Nictemeral studies are important to assess information about the variations of ecological factors in short periods of time. With the aim of studying the vertical and nictemeral variations in the Bodocongó dam, located in the Northeast of Brazil, samples were taken from four depths (Subsurface, 50% Intensity, 1% Intensity, and Bottom) at a single sampling station with a depth of 5 meters in four-hour intervals (1 pm, 5 pm, 9 pm, 1 am, 5 am, 9 am, and 1 pm), during the dry period in November 2003. The following variables were sampled: water transparency, water temperature, electric conductivity, dissolved oxygen, pH, ammonia, nitrite, nitrate, orthophosphate, and total phosphorus. Overall, no significant vertical or nictemeral variation was found for any of the variables, which is probably related to the shallow depth of the dam. However, there was a trend towards a day/night shift in the values of water temperature, electric conductivity, pH, alkalinity, and dissolved oxygen. Nutrient’s values showed no distinct pattern of distribution.

**Key words:** Nictemeral, limnological variables, dam, Northeast Brazil.

**RESUMO**

Estudos nictemerais são importantes para se obter informações sobre fatores ecológicos em curtos períodos de tempo. Com o objetivo de estudar as variações verticais e nictemerais no açude de Bodocongó localizado no Nordeste do Brasil, amostras foram coletadas de quatro profundidades (Sub-superfície, 50% Intensidade, 1% Intensidade, e Fundo) em uma única estação de coleta com 5 m de profundidade, em intervalos de 4 horas (13:00, 17:00, 21:00, 01:00, 05:00, 09:00 e 13:00), durante o período seco, em Novembro de 2003. As seguintes variáveis foram amostradas: transparência da água, temperatura da água, condutividade elétrica, oxigênio dissolvido, pH, alcalinidade, amônia, nitrato, nitrato, orto-fosfato e fósforo total. Não houve variação vertical ou nictemeral significante para nenhuma das variáveis analisadas, o que pode estar relacionado com a profundidade rasa do açude. No entanto, temperatura da água, condutividade elétrica, pH e oxigênio dissolvido mostraram uma tendência para uma variação dia/noite. Para os valores dos nutrientes não foi observado um padrão de distribuição distinto.

**Palavras-chave:** Nictemeral, variáveis limnológicas, açude, Nordeste brasileiro.

**1 INTRODUCTION**

Diurnal rhythms are usually studied to assess information about the short-period variations of ecological factors in any kind of ecosystem (Ramirez, 1996). These nictemeral studies (from the Greek Nychthémeron: one day and one night) are very useful as an attempt to understand the physical, chemical and biological interactions that occur in short periods of time (diurnal cycles) on aquatic ecosystems. Also, studying the dynamics of an ecosystem is an important way of understanding how the physical and chemical variables shift during the day/night...
cycle and how these differences can influence the life cycles of the organisms that dwell in it.

Nictemeral studies are particularly important on the tropics since there is a broader variation of the ecological variables in a diurnal cycle (24 hours) than there is in a seasonal cycle (12 months) (Ganf & Horn, 1975). In a diurnal cycle, periodic vertical reorganizations occur and this complex characteristic, particularly in shallow aquatic ecosystems, is still poorly understood (Gavilán, 1990). Also, nictemeral studies are important not only from a conceptual point of view, but also for the application of a management plan in different environments (Barbosa, 1996). Many relevant studies emphasize the importance of nictemeral researches in tropical freshwater environments (Barbosa, 1981; Melack & Fisher, 1983; Simonato, 1986; Esteves et al., 1988; Alves et al., 1988; Toledo et al., 1988; Barbosa & Tundisi, 1989; Gavilán, 1990; Bozeli et al., 1990; Bozeli et al., 1992; Huszar et al., 1994 and Ramírez, 1996), where they all agree that these tropic aquatic ecosystems are more influenced by a 24 hours cycle than by an annual cycle.

The present research aimed at studying the vertical and nictemeral variations of limnological variables in a tropical Brazilian dam during the dry period.

2 MATERIAL AND METHODS

2.1 – Study area

The Bodocongó dam (7° 13’ 11” S, 35° 52’ 21” W) is located in the city of Campina Grande, Paraíba state in the northeast of Brazil at an altitude of about 508 meters above the sea level. It has an average depth of 3 meters and a maximum depth of 6.5 meters. Historically, the first limnological researches of Brazil were carried out in the Bodocongó dam and so, it’s considered today the birthplace of Brazil’s limnology.

2.2 – Sampling procedures and data analysis

The water samples were taken from four depths (Subsurface, 50% I₀, 1% I₀, and Bottom) at a single sampling station with a depth of 5 meters at four-hour intervals during 24 hours (1:00 pm, 5:00 pm, 9:00 am, 5:00 am, 1:00 am, 5:00 am, 9:00 am and 1:00 pm) in the dry season on the 17th and 18th of November 2003. Water temperature samples were also taken at three additional depths (75% I₀, 25% I₀ and 10% I₀). Water transparency samples were taken in five intervals (1:00 pm, 5:00 pm, 9:00 am, 5:00 am and 1:00 pm). All the samples were collected using a Van Dorn bottle with a five liters capacity. Table 1 summarizes the variables and the methods used.

The resulting values were submitted to a basic descriptive statistical analysis: arithmetic mean as a central position measurement and Pearson’s coefficient of variation (CV) as relative dispersion measurement. To detect significant differences a one way Analysis of Variance (ANOVA) was used. Also, Pearson’s coefficient of correlation was used among all variables. All statistical analysis and graphs were built with the use of Statistica 5.1 and Surfer 5.0 for Microsoft Windows.

Table 1. Material and/or methods, with the respective units, used to estimate the limnological variables in the Bodocongó dam, Paraíba, Brazil

<table>
<thead>
<tr>
<th>Variables</th>
<th>Material and/or Method</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water transparency</td>
<td>30 cm Secchi disk</td>
<td>m</td>
</tr>
<tr>
<td>Water temperature</td>
<td>0.5° precision thermometer</td>
<td>°C</td>
</tr>
<tr>
<td>Electric conductivity</td>
<td>Cole Palmer conductivimeter</td>
<td>µ.S.cm⁻¹</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>Winkler method</td>
<td>mg.L⁻¹</td>
</tr>
<tr>
<td>pH</td>
<td>Hanna HI 9224 pHmeter</td>
<td>-</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>Golterman et al. (1978)</td>
<td>mg.L⁻¹</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Mackereth et al. (1978)</td>
<td>µg.L⁻¹</td>
</tr>
<tr>
<td>Nitrite</td>
<td>Mackereth et al. (1978)</td>
<td>µg.L⁻¹</td>
</tr>
<tr>
<td>Nitrate</td>
<td>Rodier (1975)</td>
<td>µg.L⁻¹</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>Mackereth et al. (1978)</td>
<td>µg.L⁻¹</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>Apha (1995)</td>
<td>µg.L⁻¹</td>
</tr>
</tbody>
</table>
3 RESULTS

The lowest and highest values of water transparency were 0.54 m (5 am) and 0.65 m (1 pm), respectively with a CV of 6.35 %.

No significant vertical variation was observed for the water temperature (p = 0.89; d.f = 6; α = 0.05). The greatest amplitude between the first depth (Subsurface) and the last (Bottom) was of 1.4 ºC at 5 pm, but traces of stratification were observed in the middle of the water column during the shift from the morning to the beginning of the afternoon (9 am to 1 pm) (Fig. 1). Although no significant nictemeral variation of the water temperature was observed (p = 1.62; d.f = 6; α = 0.05), the lowest values were observed at night and dawn (22 to 24º C) and the highest values were observed in the morning and in the beginning of the afternoon (27 to 34º C) (CV = 12.2 %) as shown in Fig. 1.

The electric conductivity values varied from 904 (5 am; 1% I_o) to 2810 (1 pm; Subsurface) µ.S.cm⁻¹ (CV = 45.41%) and the pH from 6.81 (5 am; 50% I_o) to 7.68 (1 pm; Subsurface) (CV = 4.18%). There was also no significant vertical variation for the electric conductivity (p = 0.99; d.f = 3; α = 0.05) and the pH values (p = 0.83; d.f = 3; α = 0.05) and these two variables showed similar patterns of distribution (Fig. 2). This was confirmed since these two variables were also positively significantly correlated (r = 0.88; α = 0.05). Although no significant nictemeral variation was observed for electric conductivity (p = 1.06; d.f = 6; α = 0.05) or pH (p = 4.24; d.f = 6; α = 0.05), the higher values were observed during the first three hours sampled (1 pm, 5 pm and 9 pm) and the lowest values were observed in the subsequent hours (1 am, 5 am, 9 am and 1 pm) for these two variables (Fig. 2).

High values of dissolved oxygen were observed in both vertical and nictemeral scales. The concentrations oscillated from 3.8 (1 pm; Bottom) to 12.95 mg.L⁻¹ (1 pm; 50% I_o) (CV = 18.53 %). These corresponded to a saturation percentage that varied from 45.2 to 154.1 %. However, no significant vertical (p = 0.13; d.f = 3; α = 0.05) or nictemeral (p = 0.23; d.f = 6; α = 0.05) variations were found for this variable. Thus, with the exception of the first time sampled (1 pm), which showed traces of vertical stratification, the distribution of the dissolved oxygen was relatively homogenous (Fig. 3). There was a significant negative correlation between dissolved oxygen and ammonia (r = - 0.50; α = 0.05).

The alkalinity concentrations varied from 67 (1 pm; Subsurface) to 95 mg.L⁻¹ (5 am; 1% I_o) (CV = 7.74 %) and although there was no significant vertical variation (p = 0.82; d.f = 3; α = 0.05), there was a significant nictemeral variation (p = 0.01; d.f = 6; α = 0.05). Thus, a small trend towards an increase in the concentration of alkalinity in the last hours of the study was observed (Fig. 4). Negative significant correlations between alkalinity

Figure 1. Values of water temperature (ºC) from 7 depths (m) sampled in a daily cycle in the Bodocongó dam, Northeast of Brazil.
Figure 2. Values of electric conductivity ($\mu$.S.cm$^{-1}$) and pH from 4 depths (m) sampled in a daily cycle in the Bodocongó dam, Northeast of Brazil.

Figure 3. Values of dissolved oxygen (mgO$_2$.L$^{-1}$) from 4 depths (m) sampled in a daily cycle in the Bodocongó dam, Northeast of Brazil.

and electric conductivity ($r = -0.61; \alpha = 0.05$) and between alkalinity and pH ($r = -0.52; \alpha = 0.05$) were detected.

Values of ammonia, nitrite, nitrate, orthophosphate and total phosphorus are shown in Fig. 5. No significant vertical or nictemeral variations were observed. Overall, the nutrient’s concentrations were relatively homogenous, showing no remarkable pattern of distribution (Fig. 5).

4 - DISCUSSION

No significant vertical or nictemeral variation was found in the dam for the variables sampled (alkalinity was the only exception). This
can be related, at least partially, to the shallow depth of the dam, which increases the capacity of the wind in mixing the water and consequently makes it more homogenous.

The water transparency values were very homogenous with the lower and higher values found in the beginning of the morning (less sun radiation) and the beginning of the afternoon (more sun radiation), respectively. Values of water temperature were considerably high and although no significant variation was found, a trend for a day/night shift was observed. This was expected since the waters of the dam absorbed heat from the radiation of the sun during the day and diffused heat to the atmosphere during the night. Since the values of alkalinity significantly increased during the period of study, it would be expected that the higher values of pH would also be found in these corresponding times. However, the opposite happened. Since there was a resemblance in the distribution of the electric conductivity and the pH values, the higher levels of dissolved ions in the water during the first half of the study and the lower levels during the other half, may have caused a corresponding increase and decrease in the levels of the pH, respectively. The resemblance in the distribution of the values of these two variables was also confirmed by Pearsons’ coefficient of correlation, as seen above. Alternatively, the increasing values of alkalinity show the capacity of the carbonates, bicarbonates and hydroxides in neutralizing the increasing acids in the water during the same period (Cole, 1983; Wetzel, 1993). Thus, the significant negative correlation obtained between alkalinity and pH and between alkalinity and electric conductivity in this study can be related to the neutralizing capacity of this variable. The dissolved oxygen values were considerably high in the dam indicating high levels of primary productivity.

Although the distribution was significantly homogenous, traces of stratification observed in the beginning of the study showed that there is a trend towards lower levels of oxygen in the bottom. This can be related to the lower primary productivity and to the higher rates of nutrients metabolism in the sediment in these depths. The significant negative correlation between ammonia and dissolved oxygen observed in this study showed that there is a significant use of oxygen in nitrogen’s metabolism. The nutrients values were considerably high (specially total phosphorous) and showed no significant variation along the depths and times sampled. Distribution of nitrate in tropical lakes can be directly related to the concentration of oxygen in the environment (Barbosa, 1981) as it was observed in this study from the negative correlation obtained between ammonia and dissolved oxygen. It can also be related to bacteria activity (nitrification) (Lopes, 1999). Along with oxygen concentration, water temperature is another important variable that influences the nitrogen cycle (Schäfer, 1985). These relationships show how dynamic and interrelated these variables are, especially when considering tropical environments in short periods.

Although it is out of the scope of this study to assess the trophic condition of the dam, the high values of nutrients obtained shows the level of degradation of this environment. Ceballos (1995)
studying the Bodocongó dam also found high values of nutrients, although they were considerably lower than the ones observed in the present study.
The results of the present study clearly showed that the Bodocongó is a considerably homogenous environment with no significant vertical or nictemeral variation. However, the water temperature values showed a remarkable day/night shift, which confirms the hypothesis of a broad nictemeral variation of this variable in tropical environments (Ganf & Horn, 1975). Electric conductivity, pH and alkalinity showed important relationships. The high amounts of dissolved ions observed, can be a consequence of the elevated metabolism of the nutrients (Sawyer et al., 1994), the domestic sewage (Blundi, 1998) or it can be related to the elevated evaporation rates and salty soils, which are common in the northeastern region of Brazil (Barbosa, 2002). An important relationship was also observed between dissolved oxygen and ammonia and the high amounts of oxygen in all depths may indicate high primary productivity rates and little vertical variation of the photosynthetic organisms in the water column.

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