	-	0	-	0	0	0	5	54	8	3
Dynophysis sp.	0	0	-	9	-	0	0	0	0	0	0	0
Pyrodinium sp.	0	0	-	0	-	0	0	0	0	0	0	0
Rhizoselenia sp.	0	0	-	0	-	0	0	3	0	22	10	7
Thalassiothrix sp.	0	0	-	0	-	0	4	13	7	16	0	3
Biddulphia sp.	0	17	-	26		7	8	4	2	61	4	2
Striatella sp.	0	18	-	0	-	0	0	1	7	32	4	0
Bacteriastrum sp.	0	0	-	0	-	0	0	0	0	0	0	2
Isthimia sp.	0	38	-	9	-	0	0	9	0	0	2	2
Meridiom sp.	0	40	-	9	-	0	3	0	5	13	4	5

(Continued)

App. A, Table 11 Las Croabas: Phytoplankton relative abundance of organisms. (Continued)

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Bacillaria sp.	0	0	-	0	-	0	143	36	28	0	6	0
Grammatophora	0	0	-	44	-	0	0	29	0	0	0	0
Asterionella sp.	0	0	-	0	-	0	0	0	0	0	0	96
Amphiprora sp.	0	0	-	8	-	0	0	0	0	0	0	0
Licmophora sp.	0	0	-	8	-	0	0	0	0	0	0	0
Cyclotella sp.	0	0	-	0	-	0	0	2	0	0	0	0
Triceratium sp.	0	0	-	0	-	0	0	1	0	0	0	1
Diversity Index	1.25	2.04	-	2.85	-	0.60	1.64	2.44	1.95	2.78	2.80	2.05

App. A, Table 12 Main Lagoon: Phvtoplankton relative abundance of organisms.

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Ceratium longirostris	87	7	-	147	1	0	0	0	7	31	4	171
Ceratium furca	21	1	-	7	0	4	134	7	152	53	44	42
Ceratium macroceros	0	1	-	0	0	0	0	0	0	0	3	12
Chaoteceros sp.	115	15	-	0	140	0	8	136	0	0	0	0
Cosinodiscus sp.	1	29	-	1	0	50	44	12	10	13	121	18
Nitzchia longissima	3	0	-	0	0	0	0	1	3	1	0	0
Dynophysis sp.	0	0	-	16	0	0	0	0	0	0	0	0
Pyrodinium sp.	0	0	-	1	0	171	4	2	0	0	0	0
Rhizoselenia sp.	0	0	-	0	24	0	0	5	3	0	2	0
Thalassiothrix sp.	0	0	-	0	0	0	0	0	0	41	0	0
Biddulphia sp.	0	0	-	0	0	0	0	0	0	4	0	0
Striatella sp.	0	0	-	0	4	0	0	0	0	0	0	0
Bacteriastrum sp.	0	161	-	0	0	0	0	0	0	0	0	0
Kelosira	0	0	-	0	0	0	2	0	13	0	0	0
Diversity Index	1.91	1.53	-	0.79	0.80	0.89	1.23	0.91	1.19	2.03	1.12	1.20

App. A, Table 13 Las Croabas: Zooplankton relative abundance of organisms.

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Paracalanus crassirostris	58	74	119	13	28	21	69	22	78	10	227	49
Paracalanus parvus	19	0	16	12	26	0	0	3	36	9	4	0
Euterpina acutifrons	10	9	0	0	0	20	0	13	0	10	2	25
Acartia tonsa	0	3	0	14	25	0	0	3	0	0	4	0
Acartia lilljeborgii	19	0	0	0	0	22	22	10	26	0	0	0
Podon sp.	0	0	5	0	0	0	0	0	21	9	2	0
Oithona oculata	9	28	16	0	27	85	69	61	0	83	38	24
Oithona nana	0	37	0	40	0	43	0	0	0	0	0	0
Labidocera scotti	0	0	0	0	0	0	0	0	0	0	0	0
Kronitta pacifica	22	0	3	5	0	0	0	2	0	0	0	0
Oikopleura sp.	29	0	0	0	0	22	0	2	5	0	0	23
Forams	0	0	0	0	0	0	0	29	0	32	0	0
Medusae	0	0	5	0	0	0	21	0	0	0	0	0
Barnaclae larvae	8	9	4	5	8	7	5	12	3	4	2	7
Copepod nauplii	0	0	151	27	28	0	26	134	130	74	64	0

(Continued)

App. A, Table 13 Las Croabas: Zooplankton relative abundance of organisms. (Continued)

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Crab zoea	0	0	0	0	82	0	0	0	0	0	0	0
Lobster zoea	0	0	0	0	0	0	0	0	0	0	0	0
Polychaete larvae	28	7	0	0	23	0	0	13	5	0	2	74
Fish eggs	7	0	0	2	0	0	0	0	0	0	0	0
Fish larvae	1	0	0	0	0	0	0	13	0	0	0	0
Starfish larvae	0	0	0	0	0	0	0	0	0	0	0	0
Diversity index	3.10	2.18	1.77	2.40	2.82	2.55	1.48	2.61	2.08	2.24	2.03	2.15

App. A, Table 14 Main Lagoon: Zooplankton relative abundance of organisms.

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Paracalanus crassirostris	29	31	33	46	54	218	99	144	76	129	142	59
Paracalanus parvus	8	10	29	30	42	10	11	5	56	46	18	55
Euterpina acutifrons	0	0	2	1	3	8	7	14	22	15	13	7
Acartia tonsa	5	2	3	5	1	1	4	1	10	2	1	3
Acartia lilljeborgii	3	0	7	9	3	2	5	6	2	6	2	10
Podon sp.	1	1	3	8	2	3	0	21	4	0	1	4
Oithona oculata	1	3	4	5	1	5	10	14	12	6	10	7
Oithona nana	1	2	7	11	1	4	7	11	10	5	1	4
Labidocera scotti	0	0	1	0	1	0	0	0	0	0	0	0
Kronitta pacifica	1	1	5	1	2	4	0	0	5	1	5	2
Oikopleura sp.	9	2	15	0	8	10	22	6	9	29	1	9
Forams	1	0	0	0	0	7	8	16	4	25	0	9
Medusae	0	0	0	0	1	0	0	0	0	0	0	0
Barnacle larvae	0	1	3	1	0	0	0	1	1	0	0	2
Copepod nauplii	1	0	12	4	·0	36	14	27	26	12	8	0

(Continued)

Appt. A, Table 14 Main Lagoon: Zooplankton relative abundance of organisms. (Continued)

SPECIES	MONTH 1	2	3	4	5	6	7	8	9	10	11	12
Crab zoea	1	1	2	3	7	3	1	6	9	1	0	6
Lobster zoea	0	0	0	0	1	0	0	1	1	1	0	0
Polychaete larvae	0	1	2	10	0	0	1	12	3	1	1	2
Fish eggs	8	0	0	0	11	0	6	13	4	5	0	8
Fish larvae	1	0	0	0	0	0	0	0	0	7	1	0
Starfish larvae	0	0	0	0	0	0	0	3	1	0	0	0
Diversity index	2.79	2.35	3.33	2.88	2.44	2.35	2.60	2.87	3.17	2.71	1.91	2.94

App. A, Table 15 Las Croabas Phytoplankton: % of relative species composition.

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Ceratium longirostris	51.58	0	-	12.23	-	0	1.78	0	1.14	1.27	0	10
Ceratium furca	4.21	0	0	0	-	0	18.67	0	2.86	0	0	0
Ceratium macroceros	1.05	0	-	0	-	0	0	0	1.14	2.54	2.74	4.79
Chaoteceros sp.	43.16	0	-	0	-	6.83	0	0	0	0	6.85	6.16
Cosinodiscus sp.	0	10.59	-	0	-	89.16	9.33	2.00	62.86	12.29	38.36	2.05
Nitzchia longissima	0	23.53	-	0	-	0	0	0	2.86	22.88	10.96	2.05
Dynophysis sp.	0	0	-	6.47	-	0	0	0	0	0	0	0
Pyrodinium sp.	0	0	-	0	-	0	0	0	0	0	0	0
Rhizoselenia sp.	0	0	-	0	-	0	0	3.00	0	9.32	13.70	4.79
Thalassiothrix sp.	0	0	-	0	-	0	1.78	13.00	4.00	6.78	0	2.05
Biddulphia sp.	0	10.00	-	18.71	-	4.22	3.56	4.00	1.14	25.85	5.48	1.37
Striatella sp.	0	10.59	-	0	-	0	0	1.00	4.00	13.56	5.48	0
Bacteristrum sp.	0	0	-	0	-	0	0	0	0	0	0	1.37
Isthimia sp.	0	22.35	-	6.47	-	0	0	9.00	0	0	2.74	1.37
Meridiom sp.	0	23.53	-	6.47	-	0	1.33	0	2.86	5.51	5.48	3.42

(Continued)

App. A, Table 15 Las Croabas Phytoplankton: % of relative species composition (Continued)

SPECIES	MONTH 1	2	3	4	5	6	7	8	9	10	11	12
Bacillaria sp.	0	0	-	0	-	0	63.56	36.00	16.00	0	8.22	0
Grammatophora	0	0	-	31.65	-	0	0	29.00	0	0	0	0
Asterionella sp.	0	0	-	0	-	0	0	0	0	0	0	65.75
Amphiprora sp.	0	0	-	5.76	-	0	0	0	0	0	0	0
Licmophora sp.	0	0	-	5.76	-	0	0	0	0	0	0	0
Cyclotella sp.	0	0	-	0	-	0	0	2.00	0	0	0	0
Triceratium sp.	0	0	-	0	-	0	0	1.00	0	0	0	0.68
Total number of organisms per month	190	171	-	139	-	166	225	100	175	236	73	146

Appt. A, Table 16 Main Lagoon Phytoplankton: % of relative species composition

SPECIES	MONTH 1	2	3	4	5	6	7	8	9	10	11	12
Ceratium longirostris	38.33	3.27	-	85.47	0.59	0	0	0	3.72	21.68	2.3	70.37
Ceratium furca	9.25	0.47	-	4.07	0	1.78	69.79	4.29	80.85	37.06	25.29	17.28
Ceratium macroceros	0	0.47	-	0	0	0	0	0	0	0	1.72	4.94
Chaoteceros sp.	50.66	7.01	-	0	82.84	0	4.17	83.44	0	0	0	0
Cosinodiscus sp.	0.44	13.55	-	0.58	0	22.22	22.92	7.36	5.32	9.09	69.54	7.41
Nitzchia longissima	1.32	0	-	0	0	0	0	0.61	1.60	0.70	0	0
Dynophysis sp.	0	0	-	9.30	0	0	0	0	0	0	0	0
Pyrodinium sp.	0	0	-	0.58	0	76	2.08	1.23	0	0	0	0
Rhizoselenia sp.	0	0	-	0	14.20	0	0	3.07	1.60	0	1.15	0
Thalassiothrix sp.	0	0	-	0	0	0	0	0	0	28.67	0	0
Biddulphia sp.	0	0	-	0	0	0	0	0	0	2.80	0	0
Striatella sp.	0	0	-	0	2.37	0	0	0	0	0	0	0
Bacteriastrum sp.	0	75.23	-	0	0	0	0	0	0	0	0	0
Kelosira sp.	0	0	-	0	0	0	1.04	0	6.91	0	0	0
	2.27	2.14	-	1.72	1.69	2.25	1.92	1.63	1.88	1.43	1.74	2.43

App. A, Table 17 Las Croabas Zooplankton: % of relative species composition

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Paracalanus crassirostris	28.29	44.31	37.78	11.50	10.73	8.97	37.10	7.10	25.41	4.31	162.14	25.13
Paracalanus parvus	9.27	0	5.08	10.62	9.96	0	0	0.97	11.73	3.88	2.86	0
Euterpina acutifrons	4.88	5.39	0	0	0	8.55	0	4.19	0	4.31	1.43	12.82
Acartia tonsa	0	1.80	0	12.39	9.58	0	0	0.97	0	0	2.86	0
Acartia lillgeborgii	9.27	0	0	0	0	9.40	11.83	3.23	8.47	0	0	0
Podon sp.	0	0	1.59	0	0	0	0	0	6.84	3.88	1.43	0
Oithona oculata	4.39	16.77	5.08	0	10.34	36.32	37.10	19.68	0	35.78	27.14	12.31
Oithona nana	0	22.16	0	35.40	0	18.38	0	0	0	0	0	0
Labidocera scotti	0	0	0	0	0	0	0	0	0	0	0	0
Kronita pacifica	10.73	0	0.95	4.42	0	0	0	0.65	0	0	0	0
Oikopleura sp.	14.15	0	0	0	0	9.40	0	0.65	1.63	0	0	11.79
Forams	0	0	0	0	0	0	0	9.35	0	13.79	0	0
Medusae	0	0	1.59	0	0	0	11.29	0	0	0	0	0
Barnaclae larvae	3.90	5.39	1.27	4.42	3.07	2.99	2.69	3.87	0.98	1.72	1.43	3.59
Copedod nauplii	0	0	47.94	23.89	10.73	0	13.98	43.23	42.35	31.90	45.71	0

(Continued)

App. A, Table 17 Las Croabas Zooplankton: % of relative species composition (Continued)

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Crab Zoea	0	0	0	0	31.42	0	0	0	0	0	0	0
Lobster zoea	0	0	0	0	0	0	0	0	0	0	0	0
Polychaete larvae	13.66	4.19	0	0	8.81	0	0	4.19	1.63	0	1.43	37.95
Fish eggs	3.41	0	0	1.77	0	0	0	0	0	0	0	0
Fish larvae	0.49	0	0	0	0	0	0	4.19	0	0	0	0
Starfish larvae	0	0	0	0	0	0	0	0	0	0	0	0
Total number of organisms per month	205	167	315	113	261	234	186	310	307	232	140	195

App. A, Table 18 Main Lagoon Zooplankton: % of relative species composition

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Paracalanus crassirostris	41.43	47.69	25.78	37.33	39.42	70.10	50.77	47.37	29.80	44.33	69.61	31.72
Paracalanus parvus	11.43	15.38	22.66	22.39	30.66	3.22	5.64	1.64	21.96	15.81	8.82	29.57
Euterpina acutifrons	0	0	1.56	0.75	2.19	2.57	3.59	4.61	8.63	5.15	6.37	3.76
Acartia tonsa	7.14	3.08	2.34	3.73	0.73	0.32	2.05	0.33	3.92	0.69	0.49	1.61
Acartia lillgeborgii	4.29	0	5.47	6.72	2.19	0.64	2.56	1.97	.78	2.06	.98	5.38
Podon sp.	1.43	1.54	2.34	5.97	1.46	0.96	0	6.91	1.57	0	0.49	2.15
Oithona oculata	1.43	4.62	5.47	3.73	0.73	1.61	5.13	4.61	4.71	2.06	4.90	3.76
Oithona nana	1.43	3.08	5.47	8.21	0.73	1.29	3.59	3.62	3.92	1.72	0.49	2.15
Labidocera scotti	0	0	0.78	0	0.73	0	0	0	0	0	0	0
Kronitta pacifica	1.43	1.54	3.91	0.75	1.46	1.29	0	0	1.96	0.34	2.45	1.08
Forams	1.43	0	0	0	0	2.25	4.10	5.26	1.57	8.59	0	4.84
Medusae	0	0	0	0	0.73	0	0	0	0	0	0	0
Barnacle larvae	0	1.54	2.34	0.75	0	0	0	0.33	0.39	0	0	1.08
Copedod nauplii	1.43	0	9.38	1.99	0	11.58	7.18	8.88	10.20	4.12	3.92	0
Oikopleura sp.	12.86	3.08	11.72	0	5.84	3.22	11.28	1.97	3.53	9.97	0.49	4.84

(Continued)

App. A, Table 18 Main Lagoon Zooplankton: % of relative species composition (Continued)

SPECIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Crab zoea	1.43	1.54	2.34	2.24	5.11	0.96	0.51	1.97	3.53	.34	0	3.23
Lobster zoea	0	0	0	0	0.73	0	0	.33	0.39	.34	0	0
Polychaete larvae	0	1.54	2.34	7.46	0	0	0.51	3.95	1.18	.34	.49	1.08
Fish eggs	11.43	0	0	0	8.03	0	3.08	4.28	1.57	1.72	0	4.30
Fish larvae	1.43	0	0	0	0	0	0	0	0	2.41	1.49	0
Starfish larvae	0	0	0	0	0	0	0	0.99	0.39	0	0	0
Total number of organisms per month	70	65	128	134	137	311	195	304	255	291	204	186

APPENDIX A, TABLE 19

SPECIES LIST OF THE PLANKTONIC ORGANISMS CAPTURED AND IDENTIFIED DURING THE STUDY PERIOD

Kingdom Plantae
- Bacillariophyceae
  - Centrales
    - Chaetoceros sp.
    - Cosinodiscus sp.
    - Rhizoselenia sp.
    - Biddulphia sp.
    - Bacteriastrum sp.
    - Isthimia sp.
    - Amphiprora sp.
    - Cyclotella sp.
    - Triceratium sp.
  - Pennales
    - Nitzchia longissima
    - Thalassiothrix sp.
    - Striatella sp.
    - Meridium sp.
    - Bacillaria sp.
    - Grammatophora sp.
    - Asterionella sp.
    - Licmophora sp.
  - Peridineae
    - Ceratium longirostris
    - Ceratium furca
    - Ceratium macroceros
    - Pyrodinium sp.

APPENDIX A, TABLE 19 - (Continued)

Kingdom Animalia
    Arthropoda
        Crustacea
            Paracalanus crassirostris
            Paracalanus parvus
            Acartia lilljeborgii
            Acartia tonsa
            Labidocera scotti
            Euterpina acutifrons
            Oithona oculata
            Oithona nana
            Podon sp.
            Crab zoea
            Lobster zoea
            Barnacle larvae
            Copepod nauplii

    Protozoa
            Foraminifera

    Coelenterata
            Medusae

    Annelida
        Polychaeta
            Polychaete larvae

    Echinodermata
            Starfish larvae

    Chaetognatha
            Kronitta pacifica

    Chordata
        Larvacea
            Oikopleura sp.
        Osteichthyes
            Fish larvae
            Fish eggs

APPENDIX B

App. B, Table I Light penetration in 1 x 10^3 foot candles for all the Stations during the Study period.

STA.	1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	-	-	10.0	9.0	10.0	8.5	8.5	9.0	8.5	7.6	8.9	0.29
II	-	-	-	-	0.9	0.6	1.0	2.0	1.0	0.5	0.5	0.5	0.9	0.18
III Surface	-	-	-	-	10.0	9.0	6.0	8.5	9.0	8.5	9.0	8.0	8.5	0.41
III Bottom	-	-	-	-	2.5	3.0	1.7	1.5	1.2	1.0	0.7	0.4	1.5	0.31
IV Surface	-	-	-	-	10.0	7.0	4.5	9.0	10.0	10.0	9.0	8.0	8.4	0.68
IV Bottom	-	-	-	-	0.8	0.9	1.0	2.0	1.0	0.6	0.8	0.5	9.5	0.16
V Surface	-	-	-	-	8.0	9.5	3.5	8.0	10.0	9.0	10.0	7.6	8.2	0.75
V Bottom	-	-	-	-	2.5	3.5	1.0	3.0	1.0	0.6	0.7	0.6	1.61	0.42
VI	-	-	-	-	8.0	8.0	9.0	9.5	10.0	10.0	9.0	9.0	9.1	0.27
VII	-	-	-	-	0.7	0.7	0.7	0.5	0.7	0.3	0.5	0.5	0.6	0.05
VIII Surface	-	-	-	-	6.0	7.5	7.0	9.0	9.5	10.0	8.0	9.0	8.3	0.48
VIII Bottom	-	-	-	-	1.4	2.5	2.5	2.0	1.5	1.0	1.0	1.0	1.61	0.23
$\bar{X}$	-	-	-	-	5.1	5.1	4.0	5.3	5.8	5.0	4.8	4.4		
$S_{\bar{X}}$	-	-	-	-	1.14	1.02	0.95	1.06	1.21	1.33	1.25	1.16		

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	26.0	35.2	33.9	35.0	34.8	32.0	33.0	31.0	30.0	24.0	32.0	29.6	31.4	1.02
II	25.9	35.0	35.0	35.0	35.0	32.5	33.8	32.5	28.9	23.7	31.5	30.0	31.6	1.09
III	26.0	35.0	36.5	35.7	35.2	32.0	32.9	31.8	30.5	23.8	32.9	29.9	31.9	1.12
$\bar{X}$	25.9	35.1	35.1	35.2	35.0	32.2	33.2	31.8	29.8	23.8	3.21	29.8		
$S_{\bar{X}}$	0.03	0.07	0.87	0.23	0.12	0.17	0.28	0.43	0.47	0.09	0.41	0.12		

App. B, Table 2 Salinity concentration in PPT in Station 1 during the study period.

App. B, Table 3 Salinity concentration in PPT in Station II during the study period.

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	26.5	35.3	35.0	34.7	35.0	33.0	33.2	31.4	30.0	26.9	33.0	30.3	32.0	0.88
II	26.5	34.8	35.0	35.0	34.9	33.0	33.0	31.0	30.0	28.0	33.0	32.0	32.0	0.83
III	26.5	35.0	36.4	35.4	35.0	32.9	33.0	31.2	30.2	28.0	32.6	30.0	32.2	0.89
$\bar{X}$	26.5	35.0	35.5	35.0	35.0	33.0	33.1	31.2	30.0	27.6	32.9	30.2		
$S_{\bar{X}}$	0	0.15	0.47	0.20	0.03	0.03	0.07	0.12	0.07	0.37	0.13	0.09		

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	25.8	33.1	36.0	35.0	35.8	34.2	34.6	32.7	31.0	24.5	34.0	30.0	32.2	3.32
II	26.0	33.3	36.4	35.8	35.0	34.0	35.0	33.0	31.3	23.9	33.9	30.6	32.4	1.12
III	26.0	33.3	35.8	35.0	35.0	34.0	35.0	33.0	31.2	24.0	33.8	29.5	32.1	1.09
$\bar{X}$	25.9	33.1	36.1	35.3	35.3	34.1	34.9	32.9	31.2	24.1	33.9	30.0		
$S_{\bar{X}}$	0.07	0.09	0.18	0.27	0.27	0.07	0.13	0.10	0.09	0.19	0.06	0.32		

App. B, Table 4 Salinity concentration in PPT in Station III during the study period.

App. B, Table 5 Salinity concentration in PPT in Station IV during the study period.

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	24.6	34.0	38.2	38.0	38.0	37.4	39.8	36.0	33.2	20.0	36.5	30.0	33.8	1.75
II	25.2	34.4	38.0	38.0	38.0	37.0	41.0	36.0	33.4	20.0	36.9	30.0	34.0	1.76
III	25.0	34.0	37.9	38.3	37.8	37.0	40.0	35.8	33.1	20.0	37.0	30.3	33.9	1.73
$\bar{X}$	24.9	34.1	38.0	38.1	3.79	37.1	40.3	35.9	33.2	20.0	36.8	30.1		
$S_{\bar{X}}$	0.18	0.13	0.09	0.10	0.07	0.13	0.37	0.07	0.09	0	0.15	0.10		

N	MONTH												X̄	S-X
	1	2	3	4	5	6	7	8	9	10	11	12		
I	27.2	35.0	36.5	36.4	35.0	35.0	35.8	32.8	33.0	19.6	35.0	32.1	32.8	1.41
II	27.3	35.0	36.6	36.0	35.0	35.0	35.5	33.0	33.0	19.8	35.0	32.2	32.8	1.38
III	27.0	35.0	36.0	35.9	35.0	35.0	35.5	33.6	32.9	20.0	34.7	32.0	32.7	1.36
X̄	27.2	35.0	36.4	36.1	35.0	35.0	35.6	33.1	33.0	19.8	34.9	32.1		
S-X	0.09	0	0.19	0.15	0	0	0.10	0.24	0.03	0.12	0.10	0.06		

App. B, Table 6 Salinity concentration in PPT in Station V during the study period.

App. B, Table 7 Salinity concentration in PPT in Station VI during the study period.

N	MONTH												X̄	S-X
	1	2	3	4	5	6	7	8	9	10	11	12		
I	26.1	35.0	36.2	34.8	34.9	33.9	34.0	33.0	33.6	20.6	33.6	30.0	32.1	1.31
II	26.5	35.4	36.2	35.0	35.0	34.0	34.0	33.0	34.0	20.4	34.0	30.0	32.3	1.33
III	26.0	35.0	36.0	35.0	35.2	34.2	34.5	32.6	34.2	20.5	34.0	29.9	32.3	1.34
X̄	26.2	3.51	36.1	34.9	35.0	34.0	34.2	32.9	33.9	20.5	33.9	30.0		
S-X	0.15	0.13	0.07	0.07	0.09	0.09	0.17	0.13	0.18	0.06	0.13	0.03		

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	26.3	35.0	36.8	35.0	35.3	34.0	34.0	33.0	33.5	34.7	34.0	30.0	33.5	0.80
II	26.0	35.2	36.0	36.0	35.0	34.0	34.5	33.0	33.0	33.0	34.0	30.1	33.3	0.81
III	26.0	35.0	35.9	35.0	35.0	33.8	34.0	33.0	33.5	33.0	3.40	30.0	33.2	0.78
$\bar{X}$	26.1	35.1	36.2	35.3	35.1	33.9	34.2	33.0	33.3	33.6	34.0	30.0		
$S_{\bar{X}}$	0.10	0.07	0.28	0.33	0.10	0.07	0.17	0	0.17	0.57	0	0.03		

App. B, Table 8 Salinity concentration in PPT in Station VII during the study period.

App. B, Table 9 Salinity concentration in PPT in Station VIII during the study period.

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	25.9	35.0	38.0	36.0	36.9	35.0	37.0	35.6	35.0	19.8	35.8	32.0	33.5	1.54
II	26.3	35.0	38.0	35.8	36.5	35.4	37.0	35.9	34.6	19.5	35.0	32.0	33.4	1.54
III	26.0	35.0	37.8	36.0	36.8	35.0	36.8	36.0	34.8	19.5	34.6	32.0	33.4	1.54
$\bar{X}$	26.1	35.0	37.9	35.9	36.7	35.1	36.9	35.8	34.8	19.6	34.9	32.0		
$S_{\bar{X}}$	0.12	0	0.07	0.07	0.12	0.13	0.07	0.12	0.12	0.10	0.13	0		

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	7.7	6.7	6.0	4.6	6.6	5.4	5.2	5.4	5.1	6.5	5.9	0.30
II	-	-	7.6	6.9	6.0	4.4	6.2	5.6	5.4	5.2	5.4	6.3	5.9	0.29
III	-	-	7.7	6.9	5.9	4.6	6.6	5.4	5.4	5.4	5.1	6.5	6.0	0.30
$\bar{X}$	-	-	7.7	6.8	6.0	4.5	6.5	5.5	5.3	5.3	5.2	6.4		
$S_{\bar{X}}$	-	-	0.03	0.07	0.03	0.07	0.13	0.07	0.07	0.07	0.10	0.07		

App. B, Table 10 Oxygen concentration in PPM in Station I during the Study period.

App. B, Table 11 Oxygen concentration in PPM in Station II during the Study period.

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	7.4	6.8	6.0	6.0	6.2	5.1	5.2	5.6	5.1	6.2	6.0	0.24
II	-	-	7.6	6.8	6.3	6.0	6.0	5.2	5.2	5.6	5.1	6.4	6.0	0.25
III	-	-	7.4	7.0	6.0	5.8	6.2	5.2	5.4	5.6	5.0	6.4	6.0	0.24
$\bar{X}$	-	-	7.5	6.7	6.1	5.9	6.1	5.2	5.3	5.6	5.1	6.3		
$S_{\bar{X}}$	-	-	0.07	0.07	0.10	0.07	0.07	0.03	0.07	0	0.03	0.07		

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	6.2	3.8	5.2	4.0	4.6	4.4	2.0	3.9	4.2	3.0	4.1	0.36
II	-	-	6.6	3.8	5.2	4.2	4.8	4.4	2.2	4.0	4.0	3.3	4.3	0.37
III	-	-	6.2	3.7	5.1	4.2	4.6	4.5	2.0	4.1	3.9	3.2	4.2	0.35
$\bar{X}$	-	-	6.3	3.8	5.2	4.1	4.7	4.4	2.1	4.0	4.0	3.2		
$S_{\bar{X}}$	-	-	0.13	0.03	0.03	0.07	0.07	0.03	0.07	0.06	0.09	0.09		

App. B, Table 12 Oxygen concentration in PPM in Station III during the Study period.

App. B, Table 13 Oxygen concentration in PPM in Station IV during the Study period.

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	10.1	2.2	2.2	7.7	11.2	5.0	1.0	3.6	2.0	2.2	4.7	1.17
II	-	-	10.2	2.1	2.2	7.8	11.0	5.1	0.9	3.6	2.0	2.0	4.7	1.16
III	-	-	10.2	2.2	2.2	7.6	11.2	5.0	1.0	3.5	2.1	1.8	4.7	1.17
$\bar{X}$	-	-	10.2	2.2	2.2	7.7	11.1	5.0	1.0	3.6	2.0	2.0		
$S_{\bar{X}}$	-	-	0.03	0.03	0	0.06	0.07	0.03	0.03	0.03	0.03	0.12		

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	6.9	4.8	5.9	5.0	5.2	5.1	4.0	4.6	4.6	4.4	5.0	0.26
II	-	-	6.9	4.7	5.8	4.8	5.4	5.0	4.2	4.6	4.8	4.2	5.0	0.26
III	-	-	6.9	4.8	5.8	5.0	5.2	5.0	3.8	4.6	4.7	4.1	5.0	0.28
$\bar{X}$	-	-	6.9	4.8	5.8	4.9	5.3	5.0	4.0	4.6	4.7	4.2		
$S_{\bar{X}}$	-	-	0	0.03	0.03	0.07	0.07	0.03	0.12	0	0.06	0.09		

App. B, Table 14 Oxygen concentration in PPM in Station V during the Study period.

App. B, Table 15 Oxygen concentration in PPM in Station VI during the Study period.

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	6.8	5.1	6.4	5.8	4.8	5.2	4.6	5.9	4.9	5.0	5.5	0.23
II	-	-	6.8	5.1	6.4	5.7	5.0	4.9	4.9	5.9	4.9	5.1	5.5	0.22
III	-	-	6.6	5.0	6.4	5.8	5.0	5.2	4.6	5.8	5.0	5.0	5.4	0.21
$\bar{X}$	-	-	6.7	5.1	6.4	5.8	5.0	5.1	4.8	5.9	5.0	5.0		
$S_{\bar{X}}$	-	-	0.07	0.03	0	0.03	0.07	0.10	0.21	0.03	0.03	0.03		

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	7.1	5.0	6.4	5.6	5.0	5.1	4.4	2.0	4.4	4.8	5.0	0.43
II	-	-	7.2	5.1	6.5	5.5	5.2	5.2	4.2	1.9	4.5	5.0	5.2	0.32
III	-	-	7.2	5.0	6.4	5.6	5.1	5.2	4.4	2.0	4.6	5.1	5.1	0.43
$\bar{X}$	-	-	7.2	5.0	6.4	5.6	5.1	5.2	4.3	2.0	4.5	5.0		
$S_{\bar{X}}$	-	-	0.03	0.03	0.03	0.03	0.06	0.03	0.07	0.03	0.06	0.09		

App. B, Table 16 Oxygen concentration in PPM in Station VII during the Study period.

App. B, Table 17 Oxygen concentration in PPM in Station VIII during the Study period.

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	6.8	4.8	5.6	3.0	3.5	2.2	2.2	3.4	5.1	5.1	4.2	0.49
II	-	-	6.8	4.8	5.6	2.9	3.2	2.1	2.0	3.4	5.1	5.2	4.1	0.51
III	-	-	6.7	4.7	5.6	3.0	3.5	2.2	2.0	3.3	5.2	5.3	4.1	0.50
$\bar{X}$	-	-	6.8	4.8	5.6	3.0	3.4	2.1	2.1	3.4.	5.1	5.2		
$S_{\bar{X}}$	-	-	0.03	0.03	0	0.03	0.10	0.03	0.07	0.03	0.03	0.06		

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	7.9	2.2	2.1	2.0	1.1	2.1	10.0	4.0	1.33
II	-	-	-	-	-	8.0	2.0	2.0	2.0	1.0	2.0	10.0	3.7	1.35
III	-	-	-	-	-	8.3	2.0	2.0	2.2	1.0	2.0	10.0	4.0	1.37
$\bar{X}$	-	-	-	-	-	8.1	2.1	2.0	2.1	1.0	2.0	10.0		
$S_{\bar{X}}$	-	-	-	-	-	0.12	0.06	0	0.06	0	0	0		

App. B, Table 18 Phosphate concentration in 1 x 10^{-2} / μg at /1 in Station I during the study period.

App. B, Table 19 Phosphate concentration in 1 x 10^{-2} / μg at /1 in Station II during the study period.

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	9.0	2.9	1.0	2.1	2.0	3.1	7.1	3.9	1.12
II	-	-	-	-	-	10.0	3.0	1.0	2.0	2.0	3.0	7.0	4.0	1.23
III	-	-	-	-	-	9.1	3.1	1.0	1.9	2.2	3.1	7.0		
$\bar{X}$	-	-	-	-	-	9.4	3.0	1.0	2.2	2.1	3.1	7.0	4.0	1.13
$S_{\bar{X}}$	-	-	-	-	-	0.32	0.06	0.06	0.07	0.03	0.03	0.03		

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	4.0	2.0	1.0	3.1	1.2	2.1	3.0	2.3	0.41
II	-	-	-	-	-	4.0	2.0	1.0	3.0	1.0	2.0	3.0	2.3	0.42
III	-	-	-	-	-	3.9	2.2	1.1	2.8	1.0	2.0	3.1	2.3	0.40
$\bar{X}$	-	-	-	-	-	4.0	2.1	1.0	3.0	1.1	2.0	3.0		
$S_{\bar{X}}$	-	-	-	-	-	0.03	0.07	0.03	0.09	0.07	0.03	0.03		

App. B, Table 20 Phosphate concentration in 1 x 10^{-2} / μg at /1 in Station III during the study period.

App. B, Table 21 Phosphate concentration in 1 x 10^{-2} / μg at /1 in Station IV during the study period.

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	3.0	6.1	8.0	2.0	2.0	5.1	4.0	4.3	0.84
II	-	-	-	-	-	3.0	6.0	8.0	2.0	2.0	5.0	4.0	4.3	0.84
III	-	-	-	-	-	3.3	5.9	7.9	2.1	2.2	5.1	4.1	4.4	0.79
$\bar{X}$	-	-	-	-	-	3.1	6.0	8.0	2.0	2.1	5.1	4.0		
$S_{\bar{X}}$	-	-	-	-	-	0.10	0.06	0.03	0.03	0.07	0.03	0.03		

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	-	-	-	5.4	4.8	4.0	2.2	1.0	4.0	6.4	4.0	0.70
II	-	-	-	-	-	5.0	5.0	4.0	2.0	1.0	4.0	6.0	3.9	0.67
III	-	-	-	-	-	5.0	5.0	3.9	2.1	1.3	4.0	6.0	3.9	0.63
$\bar{X}$	-	-	-	-	-	5.1	4.9	4.0	2.1	1.1	4.0	6.1		
$S_{\bar{X}}$	-	-	-	-	-	0.13	0.07	0.03	0.06	0.10	0	0.13		

App. B, Table 22 Phosphate concentration in 1 x 10^{-2} / μg at /1 in Station V during the study period.

App. B, Table 23 Phosphate concentration in 1 x 10^{-2} / μg at /1 in Station VI during the study period.

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	-	-	-	4.2	2.0	9.0	2.1	1.0	2.0	5.0	3.6	1.04
II	-	-	-	-	-	4.0	2.0	10.0	2.0	1.0	2.2	5.0	3.7	1.16
III	-	-	-	-	-	3.9	2.0	10.0	1.8	1.0	2.0	5.3	3.7	1.18
$\bar{X}$	-	-	-	-	-	4.0	2.0	10.0	2.1	1.0	2.1	5.1		
$S_{\bar{X}}$	-	-	-	-	-	0.09	0	0.33	0.09	0	0.07	0.10		

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	4.0	3.7	1.0	2.0	2.0	3.1	5.0	3.0	0.52
II	-	-	-	-	-	4.0	4.0	1.0	2.0	2.2	3.0	5.1	3.0	0.54
III	-	-	-	-	-	4.3	4.1	1.2	2.2	2.0	3.0	5.0	3.1	0.53
$\bar{X}$	-	-	-	-	-	4.1	3.9	1.1	2.1	2.1	3.0	5.0		
$S_{\bar{X}}$	-	-	-	-	-	0.10	0.12	0.07	0.07	0.07	0.03	0.03		

App. B, Table 24 Phosphate concentration in 1×10^{-2} / μg at /1 in Station VII during the study period.

App. B, Table 25 Phosphate concentration in 1×10^{-2} / μg at 1/ in Station VIII during the study period.

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	4.8	3.0	2.1	2.1	2.2	8.1	5.1	3.9	0.85
II	-	-	-	-	-	5.0	2.6	2.0	2.0	2.0	8.0	5.0	3.8	0.87
III	-	-	-	-	-	5.2	3.0	1.9	1.9	2.0	8.0	5.0	3.9	0.87
$\bar{X}$	-	-	-	-	-	5.0	2.9	2.0	2.0	2.1	8.0	5.0		
$S_{\bar{X}}$	-	-	-	-	-	0.12	0.13	0.06	0.06	0.07	0.03	0.03		

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	1.69	2.00	1.92	1.90	2.01	2.11	2.16	1.96	0.05
II	-	-	-	-	-	1.80	2.01	1.90	1.90	2.00	2.10	2.11	1.97	0.04
III	-	-	-	-	-	1.92	2.01	1.90	1.89	2.00	2.11	2.10	1.99	0.03
$\bar{X}$	-	-	-	-	-	1.80	2.01	1.91	1.90	2.00	2.11	2.10		
$S_{\bar{X}}$	-	-	-	-	-	0.07	0	0.01	0	0	0	0		

App. B, Table 26 Ammonia concentration in g at /l in Station I during the Study period.

App. B, Table 27 Ammonia concentration in μg at /l in Station II during the Study period.

N	MONTH												$\bar{X}$	$S_{\bar{X}}$
	1	2	3	4	5	6	7	8	9	10	11	12		
I	-	-	-	-	-	1.83	2.05	2.11	1.90	1.50	2.00	2.11	1.93	0.08
II	-	-	-	-	-	1.80	2.00	2.10	1.91	1.50	2.01	2.10	1.92	0.08
III	-	-	-	-	-	1.80	2.00	2.10	1.90	1.51	2.00	2.11	1.92	0.08
$\bar{X}$	-	-	-	-	-	1.81	2.02	2.10	1.90	1.50	2.00	2.11		
$S_{\bar{X}}$	-	-	-	-	-	0.01	0.02	0	0	0	0	0		

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	-	-	-	1.50	2.01	1.80	1.62	1.70	2.10	2.00	1.82	0.09
II	-	-	-	-	-	1.53	2.00	1.80	1.60	1.71	2.11	2.00	1.82	0.08
III	-	-	-	-	-	1.50	2.00	1.86	1.60	1.70	2.10	2.00	1.82	0.09
$\bar{X}$	-	-	-	-	-	1.51	2.00	1.82	1.60	1.70	2.10	2.00		
$S_{\bar{X}}$	-	-	-	-	-	0.01	0	0.02	0.01	0	0	0		

App. B, Table 28 Ammonia concentration in g at /1 in Station III during the Shudy period.

App. B, Table 29 Ammonia concentration in μg at /1 in Station IV during the Seudy period.

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	-	-	-	4.33	5.01	5.01	4.11	1.80	2.00	2.01	3.47	0.56
II	-	-	-	-	-	4.31	5.00	5.01	4.10	1.80	2.00	2.00	3.46	0.55
III	-	-	-	-	-	4.30	5.00	5.00	4.10	1.80	2.00	2.02	3.46	0.55
$\bar{X}$	-	-	-	-	-	4.31	5.00	5.01	4.10	1.80	2.00	2.01		
$S_{\bar{X}}$	-	-	-	-	-	0.01	0	0	0	0	0	0.01		

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	-	-	-	1.34	2.10	2.00	2.00	1.72	2.21	2.10	1.94	0.12
II	-	-	-	-	-	1.30	2.10	2.11	2.01	1.70	2.20	2.10	1.93	0.12
III	-	-	-	-	-	1.30	2.01	2.10	2.01	1.71	2.20	2.10	1.91	0.12
$\bar{X}$	-	-	-	-	-	1.31	2.07	2.10	1.71	2.20	2.10			
$S_{\bar{X}}$	-	-	-	-	-	0.01	0.03	0	0	0.01	0	0		

App. B, Table 30 Ammonia concentration in g at /1 in Station V during the Study period.

App. B, Table 31 Ammonia concentration in μg at /1 in Station VI during the Study period.

N	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	$\bar{X}$	$S_{\bar{X}}$
I	-	-	-	-	-	2.70	2.00	1.90	1.90	1.71	2.00	2.02	2.03	0.12
II	-	-	-	-	-	2.70	2.00	1.90	1.90	1.70	2.00	2.00	2.03	0.12
III	-	-	-	-		2.68	2.00	1.91	1.90	1.71	2.05	2.01	2.04	0.12
$\bar{X}$	-	-	-	-	-	2.69	2.00	1.90	1.90	1.71	2.02	2.01		
$S_{\bar{X}}$	-	-	-	-	-	0.01	0	0	0	0	0.02	0.01		