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AN ENVIRONMENTAL EVALUATION OF LA PLATA LAKE, TOA ALTA

THIRD QUARTERLY REPORT
(APRIL-JUNE, 1982)

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
MARINE ECOLOGY DIVISION
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MAYAGUEZ, PUERTO RICO

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UNIVERSITY OF PUERTO RICO — U.S. DEPARTMENT OF ENERGY

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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 Bayamón, 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 Schistosoma mansoni 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 and other recreational activities requires 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 constitutes 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 the large, seasonally-related temperature variations result in convective mixing of the water column. On the other hand, tropical lakes are often considered oligomictic, rarely (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 EPA Clean Lakes Program (FRL 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 Cañas River:W-3) and at one station in the lake proper (L-I).

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

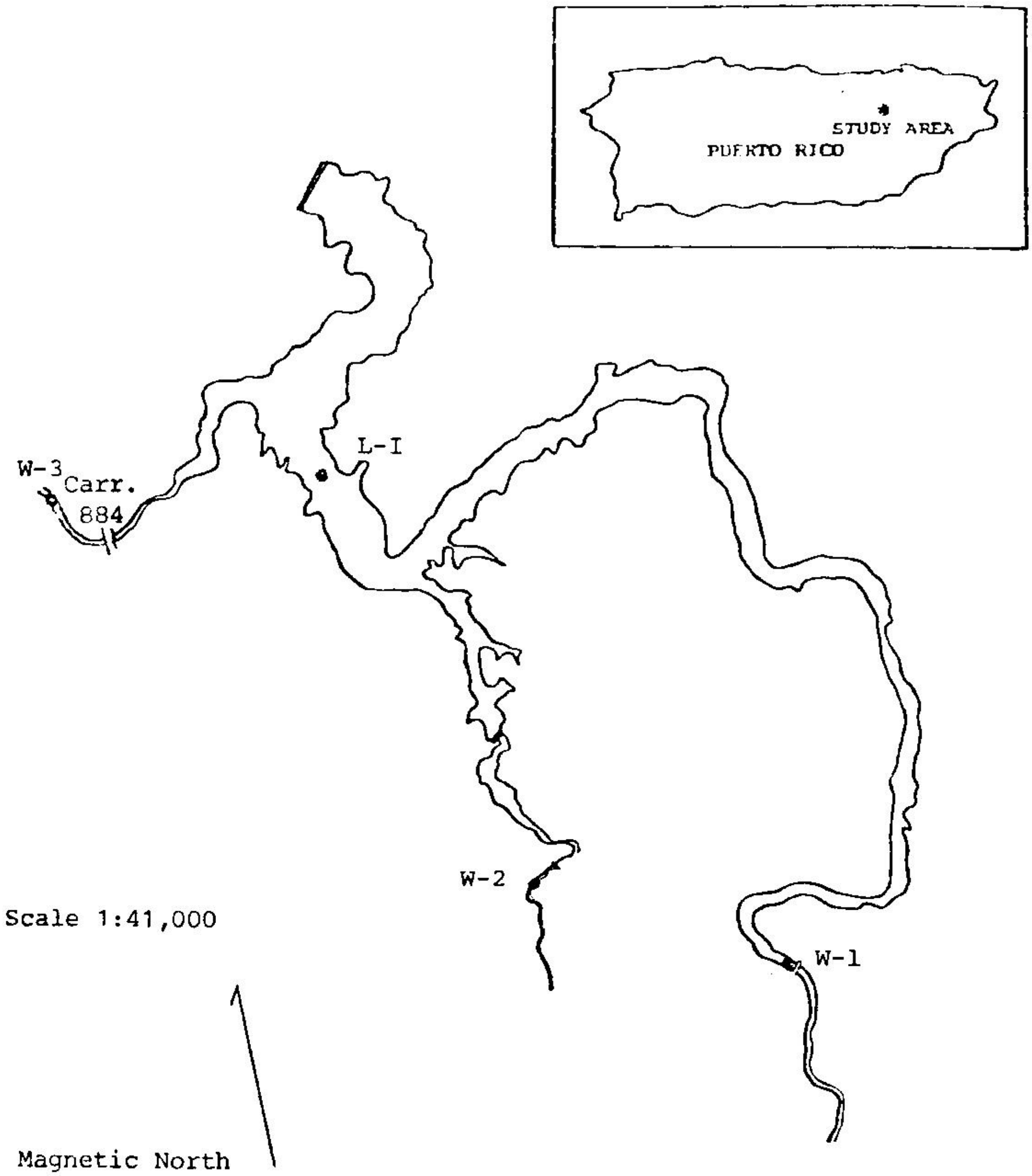
No detailed presentation of methods is made in this report. The reader is referred to the proposal and quality assurance documents for that information.

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 mayor tributaries.



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

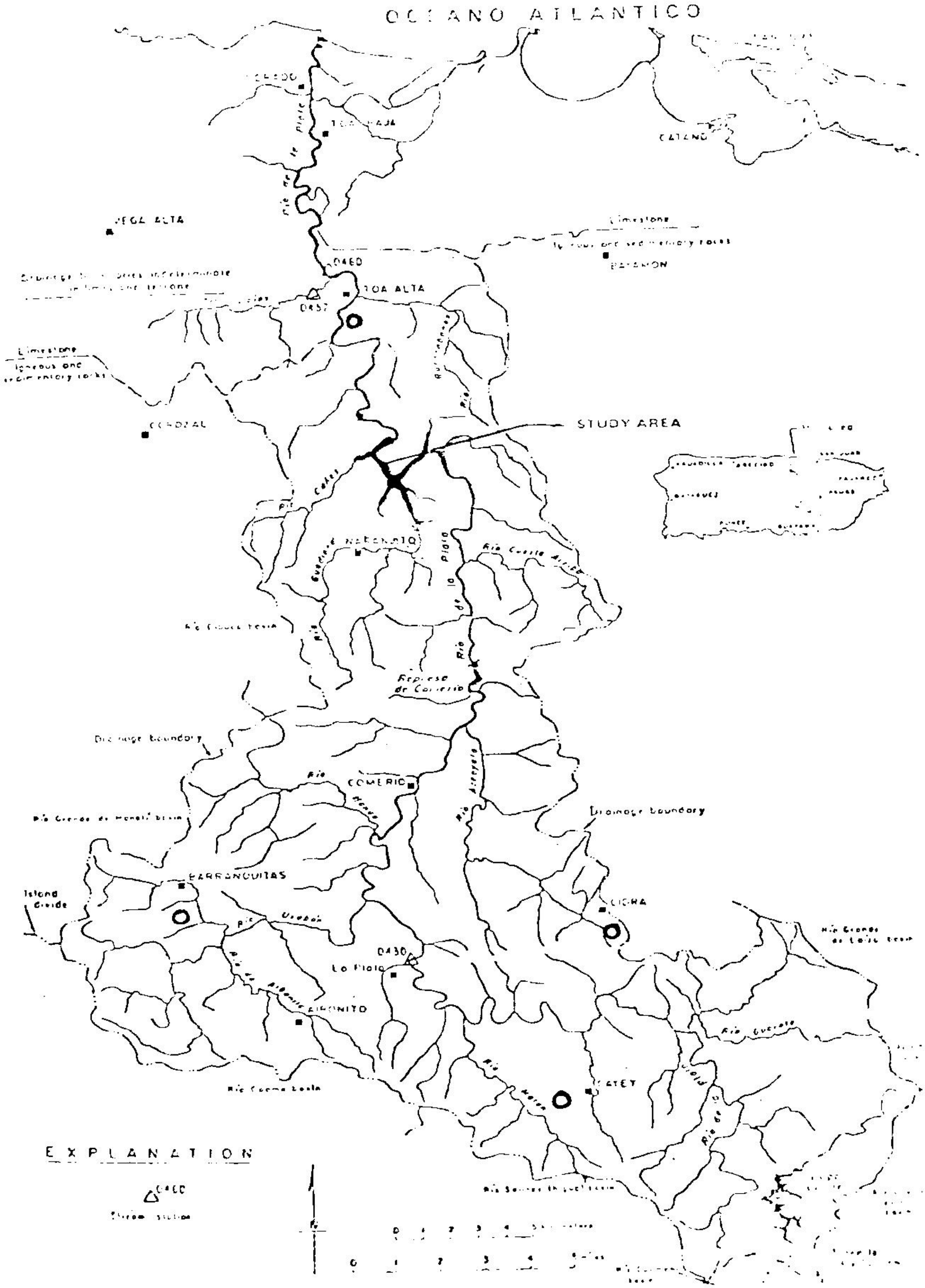
GEOMORPHIC CHARACTERISTICS OF LA PLATA BASIN

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°20' N, 66°13' 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^2. 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 to 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 in Thornthwaite's climatic index applied to Puerto Rico (Giusti and Lopez, 1967). Mean annual rainfall is approximately 180 cms (Climate of Puerto Rico and U.S. Virgin Islands: Isopleths of

Figure II. La Plata Watershed.



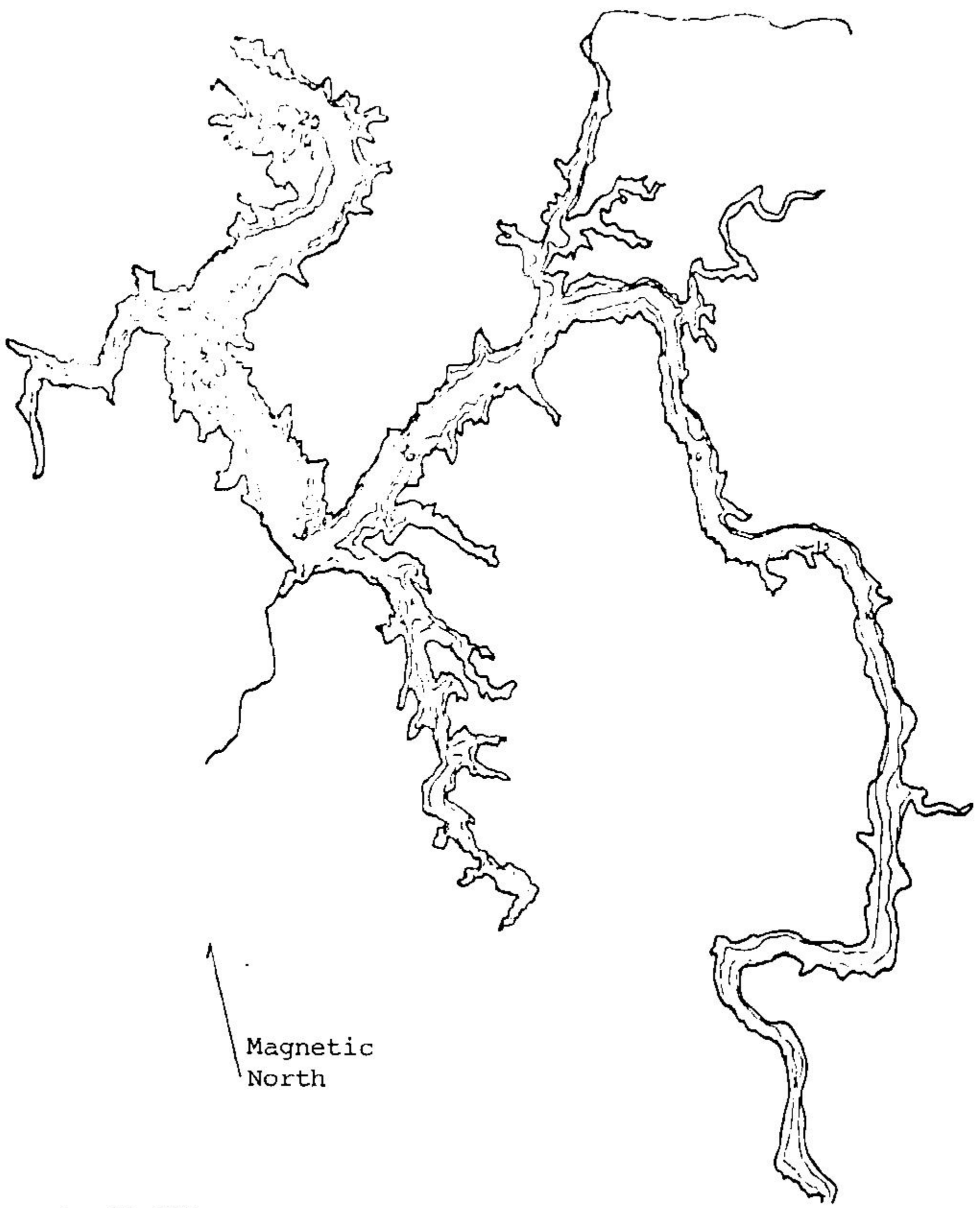
Source: U.S. Geological Survey, Surface Water Records mean annual precipitation). Historically, the distribution of rainfall over the year in Puerto Rico does not show an absolute wet season-dry season relationship, but only a relatively wet and relatively dry season (Calvesbert, 1961). The distinction 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). Ambient temperatures (based on data for the period between 1931 and 1952) fluctuate between a maximum mean of 31.1°C in July to a minimum mean of 16.7°C in January (Climate of Puerto Rico and U.S. Virgin Islands: Isopleths of mean maximum and minimum temperatures).

MORPHOMETRY AND HYDROLOGY

La Plata Lake has a volume of 3.085 X $10^7 m^3$ and a mean depth of 10 m. A bathymetric map of the lake is shown in Figure III. The lake is relatively long and narrow ($\bar{L}:\bar{W}$=19.1) and has a relatively low surface to volume relationship (relative depth is .04). 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.

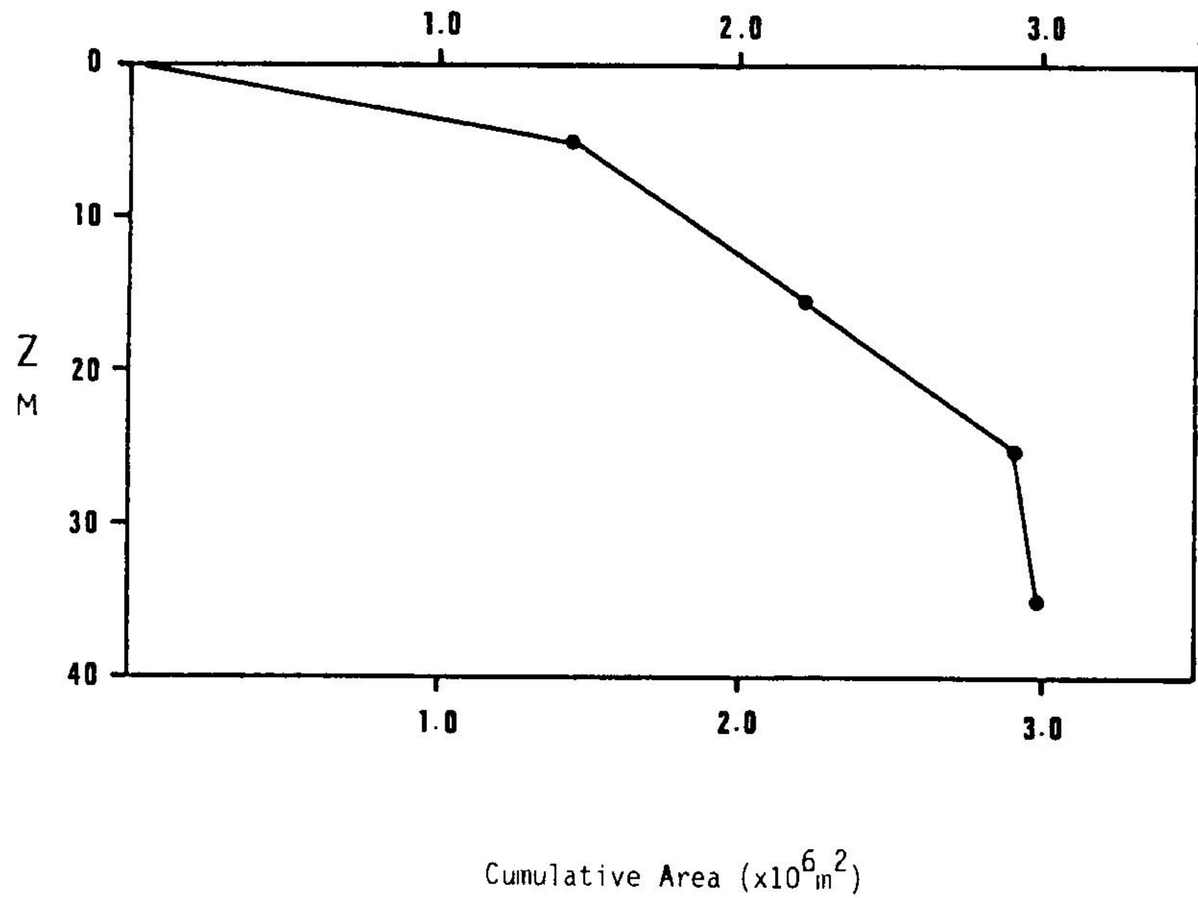
Mean monthly precipitation in the basin ranged between 32.70 cms in December, 1981 and 3.25 cms in March, 1982, averaging 12.54 cms/month (see Table II). The runoff coefficient (Q/P) determined as the average of three gauging stations in La Plata basin is 0.50 (data taken from Giusti and Gomez, 1967).

Figure III. Bathymetric map of La Plata Lake.



Scale: 1: 41,000

Figure IV. Hypsographic Curve of La Plata Lake.



Depth Intervals M	% Total Vol.	Cumulative Vol. $x10^6 m^3$
0-1	19.1	5.9
1-4	22.7	12.9
4-8	20.2	19.2
8-12	15.6	24.0
12-16	11.4	27.5
16-20	7.2	29.7
>20	4.0	30.8

TABLE I. Review of Geographical and Morphometric Characteristics of La Plata Lake.

Latitude:	18°20'N
Longitude:	66°13'W
Total Length:	9.6 km
Max. Width:	0.5 km
Surface Elevation Above MSL:	47 m
Max. Elevation of watershed:	980 m
Total Drainage Area:	4.50×10^{8} M^{2}
Volume:	3.085×10^{7} M^{3}
Surface Area:	3.07×10^{6} M^{2}
Mean Depth:	10 m
Relative Depth:	0.04
Maximum Depth:	>30 m

Mayor Tributaries	Drainage Area
La Plata River	4.050×10^{8} m^{2}
Guadiana River	2.835×10^{7} m^{2}
Cañas River	1.575×10^{7} m^{2}

TABLE II. Total Monthly Precipitation (CMS) at Recording Stations in La Plata Basin.

Stations	Oct	1981 Nov	Dec	Jan	1982 Feb	Mar	Apr	May
Toa Baja	11.20	20.09	67.74	6.91	9.75	1.68	10.03	37.95
Cidra	17.48	3.00	23.70	5.46	0.38	4.52	5.46	18.54
Cayey	8.66	4.67	20.96	2.82	0.10	4.37	3.02	17.17
Barranquitas	32.89	9.27	18.39	2.68	8.13	2.44	3.02	18.82
Monthly Means (CMS)	17.56	9.25	32.70	4.47	4.59	3.25	5.38	23.12
Standard Error	4.44	3.14	9.58	2.07	5.07	1.41	3.30	9.91

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 III describes the monthly fluctuations of discharge by tributary rivers of La Plata Lake during the study period to date.

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 1982

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 ΔT of 2.0° C/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 of 0.19 °C/m.

Table III. Net Monthly Discharge of Tributary Rivers to La Plata Lake during the period between October 1981 and April 1982.

Month	La Plata River M^3	Guadiana River M^3	Cañas River M^3	Total M^3
October	3.561×10^7	2.411×10^6	1.658×10^5	3.819×10^7
November	1.874×10^7	1.230×10^6	8.744×10^4	2.006×10^7
December	6.633×10^7	4.571×10^6	3.091×10^5	7.121×10^7
January	9.041×10^6	6.221×10^5	4.251×10^4	9.706×10^6
February	9.278×10^6	5.587×10^5	4.256×10^4	9.879×10^6
March	6.567×10^6	3.861×10^5	3.074×10^4	6.993×10^6
April	1.089×10^7	6.809×10^5	6.250×10^4	1.163×10^7
Total	$1.564 \times 10^8 m^3$	$1.046 \times 10^7 m^3$	7.406×10^5	$1.677 \times 10^8 m^3$
Monthly Mean	$2.235 \times 10^7 m^3$	$1.494 \times 10^6 m^3$	1.058×10^5	$2.395 \times 10^7 m^3$

Note: Net Discharge was Calculated as:

Net Discharge= Drainage Area X Monthly Precipitation X Runoff Coefficient — PRASA monthly water consumption at Naranjito and

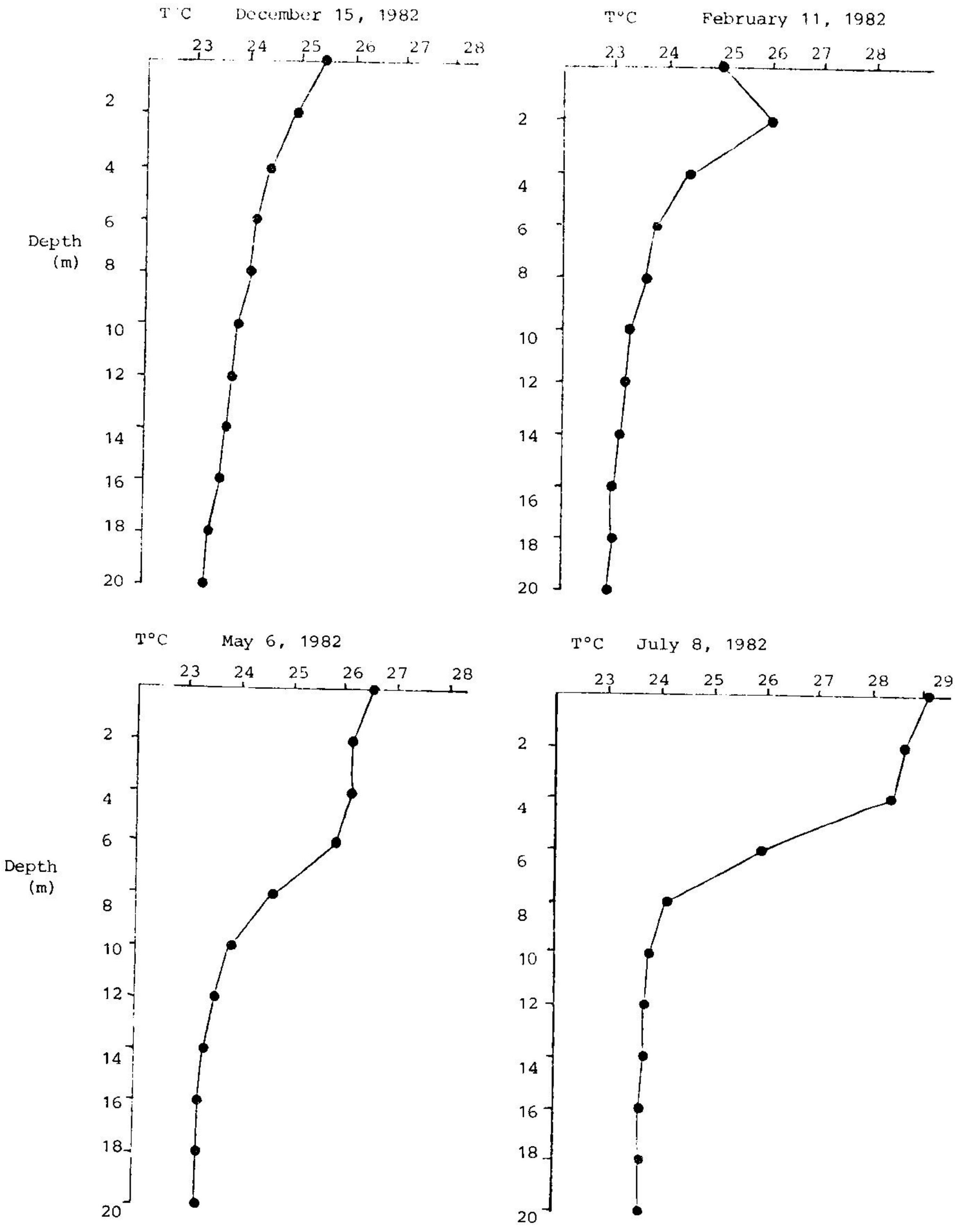
TABLE IV. Water Temperature vs. Depth at Lake Station L-I

Depth M	4-6-82 °C	5-6-82 °C	6-3-82 °C
	SAMPLING DATES		
Surface	26.5	26.5	28.2
1	26.3	26.3	28.2
2	26.1	26.1	28.1
3	25.9	26.1	28.0
4	25.7	26.1	26.0
5	25.4	26.0	24.9
6	24.8	25.8	24.3
7	24.5	25.3	24.0
8	24.2	24.6	23.8
9	23.9	24.1	23.7
10	23.8	23.8	23.65
11	23.6	23.7	23.6
12	23.5	23.5	23.6
13	23.4	23.4	23.6
14	23.3	23.3	23.55
15	23.3	23.3	23.55
16	23.2	23.2	23.55
17	23.2	23.2	23.55
18	23.2	23.2	23.55
19	23.2	23.2	23.55
20	23.15	23.2	23.55

TABLE V. Water Temperature at Tributary Stations.

Stations	4-6-82 °C	5-6-82 °C	6-3-82 °C
	SAMPLING DATES		
W-1	25.2	24.9	27.1
W-2	26.7	24.5	30.2
W-3	26.4	23.5	28.7

Figure V. Representative Profiles of Water Temperature at La Plata Lake.



Tributary rivers (Table V) averaged 25.7° C at La Plata River, 27.1°C at Guadiana River and 25.6°C at Canas River during the third quarter of the study.

Dissolved Oxygen

Clinograde oxygen profiles were maintained at the lake station L-I during the period between April and June, 1982. A strong chemocline fluctuated between 2-5 m (see Table VI). Oxygen depletion with zero values in the hypolimnion has been shown to be a recurrent lake feature in the La Plata Lake, see Figure VI. The structure of O_2 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 hills tends to prevent wind mixing and reaeration. Loading of the lake by N and P via rain-runoff is high and sustains relatively high internal primary productivity. Phytoplankton respond with densities so high in 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 areas of the lake. Where present, they virtually screen out all the light. Organic materials discharged to the lake in rain events and sedimenting phytoplankton and dead particles of hyacinths support the growth of microbes which consume available oxygen in the layers of the

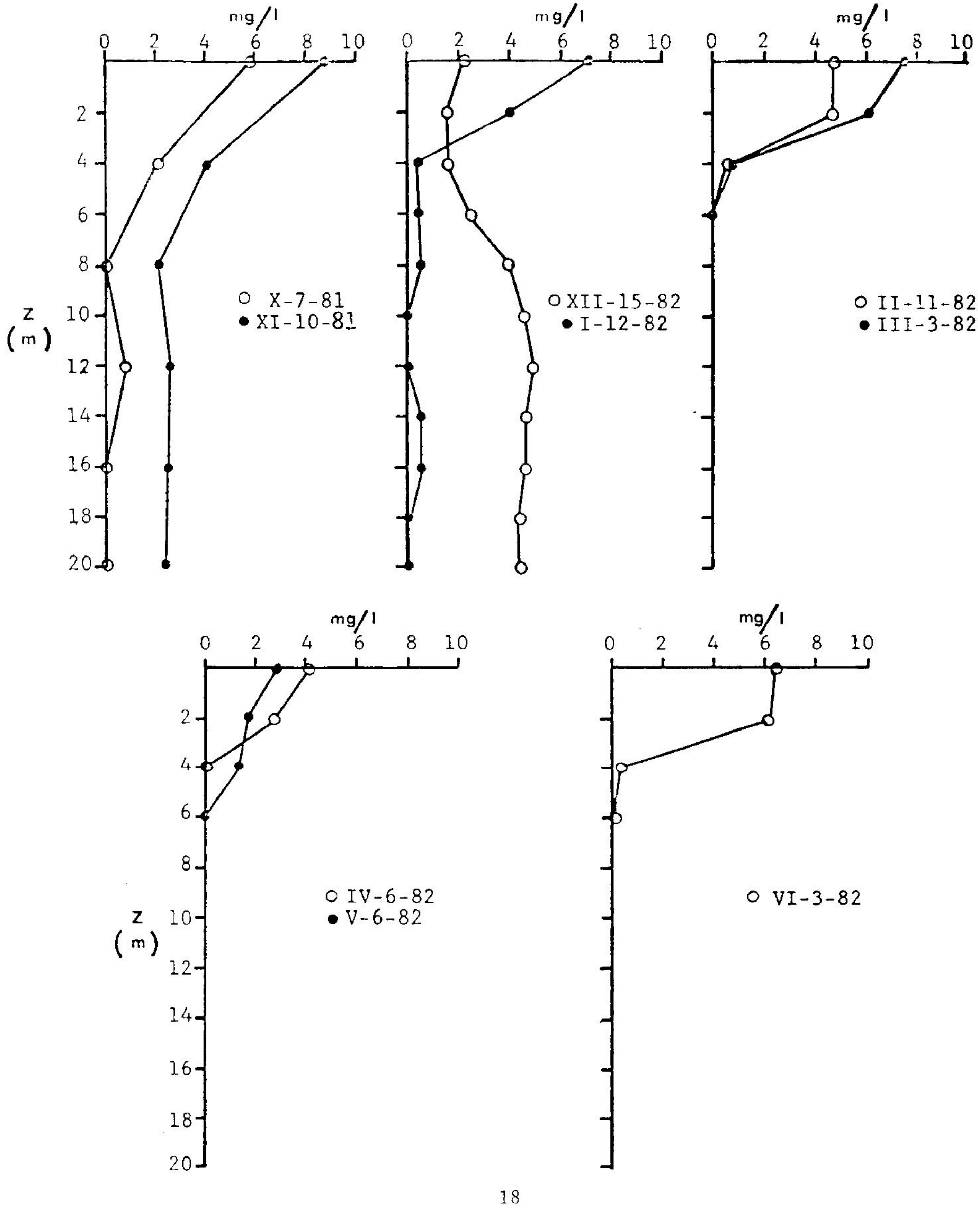
TABLE VI. Dissolved Oxygen vs. Depth at Lake Station L-I

Depth M	4-6-82 mg/l	5-6-82 mg/l	6-3-82 mg/l
	SAMPLING DATES		
Surface	4.2	2.75	6.4
1	3.8	2.1	6.4
2	2.8	1.8	6.25
3	0.6	1.8	5.8
4	0	1.4	0.4
5	0	1.3	0.2
6	0	0	0.1
7	0	0	0.05
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0

TABLE VII. Dissolved Oxygen at Tributary Stations.

Stations	4-6-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
	SAMPLING DATES		
W-1	7.04	7.9	6.46
W-2	11.0	8.03	
W-3	9.25	8.05	

Figure VI. Dissolved Oxygen Profiles at Station L-I in La Plata Lake (October 1981 through June 1982).



lake below 4-6 m and render it anaerobic and reducing. Such reducing conditions, in general, are unfavorable for the growth of phytoplankton and other aerobic life. Thus photosynthetic oxygen renewal does not occur either.

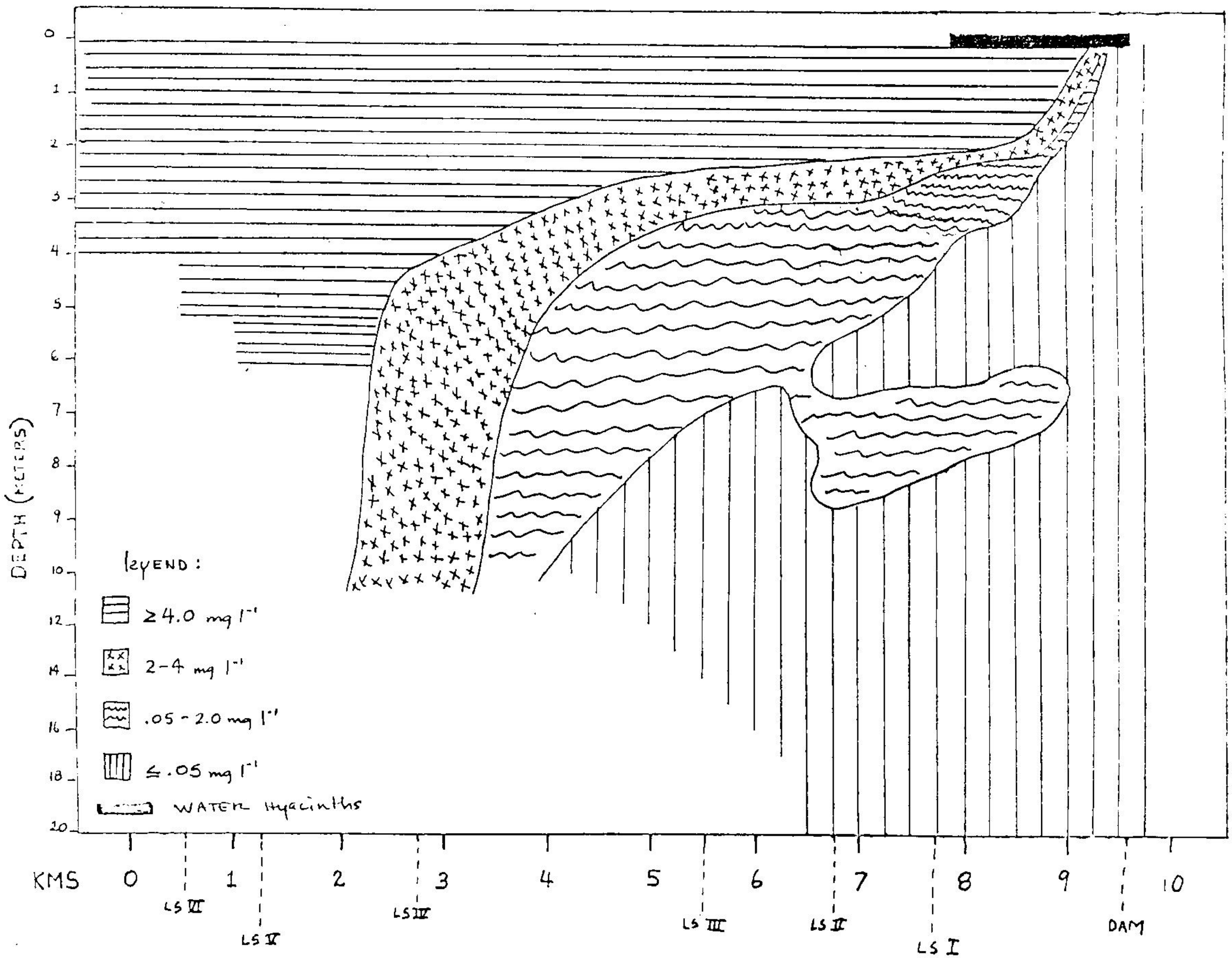
The large seasonal reduction in temperature, which in more temperate areas result in convective mixing of the water column, do not occur here and the higher and less variable temperature regime keeps metabolism high while preventing physical reaeration. The most important input of dissolved oxygen into the lake probably occurs via tributary discharge, where O_2 concentrations are consistently high in relation to concentrations at L-I. 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 Cañas River (see Table VII).

pH

Profiles of pH 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 CO_2 in the photic layers of the water column are 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 8.4 at Cañas River) allowing the

Figure VII. Dissolved oxygen isopleths vs distance at La Plata Lake (January 12, 1982).



alternate explanation that those input waters simply dominate the upper layers of the lake. For this latter explanation to hold, however, 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.

Conductivity

The average conductivities of the water column at L-I during the third quarter (April-June, 1982) were of 290 umhos/cm in April, 301 umhos/cm in May and 263 umhos/cm in June, 1982. Conductivity profiles maintained a consistent decline with depth with maximum rates of change fluctuating between 8-11 meters in April and May and 4-5 meters in June, 1982 (see Table X).

Tributary rivers presented higher conductivities than the lake during this period ($\bar{x}$ = 357 umhos/cm at La Plata, 311 umhos/cm at Guadiana and 309 umhos/cm at Cañas River) see Table XI.

Water Transparency

Secchi disk transparency averaged 1.8 m at L-I during the third quarter of the study (see Table XII). Monthly fluctuations in Secchi disk readings at L-I evidenced a minimum value in December, 1980 which corresponded to the month of higher precipitation and tributary loading of sediments (see Figure VIII). After December, 1980, monthly readings showed a gradual increase until May, 1980. Profiles of light attenuation indicated that on the average the 1% light penetration or "compensation depth" at L-I is found in the 3-4 depth interval (see Table XIII).

TABLE VIII. pH vs Depth at Lake Station L-I.

Depth M	Sampling Dates 4-6-82 Units	5-6-82 Units	6-3-82 Units
Surface	6.8	6.6	6.9
1	6.7	6.6	6.8
2	6.7	6.6	6.8
3	6.6	6.6	6.75
4	6.5	6.6	6.4
5	6.6	6.6	6.55
6	6.6	6.6	6.6
7	6.5	6.6	6.6
8	6.5	6.6	6.55
9	6.5	6.6	6.5
10	6.5	6.6	6.5
11	6.5	6.6	6.5
12	6.5	6.6	6.45
13	6.5	6.6	6.45
14	6.5	6.5	6.45
15	6.45	6.5	6.45
16	6.4	6.5	6.45
17	6.4	6.5	6.45
18	6.4	6.5	6.45
19	6.4	6.5	6.45
20	6.4	6.5	6.45

TABLE IX. PH at Tributary Stations

Stations	SAMPLING DATES 4-6-82 Units	5-6-82 Units	6-3-82 Units
W-1	7.9	8.1	7.46
W-2	8.0	7.8	
W-3	8.2	8.2	

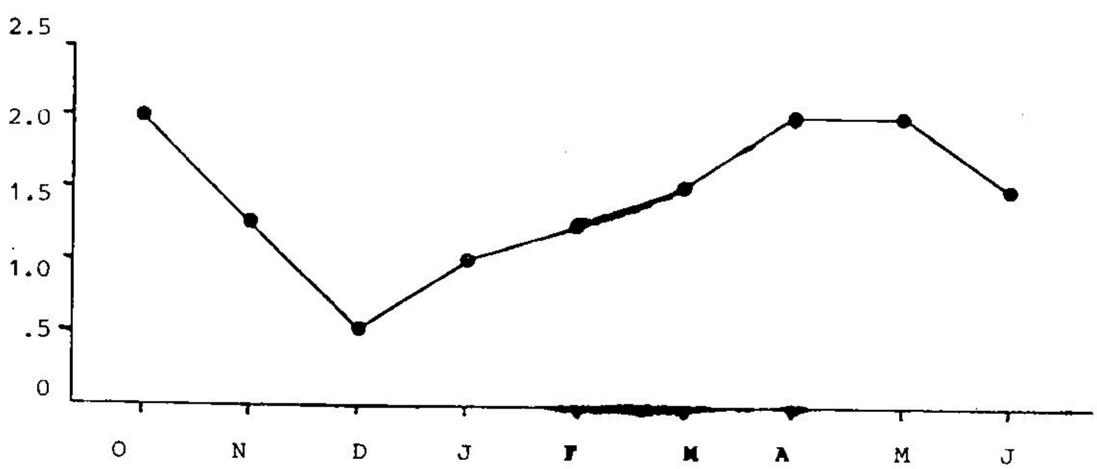
Table XIII . Profile of Light Penetration at La Plata Lake, in Foot/Candles.

Depth	11-10-81	12-15-81	1-12-82	3-3-82	6-3-82	X
0	370	4,300	160	3,800	1200	1966
1	60	210	21	1,300	290	376
2	14	18	4.5	360	110	101
3	3.3	1.8	.7	170	36	42
4	.6		.2	75	16	18
5	.1		.05	37	5.6	9
6	.02			19	1.3	4
7				7.8	.18	1.6
8				1.8	.04	0.4
9				.15		0.3

1 % of Total Light Penetration = 19.66 Foot Candles

Compensation Depth = 3-4 m

Figure VIII. Monthly variation of Secchi Disk Readings at La Plata Lake.



Mean Secchi Disk Reading = 1.4 m

TABLE X. Conductivity vs. Depth at Lake Station L-1

Depth M	4-6-82 umhos/cm	5-6-82 umhos/cm	6-3-82 umhos/cm
	SAMPLING DATES		
Surface	110-300	346	318
1	337	347	318
2	340.5	347	320
3	335	347	321
4	332	347	308
5	338	347	278
6	334	342	261
7	327	335	248
8	319	316	238
9	304	293	232
10	288	280	229
11	268	270	226
12	255	253	225
13	248.5	244	224
14	239	241	222
15	234	236	220
16	229	232	220
17	225	228	220
18	219	227	220
19	215	225	219
20	215	221	219

TABLE XI. Conductivity at Tributary Stations

Station	4-6-82 umhos/cm	5-6-82 umhos/cm	6-3-82 umhos/cm
	SAMPLING DATES		
W-1	384	394	294
W-2	325	250	357
W-3	354	217	357

Total Suspended Solids

The mean water column concentration of TSS 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). TSS concentrations at tributary rivers for the third quarter are presented in Table XV. An average profile of TSS 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 TSS, 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 2.001×10^6 kg/lake/month. La Plata River contributed 98.5% 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 mg/l in May, 1982 (see Table XVII). As previously noted there was no significant relationship between the concentration of TDS 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 XII. Secchi Disk Readings at L-I and Tributary Stations

Stations	SAMPLING DATES 4-6-82 (m)	5-6-82 (m)	6-3-82 (m)
L-I	2.0	2.0	1.5
W-1	0.75	0.4	0.5
W-2	100% (.3m)	50% (.4m)	100% (.4m)
W-3	100% (.5m)	50% (.5m)	100% (.5m)

TABLE XIV. Total Suspended Solids vs. Depth at Lake Station L-I.

Depth M	SAMPLING DATES 4-1-82 mg/ ℓ	5-6-82 mg/ ℓ	6-3-82 mg/ℓ
0	7.0	7.8	4.7
4	5.4	12.0	11.0
8	9.2	10.0	17.0
12	15.4	20.4	43.0
16	13.5	8.6	54.0
20	52.0	105.4	51.0

TABLE XV. Total Suspended Solids at Tributary Stations.

Stations	SAMPLING DATES 4-6-82 mg/ ℓ	5-6-82 mg/ ℓ	6-3-82 mg/ ℓ
W-I	14.6	31.2	16.2
W-2	9.4	732.0	22.2
W-3	8.4	512.0	13.2

Figure IX. . Mean and Standard Error of Total Suspended Solids at Station L-I (October 1981 - June 1982).

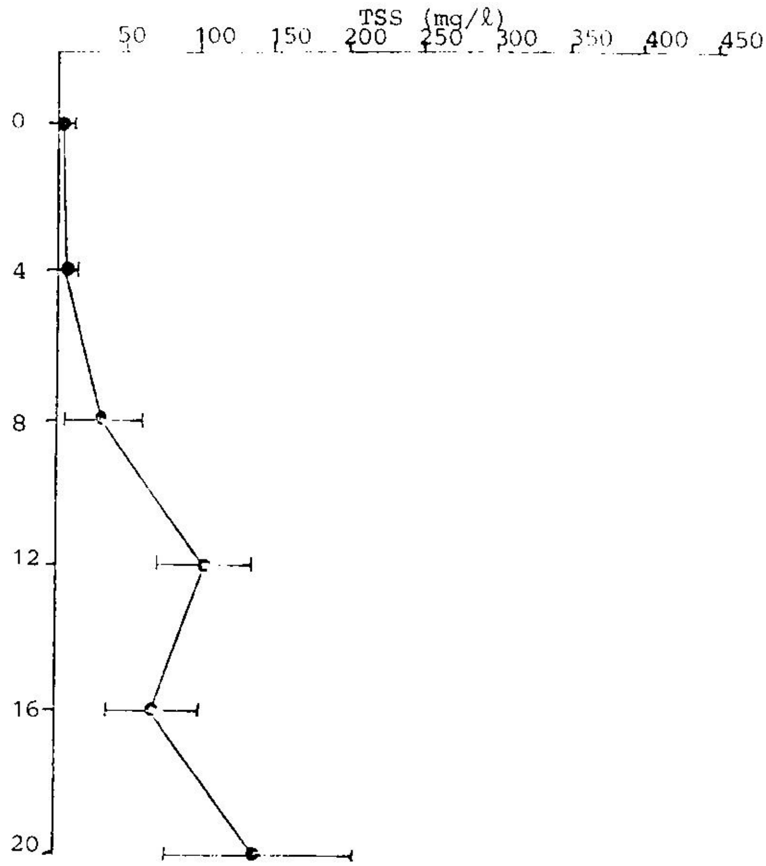


Table XVI . Suspended Sediment Loading from Tributary Rivers to La Plata Lake (October 1981 - April 1982).

Month	La Plata gr/m^3	Guadiana gr/m^3	Cañas gr/m^3	Total gr/m^3
October	2.849×10^8	1.242×10^8	5.001×10^6	4.141×10^8
November	8.114×10^9	2.337×10^7	1.189×10^6	8.138×10^9
December	4.875×10^9	2.925×10^7	2.349×10^6	4.906×10^9
January	4.611×10^7	7.465×10^5	2.342×10^6	4.920×10^7
February	2.746×10^8	3.129×10^6	6.810×10^4	2.778×10^8
March	5.976×10^7	6.178×10^5	1.535×10^5	6.053×10^7
April	1.589×10^8	6.400×10^6	5.250×10^5	1.658×10^8
Total	1.381×10^{10}	1.877×10^8	1.163×10^7	1.401×10^{10}

Monthly Mean = 2.001×10^9 $gr/m^3/mo$ or 2.001×10^6 $kg/m^3/mo$

Tributary rivers averaged 162 mg/l at La Plata, 148 mg/l at Guadiana and 167 mg/l at Cañas during this quarter of the study (see Table XVIII).

Total Alkalinity

Monthly means of total alkalinity measurements ranged between 96.2 mg/l as $CaCO_3$ in June and 158.8 mg/l as $CaCO_3$ in May, 1982. The profile of total alkalinity at the lake station L-I 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/l as $CaCO_3$ at La Plata, 112 mg/l as $CaCO_3$ at Guadiana and 104 mg/l as $CaCO_3$ at Cañas 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_3-N maintained a pattern of increase with depth during the third quarter of the study (April-June, 1982) see Table XXI. Ammonia nitrogen is generated by heterotrophic bacteria as the primary end product of 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_3-N is assimilated and metabolized by photosynthetic algae and floating macrophytes.

TABLE XVII. Total Dissolved Solids vs. Depth at Lake Station L-I.

Depth M	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
0	216	654	142
4	201	617	155
8	189	595	180
12	187	563	194
16	202	551	175
20	174	543	204

TABLE XVIII. Total Dissolved Solids at Tributary Stations.

Stations	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
W-1	243	50	194
W-2	226	19	198
W-3	240	38	223

TABLE XIX. Total Alkalinity vs. Depth at Lake Station L-I.

Depth M	SAMPLING DATES 4-1-82 mg/ℓ as $CaCO_3$	5-6-82 mg/ℓ as $CaCO_3$	6-3-82 mg/ℓ as $CaCO_3$
0	126	134	118
4	128	134	117
8	128	131	96
12	107	105	84
16	86	93	81
20	80	88	81

TABLE XX. Total Alkalinity at Tributary Stations.

Stations	SAMPLING DATES 4-1-82 mg/ℓ as $CaCO_3$	5-6-82 mg/ℓ as $CaCO_3$	6-3-82 mg/ℓ as $CaCO_3$
W-1	158	147.5	114
W-2	120	92.5	123
W-3	127	68.5	117.5

TABLE XXI. Ammonia-Nitrogen vs. Depth at Lake Station L-I.

Depth M	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
0	.01	0	.01
4	.02	0	.01
8	.04	0	.08
12	.09	.35	.39
16	.11	.56	.48
20	.48	.71	.45

TABLE XXII. Ammonia-Nitrogen at Tributary Stations.

Station	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
W-1	.04	.12	.03
W-2	.025	.015	.02
W-3	.025	.04	.02

Tributary rivers averaged 0.06 mg/l at La Plata, 0.02 mg/l at Guadiana and 0.08 mg/l at Cañas 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 mg/l in June, 1982 during the third quarter at L-I (see Table XXIII). The average profile of nitrite-nitrate concentrations reflects a weak dichotomic distribution with a maximum average concentration at 12 meters (see Figure XI). In very productive lakes where clinograde O_2 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 evidenced 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 Cañas River (see Table XXIV).

Total Kjeldahl Nitrogen

The water column average of TKN for the quarter (April-June, 1982) was 0.65 mg/l (range .52-.73 mg/l) at L-I (see Table XXV). TKN concentrations were higher in the deeper portions of the water column (see 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 of

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

Depth M	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
0	.04	0	.01
4	.01	0	.02
8	< .001	0	.23
12	< .001	.01	.01
16	< .001	.01	0
20	.01	.02	.01

TABLE XXIV. Nitrite-Nitrate at Tributary Stations.

Station	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
W-1	.66	.70	1.01
W-2	1.72	1.30	1.64
W-3	.81	1.12	1.12

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

Depth M	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
0	.49	.34	.58
4	.42	.40	.56
8	.58	.40	.54
12	.45	.71	.91
16	.87	1.08	.93
20	.32	1.23	.86

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

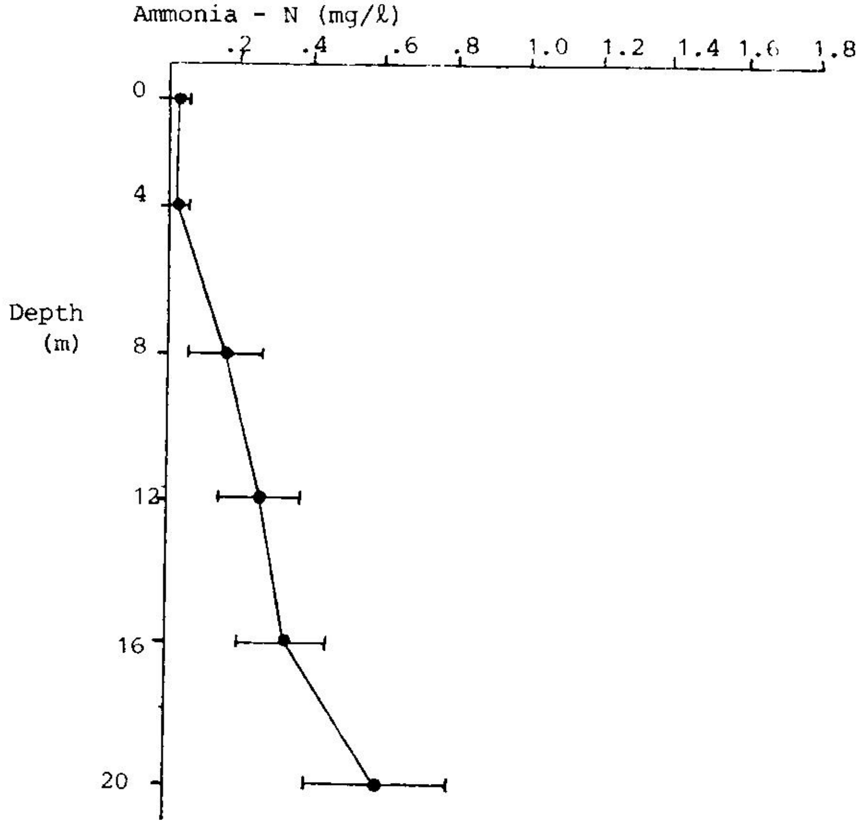
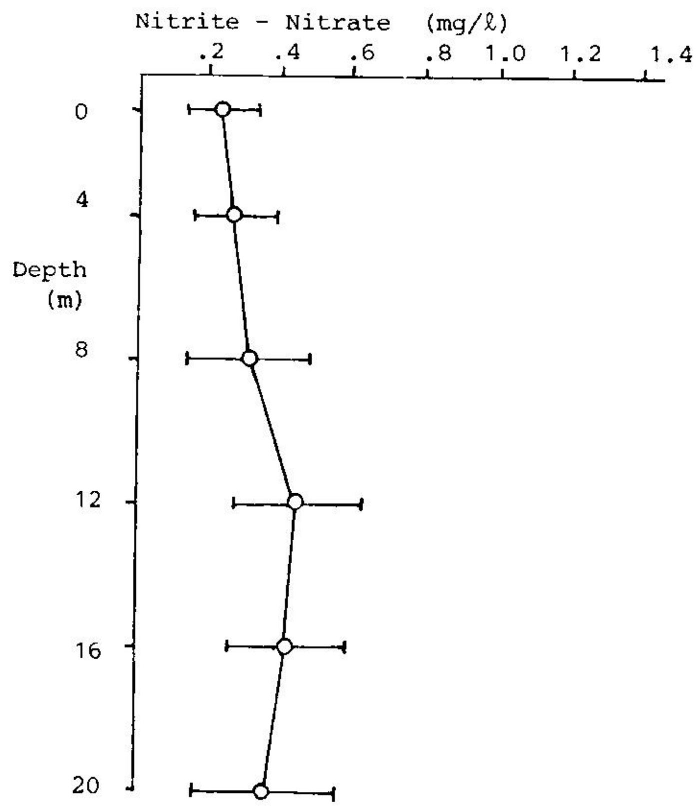


Figure XI. Mean and Standard Error of Nitrite-Nitrate Concentrations vs. Depth at La Plata Lake (October 1981 - June 1982).



TKN 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 10^4 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) suggests rapid epilimnetic removal by photosynthetic organisms (see Figure XIII). 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 EPA 440/5-80-11 document. As previously established, the main vehicle of phosphorus loading to

Figure XII. Means and Standard Error of TKN Concentrations vs. Depth at La Plata Lake (October 1981 - June 1982).

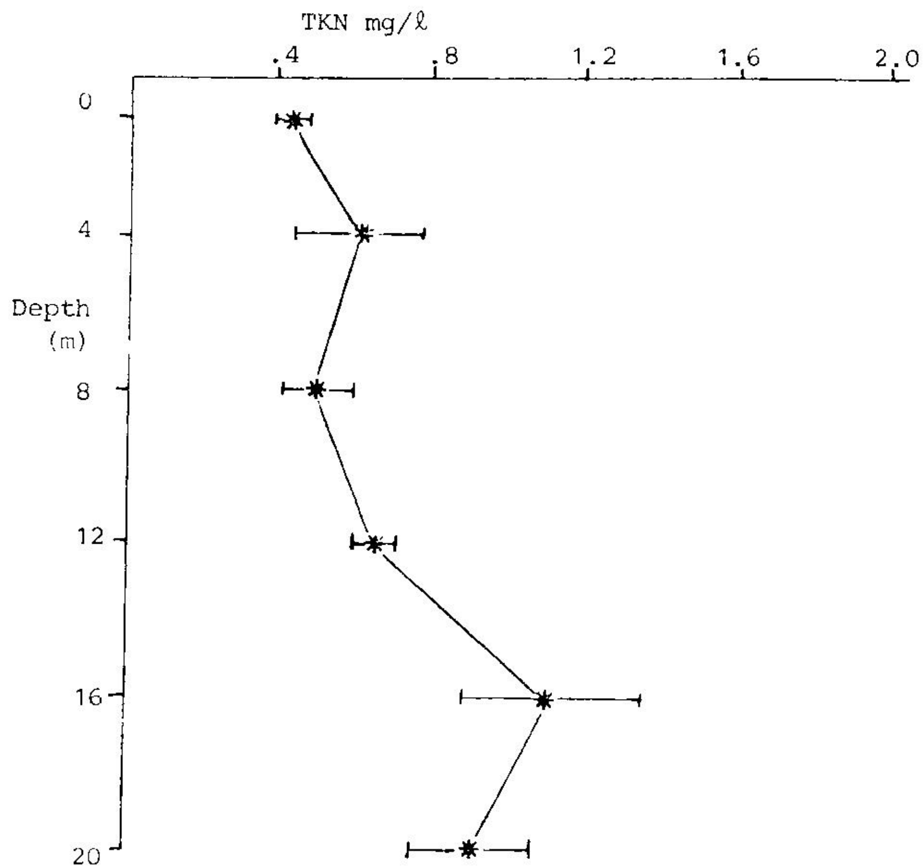


TABLE XXVI. Total Kjeldahl Nitrogen at Tributary Stations.

Stations	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
W-1	.76	.52	.47
W-2	.34	1.33	.32
W-3	.22	1.69	.20

TABLE XXVIII Soluble Reactive Phosphorus vs. Depth at Lake Station L-I.

Depth M	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
0	.04	.02	.03
4	.03	.02	.03
8	.08	.05	.13
12	.10	.06	.13
16	.11	.04	.13
20	.09	.03	.12

TABLE XXIX Soluble Reactive Phosphorus at Tributary Stations.

Stations	SAMPLING DATES 4-1-82 mg/ℓ	5-6-82 mg/ℓ	6-3-82 mg/ℓ
W-1	.24	2.14	.22
W-2	.31	.17	.26
W-3	.09	.14	.11

Table XXVII . Monthly Total Nitrogen Loading by Tributary Rivers to La Plata Lake, in Gms - P/Lake/mo.

Tributary	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total
La Plata	1.53×10^7	3.07×10^7	4.24×10^7	2.62×10^6	2.78×10^6	2.23×10^6	8.28×10^6	1.04×10^8
Guadiana	1.16×10^6	8.49×10^5	1.78×10^6	1.87×10^5	1.28×10^5	1.47×10^5	2.32×10^5	4.48×10^6
Cañas	7.29×10^4	4.20×10^4	1.17×10^5	1.19×10^4	7.66×10^3	8.60×10^3	1.38×10^4	2.74×10^5
Monthly Totals	1.65×10^7	3.16×10^7	4.43×10^7	2.82×10^6	2.92×10^6	2.38×10^6	8.52×10^6	1.09×10^8

Note: Total Nitrogen was calculated as Total Kjeldahl Nitrogen.

the lake is 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 XXXI). The estimated monthly average loading of total P to the lake via La Plata River is 6.88 X 10^6 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 gr P/m^2/yr.

The vertical distribution of total phosphorus in the water column at L-I (Figure XIX) showed no significant differences from top to bottom. On a monthly basis total phosphorus concentrations were higher during the period of high rain (October-December, 1981) 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

The monthly variations of phytoplankton abundance at the lake station L-I are presentd in Figure XXI. 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 XXX. Total Phosphorus vs. Depth at Lake Station L-I.

	SAMPLING DATES		
Depth M	4-1-82 mg/ ℓ	5-6-82 mg/ ℓ	6-3-82 mg/ℓ
0	.16	.06	.12
4	.19	.07	.12
8	.23	.09	.21
12	.19	.09	.11
16	.22	.07	.11
20	.35	.06	.10

TABLE XXXI. Total Phosphorus at Tributary Stations.

	SAMPLING DATES		
Stations	4-1-82 mg/ ℓ	5-6-82 mg/ ℓ	6-3-82 mg/ℓ
W-1	.38	.20	.26
W-2	.23	.10	.37
W-3	.12	.09	.17

Table XXXII. Monthly Total Phosphorus Loading by Tributary Rivers to La Plata Lake, in Gms - P/Lake/mo.

Tributary	Oct	1981 Nov	Dec	Jan	Feb	1982 Mar	Apr	Total
La Plata	1.28×10^{7}	1.09×10^{7}	1.52×10^{7}	1.54×10^{6}	1.86×10^{6}	1.71×10^{6}	4.14×10^{6}	4.82×10^{7}
Guadiana	8.68×10^{5}	4.43×10^{5}	7.31×10^{5}	2.43×10^{5}	1.79×10^{5}	1.08×10^{5}	1.57×10^{5}	2.73×10^{6}
Cañas	5.47×10^{4}	1.14×10^{4}	3.09×10^{4}	7.65×10^{3}	7.66×10^{3}	5.83×10^{3}	7.50×10^{3}	1.76×10^{5}
Monthly Totals	1.37×10^{7}	1.14×10^{7}	1.60×10^{7}	1.79×10^{6}	2.05×10^{6}	1.82×10^{6}	4.30×10^{6}	5.11×10^{7}

Figure XIX. Profile of Total Phosphorus Concentrations at La Plata Lake (October 1981 - June 1982).

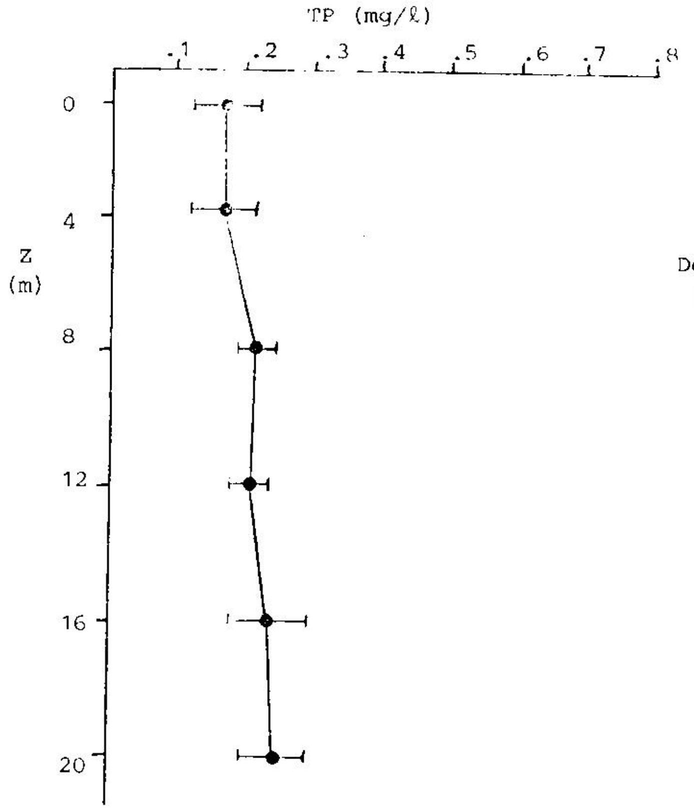


Figure XVIII Profile of Soluble Reactive Phosphorus Concentrations at La Plata Lake (October 1981 - June 1982).

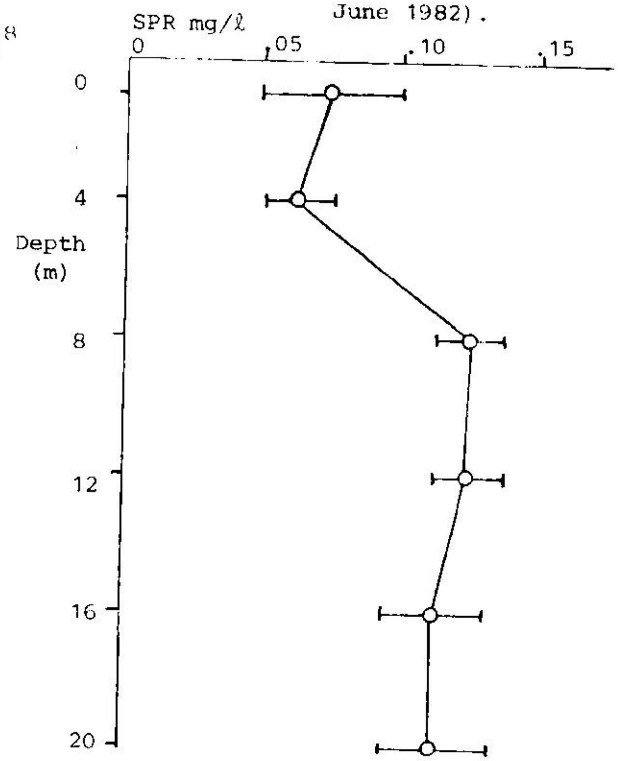


Figure XX. . Comparison of the Monthly Fluctuations of Total Phosphorus and Soluble Reactive Phosphorus in La Plata Lake.

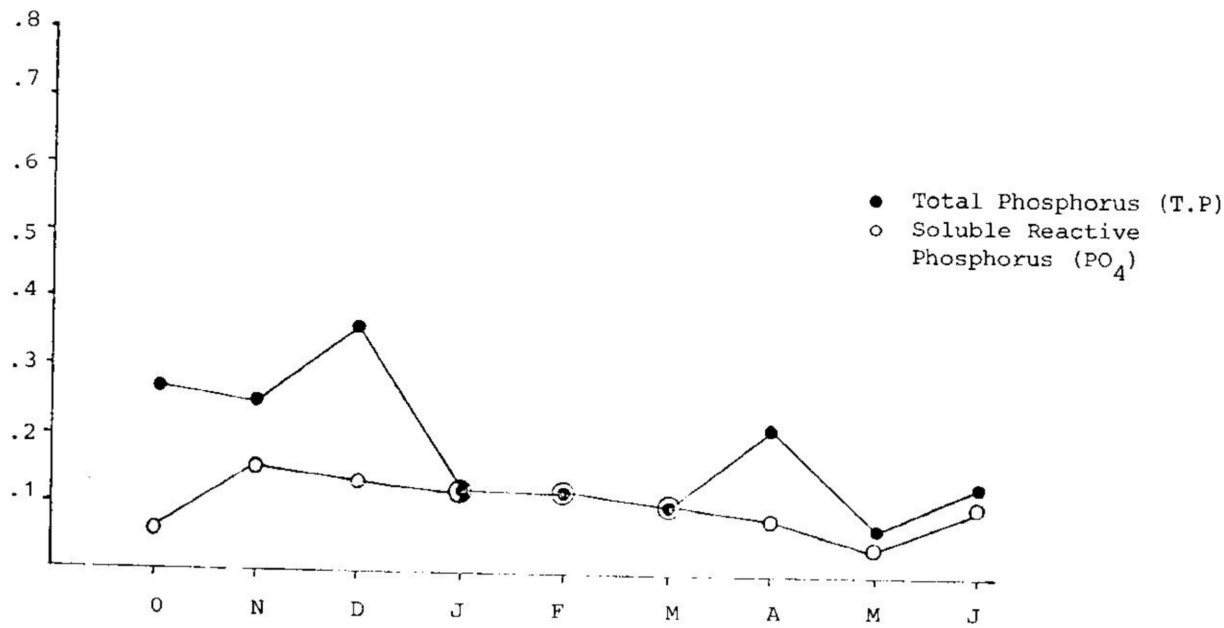


Figure XXI . Monthly variation in phytoplankton abundance at La Plata Lake, Station L-I.

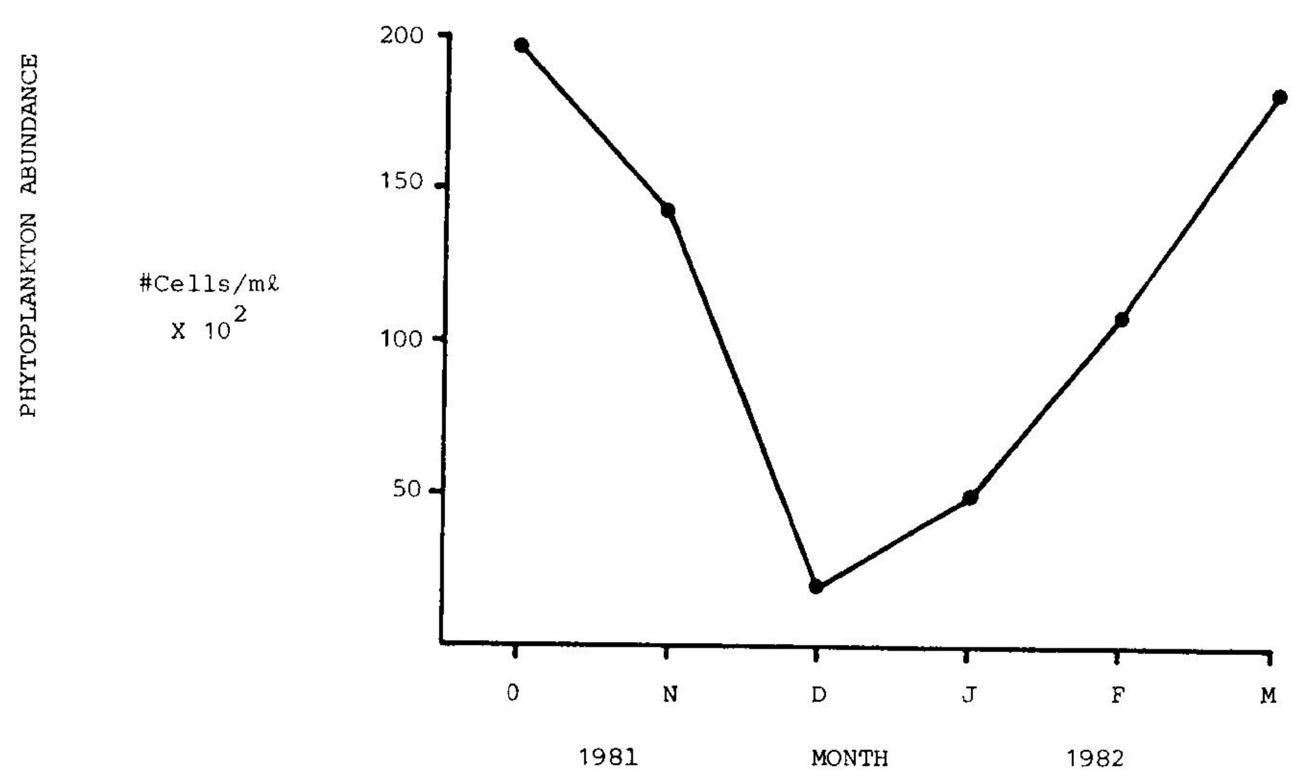
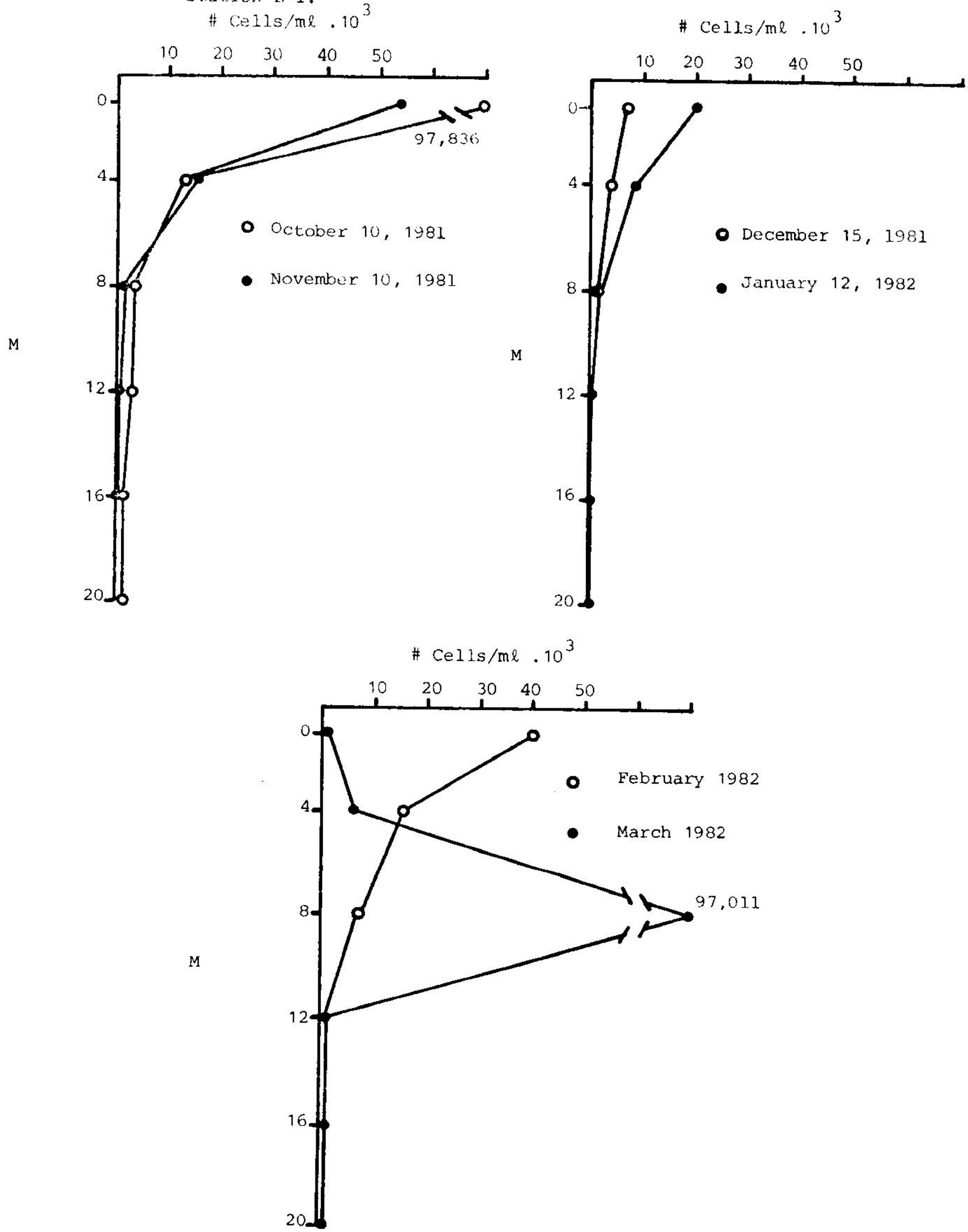


Figure XXII. Vertical distribution of phytoplankton abundance at La Plata Lake, Station L-I.



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-a concentrations measured during the summer at the lake station L-I (see Table XXXIII). 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 (see Table XXXIV) confirming the indogenous nature of the lake values. The vertical distribution of Chl-a is presented in Figure XXIV. The average surface concentrations of Chl-a measured at La Plata Lake classify this system as eutrophic according to EPA-440/5-79-015 (1979).

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 Chl-a are present in Figure XXV. Water column average concentrations of Chl-a showed a significant positive correlation (r=0.82) with water column average abundances of phytoplankton cells/ml at La Plata Lake (see Figure XXVI). Biovolume conversions of phytoplankton cell counts will be used to assess the validity of using Chl-a concentrations as a quantitative index of phytoplankton biomass in Puerto Rican lakes.

TABLE XXXIII. Chlorophyll-a vs. Depth at Lake Station L-I.

	SAMPLING DATES		
Depth M	4-1-82 mg/m^3	5-6-82 mg/m^3	6-3-82 mg/m^3
0	18.1	10.9	23.2
4	24.7	16.8	34.2
8	6.3	11.1	5.7
12	9.4	3.0	5.2
16	3.5	2.4	1.9
20	2.9	1.8	1.3

TABLE XXXIV. Chlorophyll-a at Tributary Stations.

	SAMPLING DATES		
Stations	4-1-82 mg/m^3	5-6-82 mg/m^3	6-3-82 mg/m^3
W-1	2.8	2.2	1.1
W-2	2.3	16.4	2.6
W-3	1.1	12.8	0.9

Figure XXIII. Vertical distribution of chlorophyll-a concentrations at La Plata Lake, Station L-I.

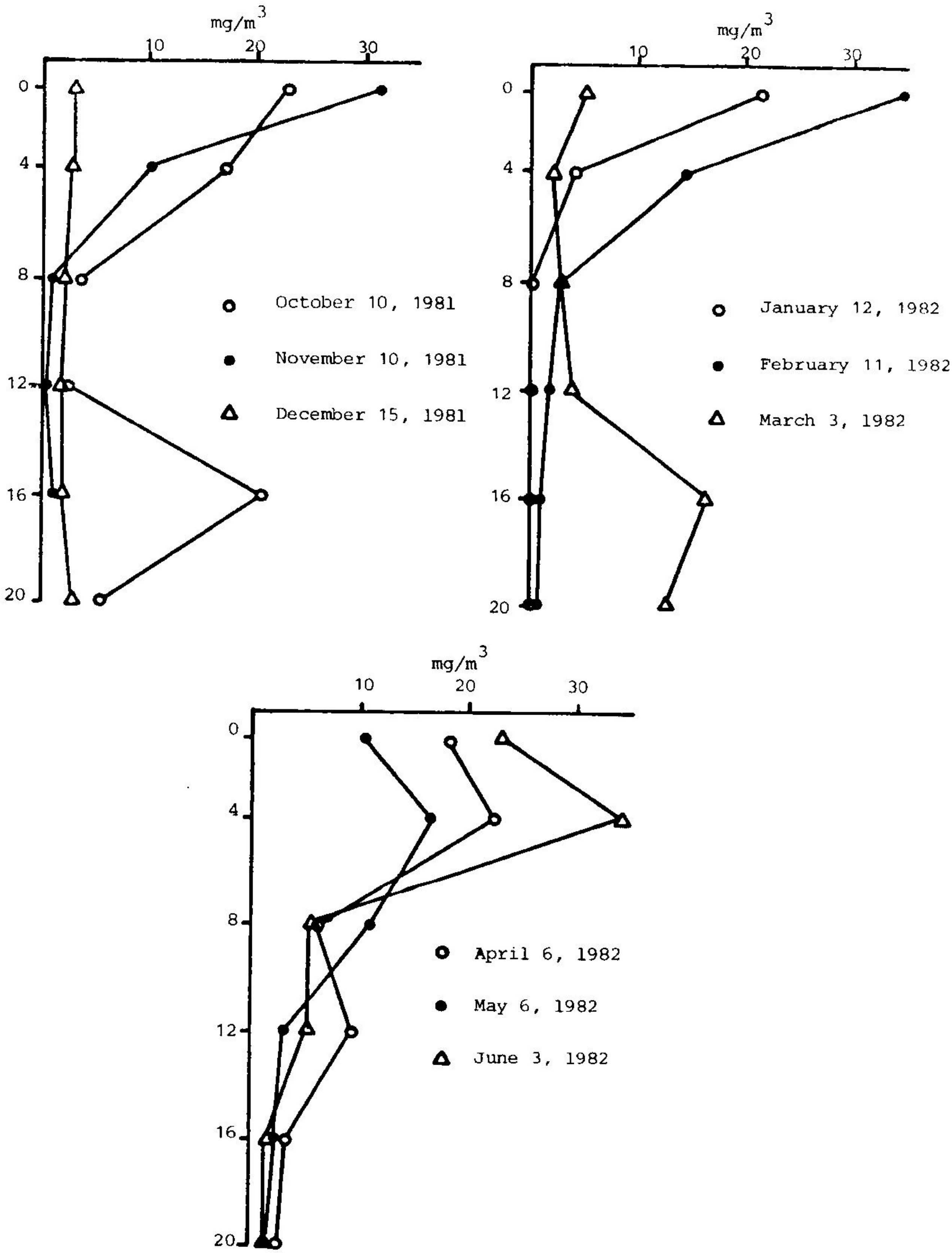


Figure XXIV. Mean and Standard Error of Chlorophyll-a Concentrations vs. Depth. (October 1981 - June 1982).

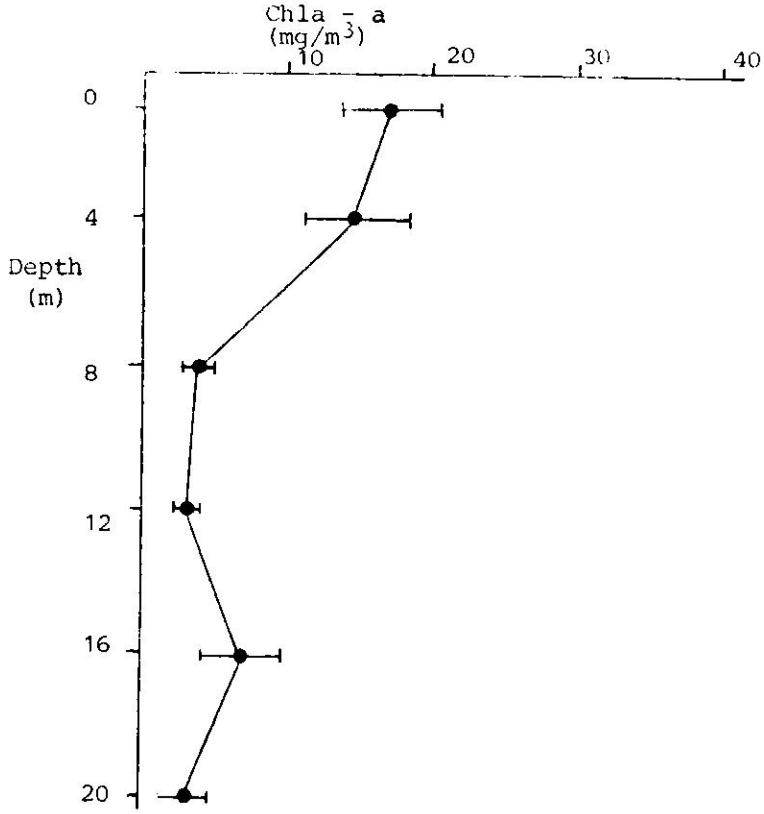


Figure XXV. Monthly Fluctuations in Chlorophyll-a Concentrations at La Plata Lake.

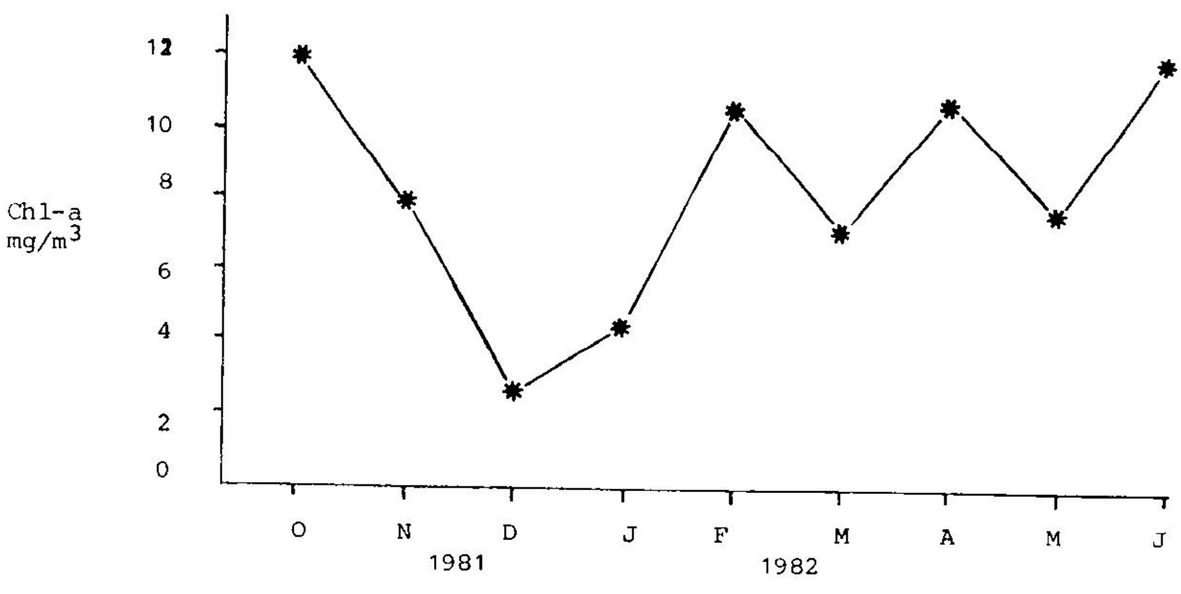
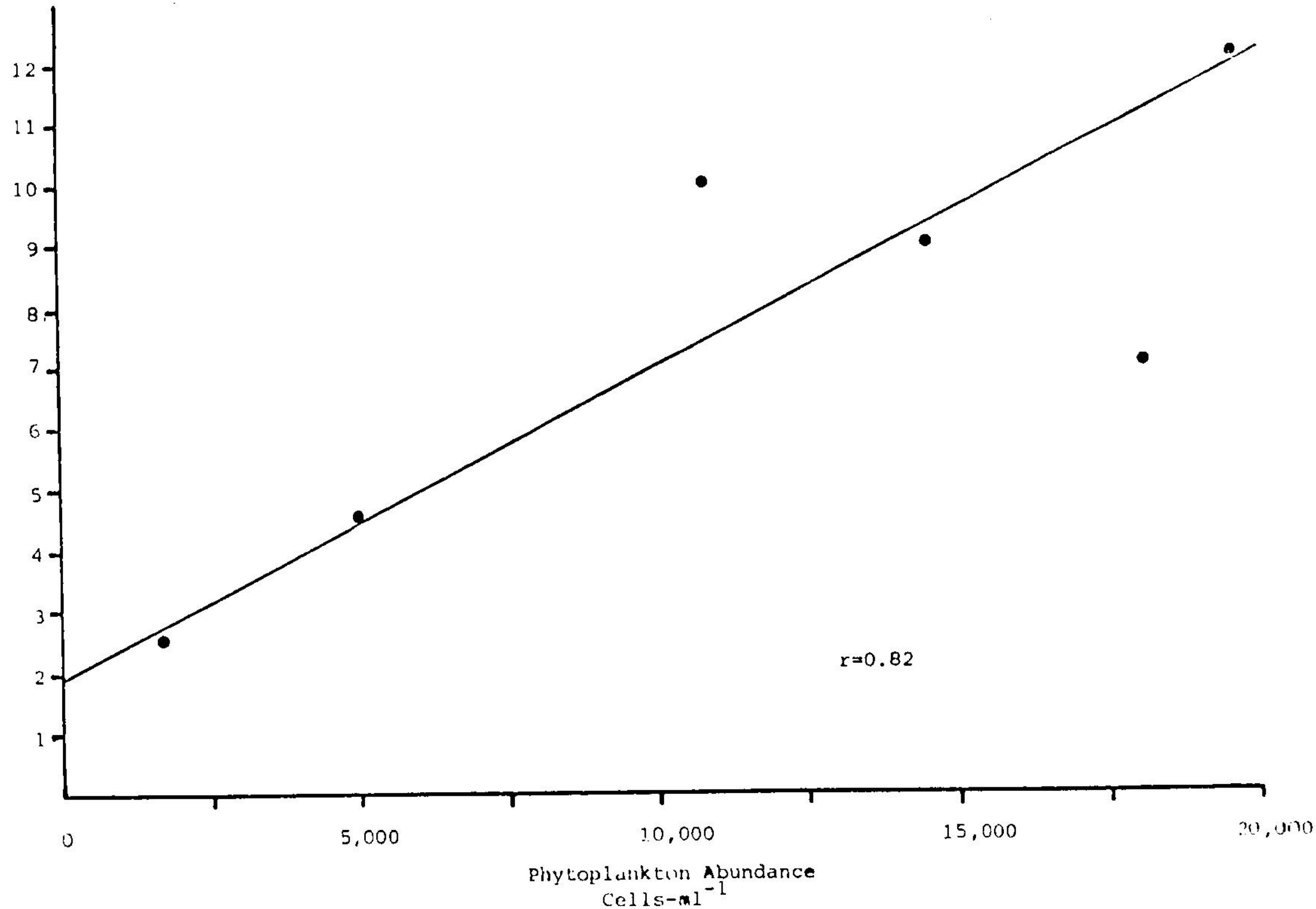


Figure XXVI. Linear relationship between average concentrations of Chlorophyll-a and abundance of phytoplankton cells/mls.



Primary Productivity

During 6 April 1982 a single experiment to estimate primary productivity was performed near station L-I using the dark-light bottle method. The results of this experiment are presented in Table XXXV. The net primary productivity at 1.0 m depth from bottles incubated in situ for 4 hours was relatively low (315 mg O_2 m^{-3} da^{-1}. Gross productivity, however, was high (≅3387 mg O_2 m^{-3} da^{-1})because of high respiration rates(≅3072 mg O_2 $m^{-3}da^{-1}$). 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.

Biological Oxygen Demand

The water column average BOD^5 at station L-I was 1.57 mg/l (range 1.05 - 2.27 mg/l), see Table XXXVI. Tributary rivers (Table XXXVII) evidenced relatively lower values (1.18 mg/l at La Plata, 1.49 mg/l at Guadiana, and 1.41 mg/l at Cañas River) suggesting that the lake BOD's are autochthonous.

Assuming, on the basis of the above estimates, an average O_2 production in the euphotic zone of the lake (0-4 m) of 1,260 mg O_2 m^{-3} da^{-1} and zero production below 4 m depth the estimated monthly production of D.O. in the water column would be of approximately 37,800 mg O_2 m^{-2} mo^{-1}. The respiration potential, calculated as a monthly BOD for the water column was 94,200 mg O_2 m^{-2} mo^{-1} (using 10 m as the mean depth). Clearly the respiration potential exceeds oxygen renewal and is consistent with the observed D.O. deficit at the lake station (P/R Ratio=0.40).

TABLE XXXV. Single Observation in Time of Primary Productivity at La Plata Lake (April 6, 1982).

1.0 Meter Depth Only   Station L-I

	A	B	$\bar{X}$
(I) Initial	6.00	6.70	6.35
(L) Light 1	6.04	6.39	6.22
(L) Light 2	6.64	6.69	6.66
Grand Mean Light		6.44 mg O_2 ℓ^{-1}	
(D) Dark	5.84	5.84	5.84

Net P. = L-I = 6.44 - 6.35 = .09 mg ℓ^{-1} 4 hrs^{-1}
Gross P. = L-D = 6.44 - 5.84 = .60 mg ℓ^{-1} 4 hrs^{-1}
Respiration = I-D = 6.35 - 5.84 = .51 mg ℓ^{-1} 4 hrs^{-1}

Net = 22.5 mg O_2 m^{-3} hr^{-1}
Gross = 150 mg O_2 m^{-3} hr^{-1}
Respiration ≅ 128 mg O_2 m^{-3} hr^{-1}

Daily Rates (Assumes 14 hr light: 10 hr dark)

Net = 315 mg O_2 m^{-3} da^{-1} ≅ 118 mg C m^{-3} da^{-1}
Respiration = 3072 mg O_2 m^{-3} da^{-1}
Gross = Net + Resp. = 3387 mg O_2 m^{-3} da^{-1} ≅ 1270 mg C m^{-3} da^{-1}

TABLE XXXVI. Biological Oxygen Demand vs. Depth at the Lake Station L-1 (January - June 1982).

	Sampling Date					
DEPTH m	1/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ	4/1/82 mg/ℓ	5/6/82 mg/ℓ	6/3/82 mg/ℓ
0	2.25	1.73	3.11	1.44	1.25	2.72
4	0.90	1.01	2.88	1.70	1.61	2.63
8	0.70	1.12	1.28	1.69	1.01	1.34
12	1.35	1.33	1.04	0.65	1.00	1.59
16	0.64	1.05	2.00	0.79	0.77	3.13
20	1.15	2.87	3.33	0.82	0.66	2.07

TABLE XXXVII Biological Oxygen Demand at Tributary Stations.

	Sampling Dates					
STATION	1/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ	4/1/82 mg/ℓ	5/6/82 mg/ℓ	6/3/82 mg/ℓ
W-1	0.92	0.58	2.02	1.01	1.35	1.18
W-2	1.30	0.36	1.34	1.28	3.82	0.86
W-3	1.38	0.38	1.34	0.86	3.73	0.77

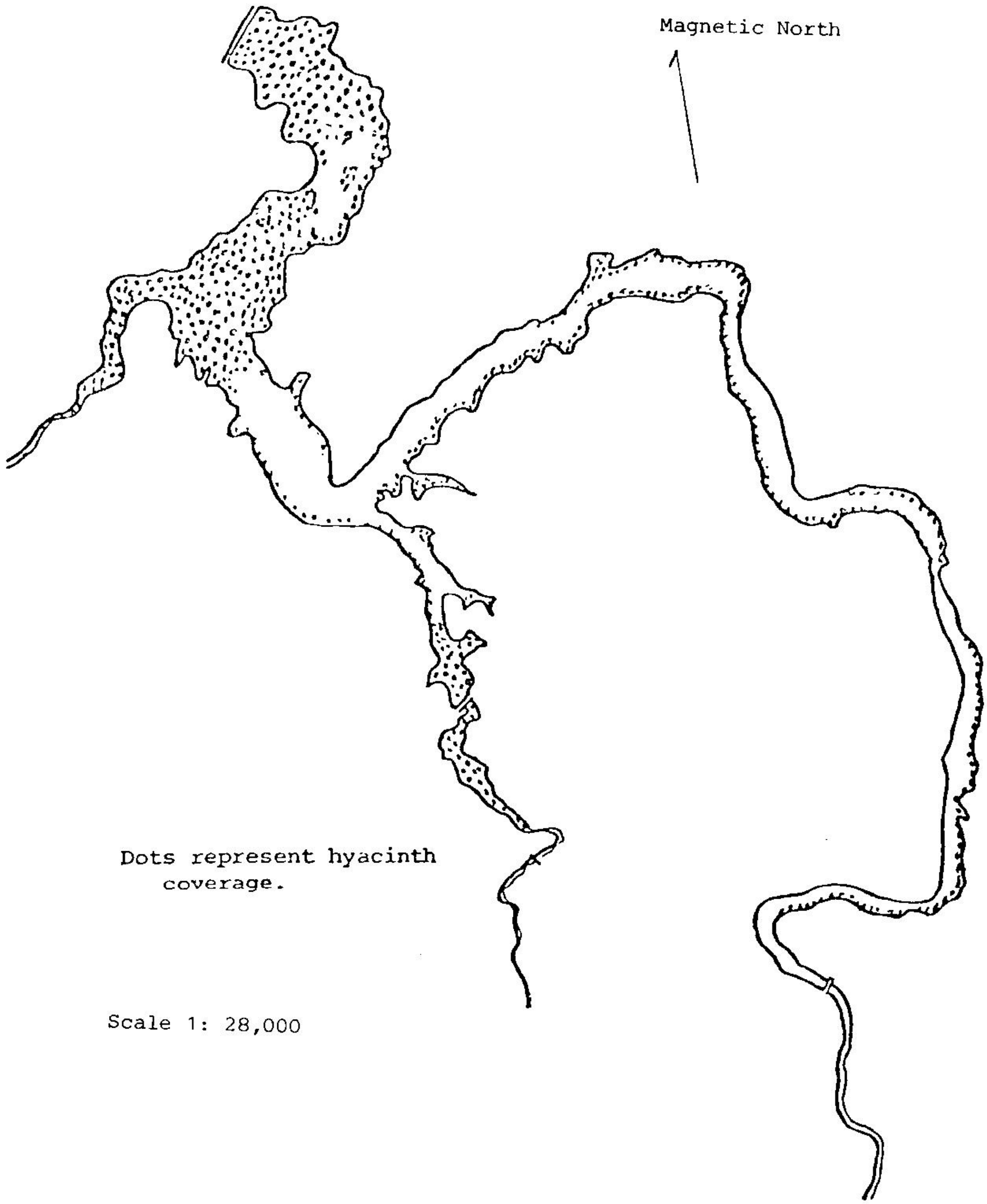
Macrophyte Coverage

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 g m^{-2} da^{-1} (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 product 1.19×10^7 g m^{-2} da^{-1} (dry weight). At .22% P the crop of plants in La Plata would be removing about 2.6×10^4 g of P per day. That rate of phosphorus removal corresponds to about

Figure XXVII. Water hyacinth coverage at La Plata Lake.



11% of the average loading to the lake. A comprehensive study of water hyacinths productivity and nutrient assimilation at La Plata Lake is highly recommended in order to examine the potential of water hyacinths as a tool in eutrophication control.

BACTERIOLOGY

Total Coliforms

Table XXXVIII presents the profiles of total coliform concentrations at L-I which resulted during the third quarter of the study (April-June, 1981). The average water column concentration was 490 MPN colonies/100 mls (range 220-957 MPN colonies/100 mls). Standard regulations of water quality (EQB, 1973) recommend an upper limit of 10.000 MPN colonies/100 mls 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, 1982.

Fecal Coliforms

Fecal coliforms averaged 272 MPN colonies/100 mls (range 58-625 MPN colonies/100 mls) 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 mls (EQB, 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).

TABLE XXXVIII Total Coliforms vs. Depth at Lake Station L-I

Depth M	SAMPLING DATES 4-1-82 MPN colonies/ml	5-6-82 MPN colonies/ml	6-3-82 MPN colonies/ml
0	330	700	220
4	130	490	130
8	230	330	490
12	330	79	2200
16	130	79	1300
20	170	79	1400

TABLE XXXIX. Total Coliforms at Tributary Stations

Station	SAMPLING DATES 4-1-82 MPN colonies/ml	5-6-82 MPN colonies/ml	6-3-82 MPN colonies/ml
W-1	280	7,300	1,500
W-2	1,300	> 24,000	39,000
W-3	2,600	> 24,000	4,950

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

Depth M	SAMPLING DATES 4-1-82 MPN colonies/ml	5-6-82 MPN colonies/ml	6-3-82 MPN colonies/ml
0	230	110	79
4	79	79	49
8	79	130	490
12	110	23	430
16	130	23	1300
20	170	8	1400

TABLE XLI. Fecal Coliforms at Tributary Stations

Stations	SAMPLING DATES 4-1-82 MPN colonies/ml	5-6-82 MPN colonies/ml	6-3-82 MPN colonies/ml
W-1	280	1,850	1,500
W-2	790	> 24,000	10,450
W-3	625	> 24,000	1,080

The higher concentrations of total and fecal coliforms observed at tributary rivers is consistent with our previous determination that tributary rivers are the most important input 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 mls. 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 mls at La Plata, 8,113 MPN colonies/100 mls at Guadiana and 8,114 MPN colonies/100 mls at Cañas River.

HEAVY METALS

The concentrations of Cu, Cd, Pb, Zn and Hg (in ug l^{-1}) 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 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 XLII. Fecal Streptococcus vs. Depth at Lake Station L-I

	SAMPLING DATES		
Depth M	4-1-82 MPN colonies/ml	5-6-82 MPN colonies/ml	6-3-82 MPN colonies/ml
0	5	8	0
4	33	33	2
8	5	8	8
12	2	2	49
16	0	5	33
20	5	2	46

TABLE XLIII. Fecal Streptococcus at Tributary Stations

	SAMPLING DATES		
Stations	4-1-82 MPN colonies/ml	5-6-82 MPN colonies/ml	6-3-82 MPN colonies/ml
W-1	66	515	1
W-2	333	> 24,000	5
W-3	330	> 24,000	13

TABLE XLIV. Concentration of Heavy Metals vs. Depth at Lake Station L-I

Depth	Hg µg/ℓ 4-6-82	Hg 5-6-82	Hg 6-3-82	Zn µg/ℓ 4-6-82	Zn 5-6-82	Zn 6-3-82	Cu µg/ℓ 4-6-82	Cu 5-6-82	Cu 6-3-82
0	10.7	4.6	4.9	8.44	27.31	<5.0	.81	1.30	1.59
4	4.9	5.0	5.8	8.44	8.44	6.84	.08	.08	.27
8	4.8	4.8	5.8	7.09	6.42	<5.0	.08	1.30	1.59
12	5.4	5.2	5.6	8.44	9.79	46.42	1.78	4.95	2.91
16	6.2	5.3	4.7	40.79	46.19	51.70	3.74	15.93	5.56
20	5.4	4.7	6.3	32.71		43.77	3.74	6.66	6.88

Depth	Cd µg/ℓ 4-6-82	Cd 5-6-82	Cd 6-3-82	Pb µg/ℓ 4-6-82	Pb 5-6-82	Pb 6-3-82	Ni µg/ℓ 4-6-82	Ni 5-6-82	Ni 6-3-82	Cr µg/ℓ 4-6-82	Cr 5-6-82	Cr 6-3-82
0	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	<5.0
4	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	<5.0
8	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	<5.0
12	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	<5.0
16	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	<5.0
20	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	<5.0

SYNTHETIC ORGANICS

Pesticide residue analysis of 12 water samples from La Plata Lake (station L-I) and major tributaries (La Plata, Guadiana and Cañas 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 analysis of pesticide residues in sediment samples during the last quarter of the study.

REPORT OF FISH MORTALITIES IN LA PLATA LAKE

May 6, 1982

During 6 May 1982 dead individuals of the "Threadfin 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 was observed, i.e., scales and fins were intact and braquiostegal 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. A copy of the original data

TABLE XLV. Concentration of Heavy Metals at Tributary Stations

Stations	Hg µg/ℓ 4-6-82	Hg µg/ℓ 5-6-82	Hg µg/ℓ 6-3-82	Zn µg/ℓ 4-6-82	Zn µg/ℓ 5-6-82	Zn µg/ℓ 6-3-82	Cu µg/ℓ 4-6-82	Cu µg/ℓ 5-6-82	Cu µg/ℓ 6-3-82
W-1	5.29	4.8	5.0	11.81	20.58	<7.45	8.24	5.96	3.57
W-2	5.02	6.6	4.5	10.87	48.88	<5.0	1.78	13.49	2.25
W-3	10.14	5.3	5.3	9.11	44.84	<5.0	1.30	9.22	1.50

Stations	Cd µg/ℓ 4-6-82	Cd µg/ℓ 5-6-82	Cd µg/ℓ 6-3-82	Pb µg/ℓ 4-6-82	Pb µg/ℓ 5-6-82	Pb µg/ℓ 6-3-82	Ni µg/ℓ 4-6-82	Ni µg/ℓ 5-6-82	Ni µg/ℓ 6-3-82	Cr µg/ℓ 4-6-82	Cr µg/ℓ 5-6-82	Cr µg/ℓ 6-3-82
W-1	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	10.82
W-2	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	<5.0
W-3	< 2.5	< 2.5	<2.5	<13.2	<13.2	<13.2	< 5.0	< 5.0	<5.0	< 5.0	< 5.0	17.66

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

Metal	Mean	Range	Surface Waters Limit Recommended
	μg/ℓ	μg/ℓ	μg/ℓ
Hg	3.19	.21 - 6.23	1.0
Cu	7.64	1.70 -13.50	40.0
Cd	1.99	1.58 - 2.50	5.0
Cr	< 10.00	Not detected	50.0
Pb	12.57	5.95 -20.2	50.0
Zn	63.30	17.65 -166.92	50.0
Ni	< 5.00	Not detected	

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

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

Source: Laboratorio Agrológico de Puerto Rico. Departamento de Agricultura form is presented as 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 the mortality by asphyxia.

July 8, 1982

During 8 July 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 big Tilapia (range 20-30 cms), some (approximately 10%) had their head decapitated. One individual which was observed still alive at the time of the mortality showed signs of asphyxia: abnormal distension of the branquiostegal 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 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).

TABLE XLVIII. Field Measurements of Temperature, Dissolved Oxygen, pH and Conductivity at the Site of Observed Mortality of fishes of the species, *Dorosoma petenense* during May 6, 1982.

[illegible]: [illegible]
[illegible]: 5-6-82

TOTAL DEPTH: 20 [illegible]
SECCHI: 1.0 m
TECH's SIGNATURE: [illegible]

TIME : 1205

[illegible]	TEMP °C	PH	D.O. [illegible]/ℓ	COND. µmhos	LIGHT foot/candles
5	2[illegible].1	6.2	1.1	380	
1	2[illegible].1	6.7	1.0	390	NOT
2	26.1	6.2	0.5	386	Measured
3	26.1	6.75	0.3	386	
[illegible]	2[illegible].1	6.[illegible]	0.2	3[illegible]	
5	26.0	6.9	0.1	394	
6	25.9	6.9	0.05	398	
7	25.9	6.8	0	398	
[illegible]	25.0	6.[illegible]	0	367	
9	24.8	6.4	0	332	
10	24.3	6.4	0	318	
11	24.1	6.4	0	309	
12	24.0	6.4	0	308	
13	24.0	6.4	0	307	
14	24.0	6.4	0	307	
15	24.0	6.4	0	306	
16	24.0	6.4	0	305	
17	24.0	6.4	0	305	
18	24.0	6.4	0	304	
19	24.0	6.4	0	303	
20	20.0	[illegible]	0	303	

STATION NOTES: Extraordinary amount [illegible] (Clupeidae) at the surface [illegible] [illegible] captured [illegible] trapped [illegible]

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 10% of the dead fish had been decapitated somehow.

PRELIMINARY SUMMARY

Reflection on the cumulated set of data has lead 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.

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 summer and more gradual gradients in other seasons. Even when thermal stratification is weak it is frequently sufficient to prevent physical exchange between hypolimnion and epilimnion except when heavy rainfall and possibly violent storms (i.e., winds) occur.

2. Dissolved oxygen stratification with anaerobic conditions persistent 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 epilimnion and hypolimnion, coupled

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

3. 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.

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

5. Low values of net primary productivity of phytoplankton are consistent with the idea that the lake has a low capacity for biological regeneration of dissolved oxygen by photosynthetic organisms in relation to the existing respiration rates.

6. Chlorophyll-a, phytoplankton abundance, water hyacinths and biological oxygen demand increase downstream from La Plata River indicating their indogenous character.

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

8. La Plata River has contributed a 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 N and 80% of the total P loading occurred during the "wet" period (Oct.-Dec., 1981). Bacteriological contamination above recommended limits are also associated to periods of high precipitation in the watershed.

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

11. Available micronutrients such as SRP and NH_3-N evidence 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 NO_2-NO_3 concentrations follows a weak dichotomic pattern.

12. Among the trace metal concentrations studied (Hg, Cu, Pb, Ni, Cr, Cd, and Zn) Zn and Hg exceed surface water standards for Puerto Rico.

13. Synthetic organics studied (copper compound, Gramaxone, 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. Being considered as possible lake restoration practices to be applied at La Plata Lake are the following:

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

(b) Implementation of BMP for the control of fertilizer and pesticides application.

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

(d) Macrophyte harvest as a tool of nutrient removal from the system, also in relation to 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.

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

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