Diurnal, vertical, and among sampling days variation of dissolved O_2, CO_2, and pH in a shallow, tropical reservoir (Garças reservoir, São Paulo, Brazil).

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ABSTRACT: Diurnal, vertical, and among sampling days variation of dissolved O_2, CO_2, and pH in a shallow tropical reservoir (Garças reservoir, São Paulo, Brazil). **Sampling of physical, chemical, and biological variables was performed at a single station at Garças reservoir in five depths at four-hour intervals during summer (3-4 March), fall (13-14 June), winter (29-30 August), and spring (29-30 November) of 1994. Dissolved oxygen, dissolved inorganic carbon forms, pH, and total alkalinity were measured. During the summer, dissolved O_2 was present in low concentrations and showed a diurnal variation of about 2.65 times greater than vertical spatial variation. The lowest diurnal variation of oxygen occurred during the winter sampling period and the highest variation in the spring. During the spring, vertical variation of O_2 was lower than in winter; diurnal variation was less than vertical variation and was not significantly different. During fall, CO_2 concentrations were lower than in the summer. Because of the uniformity of thermal profiles, diurnal variation of CO_2 was not evident during winter and spring. During the latter season, there was an increasing use of HCO_3^- as the CO_2 source for photosynthesis during the *Microcystis* bloom. Vertical variation of total CO_2 was significant during winter and spring sampling days, mainly in the spring. Lack of significant vertical variation during summer and fall was most likely due to mixing of the water column. Differences in mean pH values were only significant during fall and winter. pH value increases were associated with the continuous CO_2 demand for photosynthesis of the *Microcystis* bloom.**

Key-words: **tropical eutrophic reservoir, vertical variation, diurnal variation, seasonal variation, dissolved gases, pH.**

RESUMO: Variação nictemeral, vertical e sazonal de oxigênio dissolvido, CO_2 e pH em um reservatório tropical raso (Reservatório das Garças, São Paulo, Brasil). **Coletas de variáveis físicas, químicas e biológicas foram realizadas em uma estação de amostragem no Reservatório das Garças em cinco profundidades da coluna d'água, a intervalos de quatro horas no verão (3-4 de março), outono (13-14 de junho), inverno (29-30 de agosto) e primavera (29-30 de novembro) de 1994. Foram calculados os valores de oxigênio dissolvido, das formas de carbono inorgânico dissolvido, de pH e de alcalinidade total. O oxigênio dissolvido esteve presente em baixas concentrações no verão e apresentou variação diurna da ordem de 2,65 vezes maior que a variação vertical. A menor variação diurna do oxigênio dissolvido ocorreu na amostragem do inverno e a maior na da primavera. Neste último dia, a variação vertical do oxigênio foi menor que aquela do inverno. As variações diurnas foram menores que as verticais e não foram significativas. No outono, as concentrações de CO_2 foram menores do que no verão. Pela uniformidade dos perfis térmicos, a variação nictemeral do CO_2 foi pouco evidente durante o inverno e a primavera. Nesta última época, deve ser considerada a utilização do HCO_3^- como fonte de CO_2 para a fotossíntese através da floração de *Microcystis* presente nesse período do ano. A variação vertical do CO_2 total foi significativa durante o inverno e a primavera, principalmente na última época. No verão e outono, a variação vertical não foi significativa, provavelmente por conta da mistura da coluna d'água. Apenas durante o outono e o inverno, as diferenças** nos valores médios de pH foram consideradas significativas. Nesses dias, os aumentos de pH estiveram associados à demanda contínua de CO_2 pela fotossíntese dos *Microcystis* durante a floração.

Palavras-chave: **reservatório eutrófico tropical, variação vertical, variação diurna, variação sazonal, gases dissolvidos, pH.**

Introduction

Surface waters in contact with the atmospheric mixture of gases and water vapor will absorb some of its components. Nitrogen, oxygen, and carbon dioxide are especially important because of their essential biological roles. Oxygen is one of the most abundant atmospheric constituents (about 21 % at sea level). Carbon dioxide in the air is surpassed some 28 times in abundance by argon, for example, but it is at least 15 times more soluble in water than the two most abundant atmospheric gases (N_2 and O_2) (Wetzel, 1993; Cole, 1983).

Water mixing is very important for CO_2 availability for phytoplankton, especially to non-motile forms for which a gradient of the gas will be established in their immediate surroundings, in such a way that the CO_2 concentration just outside the cell is considerably lower than that of the gas in a steady state in water. Rapid water mixture will decrease the gas gradient in the vicinity of the cell and allow continuation of the photosynthesis process even if the cell presents low levels of CO_2 equilibrium (King, 1970).

In addition, turbulence carries absorbed O_2 to the lower levels of the water column and allows maintenance of a gradient at the surface film so that gas molecules continue to diffuse in from the air. If O_2 was distributed only by molecular diffusion it would require years for traces of the gas to reach 5 m below the water body surface (Cole, 1983).

Diurnal variations of O_2, inorganic carbon, and pH are intricately connected with biological activity, especially with respiration and photosynthesis. Inverse relationships between O_2 and pH with respect to CO_2 are expected, so that increasing values of O_2 and pH and decreasing concentrations of CO_2 are common during the day in eutrophic waters.

Garças Reservoir (23° 39' S, 46° 37' W) is a kinetic turbulent system, highly influenced by wind speed, with stratification that may last for days or weeks, and which undergoes mixing periods more than once a year. A thermal pattern of this type is comparable to the warm discontinuous polymictic pattern (Ramírez & Bicudo, 2002). These authors studied the Garças system during the period 1994-1996 and found that during summer the reservoir presented an inverted thermocline, with a high thermal resistance to mixing registered at only a few centimeters below the surface. In the fall sampling day, they observed a weak thermal gradient caused by convection cooling of the water. They also observed that the thermal behavior of the reservoir began to change in winter and continued until the spring sampling day, when the thermal gradient was emphasized, forming a well defined surface thermocline. Using the optical properties, the reservoir was classified as an ecosystem of moderate turbidity. Turbidity decreases because of abiotic factors and increases due to increased phaeopigment concentration in the spring. The latter authors also concluded that the reservoir is an ecosystem under luminical stress, and that the degree of stress to which the phytoplankton community is exposed is due to the low light penetration that increases from summer to spring. Ramírez & Bicudo (2002) also found that radiation values were low during the summer (274 ly), increased during the fall (334 ly) and winter (394 ly), and dropped slightly in the spring (390 ly). During the study period, all winds detected corresponded to light breezes according to Watanabe (1997). The lowest wind speeds were measured during the fall (MV = 0.56 $m.s^{-1}$), while mean values were the highest during the winter (MV = 1.19 $m.s^{-1}$). Predominant wind direction was opposite to the sampling station during the summer, chaotic during the fall and towards the sampling station during winter and spring sampling days.

This research aimed at describing the diurnal, vertical, and among sampling days variations of inorganic carbon forms, dissolved O_2, and pH in the Garças Reservoir in order to know on which scale (days, climatic seasons, or depths) such variables varied most. If these chemical variables behavior is related to phytoplankton variation, then the prediction was to obtain a greater effect in spring due to the *Microcystis* bloom that occurred during that sampling day.

Methods

Sampling of physical, chemical, and biological variables was performed at a single station at Garças Reservoir in five distinct depths of the water column (subsurface, 10 % I_o, 1 % I_o, 2 m from surface, and bottom) at four-hour intervals (06:00, 10:00, 14:00, 18:00, 22:00, 02:00, and 06:00 hr during the summer (3-4 March), fall (13-14 June), winter (29-30 August), and spring (29-30 November) of 1994.

Description of the study area and methods used to analyze the water's physical and chemical variables, as well as phytoplankton, are presented in Ramírez & Bicudo (2002). Presently, only methods directly related to specific results considered are described.

Dissolved O_2 was measured with the Winkler method modified for sodium-azide (Sawyer & McCarthy, 1978); free CO_2, HCO_3^-, CO_3^{-2}, and total CO_2 were estimated according to Mackereth et al. (1978); pH values were obtained directly with an Ambriex pH-meter; and total alkalinity was measured by decreasing the pH to 4.35 with 0.01N H_2SO_4. Quantitative analyses for *Microcystis* colonies were carried out with inverted microscope under 160x and 400x magnifications, following Utermöhl's (1958) sedimentation method in 2, 5 and 10 ml sedimentation chambers, depending on the numerical density of the colonies per sample. In each sample, 40 randomized fields were counted. Numerical density was calculated according to Ross (1979).

Mean values (MV) were used as measures of central tendency. Standard deviation and range (R) were used to calculate the absolute degree of dispersion of data; and Pearson's Coefficient of Variation (CV) was used as a measure of relative dispersion.

Significance values for differences among depths and hours were obtained for each sampling day via two-way analyses of variance (ANOVA) with block designs (with sampling hours as blocked variables). This design was selected even though it was recognized that data are not true replications, since samples were obtained from the same site but at different times of day or at different depths. Samples are consequently not entirely independent. The magnitude of hourly variation was quantified as the CV. Significance of the differences among the sampling days, for the above-mentioned variables, was determined by two factors ANOVA, after verification of the corresponding assumptions. In some instances, data were normalized by elimination of outliers and/or by use of logarithmic transformations. Post hoc comparisons of means were conducted with the Tukey's test.

Results

Dissolved oxygen

Variation of dissolved O_2 during the summer sampling day can be seen in Fig. 1A. Mean concentration was lower than that of other sampling days (MV = 1.15 $mg.l^{-1}$). Respective CV values were greater among hours (MV = 96.9 %) than among depths (MV = 36.5 %), suggesting high diurnal variation, about 2.65 times greater than vertical spatial variation. This observation was corroborated by the ANOVA test that revealed significant differences among sampling hours (F = 144.03, a = 0.0000).

Fig. 2 shows that the summer samples could be divided into four groups. The first group consisted of the 02:00 and 06:00 hr samples (4 March), and the second of the 06:00, 10:00, and 22:00 hr samples (3 March). The lowest O_2 concentration was documented in both groups. The third group (14:00 hr sample) and the fourth (18:00 hr sample) showed the highest O_2 concentrations.

Significant differences of O_2 concentration were observed on the fall sampling day among hours (F = 12.99, a = 0.0000) and depths (f = 6.57, a = 0.0010). The low CV value among depths (MV = 16.7 %) means that the vertical gas concentrations varied little

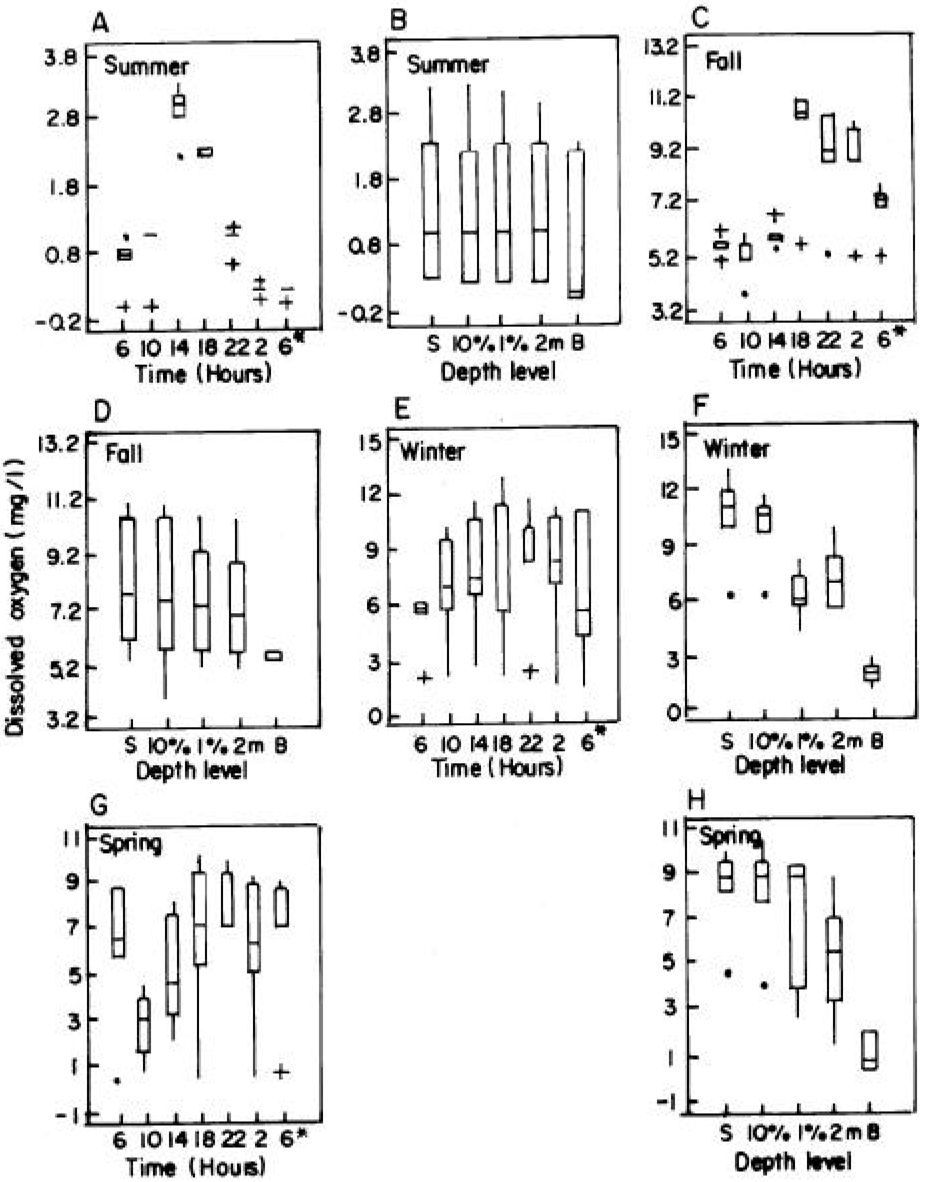

Figure 1: Box plots showing diurnal and vertical behavior of dissolved oxygen during the sampling days with significant differences in the Garças Reservoir.

compared to the other three sampling days (Tab. I). The gas behavior was similar to that detected for the summer sampling day, *i.e.* with a decrease of values towards the bottom of the reservoir and slightly clinograde curves (Fig. 1B, 1D). Mean comparison for summer and fall data showed that O_2 concentration at the bottom of reservoir was significantly different from that calculated for all other depths (Fig. 2).

During the fall sampling day, low values of O_2 occurred during the first hours, increasing from 14:00 hr, reaching its maximum at 18:00 hr, and dropping slightly towards the end of the day (Fig. 1C). Fig. 2 also shows higher O_2 concentrations during the night period compared to the day period. The highest values measured during this day (MV = 7.20 $mg.l^{-1}$) compared to 1.15 $mg.l^{-1}$ measured during the summer day agree, in

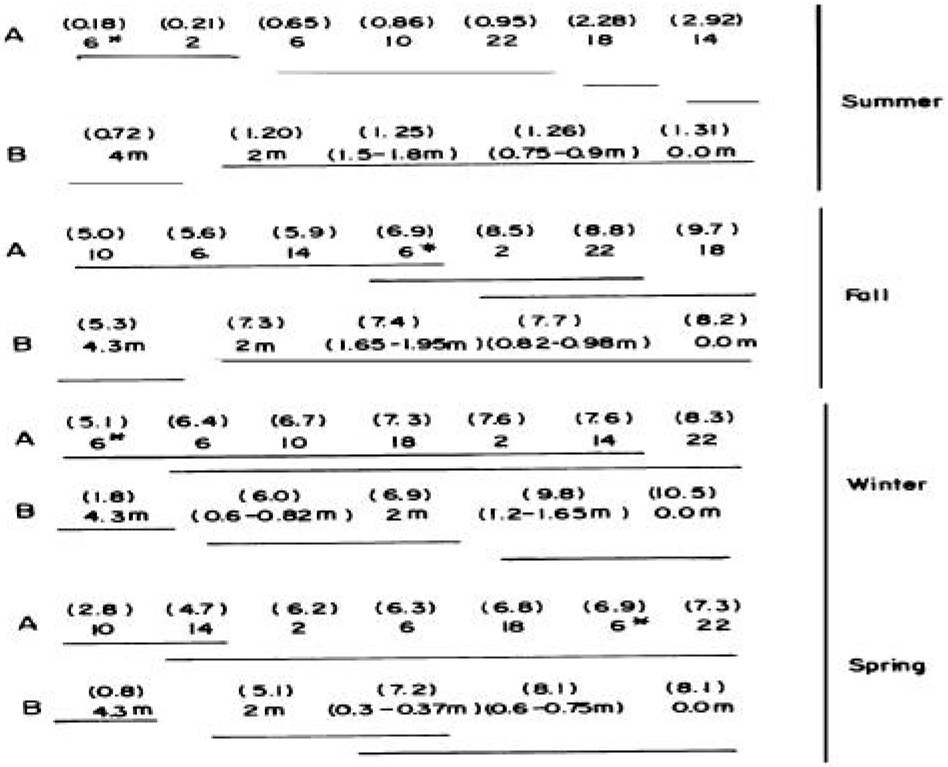

Figure 2: Mean comparisons (Tukey's test) of dissolved oxygen for sampling hours (A) and sampling depths (B) in each sampling day in the Garças Reservoir. A = diurnal variation; B = vertical variation (6* means the end of the diurnal sampling).

Table I: Dispersion values (CV) of dissolved O_2 among hours and depths in each sampling day at Garças' Reservoir.

Factor	Summer	Fall	Winter	Spring
Hour	**96.9**	**25.0**	**23.0**	**43.7**
Depth	**36.5**	**16.7**	**50.4**	**56.0**

general terms, with the greater solar radiation (334 ly compared to 274 ly during the summer day).

The lowest diurnal variation of O_2 occurred during the winter sampling day, demonstrated by the lowest CV values in Tab. 1 and verified in Fig. 1E. The O_2 values obtained in the first (06:00 hr) and the last (22:00 hr) sampling hours produced significant differences in dissolved O_2 (F = 3.2, a = 0.0187). Significant variations (F = 47.96, a = 0.0000) could also be detected at different depths, which were as prominent as those documented in the spring (see respective CV values in Tab. 1). The vertical gradient in the winter sampling day (Fig. 1F) was much more pronounced than those in the summer (Fig. 1B) and fall (Fig. 1D) days.

Behavior of O_2 during the spring sampling day (Fig. 1G-1H) was very similar to that of winter (Fig. 1E-1F), with significant differences among both hours (F = 6.83, a = 0.0003) and depths (F = 36.11, a = 0.0000). Again, based on CV values, diurnal differences were smaller than vertical ones (Tab. I). Variation in O_2 concentration with depth in spring was strikingly pronounced (R = 7.3 $mg.l^{-1}$), but smaller than in winter (R = 8.7 $mg.l^{-1}$). During spring, O_2 concentration at reservoir's bottom was the second lowest, after only that of summer.

As already mentioned, diurnal variation during the spring sampling day was very scant (Fig. 1G) and was related to small changes observed in the water temperature. Tukey's test showed that the 10:00 hr situation was significantly different from those of all other hours, with a behavior similar to that of the 14:00 hr (Fig. 2).

Highly significant differences were registered among the sampling days (F = 264.18, a = 0.0000), with those of summer and spring distinct from those of fall and winter's (Fig. 5A).

Dissolved inorganic carbon

Diurnal variation of total CO_2 was not significant during summer and spring sampling days (Tab. II). Observation of F values for the other two above sampling days in Tab. II led to the conclusion that hourly variations decreased in intensity towards spring, when no further significant differences were detected.

Free CO_2 concentrations in the summer sampling day were the highest of all measures taken, as shown by the lower than 1 free O_2:CO_2 ratio in Tab. II.

During the fall sampling day, concentrations of total CO_2 were slightly lower than in the summer (Tab.II). O_2:freeCO_2 ratio values markedly increased during this day. Diurnal variation pattern during this day showed a total CO_2 increase up to 14:00 hr, a decrease until 18:00 hr, and a new increase until 06:00 hr of the following day (Fig. 3A).

Diurnal variation of total CO_2 was less evident during winter and spring sampling days as shown in Tab. II. In addition, during the spring no significant differences were observed among sampling hours (Tab. II).

Total CO_2 values decreased from summer to spring, leading to the conclusion that there was an increasing use of the combined forms of inorganic carbon, especially HCO_3^- (Tab. II), as CO_2 source for photosynthesis during the *Microcystis* bloom.

Table II: Values of significance level, F test and mean values for total CO_2, mean values for inorganic carbon forms, and O_2:free CO_2 ratio among sampling hours in the Garças Reservoir.

Statistics	Summer	Fall	Winter	Spring
F	**0.60**	**12.45**	**4.33**	**0.42**
a	**0.7282**	**0.0000**	**0.0042**	**0.8533**
Total CO_2	**50.65**	**45.32**	**41.19**	**38.75**
Free CO_2	**13.81**	**8.28**	**3.85**	**1.30**
HCO_3^-	**52.97**	**51.23**	**50.44**	**38.89**
CO_3^{-2}	**0.02**	**0.04**	**0.44**	**4.27**
O_2/free CO_2	**0.08**	**0.87**	**1.82**	**4.51**

During winter (F = 39.15, a = 0.0000) and spring sampling days (F = 18.98, a = 0.0000), total CO_2 vertical variation was significant. Fig. 3C-3D show that total CO_2 values tended to increase toward the reservoir's bottom. On the other hand, such variation was not significant during the summer (F = 0.135, a = 0.9679) and fall (F = 0.66, a = 0.6230) sampling days.

Highly significant differences for total CO_2 (F = 63.61, a = 0.0000) were found among the four sampling days (Fig. 5B).

pH

Vertical and diurnal variations of pH are inversely related to that of total CO_2, as can be seen by comparison of Fig. 3-4.

Regarding diurnal sampling, only fall and winter sampling days showed significant variation (Tab. III). In the fall day, the lowest mean pH value (6.75) was detected at 14:00 hr (Fig. 4) and coincided with the highest values of total CO_2 (Fig. 3) measured at the same hour.

During winter, the highest mean pH value (8.09) was measured at 14:00 hr (Fig. 4). At the same time, total CO_2 values were at the lowest.

Vertical variation of pH was significant only during winter and spring sampling days (Tab. III). During the winter, two groups of layers were formed in the water column (Fig. 4C-4D): one composed by the two first depths (subsurface and 10 % I_0) and the other by the last three depths (1 % I_0, 2 m, and bottom). Unlike the winter, during the spring day the first three depths constituted the first group and the remaining two depths each constituted its own separate group.

Among the four sampling days, pH showed highly significant differences (F = 125.06, a = 0.0000) (Fig. 5C).

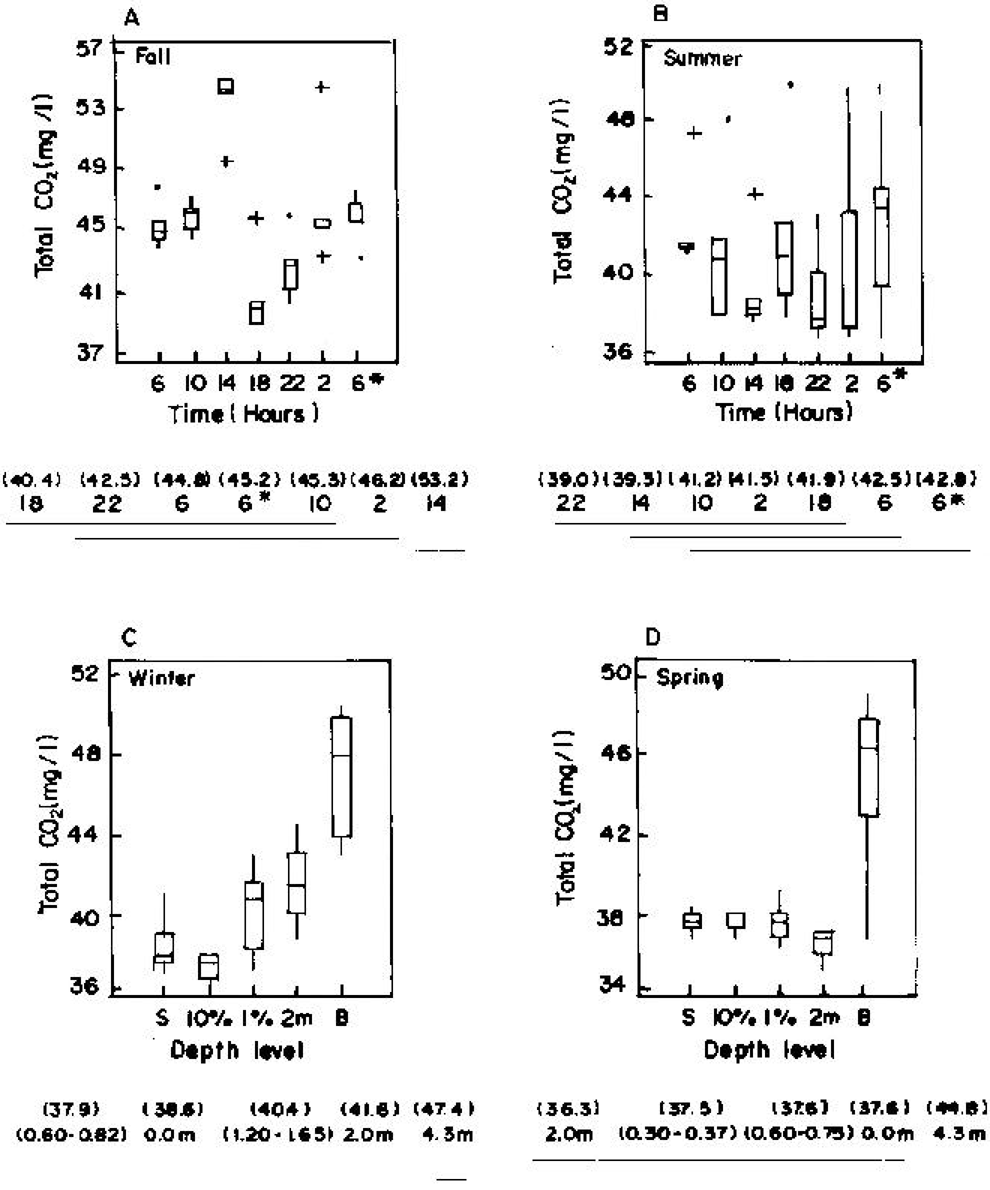

Figure 3: Box plots and mean comparisons (Tukey's test) showing diurnal and vertical variation of total CO_2 during the sampling days with significant differences in the Garças Reservoir (6* means the end of the diurnal sampling).

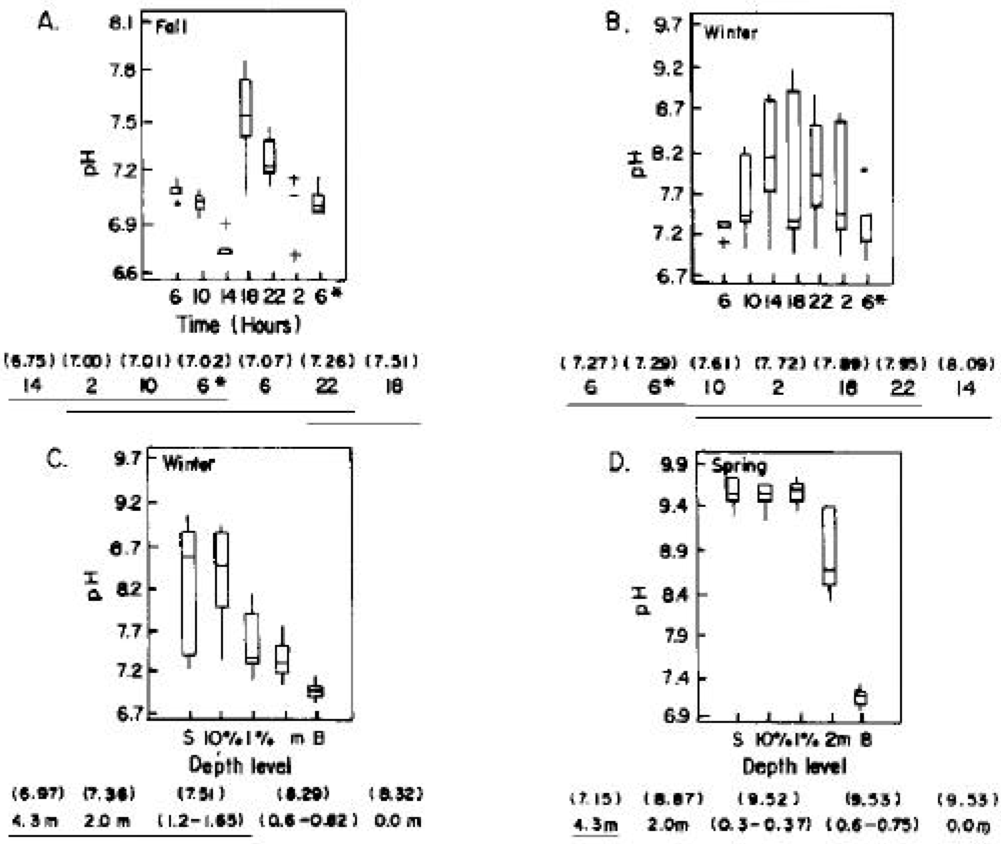

Figure 4: Box plots and mean comparisons (Tukey's test) showing diurnal and vertical behavior of pH during the sampling days with significant differences in the Garças Reservoir (6* means the end of the diurnal sampling).

Table III: Significance level and F values for diurnal and vertical variations of pH in each sampling day at Garças Reservoir.

Factor	Statistics	Summer	Fall	Winter	Spring
Hours	**F**	**0.80**	**11.51**	**4.23**	**1.82**
	a	**0.5815**	**0.0000**	**0.0048**	**0.1365**
Depth	**F**	**0.33**	**0.98**	**20.59**	**139.47**
	a	**0.8566**	**0.4344**	**0.0000**	**0.0000**

Table IV: Mean values of pH, free CO_2, total alkalinity, and numerical density of Cyanophyceae in each sampling day at the Garças Reservoir.

Variable	Summer	Fall	Winter	Spring
pH	**6.85**	**7.09**	**7.69**	**8.92**
Free CO_2 (mg.l^{-1})	**13.81**	**8.28**	**3.85**	**1.30**
Total alkalinity (mEq.l^{-1})	**0.86**	**0.84**	**0.83**	**0.80**
Cyanophyceae (colonies.ml^{-1})	**98035**	**230139**	**206487**	**433515**

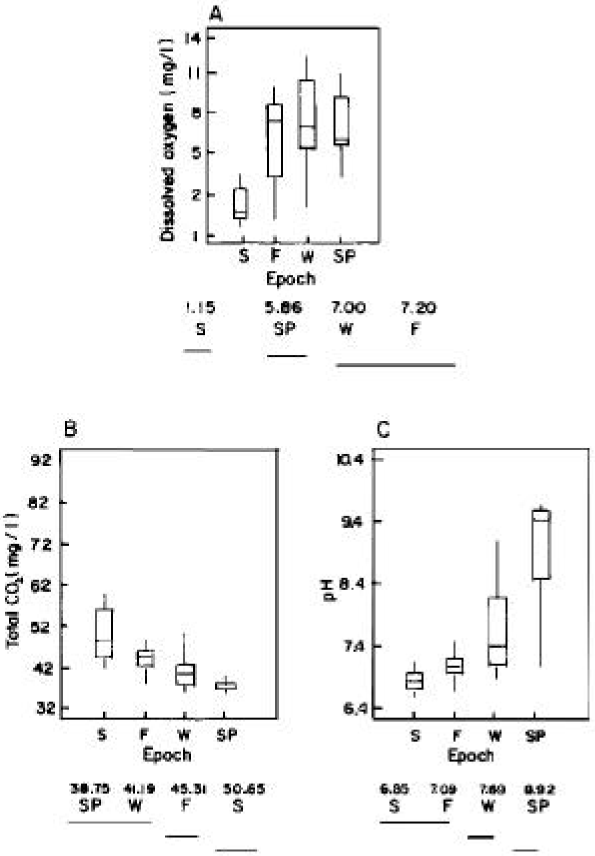

Figure 5: Box plots and mean comparisons (Tukey's test) showing behavior of dissolved oxygen, total CO_2 and pH among the sampling days in the Garças Reservoir. S = summer; F = fall; W = winter; SP = spring.

Discussion

In general, diurnal variations of O_2 were due to air temperature and wind speed. However, the highest night concentrations of this gas during the fall day are not easily explained since wind speed decreased during these hours. Possibly gas solubility increased with the decrease in water temperature during the night due to heat loss by convection and turbulence generated by submergence of the much colder surface water layers. Such high night concentrations could be an indication of a low heterotrophic activity that implies low O_2 consumption during the night period (Huszar et al., 1994; Carmouze, 1994).

The reason for the diurnal behavior of O_2 during the spring, like that of winter, was increased wind speed up to 14:00 hr, slightly decreasing the O_2 concentration gradient (Ramírez & Bicudo, 2002).

Oxygen concentration at the reservoir bottom during spring was the second lowest after those of summer (MV = 8.2 $mg.l^{-1}$) and spring, due to the length of the stratification period that extended throughout the sampling day (Ramírez & Bicudo, 2002).

Low concentrations of dissolved O_2 detected during the summer sampling day could not be attributed to an atypical behavior of that day's measured solar radiation, even though it had the smallest value registered of all four sampling days (247 ly). Nor could such low values be attributed to low wind speeds (1.98 $m.s^{-1}$) since the mean O_2

concentration during the summer sampling day was the second highest measured during the entire study period. Such behavior may be due to one of the following reasons: (1) the mixture of the water column and subsequent high suspended organic matter concentration (42.5 mg.l^{-1}) of the entire study period, which possibly increased O_2 consumption; (2) the relatively high water temperatures during the summer sampling day, which contributed to the diminution of O_2 solubility; and (3) the high concentration of N-NH_4^+ (MV = 1,658.68 μg.l^{-1}) that, according to Esteves (1998), greatly influences O_2 dynamics, provided that 3.6 mg.l^{-1} of O_2 are necessary for oxidation of 1 μg of NH_4^+.

The lowest diurnal variation in the winter sampling day resulted from the fact that the clinograde curves presented for O_2 throughout the day were less prominent during these hours due to an increase in wind speed in that period, which consequently destabilized the water column and slightly altered the gas behavior pattern.

High CO_2 concentrations in the summer sampling day were not completely consumed by photosynthesis during that day, and were due to the high concentrations of suspended material in the water (42.5 mg.l^{-1}) and to the high temperatures. These facts contributed to an increased demand of dissolved O_2. Consequently, the smallest values of O_2 were observed that day (Fig. 2)

The increase in the O_2:free CO_2 ratio values during the fall day were most probably due to a decrease of the heterotrophic activity during the dark period which did not let free CO_2 values to increase (Tab. II). Greater CO_2 values at 14:00 hr of this day are not easy to explain and may be a consequence of photosynthesis inhibition due to high solar radiation during that day (Ramírez & Bicudo, 2002).

A possible explanation for the diurnal variation of CO_2 in the winter and spring sampling days was the thermal profiles uniformity obtained during these days (Ramírez & Bicudo, 2002) and the smaller free CO_2 and total CO_2 concentrations. Consequently, a noticeable increase of the O_2:free CO_2 ratio was observed during both days (Tab. II). Such increase was related to the already mentioned decrease of free CO_2 due to its fixation by the *Microcystis* species in the reservoir, which started blooming during the winter and reached its maximum during the spring (Nogueira, 1996).

An explanation for the non-inhibition of photosynthesis by the high solar radiation during the spring sampling day could be the alteration in the phytoplankton community's taxonomic composition, which changed from populations that were not adapted to high solar radiation values to others that were capable of tolerating the new condition, as was the case of the *Microcystis*' populations whose dominance started at that time (Nogueira, 1996).

The lack of significant vertical variation in total CO_2 during the summer and fall sampling days was most likely due to the fact that the water column was usually mixed during those days (Ramírez & Bicudo, 2002), breaking all possible gradients that could be detected in the water column, as happened during the winter and spring sampling days.

The lowest mean pH value registered at 14:00 hr in the fall day coincided with the beginning of the thermocline formation. This condition is different from those pH values shown at 06:00 (beginning of samplings), 18:00, and 22:00 hr (Fig. 4), when the water column was almost entirely isothermic (Ramírez & Bicudo, 2002).

Vertical pH behavior during the winter and spring sampling days was largely connected to the reservoir's mixing pattern that decreased during these days (Ramírez & Bicudo, 2002). During the spring day, pH vertical gradient was more conspicuous. The similar and higher pH values detected up to the limit of the photic zone during these two sampling days were due to a higher CO_2 demand for photosynthesis and the wind action that mixed the upper layers and consequently reduced all possible differences.

In conclusion, the lowest pH values, O_2 demand, and CO_2 liberation from the reservoir's bottom were due to decomposition of *Microcystis* and some other organisms, which were oxidized by hypolimnetic bacteria. Consequently, by comparing O_2 vertical behavior (Fig. 1F) to that of total CO_2 (Fig. 3C-3D) and pH (Fig. 4C-4D) in the winter and spring sampling days, one can see that the curves of total CO_2 are inverse to those of dissolved O_2 and pH.

The significant differences among the four sampling days for O_2 and total CO_2 were basically connected to the thermal profile during the summer and spring sampling days (Fig. 5). Progressive increment of pH values and decrease of total CO_2 from summer to spring sampling were explained by King (1970), who stated that for any alkalinity value, the use of carbon during photosynthesis causes an increase of pH associated with alteration of the carbonate equilibrium. The final result is a progressive shortening of the period in which a certain type of alga will have a sufficient CO_2 availability before it is replaced by another alga with a higher tolerance to lower concentrations of that gas in the water. The replacing alga temporally dominates the system, until the water's CO_2 equilibrium drops again and another kind of alga replaces it. In this way, pH increases associated with the continuous CO_2 demand for photosynthesis allow the blue-greens to be the last to dominate the system, exactly as occurred in the present study. As a consequence, during spring, alkalinity slightly decreased while pH increased significantly (Tab. IV).

According to King (1970), a decrease of CO_2 availability explains a successional pattern that culminates with the dominance of blue-green algae that can tolerate low concentrations of that gas. This process apparently continues until the CO_2 concentration decreases to a level that only that alga group is able to use. Such blue-green algae dominance during low CO_2 and high pH periods have been documented by several others authors (Shapiro, 1973, 1984, 1990; Vincent & Silvester, 1979). Not surprisingly, the carbonate-bicarbonate system equilibrium seems to be the most important factor in governing alga activity in aquatic systems. Furthermore, besides functioning as a primary buffering agent, this system represents the only significant source of photosynthetic carbon reserve (King, 1970).

Conclusion

While variation in dissolved oxygen and total CO_2 was greatest between sampling days, pH varied most between depths and in the spring sampling day. Hourly variation in oxygen was greatest in summer, total CO_2 and pH in fall. Across the gravity-light axis, total CO_2 variation was most pronounced in the winter, whereas pH variation was so in the spring.

Results presently obtained partially support the research hypothesis signifying that oscillations in phytoplankton behavior, especially the spring *Microcystis*' bloom, were not the only important variables. In fact, thermal behavior of the lake together with the bloom affected the gas behavior in the water body studied.

Acknowledgments

The authors are especially grateful to the Red Latinoamericana de Botánica for a doctoral fellowship given to the senior author (John J. Ramírez); to the Instituto de Biología of the Universidad de Antioquia in Medellin, Colombia, and to the Instituto de Botânica of the São Paulo State Department of Environment, Brazil, for clerical scientific support.

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Received: **04 October 2001**
Accepted: **16 June 2003**