Seasonal variation of some limnological factors of lagoa do Guaraná, a várzea lake of the High Rio Paraná, State of Mato Grosso do Sul, Brazil

Sidinei M. THOMAZ (1), Fabio A. LANSAC TÔHA (2), Maria C. ROBERTO (1), Francisco A. ESTEVES (3), Adauto F. LIMA (1)

SUMMARY

Lagoa do Guaraná, located in the várzea (floodplain) of the High Rio Paraná, displayed pronounced seasonal variation in water quality. This seasonality is attributed to two factors : first, the hydrological regime of the Rio Paraná causes rhythmic changes in lake depth and the inundated várzea area; and second, rainfall seasonally increases input of dissolved organic carbon (humic compounds) and nutrients from local tributary streams.

KEY WORDS : Floodplain — High Rio Paraná — Várzea lake — Brazil — Water quality — Hydrological regime.

RÉSUMÉ

VARIATION SAISONNIÈRE DE QUELQUES FACTEURS LIMNOLOGIQUES DANS UN LAC DE VÁRZEA DU HAUT-PARANÁ, LE LAC GUARANÁ, ÉTAT DO MATO GROSSO DO SUL, BRÉSIL

Le lac de Guaraná présente de fortes variations saisonnières des conditions physico-chimiques du milieu. Celles-ci sont attribuées à deux causes principales : d'une part, le régime hydrologique du Paraná qui provoque des modifications de niveau dans le lac et l'inondation de la várzea et, d'autre part, les pluies qui augmentent les apports de carbone organique (composés humiques) et des nutriments par les petits affluents tributaires.

MOTS CLÉS : Plaine d'inondation — Haut-Paraná — Lac de várzea — Brésil — Qualité de l'eau — Régime hydrologique.

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(1) *Universidade Estadual de Maringá. Nupelia — Núcleo de Pesquisas em Limnologia, Ictiologia e Aqüicultura. Av. Colombo, nº 3690, Caixa Postal 331. CEP 87020. Maringá/Paraná. Brazil.*

(2) *Universidade Estadual de Maringá. Departamento de Biologia/Nupelia.*

(3) *Universidade Federal do Rio de Janeiro. Departamento de Ecologia. Bloco A. I. Fundão. CEP 21941. Rio de Janeiro/RJ. Brazil.*

Resumen

Variación sazonal de algunos factores limnológicos de una laguna de várzea del Alto Rio Paraná, laguna del Guaraná, Estado do Mato Grosso do Sul, Brasil

La laguna del Guaraná localizada en la llanura de inundación del Alto Rio Paraná presentó pronunciada variación sazonal en la calidad del agua. La sazonalidad observada puede ser atribuida basicamente a dos factores : a) *regimen hidrológico del Rio Paraná que provoca alteraciones en la profundidad de la laguna y en la área de la várzea que es alagada;* b) *lluvia que eleva la entrada de carbono organico disolvido (compuestos húmicos) y nutrientes através de cauces locales.*

PALABRAS CLAVES : Llanura de inundación — Alto Rio Paraná — Laguna de várzea — Brasil — Calidad del agua — Regimen hidrologico.

INTRODUCTION

River-floodplain systems have attracted the attention of numerous investigators due to their great regional importance, for instance to great migratory fishes (BONETTO, 1976; WELCOMME, 1980). In these ecosystems, characterized by the presence of lotic, lentic, and aquatic-terrestrial transitional environments, the hydrological regime is the principal factor responsible for the seasonality of ecological events (JUNK *et al.*, 1989).

Among the more prominent lentic environments in these systems are the várzea lakes. These lakes, which are usually shallow, are formed from the principal river activity with which they keep different degrees of link. Consequently, their limnological characteristics undergo profound changes during the hydrological cycle, due to the intense exchange of matter and energy with the principal river (FISHER, 1978; FURCH and JUNK, 1985; HAMILTON and LEWIS, 1987). Limnological studies of várzea lakes of the Middle and Lower Rio Paraná were performed by BONETTO (1975, 1976), EMILIANI (1981), and BONETTO *et al.* (1984), among others. THOMAZ (1991), THOMAZ *et al.* (1992) and LANSAC TÔHA *et al (in press)* carried out general studies of lakes of the High Paraná.

The present study was undertaken in order to analyze the seasonal variation of some limnological factors of a várzea lake, Lagoa do Guaraná, situated near the High Rio Paraná, on the floodplain extending through the State of Mato Grosso do Sul. The regional hydrological regime was used to try to interpret the seasonal patterns of the different limnological variables obtained in Lagoa do Guaraná.

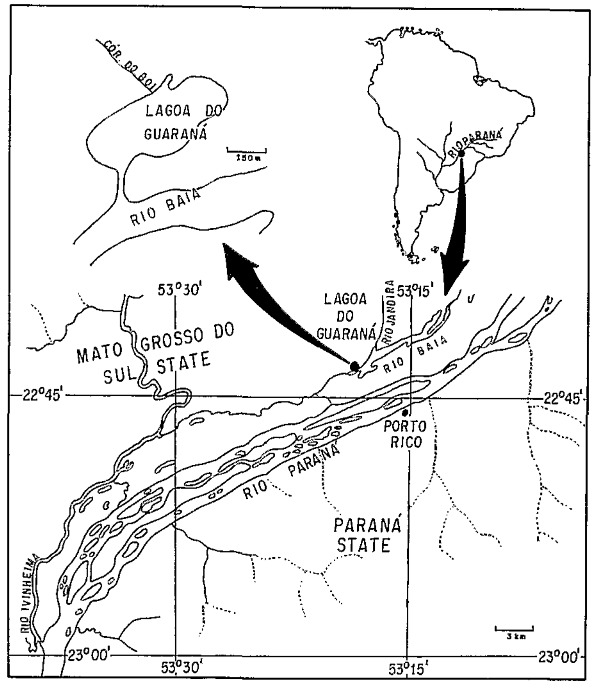


FIG. 1. — Situation of Lagoa do Guaraná.
Localisation du lac Guaraná.

STUDY AREA

Lagoa do Guaraná is situated at 53°20′W, 22°42′S, on the right bank of the Rio Baia which has white water during most part of the year; the two are linked by a permanent canal (Fig. 1). The várzea (floodplain) is composed of Quaternary sediments transported by the Rio Paraná (FERNANDEZ, 1990). The lakeshores are colonized by grasses, predominantly *Panicum pernambucense* (Spreng.) Mez ex Pilger, and the littoral zone by moderate populations of the aquatic macrophytes *Eichhornia azurea* Kunth and *Eichhornia crassipes* (Mart.) Solms. Lagoa do Guaraná receives the influents Córrego do Boi and Riacho Jandira, both backwater streams draining areas of the plain which are not subject to flooding.

The regional hydrological cycle is determined by fluctuations in the level of the Rio Paraná. During the year of study, the high-water period can be considered to have occurred between November 1987 and June 1988, the time of greatest rainfall. Low-water periods occurred from June to October

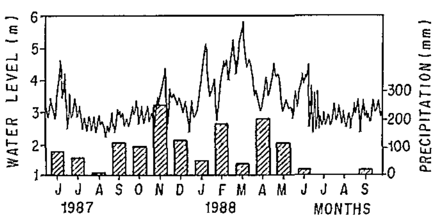


FIG. 2. — Water level of Rio Paraná in Porto São José (State of Paraná) and local monthy precipitation.
Niveau de l'eau du Paraná à Porto São José (État du Paraná) et pluie locale mensuelle.

1987 and July to September 1988 (Fig. 2). Daily variations of river levels did not produce marked flooding and drawdown phases during the periods of study.

METHODS

Monthly samples were taken between 09:00 and 11:00h, from June 1987 to September 1988 in the center of Lagoa do Guaraná. Water transparency was measured by Secchi disc, and water temperature was taken every 20 cm of depth with a thermistor. Next, water samples were collected with a Van Dorn bottle at the surface, middle and bottom of the water column, transferred to polyethylene flasks, and taken in iceboxes to the laboratory. The following analyses were performed : pH and conductivity; dissolved oxygen by Winkler methods as modified by GOLTERMANN *et al.* (1978); and total alkalinity by titration as described by MACKERETH *et al.* (1978).

An aliquot of each sample was filtered through Whatmann GF/C filters, which were dried and frozen for later determination of the chlorophyll *a* concentration (GOLTERMANN *et al.*, 1978). The filtered water was also frozen for determination of dissolved organic carbon (DOC) content, following the method proposed by LEWIS and TYBURCZY (1974), modified by LEWIS and CANFIELD (1977)). A second aliquot was fixed with concentrated H_2SO_4, for determinations of total phosphorus and Kjeldahl nitrogen (MACKERETH *et al.*, 1978). Concentrations of free CO_2 were determined according to MACKERETH *et al.* (1978).

The daily water levels of the Rio Paraná, taken at the municipality of Porto São José (State of Paraná), were provided by Itaipu Binacional. The results of precipitation measurements refer to the municipality of Porto Rico (State of Paraná) and were provided by DNAEE.

RESULTS AND DISCUSSION

The isotherms obtained in Lagoa do Guaraná during the sampling period are shown in Fig. 3. Temperatures ranged between 14.7 °C at lake bottom in June 1987 and 29.6 °C at the surface in January 1988. There was a distinct seasonal pattern, differences up to 12.8 °C being observed at the surface in the course of the year. During the warmer months, which coincided with the high water period, the greatest differences between the surface and bottom

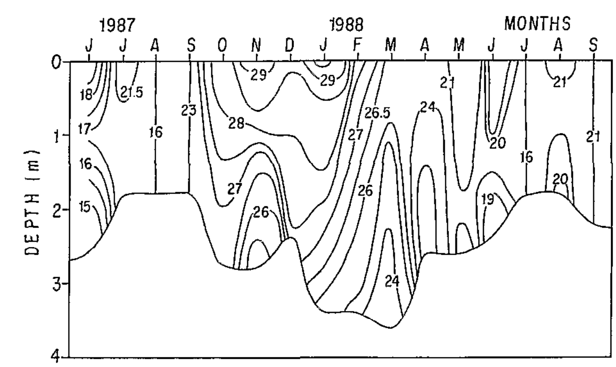
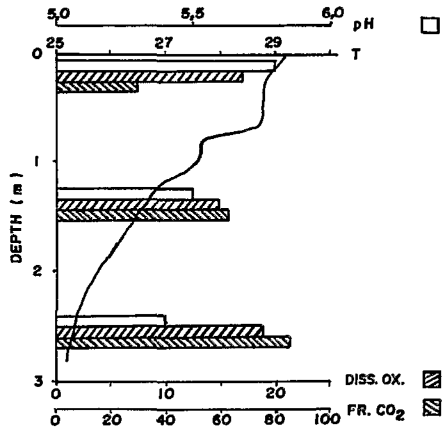


FIG. 3. — Annual cycle of temperature depth-time diagram. Hour of measurements : 9 a.m.
Diagramme profondeur-temps de la température sur un cycle annuel. Les mesures ont été faites à 9 h le matin.

temperatures were observed, suggesting the development of more stable thermal stratification during this time. This observation is reinforced by the results shown in Fig. 4, which demonstrate a heterogeneous vertical distribution of several variables in November 1987, when the highest vertical thermal gradient of 4.0 °C was measured.



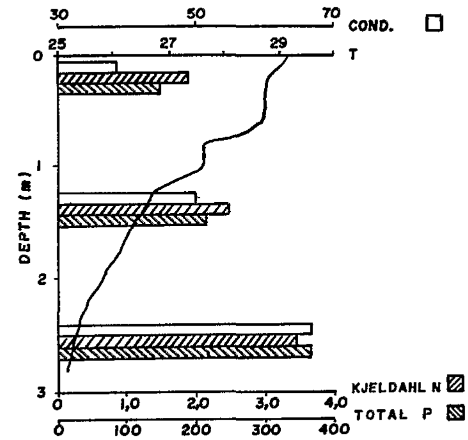


FIG. 4. — Relationship between thermal stratification and vertical distribution of pH, electrical conductivity (µS/cm), dissolved oxygen (% saturation), Kjeldahl-N (mg/l) and total-P (µg/l), obtained in November 1987.
Relation entre la stratification thermique et la distribution verticale du pH, de la conductivité (µS/cm), de l'oxygène dissous (% de saturation), N-Kjeldahl (mg/l) et P-total (µg/l).

THOMAZ (1991) also demonstrated persistent thermal stratification during the high water period in two várzea lakes of the High Rio Paraná, in which were analyzed the seasonal and daily temperature changes. This pattern is also frequently found in Amazonian várzea lakes, which are also usually deeper (JUNK, 1984; TUNDISI *et al.*, 1984; MACINTYRE and MELAK, 1988).

The supposed importation of humic compounds during months of higher rainfall also influenced pH values, since the lowest pH (5.1 at all three depths) was measured in December 1987 (Fig. 5b). However, in addition to the humic compounds imported from local tributaries, the low pH values can be attributed to the rise in concentration of free CO_2 (Fig. 5c), as well as to liberation of humic compounds by decomposition of the organic matter of grasses that grow in the várzea during low water period, as suggested by HELBING *et al.* (1986). Decomposition rates are probably accelerated during this period by high water temperatures (> 28.0 °C).

In the present study, high decomposition rates are also indicated by the rapid decrease in dissolved oxygen concentrations observed at the beginning of the high water period (Fig. 5d). This parameter showed values between 3.7 % saturation in the deep layer in January 1988 and 104.7 % saturation at the surface in October 1987. The low dissolved oxygen values observed during the high water period can be attributed, in addition to decomposition, to the chemical oxidation of humic compounds, as suggested by RAI and HILL (1981) and WETZEL (1981). Reduction in dissolved oxygen values during raising water and high water periods is also frequently observed in Amazonian várzea lakes (SCHMIDT, 1973; RAI and HILL, 1982; LOPES *et al.*, 1983; ODINETZ COLLART and MOREIRA, 1989).

DOC concentrations ranged between 2.1. mgC/l at the surface in February 1988 and 19.7 mgC/l in the middle of the water column in November 1987 (Fig. 5e). According to STEINBERG and MUENSTER (1985), DOC of continental water is in general composed predominantly of humic compounds. These compounds significantly influence the dynamics of other limnological factors such as Secchi depth and pH. The relationship observed between these three variables is illustrated by Fig. 6. Concerning Secchi depth, the values ranged between 0.25 m in November 1987 (month with the highest values of DOC) and 1.05 m in June 1988.

The electrical conductivity values (calculated at 25 °C), which ranged between 18 µS/cm at the three depths in September 1987 and 67 µS/cm near the bottom in November 1987, showed marked seasonal variation, with highest values observed during the high water period (Fig. 5f). The high values observed in November 1987 can be attributed to the runoff, especially the one which comes from areas outside the várzea, where the ranching activity is intense. The high values observed between January and April 1988 are due to the entrance of water from Rios Baia and Paraná, since especially the latter river shows electrical conductivity values higher than those in its associated várzea lakes (THOMAZ, 1991).

Total alkalinity values followed the same seasonal pattern described for electrical conductivity; results ranged between 0.097 mEq/l at the surface in

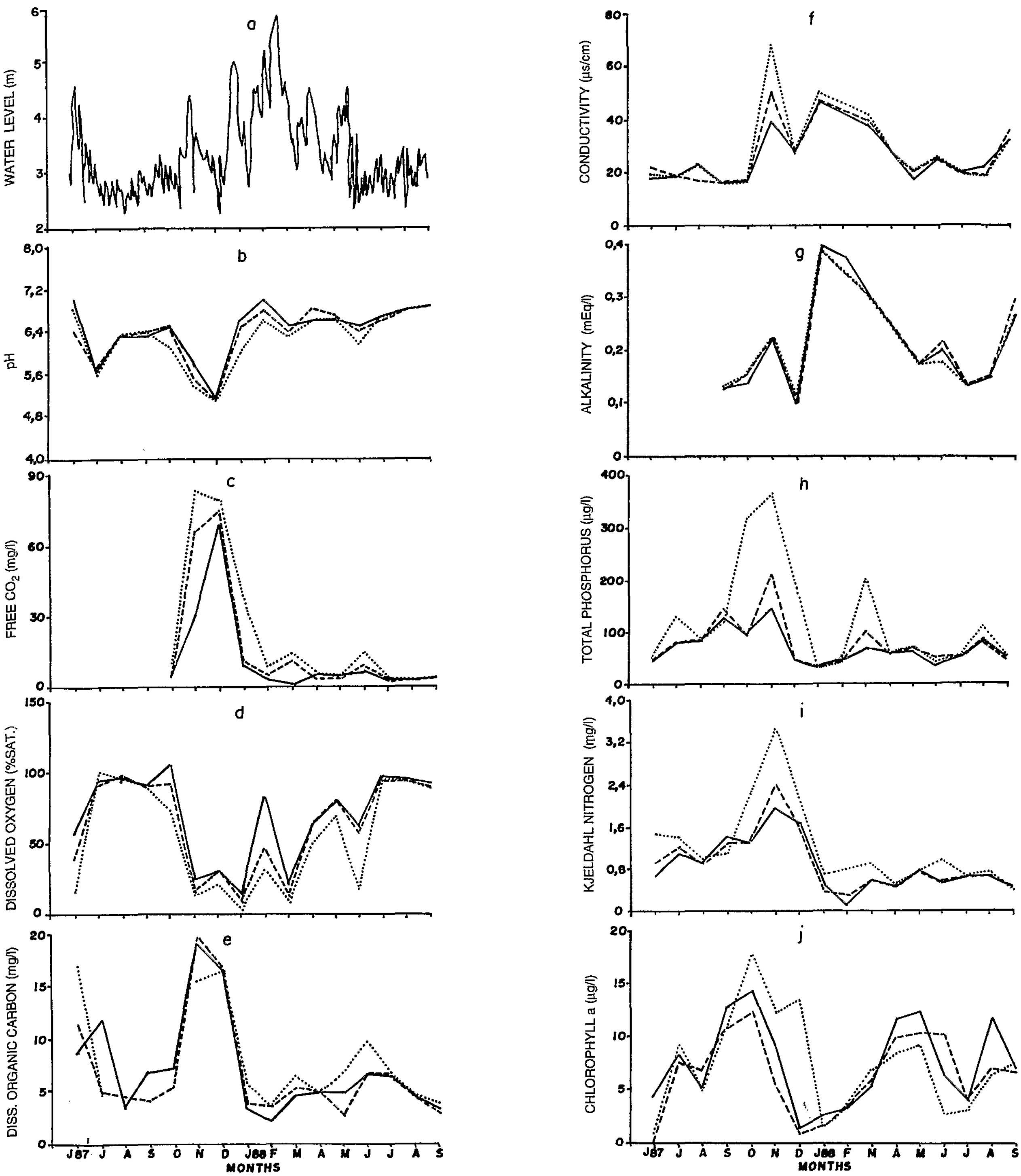


FIG. 5. — Seasonal variation of : a) water level (m), b) pH, c) free CO_2 (mg/l), d) dissolved oxygen (% saturation), e) dissolved organic carbon (mg/l), f) electrical conductivity (µS/cm ; 25 °C), g) total alkalinity (mEq/l), h) total phosphorus (µgl/l), i) Kjeldahl nitrogen (mg/l) and j) chlorophyll *a* (µg/l). —— surface, ---- intermediate layer, ... bottom.

Variations saisonnières de : a) niveau de l'eau (m), b) pH, c) CO_2 libre (mg/l), d) oxygène dissous (% de saturation), e) carbone organique dissous (mg/l) ; f) conductivité (µS/cm; 25 °C), g) alcalinité totale (mEq/l) h) phosphore total (µg/l), i) azote Kjeldahl (mg/l), j) chlorophylle a *(µg/l).* —— *surface,* ---- *couche intermédiaire,* .... *fond.*

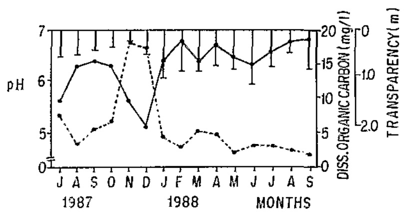


FIG. 6. — Relationship among dissolved organic carbon (----), pH (—) and transparency.
Relation entre le carbone organique dissous (----), le pH (——) et la transparence de l'eau.

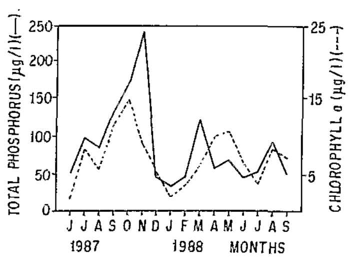


FIG. 7. — Relationship between total phosphorus and chlorophyll *a*. Chlorophyll *a* (µg/l) = 11.8335 + 4.3969. ln P-total (µg/l); r = 0.67; $p < 0.002$.
Relation entre le phosphore total et la chlorophylle a. *Chlorophylle* a *(µg/l) = 11,8335 + 4,3969. ln P-total (µg/l); r = 0,67; p < 0.002.*

December 1987 and 0.400 mEq/l, also at the surface, in January 1988 (Fig. 5g).

The low total alkalinity values observed in December 1987 can be associated with the high DOC concentrations in the same month, since organic acids can neutralize the bases related to the buffering capacity. The low buffering capacity in aquatic environments influenced by humic compounds was also observed by RAI and HILL (1981) in the Amazon Lago Tupé, and by ESTEVES *et al.* (1984), in coastal lakes of the State of Rio de Janeiro, Brazil. These authors obtained total alkalinity values less than 0.12 mEq/l in blackwater lakes.

Concentrations both of Kjeldahl nitrogen and total phosphorus followed the same seasonal pattern of variation ($r = 0.52$, $p < 0.02$), with high values observed in November 1987 (365 µg/l for phosphorus, and 3.44 mg/l for nitrogen - Fig. 5h and 5i). These high concentrations, observed at the beginning of the high water period, can be attributed to nutrient liberation by leaching of decomposed organic matter accumulated in the várzea during the dry season. The rise in nutrient concentrations in October 1987, that is before the beginning of the high water period, can be associated with flushing of soil nutrients by precipitation. This factor must be important for Lagoa do Guaraná, since the nearby streams flow through regions of intensive ranching activity. The results for total phosphorus and Kjeldahl nitrogen obtained in November 1987 in other várzea lakes along the High Rio Paraná which are not influenced by local tributaries were considerably lower than those observed in Lagoa do Guaraná (THOMAZ, 1991).

Elevation of nutrient concentrations at the beginning of the flood is a frequently observed phenomenon in Amazon várzea lakes (SCHMIDT, 1973; SANTOS 1980; LOPES *et al.*, 1983; RAI and HILL, 1984). These authors mention decomposition of various species of floating grasses as an important factor in elevating concentrations of nitrogen and phosphorus in várzea lakes. However, nutrient input with water from the principal river must be considered, as demonstrated by FISHER (1978) for lakes associated with Rio Solimões, HAMILTON and LEWIS (1987) for lakes associated with the Orinoco, and BONETTO (1976) for lakes associated with the Middle Paraná. Conversely Rios Baia and Paraná dilutes Lagoa do Guaraná, since the water, specially of Rio Paraná contains lower concentrations of Kjeldahl nitrogen and total phosphorus than does the water of Lagoa do Guaraná (THOMAZ *et al.*, 1992). Consequently, during the flood peak, these values are reduced in the lake.

Chlorophyll *a* concentrations ranged from undetectable levels (< 1.0 µg/l) in the middle of the water column in June 1987, to 17.7 µg/l in the deep water in October 1987 (Fig. 5j). The seasonal variation showed a bimodal pattern of distribution, with the highest values obtained at the end of low and high water periods. The reduction in the phytoplankton biomass, expressed by the chlorophyll *a* values, was apparently caused by the elevation of river levels and low residence time from November 1987 to February 1988 and by the decrease in temperature in June 1987 and June-July 1988.

The effects of the hydrological regime on the dynamics of the phytoplankton biomass were also suggested by BONETTO *et al.* (1983) for the Middle Paraná, Argentina, and by EMILIANI (1981) for a várzea lake in the same reach. The latter author also suggested that temperature influenced the phytoplankton.

In Lagoa do Guaraná a close relation was also observed between the concentration of chlorophyll *a* and total phosphorus (Fig. 7). This observation leads to the preliminary suggestion that phosphorus is a environmental limiting factor.

FINAL REMARKS

The seasonality of the limnological variables studied in Lagoa do Guaraná was determined basically by the action of two forcing functions : the hydrological regime of Rio Paraná, which causes changes in the depth of the lake and in the flooded area of várzea ; and local precipitation, which directly influences inputs of DOC (humic compounds) and of nutrients by means of local tributaries, which drain adjacent regions of the várzea.

In months of high precipitations, when the water level started to rise, high concentrations of free CO_2, DOC, total phosphorus and Kjeldahl nitrogen, as well as high electrical conductivity values, were observed. These results can be attributed to input of water from Córrego do Boi and Riacho Jandira, and to decomposition of várzea organic matter, associated with a decrease in the concentration of dissolved oxygen. These inputs of water rich in humic compounds also caused significant changes in pH and Secchi values in Lagoa do Guaraná.

During the months of high water of the Rio Paraná (January-March 1988), water from Rios Baía and Paraná diluted the water of Lagoa do Guaraná and assumed a predominant role in determining limnological variables. During this period low concentrations of DOC, total phosphorus, and Kjeldahl nitrogen, and high Secchi values were obtained. The values of electrical conductivity remained high, due to higher salt content in the Rio Paraná than in Lagoa do Guaraná.

During the low water period, the electrical conductivity values decreased, mainly due to the input of water from local tributaries which carry low salt content during this period (Thomaz, 1991).

These results indicate that the seasonality of the limnological variables studied in Lagoa do Guaraná results from interaction between the waters of small local tributaries and the hydrological regime of the principal river (Rio Paraná), this last to be considered as a dominating regional factor.

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REFERENCES

Bonetto (A. A.), Zalocar (Y.) and Lancelle (H. G.), 1984. — A limnological study of an oxbow-lake covered by *Eichhornia crassipes* in the Paraná River. *Verh. Internat. Verein Limnol.*, 22 : 1315-1318.

Bonetto (A. A.), 1975. — Hydrologic regime of the Paraná River and its influence on ecosystems. *In* : A. D. Hasler, ed. *Coupling of land and water systems.* Springer Verlag. New York : 175-197.

Bonetto (A. A.), 1976. — *Calidad de las aguas del rio Paraná : Introduccion a su estudio ecologico.* Argentina : YN-CYTH-PNUD-Onu, 202 p.

Bonetto (A. A.), Domitrovic (Y. Z.) y Valleros (E. R.), 1983. — Fitoplancton y produccion primaria del rio Alto Paraná (Argentina), *Physis*, 41 (101) : 81-93.

Odinetz Collart (O.) and Moreira (L. C.), 1989. — Quelques caractéristiques physico-chimiques d'un lac de várzea en Amazonie centrale (Lago do Rei, île de Careiro). *Rev. Hydrobiol. trop.*, 22 (3) : 191-199.

Emiliani (M. O. G.), 1981. — Fitoplancton de uma laguna aluvial del Paraná Medio («Los Matadores», Santa Fé, Argentina). II. Factores ecologicos associados a la distribuición de las especies. *Ecologia*, (6) : 73-77.

Esteves (F. A.), Ishii (J. H.) and Camargo (A. F. M.), 1984. — Pesquisas limnológicas em 14 lagoas do litoral do Estado de Rio de Janeiro. *In* : Lacerda L. D., Araujo D. S. O., Cerqueira R., orgs. *Restingas : origem, estrutura, processos.* Niterói : 443-454.

Fernandez (O. V. Q.), 1990. — *Mudanças no canal fluvial do rio Paraná e processos de erosão das margens : região de Porto Rico, PR.* Rio Claro, Instituto de Geociências e Ciências Exatas da Universidade Estadual Paulista, 96 p. (Dissertação de Mestrado).

Fisher (T. R.), 1978. — Plâncton e produção primária em sistemas aquáticos da bacia da Amazônia Central. *Supl. Acta Amazonica*, 8 (4) : 43-54.

FURCH (K.) and JUNK (W. J.), 1985. — Dissolved carbon in a floodplain lake of the Amazon and in the River channel. *Mitt. Geol. Palaont. Inst. Univ. Hamburg Scope/Unep Sonderband*, 58 : 285-298.

GOLTERMAN (H. L.), CLYMO (R. S.) and OHMSTAD (M. A. M.), 1978. — *Methods for physical and chemical analysis of fresh waters*. Blackwell Scientific Publication. Oxford, 214 p.

HAMILTON (S. K.) and LEWIS (W. M., Jr.), 1987. — Causes of seasonality in the chemistry of a lake on the Orinoco River floodplain, Venezuela. *Limnol. Oceanogr.*, 32 (6) : 1277-1290.

HELBING (U. W.), ESTEVES (F. A.), TILZER (M. M.) and STABEL (H. H.), 1986. — Influência dos produtos de decomposição da macrófita aquática *Nymphoides indica* (L.) O. Kuntze, na composição química da água da represa do Lobo (Broa), São Paulo. *Acta Limnol. Brasil.*, 1 : 611-637.

JUNK (W. J.), 1984. — Ecology of the várzea floodplain of Amazonian white water rivers. *In* : Sioli, H., ed. *The Amazon. Limnology and landscape ecology of a mighty tropical river and its basin*. Dr. W. Junk Publishers, Dordrecht : 215-243.

JUNK (W. J.), BAYLEY (P. B.) and SPARKS (R. E.), 1989. — The flood pulse concept in river-floodplain systems. *Can. Spec. Publ. Fish. Aquat. Sci.*, 106 : 110-127.

LANSAC TÔHA (F. A.), LIMA (A. F.), THOMAZ (S. M.) and ROBERTO (M. C.), in press. — Zooplancton de uma planicie de inundação do rio Paraná. II. Variação sazonal e influência dos níveis fluviométricos sobre a comunidade. *Acta Limnol. Brasil.*, 4.

LEWIS (W. M., Jr.) and TYBURCZY (J. A.), 1974. — Amounts and spectral properties of dissolved organic coumpounds from some freshwaters of the southeastern U. S. *Arch. Hydrobiol.*, 74 (1) : 8-17.

LEWIS (W. M., Jr.) and CANFIELD (D.), 1977. — Dissolved organic carbon in some dark Venezuelan water and a revised equation for spectrophotometric determination of dissolved organic carbon. *Arch. Hydrobiol.*, 79 (4) : 441-445.

LOPES (U. B.), SANTOS (U. M.) and RIBEIRO (M. N.), 1983. — Limnologia química do lago do Arroz (Ilha do Careiro), suas flutuações em função do meio hídrico do rio Amazonas. *Acta Amazonica*, 13 (2) : 227-253.

MACINTYRE (S.) and MELACK (J. M.), 1988. — Frequency and depth of vertical mixing in an Amazon floodplain lake (L. Calado, Brazil). *Verh. Internat. Verein. Limnol.*, 23 : 80-85.

MACKERETH (F. Y. H.), HERON (J. G.) and TALLING (J. J.), 1978. — Water analysis : some revised methods for limnologists. Freshw. *Biological Assoc.*, 36, 120 p.

RAI (H.) and HILL (G.), 1981. — Physical and chemical studies of lago Tupé, a Central Amazonian black water «ria Lake». *Int. Revue ges. Hydrobiol.*, 66:137-182.

RAI (H.) and HILL (G.), 1982. — On the nature of the ecological cycle of lago Janauari, a Central Amazonian ria/várzea lake. *Trop. Ecology*, 23 (1) : 1-49.

RAI (H.) and HILL (G.), 1984. — Microbiology of Amazonian waters. In : Sioli, H., ed. *The Amazon. Limnology and landscape ecology of a mighty tropical river and its basin.* Dr. W. Junk Publishers, Dordrecht : 413-441.

SANTOS (U. M.), 1980. — Aspectos limnológicos do lago Grande (Amazônia Central) face as alterações do meio hídrico da regiaõ. *Acta Amazonica*, 10 (4) : 797-822.

SCHMIDT (G. W.), 1973. — Primary production of phytoplankton in the three types of Amazonian waters. II. The limnology of a tropical floodplain lake in central Amazonia (lago Castanho). *Amazoniana*, 4 (2) : 139-203.

STEINBERG (C.) and MUENSTER (U.), 1985. — Geochemistry and ecological role of humic substances in lakewater. *In:* Aiken, G. R., Macknight, D. M., Wershaw, R. L., Maccarthy, P. ed. *Offprints from humic substances in soil, sediment, and water : geochemistry, isolation, and characterization.* John Wiley and Sons : 105-144.

THOMAZ (S. M.), 1991. — *Influência do regime hidrológico (pulsos) sobre algumas variáveis limnológicas de diferentes ambientes aquáticos da planicie de inundação do alto rio Paraná, MS, Brasil.* São Carlos, Universidade Federal de São Carlos, 294 p. (Dissertação de Mestrado).

THOMAZ (S. M.), ROBERTO (M. C.), LANSAC TÔHA (F. A.), LIMA (A. F.) and ESTEVES (F. A.), 1992. — Características limnológicas de uma estação de amostragen do alto rio Paraná e outra do baixo rio Ivinheima — PR, MS — Brasil. *Acta Limnol. Brasil.* 4 : 32-51.

TUNDISI (J. G.), FORSBERG (B. R.), DEVOL (A. H.), ZARET (T. M.), TUNDISI (T. M.), SANTOS (A.), RIBEIRO (J. S.) and HARDY (E. R.), 1984. — Mixing patterns in Amazon lakes. *Hydrobiologia*, 108 : 3-15.

WELCOMME (R. L.), 1980. — *Cuencas fluviales. FAO Doc. Tec. Pesca*, 202 : 1-62.

WETZEL (R. G.), 1981. — *Limnology*. Saunders, Philadelphia, 743 p.