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SCIENCE REPORT - M-158

AN ENVIRONMENTAL EVALUATION OF LA PLATA LAKE, TOA ALTA

THIRD QUARTERLY REPORT (APRIL-JUNE, 1982)

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

MARINE ECOLOGY DIVISION

COLLEGE STATION MAYAGUEZ, PUERTO RICO

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INTRODUCTION

La Plata Lake is one of the most important water reservoirs of the island of Puerto Rico. It supplies the domestic and industrial water requirements of the municipalities of Bayamon, Toa Alta, Toa Baja, Naranjito, Comerio, Dorado, Cataño and some sections of the metropolitan area of San Juan. The lake is also a very attractive resource for recreational activities such as camping, boating, fishing, swimming, and others.

The Lake, which was formed largely as an impoundment of La Plata River, developed acute water quality problems shortly after the end of its construction in 1976. In a study conducted in 1977, Carvajal (1979) indicated that oxygen depletion below 4-5 m, eutrophication, bacteriological concentrations above acceptable standards, choking of the lake surface by water hyacinths and the presence of infective stages of schistosomiasis were the major water quality problems affecting La Plata Lake. Martinez (1979) also concluded that the trophic state condition of La Plata Lake was eutrophic. The management of artificial lakes for water production continues to be a challenge.

And other recreational activities require understanding of the basic unit and the hydrographic characteristics of the basin and its relationship with the local climatological pattern. The strategies for management and water quality regulations have been generally extrapolated from studies related to temperate region systems. However, there are significant differences in the natural pattern of water quality between the tropical Puerto Rican lakes and the lakes from temperate regions. The dynamics of temporal variability constitute one of the central differences among temperate and tropical regimes. Temperate systems are generally monomictic or dimictic (having one or two periods of free circulation), where large, seasonally-related temperature variations result in convective mixing of the water column. On the other hand, tropical lakes are often considered oligomictic, scarcely (or very slowly) mixed or polymictic, frequently mixed. Mixing or the actual turnover of the lake may depend on the magnitude of tributary river discharge and the occurrence of storms. This concept was clearly documented by Quinones-Marquez (1980) at Loiza Lake. The present investigation is conceived under the EPA Clean Lakes Program (PRL 1388-4) as a diagnostic-restoration/feasibility study of La Plata Lake. The principal objectives of the study are: (1) To provide a basic characterization of the water quality of La Plata Lake as an input-output system. (2) To identify among measured inputs those potentially important in water quality degradation. (3) To study the natural patterns of spatial and temporal variability of important lake quality features. (4) To develop recommendations needed for the restoration of the water quality of La Plata Lake.

APPROACH: In order to achieve the above-mentioned objectives, the following sampling scheme has been designed: (1) Establish a routine sampling of selected water quality measurements at the three main tributaries to La Plata Lake (La Plata River: W-1; Guadiana

River: W-2; and Cafas River: W-3) and at one station in the lake proper (L-1).

(2) Design special investigations needed to understand the effect that unusual climatological events

have on the condition of the lake water quality.

(3) Perform oversampling of selected water quality parameters in order to understand the level of uncertainty inherent to sampling and analytical variability.

METHODS: No detailed presentation of methods is made in this report. The reader is referred to the proposal and quality assurance documents for that information. The location of sampling stations at the lake and major tributaries is presented in Figure 1.

RESULTS: The results from water samples and field measurements taken during the third quarter of the study (April-June, 1982) are included in Tables I thru XLVII along with a preliminary analysis of the existing data up-to-date.

Figure I. Location of sampling stations at La Plata Lake and major tributaries. Scale 1:41,000 Magnetic North

A brief discussion on fish mortalities observed at La Plata during sampling activities has been incorporated as part of this report.

GEOMORPHIC CHARACTERISTICS OF LA PLATA BASIN:

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La Plata Lake is located between the municipalities of Toa Alta and Naranjito in the interior mountainous region of the northeastern section of Puerto Rico. The centroid of the lake is at 18 degrees20'N, 66 degrees13 W and is located in the Naranjito quadrangle of the U.S.C.S. 7.5 topographic maps of Puerto Rico. The surface elevation of the Lake is at 47 m above MSL, maximum elevation of the surrounding watershed is at approximately 980 m (Picó, 1975). The lake has maximum extensions of 0.5 km width and 9.6 km length, covering a surface area of 3.07 km squared. The La Plata River watershed (see Figure II) represents approximately 90% of the total drainage area. The drainage basins of Guadiana and Canas River account for approximately 6.2 and 3.5 percent of the total drainage area respectively. The topographic relief of the basin is characterized by moderately elevated terrain.

The text seems to refer to geographical and climatic characteristics of a region, possibly Puerto Rico. Here's a revised version with corrections to typos, punctuation, and formatting:

The region is characterized by very steep slopes, with well-drained soils on side slopes and rounded hilltops of strongly dissected uplands (Boccheciamp, 1978). The soils are formed in residuum from basic volcanic rocks. The climate of the region is described as humid according to Thornthwaite's climatic index applied to Puerto Rico (Giusti and Lopez, 1967). The mean annual rainfall is approximately 190 cm (Climate of Puerto Rico and U.S. Virgin Islands: Isopleths of mean annual precipitation).

Historically, the distribution of rainfall over the year in Puerto Rico does not show an absolute wet season-dry season relationship, but only a relatively wet and relatively dry season (Calvesbert, 1961). The distinction between the two seasons is less marked in the northern section of the island but, in general, the dry season normally begins in February and ends in April (Calvesbert, 1961).

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Ambient temperatures (based on data for the period between 1931 and 1952) fluctuate between a maximum mean of 31.1 degreesC in July to a minimum mean of 16.7 degreesC in January (Climate of Puerto Rico and U.S. Virgin Islands: Isopleths of mean maximum and minimum temperatures).

La Plata Lake has a volume of 3.085 X 10^7 m^3 and a mean depth of 10m. A bathymetric map of the lake is shown in Figure 122. The lake is relatively long and narrow (L:W=19.1) and has a relatively low surface to volume relationship (relative depth is 0.4). The depth distribution of volume is roughly conical, as shown in Figure IV, approximately 64% of the total volume is found in the 0-8 m depth interval.

Table I reviews some morphometric and geographical characteristics of La Plata Lake. Mean monthly precipitation in the basin ranged between 32.70 cm in December, 1981 and 3.25 cm in March, 1982, averaging 12.54 cm/month (see Table II). The runoff coefficient (Q/P) determined as the average of three gauging stations in La Plata basin is 0.50 (data taken from Giusti and Gomez, 1967).

Please note that due to the fragmented nature of the original text, some sentences may not make complete sense without further context or information.

"62 we oz-9t ws suc wT ot-et ove ost z-8 z'6t zoz a ez Lew rt 6s L6t 1-0 0 eMg0TX "TOA "TOA x " " atyeiming TRIOL % sTeazeauy yadag sax oanby "

This text seems to be garbled and uninterpretable. Therefore, it cannot be fixed without further context or clarification.

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Table 1. Review of Geographical and Morphometric Characteristics of La Plata Lake.

Latitude: 10 degrees20'N

Longitude: 138 degreesE

Total Length: 9.6 km

Max. width: 0.5 km

Surface Elevation above MSL: [Information Missing]

Max. Elevation of watershed: 980m

Volume: 4.50 x 10^?

Surface Area: 3.07 x 10^8 m^2

Mean Depth: [Information Missing]

Relative Depth: 0.08

Maximum Depth: 330m

Tributaries Drainage Areas:

La Plata River: 4.050 x 10^8 m^2

Guadiana River: 2.835 x 10^7 m^2

Cafas River: 3.575 x 10^7 m^2

The following text seems to be garbled and uninterpretable. Therefore, it cannot be fixed without further context or clarification.

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GOTO fea voy a WE we a a z061 et Wifseg Sieg PT oy suoTeeas Bulpvooy W (se) wise itiosag Aiiuoy Tear TE STE"

The net discharge by tributary rivers (considering consumption of water by PRASA) for the period between October, 1981 and April, 1982 was 1.677 x 10^8 m^3, which equals 2.4 x 10^7 m^3/month. The theoretical replacement time was 23 days. Table II describes the monthly fluctuations of discharge by tributary rivers of La Plata Lake during the study period. During 1981 La Plata Lake averaged a daily supply of drinking water of 42 million gallons (Ing. Joglor-PRASA, personal communication).

LIMNOLOGICAL CHARACTERIZATION OF LA PLATA LAKE AND MAJOR TRIBUTARIES - THIRD QUARTER 1962

Water Temperature: Water temperature profiles at La Plata Lake (Table IV) presented a gradual decline with depth during the months of April and May, 1982. The month of June, 1982 evidenced the establishment of a thermocline between the depths of 3-4 m with a Maximum 07 of 2.0 degreesC/m. The presence of a thermocline constitutes evidence of stronger thermal stratification in the water column. Monthly temperature profiles (Figure V) are suggestive of a seasonally related trend toward increased thermal stratification.

In the summer, the average rate of temperature decline with depth during the third quarter of the study (April-June, 1982) was 0.19 degreesC/m.

Table 411: Monthly Discharge of Tributary Rivers to La Plata Lake during the period between October 1961 and April 1962

River	October	November	December	January	February	March	April	Total	Monthly Mean
La Plata	3.561 x 10^7	1.974 x 10^7	6.633 x 10^7	9.041 x 10^7	9.276 x 10^8	6.567 x 10^8	4.089 x 10^7	1.564 x 10^9	2.235 x 10^8
Guaña	2.414 x 10^8	1.230 x 10^8	4.571 x 10^8	6.221 x 10^8	5.887 x 10^8	2.061 x 10^8	6.809 x 10^8	1.046 x 10^9	1.494 x 10^8
Caras	1.658 x 10^8	8.744 x 10^4	3.091 x 10^8	4.251 x 10^8	4.256 x 10^8	3.074 x 10^4	6.250 x 10^8	7.406 x 10^8	4.058 x 10^8
Total	3.019 x 10^7	2.006 x 10^7	7.121 x 10^7	9.706 x 10^7	9.879 x 10^8	6.993 x 10^8	1.163 x 10^7	1.677 x 10^9	2.395 x 10^8

Note: Net Discharge was calculated as: Net Discharge Drainage, Monthly Runoff, PRASA monthly water area, precipitation coefficient consumption at Naranjito.

Water Temperature vs. Depth at Lake Station:

Depth	Surface	1	2

3	26.1	26.4	28.1
5	26.0	24.9	-
6	25.8	24.3	-
7	25.3	24.0	-
8	23.6	23.8	-
9	23.7	-	
10	22.8	23.65	-
11	23.7	23.6	-
12	23.6	-	
14	23.6	-	
15	23.55	-	
16	23.3	23.55	-
18	22.2	23.55	-
20	23.2	23.55	-

Table V: Water Temperature at Tributary Stations

Sampling Dates	Stations
6-02-82	25.2
5-06-82	24.9
6-03-82	26.7
4-02-82	24.5
3-02-82	30.2
2-03-82	23.5

|1-04-82|28.7|

Figure 1: Representative Profiles of Water Temperature at Depth

The average temperature of tributary rivers (Table V) was 25.7 degreesC at La Plata River, 20.1 degreesC at Guadiana River and 25.6 degreesC at Canas River during the third quarter of the study. Oxygen profiles were maintained at Lake Station 1-1 during the period between April and June, 1982. A strong chemocline fluctuated between 2-5 m (see Table VI). Oxygen depletion with zero values was observed.

In the hypolimnion, it has been shown to be a recurring lake feature in La Plata Lake, as seen in Figure VI. The structure of O2 distribution in La Plata Lake is dictated by complex physical, hydrodynamic, and biochemical factors. The major features are probably lake morphometry, nutrient loading and biological response, chemical and biological oxygen demand, tributary flow, and the tropical setting.

The lake has a relatively low surface-to-volume relationship (relative depth is .04) and its location, protected by high mills, tends to prevent wind mixing and reaeration. The loading of the lake by N and P via rain runoff is high and supports relatively high internal primary productivity. Phytoplankton respond with densities so high at the surface that light penetration is restricted (compensation depth is only 3-4 m even in open water areas). Water hyacinth crops are high and cover approximately

40-50% of the total surface area of the lake. Where present, they virtually block out all light.

Organic materials discharged into the lake during rain events and sedimenting phytoplankton and dead hyacinth particles support the growth of microbes which consume available oxygen in the layers of the lake below 4-6 m, rendering it anaerobic and reducing. Such reducing conditions, in general, are unfavorable for the growth of phytoplankton and other organisms.

TABLE VI. Dissolved oxygen vs. depth at Lake Station (Sampling Dates)

Depth: 4-6, 5-6, 0-6, 1-6, 2-6, 3-6, 4-6, 5-6, 6-6, 7-6, 8-6, 9-6, 10-6, 11-6, 12-6, 13-6, 14-6, 15-6, 16-6, 17-6, 18-6, 19-6

Surface mg: 4.2, 2.75, 6.4, 1.28, 2.4, 6.4, 2.2, 2.8, 1.6, 2.5, 0.6, 5.8, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0

TABLE VII. Dissolved Oxygen at tributary stations (Sampling Dates)

Stations: 4-6-82, 5-6-82, 6-6-82, 7-6-82

Oxygen level: 7.04, 7.9, 6.46, 11.0

Figure VI. Dissolved oxygen profiles at Station I-1 in La Plata Lake (October 1981 through June

1982).

The lake, below 4-6 m, is rendered anaerobic and reducing due to the consumption of available oxygen by microbes. These conditions, generally, are unfavorable for the growth of phytoplankton and other organisms.

Aerobic life. Thus, photosynthetic oxygen renewal does not occur either. The large seasonal reduction in temperature, which in more temperate areas results in convective mixing of the water column, does not occur here. The higher and less variable temperature regime keeps metabolism high while preventing physical aeration. The most important input of dissolved oxygen into the lake probably occurs via tributary discharge, where O2 concentrations are consistently high in relation to concentrations at L1. The distribution of dissolved oxygen in the lake reflects higher concentrations in a gradient toward La Plata River and at the surface of the water column (see Figure VII). The average dissolved oxygen concentrations at tributary rivers during the third quarter (April-June, 1982) were 7.1 mg/l at La Plata, 9.1 mg/l at Guadiana, and 8.3 mg/l at Cafas River (see Table VII).

pH Profiles measured at station L-I during the third quarter of the study are presented in Table VIII. pH values were generally higher in the upper strata and gradually declined with depth (range 6.9-6.4). The photosynthetic removal of CO2 in the photic layers of the water column is postulated to be involved in the maximum values observed. However, tributary rivers also presented higher pH values than the lake (means of 7.8 at La Plata, 8.3 at Guadiana, and 6.4 at Cafas River), allowing the alternate explanation that those input waters simply dominate the upper layers of the lake. For this latter explanation to hold, however, it requires that the colder input water turbulently displaces or mixes with the warmer surface layers. Table IX presents pH values at tributary rivers during the period between April and June, 1982.

Regarding conductivity, the average conductivities of the water column at L-I during the third quarter (April-June, 1982) were 290 umhos/cm in April, 302 umhos/cm in May, and 263 umhos/cm in June, 1982. Conductivity profiles maintained a consistent decline with depth with maximum rates of...

The text reads as follows after correction:

The change fluctuated between 8-11 meters in April and May, and 4-5 meters in June, 1982 (see Table X). The tributary rivers presented higher conductivities than the lake during this period (% = 357 umhos/cm at La Plata, 311 umhos/cm at Guadiana, and 309 umhos/cm at Cafias River) see Table XT. Water transparency, Secchi disk transparency averaged 1.8 m at L-1 during the third quarter of the study (see Table XII). Monthly fluctuations in Secchi disk readings at T-1 evidenced a minimum value in December, 1980 which corresponded to the month of higher precipitation and tributary loading of sediments (see Figure VITR). After December, 1980, monthly readings showed a gradual increase until May, 1980. Profiles of light attenuation indicated that on average the 18 light penetration or "compensation depth" at INI is found in the 3-4 depth interval (see Table XRRR).

TABLE VT. pH vs Depth at Lake Station LER. Sampling Dates:

Depths: 46-82, 56-82, 6-302

Units: nies, units, unite, _ surface 68, 6.6, 69, 1, 6.7, oe, 68, 2, 6.6, 68, a, 6.6, 6.6, 6.7, 4, 6.5, 66, 64, 5, 6.6, 66, 6.55, 6, 6.6, 6.6, 6.6, 7, 65, 66, 6.6, 8, 65, 6.6, 6.55, degrees, 6.5, 6.6, 65, 10, 6.5, 6.6, 65, 11, 6.5, 66, 65, 2, 6.5, 6.6, 6.48, 3, 65, 6.6, 6.45, 14, 6.5, 6.5, 6.45, 15, 6.48, 6.5, 6.48, 16, 6.4, 6.5, 6.48, 17, 6.4, 65, 6.48, 18, 6.4, 65, 6.45, 19, 6.4, 65, 6.45, 20, 6.4, 65, 6.45.

TABLE IX. pH at Tributary Stations

Sampling Dates: Stations: 4-6-2, 56-42, 63-82

Units: unite, units, units, wt, 19, a, 7.46, wa, 8.0, 1, WS, 8.2, 82

Table MATT. Profile of Light Penetration at La Plata Lake, in Foot/candles

Depths: sonore, 2en5-oy, tag, ag, gee, x, degrees, 30, 4,200, 160, 2,000, 200, 1966, 1, 60, 210, 2, 1,300, 290, 376, 2, 16, as, 360, 10, 01, 3, 33, oe, 7, 170, 26, a, 6, 2, %, 6, 18, 5, 1, 05, 37, 56, degrees, 02, 9, 1, 7, 78, a8, 16, 2, oy, 08, oa, degrees, as, 0.3, 18

Total Light Penetration: 19.66 Foot-candles

Compensation depth: n

Figure VI.1. Monthly variation of Secchi Disk Readings at La Plata Lake. Mean Secchi Disk Reading: 1.48

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Conductivity vs. Depth at Lake Station 4-1

Sampling Dates: 46-62, 5-6-82

Units: umhos/cm, umhos/cm, tumor

Depths: Ze, 110-300, 346, ae, 337, 347, ae, 340.5, ar, a2

Unfortunately, the text provided seems to be a mix of random numbers, codes, and some coherent sentences. It's impossible to provide a proper correction without knowing the context or what the codes and numbers represent.

However, the coherent parts of the text can be cleaned up as follows:

Total Suspended Solids

The mean water column concentration of 785 at L-I during the third quarter of the study (April-June, 1982) was 24.9 mg/l. In general, the vertical profile maintained its consistent increase with depth during this quarter (see Table XIV). Its concentrations at tributary rivers for the third quarter are presented in Table XV. An average profile of 165 vs depth at the lake station L-I has shown significant differences in its vertical distribution (see Figure IX). Considerable variation has been observed on a monthly basis in water column averages of 88, these variations are associated with high sediment loading to the lake during periods of high rainfall and tributary discharge. Table XVI presents the monthly suspended sediment loading by tributary rivers to La Plata Lake. The monthly loading rate has been calculated as 2.001 x 106 kg/lake/month. La Plata River contributed 98.58% of the total sediment load to the lake.

Total Dissolved Solids

TDS averaged 319 mg/l in the water column at L-I during the third quarter of the study (April-June, 1982). Monthly means ranged between a minimum of 175 mg/l in June and a maximum of 587 g/l in May, 1982 (see Table XVII). As previously noted, there was no significant relationship between the concentration of 7S and the specific conductance of the water at La Plata Lake. The relationship between specific conductance to TDS will vary depending on the distribution of the major chemical species present (Water Quality Criteria, 1973).

Table XVIII: Depth Readings at JX1 and Tributary Stations

Sampling Dates Stations 6-82 5-6-8 etc...

Unfortunately, without context or additional information, I can't provide more comprehensive corrections.

0.8 was 1908 (3m) so (am) is) 3 rows ($m) so (Sm i) sasuE x Total Suspended Solids vs. Depth at Lake Station t-1. 'Swirling Dates' Depth 41-82 6-382 East 7.0 47 4 5. 8.0 8 9.2 17.0 2 15. 3.0 6 13.5 54.0 2 52.0 51.0. Table XV: Total Suspended Solids at Tributary Stations. Sampling Dates Stations: e382, tt, wr, me, na, 16.2, we, 2.4, n2.0, aa, ws, a4, si2.0, na 26.

Figure 1x: Mean and Standard Error of Total Suspended Solids at Station te1 (October 1981 - June 1982) se 08 0. Below parts per million (ppm) ps0 7 8 1. Table XVI: Suspended Sediment Loading from Tributary Rivers to La Plata Lake (October 1981 - April 1983). On to La Plata, Guadiana, Cahas. Total e/a fms ey: October 2.949 x 108, 242 x 10%, 5.001 x 108, 4st x 108. November e114 x 109, 337 x 107, ates x 10%, 8.338 x 10?. December 4.875 x 107, 2.925 x 107, 2,349 x 10%, 4.906 x 10. January 4.611 x 107, 7.465 x 108, 2,342 x 10%, 4.920 x 107. February 2.786 x10, 4.129 x WS, 6.810 x To, 2.778 x 108. March 5.976 x 107, Gre x oS, 4,535 x 10%, 6.053 x 107. Ports 1.509 x 108, G00 x 106, 5.250 x 11, 658 x 108. Total t.30rx 1092, tar7 x 10%, 4.169 x 107, sao x 10. Monthly Mean = 2.091 x 10? gx/a?/me 27, 2.001 10 degrees kg/mm.

Tributary rivers averaged 162 mg/l at La Plata, 148 mg/1 at Guadiana, and 167 mg/1 at Cafas during this quarter of the study (see Table XVIII). Total Alkalinity: Monthly means of total alkalinity measurements ranged between 96.2 mg/l as Caco3, in June and 151 mg/l as Caco3 in May, 1982. The profile of total alkalinity at the Lake station L-1 presented higher alkalinities in the upper strata where aerobic conditions prevail and pH values are higher (see Table XIX). Lower alkalinities result below the oxygen chemocline. Tributary rivers averaged 140 mg/1 as Caco3 at La Plata, 112 mg/l as $CaCO_3$ at Guadiana, and 104 mg/l as $CaCO_3$ at Calas during the third quarter of the study (April-June, 1982) see Table XX.

Nutrients of Biological Interest: Ammonia Nitrogen (NH_3-N) Water column average concentrations of NH_3-N ranged between 0.12 mg/l in April and 0.27 mg/l in May, 1982. The profile of

NH_4-N maintained a pattern of increase with depth during the third quarter of the study (April-June, 1982) as shown in Table XR. Ammonia nitrogen is generated by heterotrophic bacteria as the primary end product of the decomposition of organic matter, either directly from proteins or from other nitrogenous compounds (Wetzel, 1975). High concentrations of NH_3-N in the hypolimnion may be the result of accumulation under anoxic conditions in the bottom strata of the lake (see Figure X). Under aerobic conditions in the trophogenic zone, NH_4-N is assimilated and metabolized by photosynthetic algae and floating macrophytes.

TABLE XIV. Total Dissolved Solids vs. Depth at Lake Station LZ.

SAMPLING DATES Depth Feb-82 Nov-82 Jun-82 mg/l

_na/? _na/? _na/?.

TABLE XV. Total Dissolved Solids at Tributary Stations.

SAMPLING DATES Stations Feb-82 Nov-82 Jun-82 mg/l

TABLE XVI. Temporal Alkalinity vs. Depth at Lake Station LZ.

SAMPLING DATES Depth Feb-82 Nov-82 Jun-82 mg/l as $CaCO_3$

TABLE XVII. Total Alkalinity at Tributary stations.

SAMPLING DATES Stations Feb-82 Nov-82 Jun-82 mg/l as $CaCO_3$

TABLE XVIII. Ammonia-Nitrogen vs. Depth at Lake Station LZ.

SAMPLING DATES Depth Feb-82 Nov-82 Jun-82 mg/l

TABLE XIX. Ammonia-Nitrogen at tributary stations

SAMPLING DATES Station Feb-82 Nov-82 Jun-82 mg/l

Tributary rivers averaged 0.06 mg/l at La Plat, 0.02 mg/l at Guadiana and 0.08 mg/l at Cahas during the third quarter of the study (see Table XXII). Nitrite - Nitrate (NO_2-NO_3 as N) Nitrite-nitrate concentrations ranged between 0.01 mg/l in May and 0.05

The nitrite-nitrate concentrations reflected a weak dichotomic distribution with a maximum average concentration at 12 meters in June 1982, during the third quarter at L-I (Refer to Table XXIII). In productive lakes where clinograde 0 profiles prevail, a dichotomic distribution of NO_3-NO_2 concentrations may result when nitrate is removed by assimilation in the trophogenic layer and reduced under anoxic conditions near the bottom of the water column (Hutchinson, 1957).

Tributary rivers showed substantially higher concentrations of NO_3-NO_2 during the third quarter of the study with means of 0.79 mg/l at La Plata, 1.55 mg/l at Guadiana, and 1.02 mg/l at Cahas River (Refer to Table XXIV). The total Kjeldahl Nitrogen (TKN) for the quarter (April-June 1982) averaged

0.65 mg/l (range 0.52-0.73 mg/l) at L-I (Refer to Table XXV). TKN concentrations were higher in the deeper parts of the water column (Refer to Figure XII).

These higher concentrations near the bottom are possibly associated with the sedimentation and accumulation of organic compounds there. Tributary rivers, specifically La Plata River, presented lower concentrations.

TABLE III: Nitrite-Nitrate vs. Depth at Lake Station L-I.

Sampling Dates:

Depth	4-1-82	5-6-82	6-3-82
0	201	02	<0.001
20	101	202	00

TABLE IV: Nitrite-Nitrate at Tributary Stations

Sampling Dates:

Station	4-1-82	5-6-82	6-3-82
2	1.72	1.30	1.68

TABLE V: Total Kjeldahl Nitrogen vs. Depth at Lake Station L-I.

Sampling Dates:

Depth	4-1-82	5-6-82	6-3-82
20	12	4.23	2.86
32	---	---	---

Figure X: Mean and Standard Error of Ammonia-Nitrogen Concentrations vs. Depth (October 1981 - June 1982).

Figure XI: Mean and Standard Error of Nitrite-Nitrate Concentrations vs. Depth at La Plata Lake (October 1981 - June 1982).

Nitrite - Nitrate (99/2)

Page 1.0, 12 degrees depth, 'e) ® 20 33

TKN was higher than those measured at the lake (see Table XXVI), implying that the lake is internally recycling nitrogen or fixing atmospheric sources. The average monthly loading of nitrogen into La Plata Lake has been calculated as 1.56 X 104 kg N/lake/month (see Table XXVII). La Plata River contributed 95% of the total N loading to the lake. A seasonality related maximum of N loading was observed since 85% of the total loading occurred during the first three months of the study (October-December, 1981) which corresponded to the period of higher precipitation in the watershed basin.

Soluble Reactive Phosphorus

The water column average of SRP concentrations at L-I during the third quarter was 0.07 mg/l (range .04~.095 mg/l), see Table XXVIII. SRP is the most available source of phosphorus for phytoplankton and aquatic vegetation in their metabolic processes. Lower concentrations of SRP above the chemocline (4m) suggest rapid epilimnetic removal by photosynthetic organisms (see Figure XI). All tributary stations evidenced higher concentrations of SRP during the third quarter indicating their importance in delivering nutrients to the lake (see Table XXIX).

Total Phosphorus

Total phosphorus concentrations presented a water column average of 0.14 mg/l at L-I during the third quarter of the study (see Table XXX). This concentration characterizes the lake as hypereutrophic according to BPA 440/5-80~11 document. As previously established, the main vehicle of phosphorus loading to

TABLE SX, Total Kjeldahl Nitrogen at Tributary stations. Stations 5-6-82 6-3-2

TABLE XXVII, Soluble Reactive Phosphorus vs. Depth at Lake Station L1: SAMPLING DATES

TABLE XXIX, Soluble Reactive Phosphorus at Tributary stations. SAMPLING DATES Stations 4-10-2

This text appears to be a mix of seemingly random characters, symbols, and sections of a scientific report. Without knowing the original intent or context, it's difficult to provide a perfect correction. However, based on the coherent parts, I can provide this edit:

Unknown text.

The lake is the La Plata River. The average concentration of total Phosphorus at La Plata River during the third quarter of the study was 0.28 mg/l (see Table XXI). The estimated monthly average loading of total phosphorus to the lake via La Plata River is 6.88 x 10 g P/lake/month, which represents 94% of the total monthly average loading of phosphorus to the lake (see Table XXXII). The estimated areal loading of phosphorus based on these figures is 28.5 gt P/m2/yr.

The vertical distribution of total phosphorus in the water column at L-I (Figure IX) showed no significant differences from top to bottom. On a monthly basis, total phosphorus concentrations were higher during the period of high rainfall (October-December, 1961) in the watershed. During periods of low discharge, most of the phosphorus was found as soluble reactive phosphorus (see Figure XX).

BIOLOGICAL CHARACTERISTICS

Phytoplankton Abundance and Distribution

Monthly variations of phytoplankton abundance at the lake station L-I are presented in Figure XXXI. The large reductions in abundance which resulted after October, 1981 were related to a marked increase in tributary discharge and rapid turnover rates evidenced during the period from October-December, 1981. After December, the lake experienced less flushing allowing more time for phytoplankton growth and reproduction. The vertical distribution of phytoplankton cells in the water column (Figure XXII) at L-I evidenced substantially higher abundances at the surface and 4 m during the period between.

TABLE XI: Total Phosphorus vs. Depth at Lake Station

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Fable XX. Total Phosphorus at Tributary Stations.

Sampling Pairs Stations: 4-102, 56-02, 63-82, 7

Measurement mast o/h 1, 38, 20, 226, 2, 23, 10, a7, -2, +09, v 39

Various data details

Figure: Profile of Total Phosphorus

Figure: Profile of Soluble Concentrations at La Plata Lake

Reactive Phosphorus (October 1981 - June 1982) Concentrations at La Plata Lake (October 1981 - June 1982)

Graphical representation of the monthly fluctuations of Total Phosphorus and Soluble Reactive Phosphorus in La Plata

Various data details

Figure: Vertical distribution of phytoplankton abundance at La Plata Lake Station

Calendar dates: October 10, 1981, December 15, 1981, November 10, 1981, January 12, 1982, February 1982, March 1982

October, 1981 and February, 1982: However, the maximum peak of abundance shifted to the 8 m depth in the month of March, 1982. The shift towards a deeper maximum in phytoplankton abundances was also reflected in chlorophyll concentrations measured during the summer at the lake station L-I (see Table XXIII). The variation from previously higher abundances in the surface to deeper maximums of abundance observed during the summer (Figure XXIII) may be related to higher surface temperatures and diminished inorganic turbidity during the summer months. Tributary rivers evidenced relatively lower.

Concentrations of chlorophyll-a are confirmed in Table XXXIV, highlighting the indigenous nature of the lake values. The vertical distribution of chlorophyll-a is presented in Figure XXIV. The average surface concentrations of chlorophyll-a measured at La Plata Lake classify this system as eutrophic, according to EPA~440/5-79-015 (1973). Chlorophyll-a concentrations are considered as a biological manifestation of nutrients in aquatic systems and applied as a direct index of phytoplankton biomass (Hern, et al., 1981). Monthly fluctuations of chlorophyll-a are presented in Figure XXV. Water column average concentrations of chlorophyll-a showed a significant positive correlation (r=0.82) with water column average abundances of phytoplankton cells/ml at La Plata Lake (see Figure XAVI). Biovolume conversions of phytoplankton cell counts will be used to assess the validity of using chlorophyll-a concentrations as a quantitative index of phytoplankton biomass in Puerto Rican lakes.

Table XXXIV presents chlorophyll-a at tributary stations on various sampling dates.

Figures are presented for the vertical distribution of chlorophyll-a at Station 1 on various dates from October 10, 1981, to May 6, 1982.

Figure IV presents the mean and standard error of chlorophyll-a concentrations at La Plata Lake, and monthly fluctuations.

Primary productivity is discussed with reference to an experiment conducted on April 6, 1982, using the dark-light bottle method. The results of this experiment are presented in Table XXXV. The net primary productivity at 1.0m depth from bottles incubated in situ for 4 hours was relatively low (315 mg O2/23 dal). Gross

The productivity was high, however, at 3,387 mg O2/day, due to high respiration rates of 1,072 mg O2/mm3/day. The results from this single observation in time at La Plata Lake are consistent with the idea that this system has a low capacity for biological regeneration of dissolved oxygen by photosynthetic organisms in relation to the existing respiration rates. The average Biological Oxygen Demand (BOD) in the water column at station L-I was 1.57 mg/L (range 1.05 - 2.27 mg/L), as shown in Table XXXVI. Comparatively lower values were observed in tributary rivers (Table XXXVII), with 1.18 mg/L at La Plata, 1.49 mg/L at Guadiana, and 1.41 mg/L at Cahas River. This suggests that the lake's BODs are autochthonous.

Assuming an average oxygen production of 1,260 mg O2/m3/day in the euphotic zone of the lake (0-4 m) and zero production below a depth of 4m, the estimated monthly production of oxygen in the water column would be approximately 37,800 mg O2/month. The respiration potential, calculated as a monthly BOD for the water column, was 94,200 mg O2/month (using 10 m as the average depth). Clearly, the respiration potential exceeds oxygen renewal, consistent with the observed oxygen deficit at the lake station (P/R Ratio: 40).

Please see Table XXXVI for a single observation of primary productivity at La Plata Lake on June 6th, 1982. The initial light at 1.0 meter depth for station L-I was 6.38 0 08 mg O2, with a net respiration rate of 22.5 mg O2, and a gross respiration rate of 150 mg O2. The daily rates assuming 14 hours of light and 10 hours of dark were: net = 318 mg O2, respiration = 3,072 mg O2, and gross = 3,387 mg O2.

Please refer to the subsequent pages for additional information and data.

recommended.

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Macrophyte Coverage

The dominant macrophyte species present in Lake La Plata is the water hyacinth, Eichhornia crassipes. Visual estimates suggest that 40-50% of the total lake surface area is impacted by water hyacinths. The criteria in evaluating the area impacted within 2 x Secchi disk depth was not considered in view of the fact that E. crassipes is a floating macrophyte species which invades lake surface waters and is not limited by light penetration. Water hyacinths may induce or enhance dissolved oxygen deficiencies in the water column by limiting light penetration and inhibiting photosynthesis. They also represent a recreational problem by obstructing navigation and fishing.

An illustration of hyacinth cover in La Plata Lake is presented in Figure XXVII. The fast growth rates and nutrient assimilation by water hyacinths represents a potential tool of nutrient removal in aquatic systems for Puerto Rico. Extensive experimentation in the use of water hyacinth for nutrient removal in sewage treatment ponds was reported by Wolverton and McDonald (1978).

The productivity of water hyacinths in Carraizo Lake was calculated by Nevarez and Villamil (1981) to be approximately 9.7 gm squared day (dry weight) with an average elemental phosphorus composition of .22% of the dry weight per plant. Assuming such rates apply, the observed standing crop of hyacinths at La Plata Lake produces 1.19 x 107 g m squared day (dry weight), at .228 P the crop of plants in La Plata would be removing about 2.6 x 104 g of P per day. That rate of phosphorus removal corresponds to about 52.

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Figure MWIL

Water hyacinth coverage at La Plata Lake. Magnetic North 4 points represent hyacinth Scale 1: 28,000

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It is highly recommended to conduct a comprehensive study of water hyacinths' productivity and nutrient assimilation at La Plata Lake.

The text is revised as follows:

It is recommended to examine the potential of water hyacinths as a tool in eutrophication control.

BACTERIOLOGY

Total Coliforms

Table XXXVII presents the profiles of total coliform concentrations at L-I which resulted during the third quarter of the study (April-June, 1961). The average water column concentration was 490 MPN colonies/100 ml (range 220-957 MPN colonies/100 ml). Standard regulations of water quality (208, 1973) recommend an upper limit of 10,000 MPN colonies/100 ml for superficial waters of Puerto Rico. Tributary rivers evidenced relatively higher concentrations of total coliforms than the lake station (see Table XXXIX). Guadiana River presented concentrations above the standards during the months of May and June, 1982. Cañas River presented concentrations above the standards during the month of May, 1962.

Fecal Coliforms

Fecal coliforms averaged 272 MPN colonies/100 ml (range 58-625 MPN colonies/100 ml) at L-I during the third quarter (see Table XL). The standard regulation of water quality recommends an upper limit of 2,000 MPN colonies/100 ml (203, 1973). Guadiana River presented concentrations above the standard during the months of May and June, 1982. Cañas River presented concentrations above the standard during the month of May, 1982 (see Table XLI).

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TABLE 1UViTT (Total Coliforms vs. Depth at Lake Station)

Sampling Dates: 4-1-82, 5-6-82, 6-3-82

MPN colonies/ml: 330, 700, 220

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TABLE XL (Fecal Coliforms vs. Depth at Lake Station L-I)

Sampling Dates: 4-1-82, 5-6-82, 6-3-82

MPN colonies/ml: 20, 110, 19

TABLE tz (Fecal Coliforms at Tributary Stations)

Sampling Dates: 5-6-82, 6-3-82

MPN colonies/ml: Data not provided

Colonial MPN colonies/1: wt 280, 1,850, 1,500, 790, >24,000, 10,480, 625, >24,000, 1,080, 56

The higher concentrations of total and fecal coliforms observed at tributary rivers are consistent with our previous determination that tributary rivers are the most critical source of bacteriological contamination to La Plata Lake.

Fecal streptococcus Table XLII presents the concentrations of fecal streptococcus at L-I during the third quarter (April-June, 1982). Water column averages ranged between 8-23 MPN colonies/100 ml. Evidence of fecal streptococcus contamination was found on all sampling dates. Concentrations were higher at tributary stations (see Table XLIII) with means of 194 MPN colonies/100 ml at La Plata, 8,113 MPN colonies/100 ml at Guadiana and 1,114 MPN colonies/100 ml at Cafas River.

HEAVY METALS

The concentrations of Cu, Cd, Pb, and Hg (in ug 174) at the lake station L-I and tributary rivers are presented in Tables XLIV and XLV. The average concentrations of heavy metals determined during the study period to date (Table XLVI) reflect values above the standard for surface waters of Puerto Rico for Hg and zinc. The origin of high Hg concentrations found in the water column at L-I is presently considered as a non-point source given the fact that the high concentrations result from all tributary stations sampled. Immediate attention to the occurrence of Hg in La Plata Lake will be performed during the last quarter of the study. Special investigations will include analysis of the lake's sediment and bioaccumulation in the tissues of nektonic organisms including fishes and crustaceans.

TABLE III: Fecal Streptococcus vs. Depth at Lake Station IO

SAMPLING DATES: Depth a1-e2, 56-02, 6-302; MPN colonies/ml: 5, 8, 4, 3, 3, 2, 5, 8, 2, 2, 6, 5, 3, 20, 5, 2, 6

TABLE IV: Fecal Streptococci at Tributary Stations

SAMPLING DATES, Stations a1-e2, 56-02, 6-302; MPN colonies/ml

MPN colonies/ml MEN colonies/ml WM 66 515 1 2 333 > 24,000 5 WS. 330 > 24,000 A

SYNTHETIC ORGANICS

Pesticide residue analysis of 12 water samples from La Plata Lake (station L-I) and major tributaries (La Plata, Guadiana, and Canas River) failed to present any detectable concentrations (see Table XLVII). Samples were collected on 1 April 1982 and analyzed on 4 June 1982 by the Agrological Laboratory of Puerto Rico. The methodology for these determinations followed EPA procedures and regulations. CEER will conduct an analysis of pesticide residues in sediment samples during the last quarter of the study.

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REPORT OF FISH MORTALITIES IN LA PLATA LAKE

May 6, 1982

During 6 May 1982, dead individuals of the "Phreadfin shad" Dorosoma petenense (Gunther) were observed trapped within a dense hyacinth mat approximately 4.5 km downstream from the bridge (Road 164) at La Plata Lake. Mortality was estimated to be approximately one thousand individuals. Most specimens were freshly dead, but some were swimming weakly at the surface and could be easily captured by hand. No signs of apparent disease were observed, i.e., scales and fins were intact and branchiostegal filaments did not show evidence of severe parasitological infection. Individuals which were still alive were seen trying to breathe at the surface with an apparent oxygen deficiency. Gill membranes were clearly distended. Field measurements of dissolved oxygen, pH, conductivity, and water temperature were performed at the site of the mortality immediately after the observation.

Table Alvi. Water Column Means and Range of Heavy Metal Concentrations in La Plata Lake (October 1981 - June 1982), in ug/l.

Surface Waters Light Data Mean Range Recommended Value

Hg 3.19 2 - 6.23 10

Co 7.64 4.70 - 13.50 40.0

Ca 1.99 1.58 - 2.50 5.0

Ce © 10.00 Not detected 50.0

Cy 12.57 5.98 -20.2 50.0

Za 63.30 17.65 -166.92 50.0

5.00 Not detected 62

Table XLVII. Concentration of Pesticides in Water Samples from La Plata Lake.

Pesticide	Copper Compound	Granaxone	Organochlorinated Pesticides	Organophosphates	Carbamates
Concentration	Not detected	Not detected	Not detected	Not detected	Not detected

Source: Laboratorio Agrológico de Puerto Rico, Departamento de Agricultura

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Information is presented in Table XLVIII. Low dissolved oxygen concentrations at the surface and almost zero oxygen below the root zone of the water hyacinths may have acted as a trap and caused mortality by asphyxia.

July 8, 1982

During July 8, 1982, about 100 dead individuals of Tilapia spp. were seen floating at the surface and washed to the shores of La Plata Lake. The higher abundances were observed within one kilometer from the bridge (Road 164) of La Plata River. The specimens observed were all large Tilapia (range 20-30 cms), some (approximately 108) had their heads decapitated, one individual which was observed still alive at the time of the mortality showed signs of asphyxia: abnormal distension of the branchiostegal membranes and pronounced pulsation of the opercular flap. Dissolved oxygen at the site of higher accumulation of dead or stressed fish was between 6.0 mg/l and 7.0 mg/l (measurements were made at midwater, total depth was 3 meters). Most of the individuals, however, were in an advanced stage of decomposition, indicating that the mortality may have started several days before. The available data do not permit any strong inference to be made regarding the cause of death. Any explanation of this event must take into account the following points: 1) The kill apparently affected only large individuals of one species, Tilapia. 2) The dying fish showed evidence of respiratory stress. 3) No visual evidence of active contamination (e.g., oil).

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Table XLVIII. Field Measurements of Temperature, Dissolved Oxygen, pH, and Conductivity at the Site of Observed Mortality of Fish on May 6, 1982. Series of...

He found 65

4) The limnological features of this and/or nearby station were within the range regarded as normal for this site.

5) The deaths had been occurring over a period of several days.

6) A curious and possibly related phenomenon is the observation that roughly 108 of the dead fish had been decapitated somehow.

PRELIMINARY SUMMARY

Reflection on the accumulated set of data has led to a number of related conclusions or observations with respect to the general nature of the La Plata system. A tentative and relatively unordered list of such observations follows:

The reader is cautioned that this list is tentative, incomplete and probably in error with respect to some of the specifics. It has been included as an indication of direction for comment but not for citation.

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1) There is increasing evidence that La Plata is driven by hydrological events rather than seasons. Thermal stratification may have a seasonal component with obvious thermoclines in some seasons and more gradual gradients in other seasons. Even when thermal stratification is weak, it is frequently sufficient to prevent physical exchange between the hypolimnion and epilimnion except when heavy rainfall and possibly violent storms (i.e., winds) occur.

2) Dissolved oxygen stratification with anaerobic conditions persisting below 4 meters is a dominant feature of the lake key to its functioning as a system. The cause seems to be the physical separation of the epilimnion and hypolimnion, coupled

66 with substantial organic input both from tributary BOD and net productivity of water hyacinths maintained at high levels as a result of nutrient input.

The plankton subsystem of the lake is substantial but restricted in depth distribution and potential effect because of the combination of light restriction under the hyacinth mat and unfavorable conditions (anaerobiosis) in depths greater than 2-5 meters.

The dissolved oxygen profile is clinograde with a strong chemocline between 2-5 m.

5) Low values of net primary productivity of

The phytoplankton data suggests that the lake has a low capacity for biological regeneration of dissolved oxygen by photosynthetic organisms in relation to the existing respiration rate. Chlorophyll-a, phytoplankton abundance, water hyacinths, and biological oxygen demand increase downstream from La Plata River, indicating their indigenous character.

7. The loading of nutrients, suspended sediments, dissolved oxygen, and bacteriological contamination are largely contributed by tributary rivers.

8. La Plata River has contributed to 95% of the total nitrogen and 94% of the total phosphorus loading to the lake during the study period to date.

9. Approximately 85% of the total nitrogen and 80% of the total phosphorus loading occurred during the "wet" period (October to December, 1981). Bacteriological contamination above recommended limits is also associated with periods of high precipitation in the watershed.

10. The measured concentrations of total phosphorus and chlorophyll-a continue to be high and are consistent with the classification of La Plata as an eutrophied system.

11. Available micronutrients such as soluble reactive phosphorus (SRP) and ammonium nitrogen (NH4-N) show higher concentrations in the hypolimnion, suggesting rapid epilimnetic removal by photosynthetic organisms and accumulation under the anoxic strata of the lake. The vertical distribution of nitrite and nitrate (NO2-NO3) concentrations follows a weak dichotomic pattern.

12. Among the trace metal concentrations studied (titanium, copper, lead, nickel, chromium, cadmium, and zinc), zinc and mercury exceed surface water standards for Puerto Rico.

13. Synthetic organics studied (including copper compounds, Gramoxone, organochlorinated pesticides, organophosphates, and carbamates) failed to present detectable concentrations in water samples from the lake and major tributaries.

14. Special close-time interval sampling has indicated that the standard lake station L-I is essentially the same (within a small acceptable sampling error) as a station adjacent to the dam and may, therefore, fairly represent the main body of the Lake.

15. This lake is being considered for possible lake management strategies.

Restoration practices to be applied at La Plata Lake are as follows:

(a) Reduction or diversion of nutrient-rich point sources in the basin.

(b) Implementation of an AMP for the control of fertilizer and pesticide application.

(c) Employment of barrier strip of vegetation along the shorelines of the lake.

(2) Use of macrophyte harvest as a tool for nutrient removal from the system, also considering some economic use in the basin.

(e) Implementation of BMP for the control of non-point sources of nutrient contamination in the basin (e.g., livestock, poultry, etc.).

(f) Implementation of reforestation practices in critical areas of erosion.

(3) Use of mechanical aeration to reduce stratification and enhance the fisheries potential of the system.

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