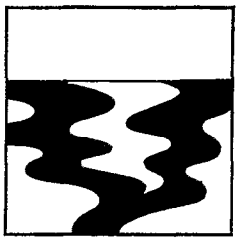

Planktonic Protozoa in a Tropical Reservoir : Temporal Variations in Abundance and Composition

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ABSTRACT

Ciliates and amoebae observed in the Lobo Reservoir (State of São Paulo, Brazil) were studied from September 1984 to October, 1985. Surface water samples were collected at 2-week intervals at two different points, open water (Station 1) and in the shallowest area of the reservoir (Station 2), heavily influenced by aquatic macrophytes, and examined for planktonic protozoa composition and density. Chlorophyll a *was analyzed and a few ecological parameters such as dissolved oxygen, pH, and water temperature were measured. No significant relationships were revealed between the seasonal distribution of protozoa and those of the factors measured. Concerning the protozoa density a high-density period was detected from February to May with a mean number of* 3.98×10^3 *protozoa* l^{-1} *at Station 1 and* 5.08×10^3 *protozoa* l^{-1} *at Station 2. The rest of the year the density was low. The mean number of organisms at the high-density period was approximately 4-fold that obtained during the low-density one. The highest planktonic protozoa density occured at Station 2, with* 9.87×10^3 *protozoa* l^{-1}*. The ciliates occurring at highest densities were* Colpoda sp. *(?),* Halteria grandinella, Mesodinium pulex, *and* Strombidinopsis setigera.

KEY WORDS : Microzooplankton — Ciliates — Amoebae — Lobo Reservoir — Seasonal distribution — South America — Freshwater.

RÉSUMÉ

PROTOZOAIRES PLANCTONIQUES DANS UN RÉSERVOIR TROPICAL : VARIATIONS SAISONNIÈRES D'ABONDANCE ET COMPOSITION

Les ciliés et amibes ont été étudiés dans le réservoir Lobo (État de São Paulo, Brésil) de septembre 1984 à octobre 1985. Avec le propos d'étudier l'abondance et la composition des protozoaires, des échantillonnages bimensuels ont été effectués à deux stations; en surface à la station 1 dans la région profonde et peu influencée par les rives, et à la station 2, dans une région moins profonde du réservoir, où on peut signaler un très grand nombre de macrophytes aquatiques. La chlorophylle a, *l'oxygène dissous, le pH et la température de l'eau, ont été également mesurés. Nous*

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n'avons pas mis en évidence de relation significative entre la distribution saisonnière des protozoaires et celle observée pour les paramètres écologiques mesurés. On a signalé une période de forte densité de février à mai avec un nombre moyen de 3,98 × 10^3 protozoaires l^{-1} pour la station 1 et 5,09 × 10^3 pour la station 2. Dans les autres mois la densité a été peu élevée. Le nombre moyen d'organismes dans la période de haute densité fut 4 fois plus grand que celui obtenu dans la période de densité peu élevée. La plus haute densité de protozoaires planctoniques fut observée à la station 2 avec 9,87 × 10^3 organismes l^{-1}. Les ciliés les plus abondants furent Colpoda sp. *(?),* Halteria grandinella, Mesodinium pulex *et* Strombidinopsis setigera.

MOTS-CLÉS : Microzooplancton — Ciliés — Amibes — Réservoir Lobo — Distribution saisonnière — Amérique du Sud — Eaux douces.

RESUMEN

PROTOZOARIOS PLANCTÓNICOS EN UNA REPRESA TROPICAL : VARIACIONES TEMPORALES EN ABUNDANCIA Y COMPOSICIÓN

Ciliados y amibas observados en la Represa del Lobo (Estado de São Paulo-Brasil) fueron estudiados desde septiembre de 1984 hasta octubre de 1985. Con intervalos de dos semanas fueron colectadas muestras de la superficie del agua en dos puntos diferentes, en agua abierta (estación 1) y en el área de menor profundidad de la represa bajo fuerte influencia de los macrófitos acuáticos (estación 2), para cada muestra se determinó la composición y densidad de protozoarios planctónicos, se analizó la clorofila a *y algunos parámetros ecológicos tales como oxigeno disuelto, pH y temperatura del agua fueron medidos. No fué revelada ninguna relación significativa entre la distribución estacional de protozoarios y los parámetros medidos. Respecto a la densidad de protozoarios fué detectado un periodo de alta densidad de febrero a mayo, con un número médio de 3,98 × 10^3 protozoarios l^{-1} en la Estación 1 y 5,08 × 10^3 protozoarios l^{-1} en la estación 2. El resto del año la densidad fué baja. El número médio de organismos en el periodo de alta densidad fué aproximadamente 4 veces más que el obtenido durante el periodo de baja densidad. La densidad más alta de protozoarios planctónicos ocurrió en la estación 2 con 9,87 × 10^3 protozoarios l^{-1}. Los ciliados encontrados en mayores densidades fueron :* Colpoda sp. *(?),* Halteria grandinella, Mesodinum pulex *et* Strombidinopsis setigera.

PALABRAS CLAVES : Microzooplancton — Ciliados — Amibas — Represa del Lobo — Distribución estacional — América del Sur — Agua dulce.

INTRODUCTION

The zooplanktonic community has been extensively studied, though protozoa have been rarely included in these studies. This is due to the fact that other components of the zooplanktonic community are considered to be more important and also to the methodological difficulties involved in this type of study.

Recent reports have emphasized the need for studies on planktonic protozoa (PACE & ORCUTT, 1981 ; BEAVER & CRISMAN, 1982 and HUNT & CHEIN, 1983). Protozoa are known to play an important role by consuming bacteria and thus reducing their numbers in environments rich in organic matter (JAVORNICKY & PROKESOVÁ, 1963). They also consume phytoplankton (BROOK, 1952) and can be consumed by Cladocera, Copepoda and Rotifera (SOROKIN & PAVELJEVA, 1972 ; BERK *et al.*, 1977 and PORTER *et al.*, 1979), in addition to being highly efficient in releasing phosphorus (JOHANNES, 1965 ; BUECHLER & DILLON, 1974 and PORTER *et al.*, 1979).

SMETACEK (1981), in a study of the zooplankton cycle in a marine environment, showed that protozoa act as a link in the food chain of the sea between small planktonic organisms to the large metazooplanktonic herbivores.

High protozoa densities (10^2-10^5 protozoa l^{-1}) have been reported to occur in several lakes by PACE & ORCUTT (1981). When studies in planktonic protozoa were first started at the Lobo Reservoir (State of São Paulo, Brazil), in 1983, densities of 9 × 10^3 protozoa l^{-1} were detected.

The present investigation was undertaken to study the abundance and frequency of planktonic ciliates and amoebae and some ecological parameters in a shallow and mesoligotrophic tropical environment.

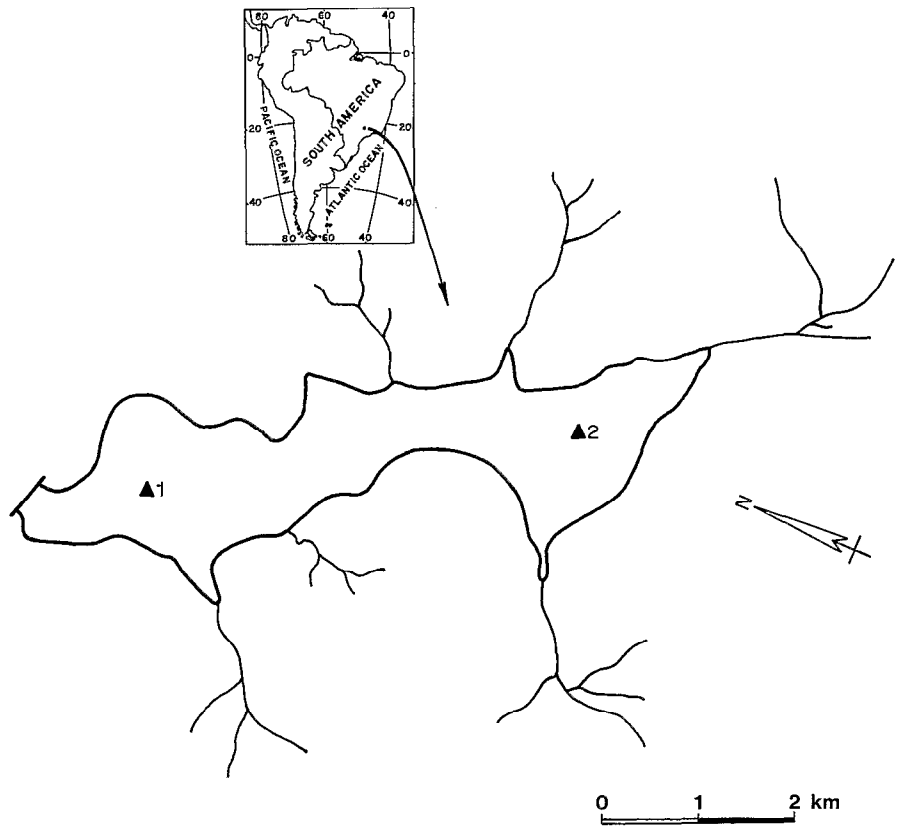

FIG. 1. — Lobo Reservoir — sampling stations
Réservoir du « Lobo » — stations d'échantillon

SITE DESCRIPTION

The Lobo Reservoir (fig. 1) is an artificial reservoir located in the Center-West region of the State of São Paulo, Brazil (47°49′ W and 22°15′ S), 7.5 km in length and averaging 0.9 km in width. Surface is 6.8 km² and mean depth is 3.0 m. A feature of the reservoir is its instability caused by the action of winds which frequently breakdown the weak stratification of the water. The drop in lake level is not accentuated even in the dry season. The residence time of the water in the reservoir is about 21 days (J. G. TUNDISI, personal communication). Station 1 (about 6.0 m) is located near the dam, where the Reservoir is deepest, and does not present aquatic vegetation. Station 2, with a well developed marginal region, has aquatic vegetation, mainly *Nymphoides indica* and *Pontederia cordata*, and a depth of approximately 2.0 m.

METHODS

Surface water samples for qualitative and quantitative protozoa analysis were collected between 9.00 and 10.00 h from September 1984 to October 1985 at the surface of the two stations in the Lobo Reservoir (fig. 1). Temperature and pH were measured throughout the collection period. Dissolved oxygen concentration was measured, starting in February 1985, and chlorophyll *a* concentration, starting in May 1985.

Microzooplankton was collected with a 2-liter Van Dorn bottle; 200 ml of this sample was fixed immediately with 8.6 ml of a saturated $HgCl_2$ solution and stained with 0.04% bromophenol blue (PACE & ORCUTT, 1981). Three subsamples were counted in a Sedgwick-Rafter chamber and examined with a microscope (100 x).

Protozoa were identified according to the work by KAHL (1930-1935), JAHN *et al.* (1949), PENNAK

TABLEAU I

Environmental data of the two sampled stations
Variables physico-chimiques aux deux stations

Date \ Station	Secchi Disk (m)		Dissolved Oxygen (mgl^{-1})		Chlorophyll a (μgl^{-1})	
	1	2	1	2	1	2
09/24	1.30	1.55	-	-	-	-
10/08	1.30	0.95	-	-	-	-
10/22	1.50	1.40	-	-	-	-
11/12	1.55	0.95	-	-	-	-
11/26	1.40	0.70	-	-	-	-
12/03	1.10	0.90	-	-	-	-
12/12	1.25	1.10	-	-	-	-
01/07	1.80	1.60	-	-	-	-
01/21	1.60	1.30	-	-	-	-
02/27	1.60	1.50	7.57	7.16	-	-
03/13	1.90	0.70	7.23	6.81	-	-
03/27	1.40	0.70	6.90	8.43	-	-
04/10	1.30	1.15	6.52	7.13	-	-
04/24	1.70	1.40	6.81	6.85	-	-
05/08	2.05	1.50	7.74	7.88	5.38	3.96
05/20	2.00	1.80	9.28	9.72	6.48	5.50
06/05	1.70	0.70	10.46	8.59	9.23	6.92
06/17	1.70	1.30	8.86	8.63	6.04	4.62
07/03	1.50	0.80	8.82	8.82	6.15	5.82
07/17	1.20	0.30	8.93	8.74	5.81	5.50
08/07	1.40	0.40	7.89	7.30	2.20	5.97
08/19	1.65	0.45	7.15	9.06	2.64	5.65
09/18	1.70	0.90	7.39	8.11	4.84	5.27
09/25	1.80	0.70	8.90	9.34	3.52	4.84
10/09	1.80	0.40	8.42	8.10	3.74	4.08
10/30	1.50	0.50	7.95	7.85	2.42	4.84
$\bar{X}$	1.57	0.99	8.05	8.15	4.87	5.25

- No data available

(1953), EDMONDSON (1959), BICK (1972), KUDO (1977) and CORLISS (1979).

Water temperature was measured with a reversion thermometer coupled to a Nansen bottle and with a IBT mercury thermometer. Oxygen dissolved in water was measured by the technique of Winkler (GOLTERMAN & CLYMO, 1969). pH was measured in the laboratory with a Micronal model B271 pH-meter within 1 to 2 h of collection. Chlorophyll *a* concentration (phaeopigments not included) was determined by the technique of GOLTERMAN *et al.* (1978).

RESULTS

The seasonal variations of water transparency, dissolved oxygen, and chlorophyll *a* are shown in Table I. Dissolved oxygen was close to saturation during all measurements. Chlorophyll *a* fluctuation showed two distinct phases : a period from May to June during which Station 1 always showed values higher than those observed at Station 2, and a period from August to October during which the opposite occurred. The maximum chlorophyll value observed at Station 1 was 9.23 $\mu g\ l^{-1}$ and at Station 2, 6.92 $\mu g\ l^{-1}$, with both values being obtained in July.

Temperature and pH profiles at both stations are shown in (fig. 2). The highest temperatures were recorded from October to March, with a maximum value of 26.6 °C. The minimum values were observed in July, with values of 18 to 19 °C. pH was 6.5 ± 0.3 throughout the year at the two sampled stations. A probably erroneous value of 5.4 was detected at Station 1.

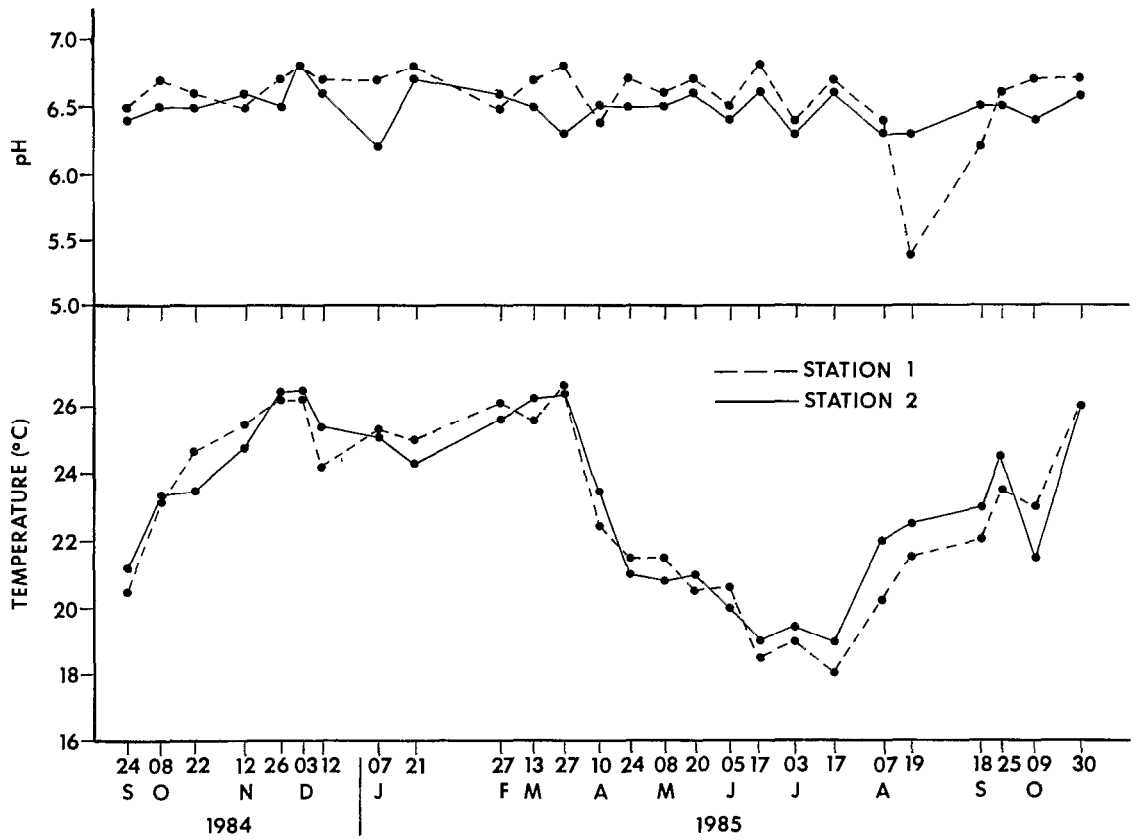

FIG. 2. — Seasonal Variation of Temperature and pH in the Lobo Reservoir, from September 1984 to October 1985
Variations saisonnières de la température et le pH de l'eau dans le réservoir du « Lobo » de septembre 1984 à octobre 1985

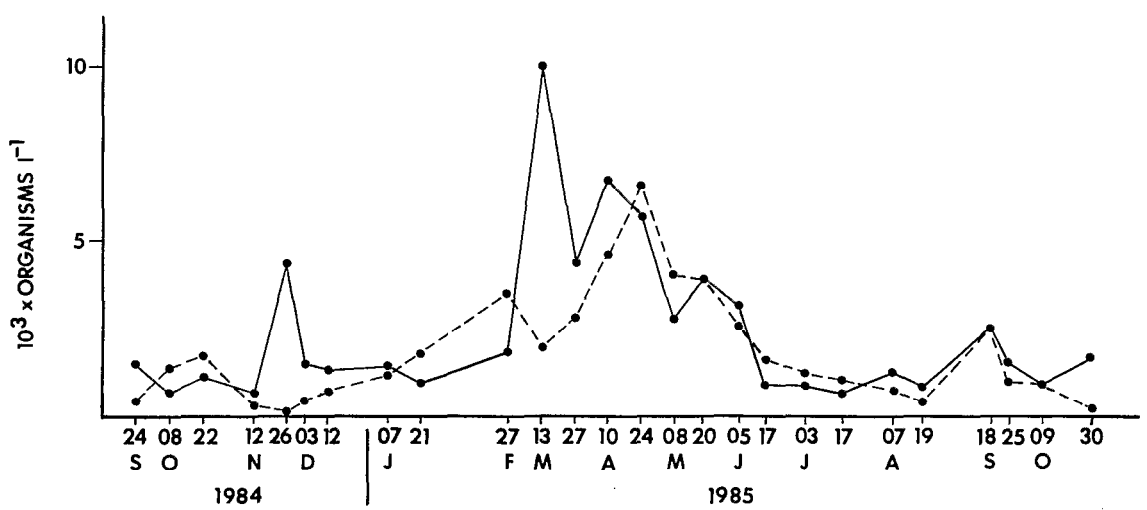

FIG. 3. — Seasonal distribution of total planktonic protozoa, from September 1984 to October 1985
Distribution saisonnière d'ensemble des protozoaires du plancton de septembre 1984 à octobre 1985

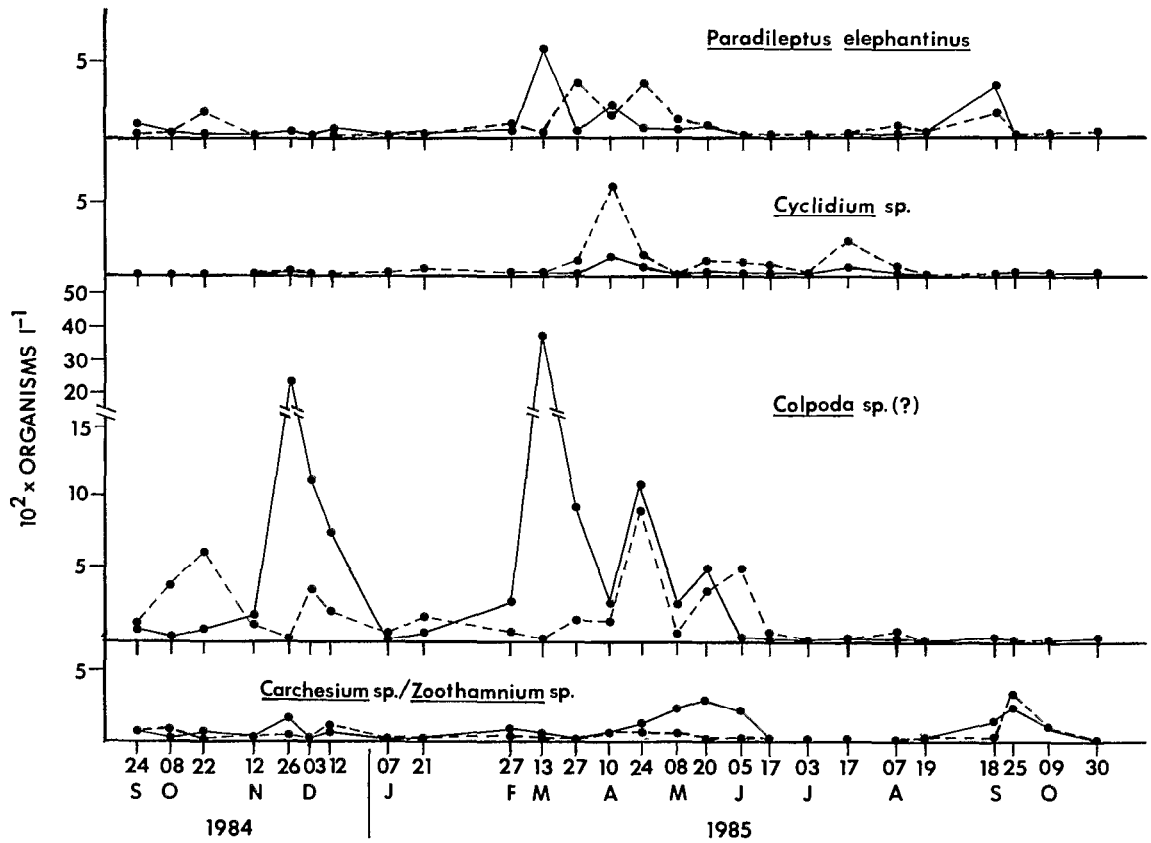

FIG. 4a. — Seasonal distribution of the numerically most important species in the Lobo Reservoir, from September 1984 to October 1985

Distribution saisonnière des espèces plus importantes numériquement dans le réservoir du « Lobo », de septembre 1984 à octobre 1985

The seasonal distribution of protozoa populations in the Lobo Reservoir is presented graphically in (fig. 3). Two different periods can be observed with respect to the density of protozoa detected, i.e. a low-density period from September to January and from July to October, and a high-density period from February to May. The mean number of organisms detected during the low-density period was 1.08×10^3 protozoa l^{-1} at Station 1 and 1.42×10^3 protozoa l^{-1} at Station 2. During the high-density period, the mean number at Station 1 was 3.98×10^3 protozoa l^{-1} while at Station 2 it was 5.08×10^3 protozoa l^{-1}. Thus, during the high-density period the mean number of organisms was approximately 4-fold that obtained during the low-density period.

The highest planktonic protozoa density occurred at Station 2, with 9.87×10^3 protozoa l^{-1} (March). The maximum value obtained at Station 1 was 6.63×10^3 protozoa l^{-1} (April).

Two groups of protozoa, ciliates and amoebae, were considered in the present study. Of the two, ciliates showed greater abundance and diversity, whereas amoebae occurred at low densities. Only the most abundant protozoa are presented graphically. These included *Carchesium sp./Zoothamnium sp.*, *Colpoda sp.* (?), *Cyclidium sp.*, *Halteria grandinella*, *Mesodinium pulex*, *Paradileptus elephantinus*, *Strombidinopsis seligera*, *Strombidium sp.*, *Urotricha farcta*, and *Vorticella spp.*

The seasonal distribution of the numerically most important species present in the Lobo Reservoir is shown in figures 4a, b, c. Descriptions of each taxon are given below :

Carchesium sp./Zoothamnium sp.

These two *Peritrichida* genera are differentiated by contraction of the stalk. However, since this distinction cannot be made in fixed samples, the two were counted together. Maximum density at Sta-

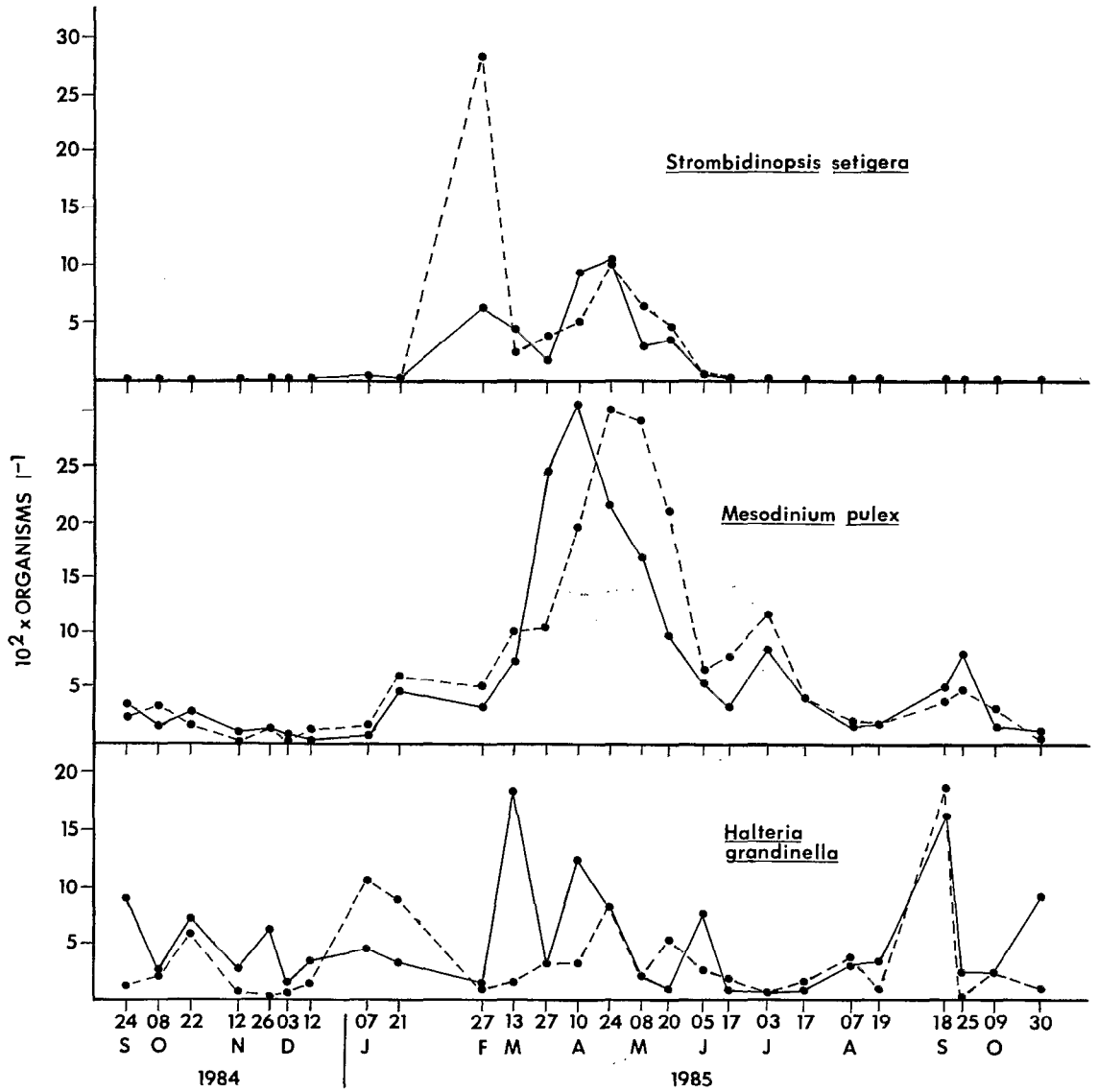

FIG. 4b. — Seasonal distribution of the numerically most important species in the Lobo Reservoir, from September 1984 to October 1985

Distribution saisonnière des espèces plus importantes numériquement dans le réservoir du «Lobo», de septembre 1984 à octobre 1985

tion 1 was 0.32 × 10^3 protozoa l^{-1}, and at Station 2, 0.23 × 10^3 protozoa l^{-1}, both values being obtained in September, 1985 (fig. 4a).

Colpoda sp. (?)

This undetermined species ciliate, which is very similar to *Colpoda*, occurred in large numbers at the site studied. Maximum densities were 4.36 × 10^3 protozoa l^{-1} in March at Station 2, and 0.91 × 10^3 protozoa l^{-1} in April at Station 1. The ciliate showed two peaks at Station 2, whereas several smaller peaks occurred at Station 1 during the collection period (fig. 4a).

Cyclidium sp.

This protozoa was less abundant at Station 2, with a maximum density of 0.14 × 10^3 protozoa l^{-1}, than at Station 1, where maximum density was 0.61 × 10^3 protozoa l^{-1}, both values being obtained in April (fig. 4a).

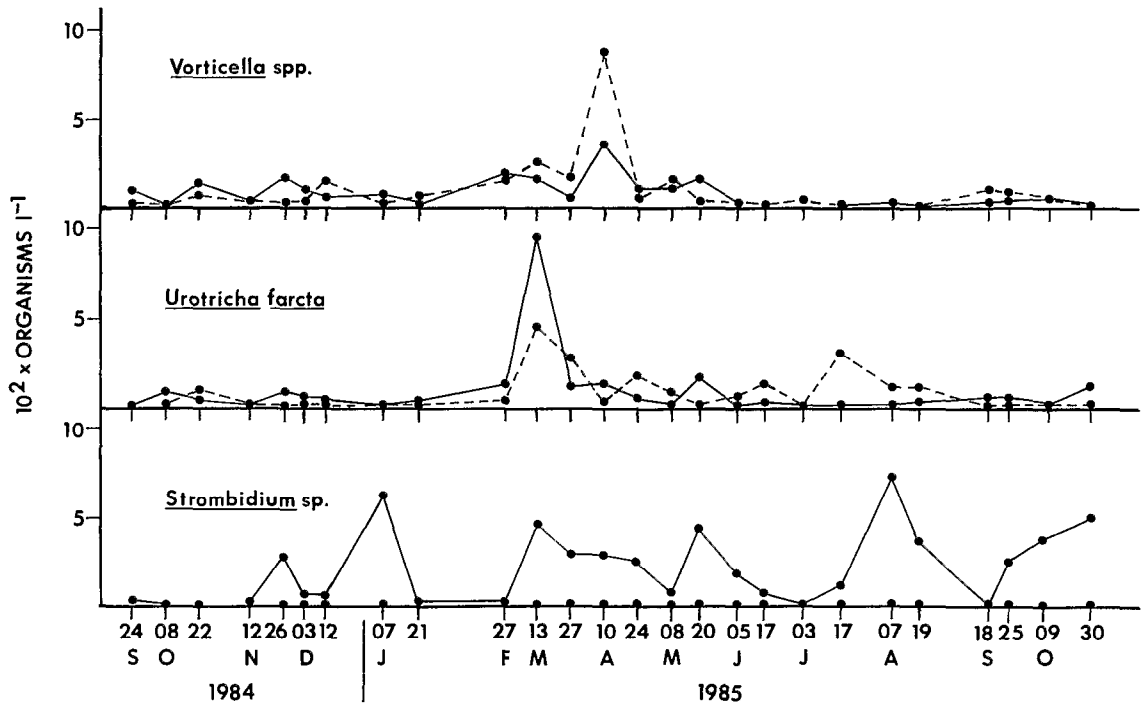

FIG. 4c. — Seasonal distribution of the numerically most important species in the Lobo Reservoir, from September 1984 to October 1985

Distribution saisonnière des espèces plus importantes numériquement dans le réservoir du «Lobo», de septembre 1984 à octobre 1985

Paradileptus elephantinus

This ciliate occurred at higher densities in October, 1984 and from March to April, 1985, though densities were never very low during the other months of collection. Maximum densities were 0.35×10^3 protozoa l^{-1} at Station 1 and 0.60×10^3 protozoa l^{-1} at Station 2, both values obtained in March (fig. 4a).

Halteria grandinella

This ciliate showed irregular distribution. There was a series of peaks with a maximum of 1.85×10^3 protozoa l^{-1} in March 1985 at Station 2, whereas at Station 1 there were four distinct peaks in October, January, April and September, with maximum density (1.80×10^3 protozoa l^{-1}) occurring in September, 1985 (fig. 4b).

Mesodinium pulex

M. pulex showed quite similar distribution at both stations, with low densities from September, 1984 to January, 1985 and from August to October, 1985, followed by a marked increase from February to June. Maximum densities were 2.88×10^3 protozoa l^{-1} at Station 1 and 2.92×10^3 protozoa l^{-1} at Station 2, both values being obtained in April (fig. 4b).

Strombidinopsis setigera

The seasonal distribution of this ciliate was quite similar at both stations, where it occurred only from February to June in relatively abundant numbers. Maximum density at Station 1 was 2.66×10^3 protozoa l^{-1} in February, and at Station 2 it was 1.05×10^3 protozoa l^{-1} in April (fig. 4b).

Strombidium sp.

Although this ciliate was frequently present in the samples collected at Station 2, it did not occur at high densities in the reservoir. At Station 2, the maximum density was 0.65×10^3 protozoa l^{-1} in January, whereas at Station 1, 0.02×10^3 protozoa l^{-1} (fig. 4c).

Urotricha farcta

The highest densities of this ciliate at both

stations occurred on March, 1985 : 0.45 × 10^3 protozoa l^{-1} at Station 1 and 0.94 × 10^3 protozoa l^{-1} at Station 2 (fig. 4c).

Vorticella spp.

Even though constantly present in the study site, this *Peritrichida* genus appeared in small numbers throughout the period of collection, with highest density occurring on April, 1985 both at Station 1 (0.88 × 10^3 protozoa l^{-1}) and at Station 2 (0.34 × 10^3 protozoa l^{-1}; fig. 4c).

DISCUSSION

Seasonal fluctuations

Among the physico-chemical variables investigated at the Lobo Reservoir, temperature showed a pattern commonly observed in shallow and turbulent aquatic ecosystems. pH varied little around 6.5 and the concentration of dissolved oxygen was between 6.52 mg l^{-1} and 10.46 mg l^{-1}, corresponding to 84 to 130 per cent saturation, with the environment being well oxygenated throughout the collection period. Chlorophyll concentration, measured from May to October 1985, was relatively low with a maximum of 9.23 μg l^{-1}. These data confirm results obtained previously for this reservoir (TUNDISI *et al.*, 1977) which is one of the most extensively studied sites in Brazil.

Highest densities of planktonic protozoa in the Lobo Reservoir were observed from February to May. For the same site it has been reported that high densities of phytoplankton occur from December to February (WATANABE, 1981). It seems that with the death of these organisms there is greater decomposition and, consequently, a larger number of bacteria and amount of detritus available for the protozoa, which in turn increase in density. Similar situation relating a large abundance of protozoa after the death of the phytoplankton and simultaneous bacterial growth has been previously observed in Lake Dalnee (Kamchatka, USSR) by SOROKIN & PAVELJEVA (1972).

In the present study, the composition and abundance of the protozooplankton were investigated by identifying the main species and by counting all the individuals in each sample. Ciliates were predominant among the groups analyzed, a fact also observed by CAIRNS & RUTHVEN (1972) in samples taken from a pond near Sandy Point (Abaco Island, Bahamas); by SMETACEK (1981) in the Bay of Kiel (Germany), and by HUNT & CHEIN (1983) in Cayuga Lake (New York, USA). The ciliates most abundant in the Lobo Reservoir were *Colpoda sp.* (?), *Halteria grandinella*, *Mesodinium pulex* and *Strombidinopsis setigera*, whereas *Carchesium sp./Zoothamnium sp.*, *Cyclidium sp.*, *Paradileptus elephantinus* *Strombidium sp.*, *Urotricha farcta* and *Vorticella spp.* showed more limited distribution.

The species of amoebae detected were *Arcella sp.*, *Difflugia lobostoma*, *Difflugia sp.* and *Lesquereusia sp.* (Testacidae) and, more rarely, some representatives of Amoebae, specially at Station 2. Since the densities observed were very low these organisms were not counted separately.

Comparison between Stations 1 and 2

The stations where sampling was carried out have different characteristics. Most of the information about them is based on work performed by other authors interested in this same site.

Station 1 has no aquatic vegetation and the organic matter detected there is derived from vegetative debris from the upper region of the reservoir where macrophytes are abundant. Station 2 is a site where the microphytoplankton (cells > 50 μm) is predominant (WATANABE, 1981) and bacteria are abundant (GODINHO, 1976). At this station, macrophytes contribute a large amount of organic matter which persists in the water column and is eventually deposited in the sediment. As observed by MATSUMURA-TUNDISI & TUNDISI (1976), Station 2 has zooplankton (specially rotifers) in greater densities than Station 1. Co (1979) detected the presence of large numbers of oligochaetae and tubificids in the sediment of the macrophyte region.

From the results of this study it can be concluded that the ciliates showing the greatest similarities in seasonal and spatial distribution were *Carchesium sp./Zoothamnium sp.*, *Cyclidium sp.*, *Mesodinium pulex*, and *Strombidinopsis setigera*. The remaining ciliates showed population peaks at different times at the two stations. *Cyclidium sp.*, *Mesodinium pulex*, *Paradileptus elephantinus*, *Strombidinopsis setigera*, *Urotricha farcta* and *Vorticella spp.* were predominant from February to May and were present both at Station 1 and Station 2, even though some of them showed maximum abundance at different times between stations. *Colpoda sp.* (?) and *Strombidium sp.* showed several peaks and preferentially occurred at Station 2; *Halteria grandinella* showed several peaks and occurred at both stations; *Carchesium sp./Zoothamnium sp.* appeared in small amounts at both stations and were homogeneously distributed throughout the period.

It is well known that several factors can regulate the distribution of organisms in an aquatic environment. Among them are temperature, pH, and concentrations of oxygen, CO_2, organic nutrients,

trace elements — Zn, Co, etc. — and vitamins (BAMFORTH, 1958; BRAGG, 1960). The quality and quantity of food available (NOLAND, 1925), predator-prey ratio, and competition among organisms also may effect population distributions (BICK, 1973). The seasonal periodicity of the populations probably is not determined by each of these factors individually but rather by a combination of several of them acting at different intensities and times (WELCH, 1952). Altough the temporal variations in abundance and composition for planktonic protozoa in Lobo Reservoir have been considered in this study it is not possible to present a simple explanation for the results obtained. Therefore, further work is required to find out why or how ecological factors may influence protozoan population composition and successions in the reservoir.

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