Limnological characteristics of the water bodies of the Corutuba Nesting Site in Brazil's Pantanal.

ABDO[1], M.S.A. & DA SILVA[1], C.J.

[1] Federal University of Mato Grosso – Institute of Biology – Project of Ecology Gran Pantanal/Post-Graduate Program Ecology and Conservation of the Biodiversity.

ABSTRACT: Limnological characteristics of the water bodies of the Corutuba nesting site in Brazil's Pantanal. The purpose of this research was to identify the changes in the limnological variables of the Corutuba nesting site, which are strongly influenced by the presence of thousands of colonial birds, according to the annual flood pulse. The Corutuba nesting site system comprises the Corixo Grande and Corixinho canals, the Cuiabá river and the Baía Ninhal Corutuba (Corutuba nesting site lake). Data were collected monthly, from October 1995 to September 1996. The physical and chemical characteristics of the water surface displayed variations between the flood and dry phases. The two phases showed significant differences in relation to the electrical conductivity and the concentration of nutrients in the water bodies, which were most pronounced in the Baía Ninhal Corutuba and the Corixo Grande canal. The highest values were obtained during the dry season, due to the concentration effect of disconnection from the river, low water levels, increased evaporation, decomposition of aquatic macrophytes, and the contribution of the birds present in this period. The principal component analysis (PCA) revealed that there were differences among the four studied environment, especially the dry season. However the Baía Ninhal Corutuba showed high spatial difference, i.e., it is more strongly controlled by flood pulses.
Key-words: Mato Grosso's Pantanal, Cuiabá river, Ninhal, Limnology.

RESUMO: Características limnológica dos corpos d'água do ninhal Corutuba, Pantanal. Esta pesquisa teve como objetivo verificar as mudanças nas variáveis limnológicas, em função do pulso de inundação anual no sistema do Ninhal Corutuba, fortemente influenciado pela presença de milhares de aves coloniais. O sistema do Ninhal Corutuba está formado pelos Corixo Grande e Corixinho, pelo Rio Cuiabá e Baía Ninhal Corutuba. As coletas foram realizadas mensalmente, de outubro de 1995 a setembro de 1996. As características físicas e químicas da superfície da água apresentaram variações entre os períodos de cheia e estiagem. As diferenças entre os dois períodos foram significativas em relação à condutividade elétrica e à concentração de nutrientes nos corpos de água estudados, sendo mais acentuadas na Baía Ninhal Corutuba e Corixo Grande. Os valores mais elevados foram obtidos na estiagem, por causa do efeito da concentração face à desconexão do rio, à diminuição do nível de água, ao aumento da evaporação, à decomposição das macrófitas aquáticas e à contribuição das aves presentes neste período. A análise de componentes principais (PCA) mostrou que há diferenças entre os quatro ambientes estudados, principalmente, no período da estiagem. Entretanto a Baía Ninhal Corutuba foi a que apresentou maior dissimilaridade, ou seja, sofre maior influência dos efeitos do pulso de inundação.
Palavras-chave: Pantanal Mato-grossense, Rio Cuiabá, Ninhal, Limnologia.

Introduction

Floodplains are "areas periodically flooded by the lateral overflowing of rivers and lakes, and/or by direct rainfall or by underground water; the resulting physicochemical environment causes morphological, anatomical, physiological, and phenological responses, and/or ethological adaptations in the biota, and produces characteristic community structures" (Junk et al., 1989). The floodplain is "an aquatic/terrestrial transition zone (ATTZ)" because an alternation between a terrestrial and an aquatic phase is observed during the year (Junk, 1999).

The flood pulse produces a series of transformations in the limnological characteristics of water bodies, promoting an increase or decrease in the transparency in the water, pH, and electrical conductivity and in the concentration of nutrients (Esteves, 1988; Furch, 1997; Lewis et al., 2000; Leite & Fonseca, 2002). The effects of the flood pulse have been assessed in several ecosystems, especially those of the Amazon (Junk,1997) and the upper Paraná river floodplain (Vazzoler et al., 1997).

Based on the flood pulse concept applied to the Pantanal plain, Junk & Da Silva (1999) emphasized its effects on the ecological processes, on the biotic diversity and on the units of landscape of this biome. Thus, the maintenance of the natural hydrological regime has been considered essential for the conservation of the ecological processes and the biodiversity of Mato Grosso's Pantanal (Da Silva, 2000; Da Silva et al., 2001).

Mato-Grosso's Pantanal displays a variety of landscape units with many types of aquatic and terrestrial habitats, and abundant food and reproduction sites that shelter numerous animal and plant species (Junk, 1993; Da Silva, 2000; Da Silva et al., 2001). Studies carried out in various bays of the Pantanal have shown that the flood pulse influences the spatial and temporal variation of the limnological characteristics (Da Silva & Pinto-Silva, 1989; Da Silva & Esteves, 1995; Hardoim & Heckman, 1996; Heckman, 1998; Penha et al., 1998 a, b; Abdo & Da Silva, 2001; Nogueira et al., 2002; Girard et al., 2003). However, there are no studies that evidence these effects for bay systems associated with thousands of colonial birds, such as the Corutuba nesting site. These systems are presumably the recipients of a greater contribution and concentration of nutrients originating from animal excrements and food residues, which may lead to a process of eutrophication. The work aims to evaluate the effect of the flood pulse on the temporal and spatial variations of the limnological characteristics of a system associated with the presence of colonial aquatic birds.

Material and methods

The Corutuba nesting site is composed of the Baía Ninhal Corutuba and the Corixo Grande and Corixinho canals, which result from a complex drainage network formed locally by abandoned meanders, depressions and drainage canals fed by the Cuiabá river (Fig. 1). The Corutuba nesting site is located on the left-hand side of the Cuiabá river at its confluence with the Jacurutubinha stream, at 16°28'187"S and 56°07'536"W, downstream from the town of Barão de Melgaço in the state of Mato Grosso's Pantanal region.

The annual regime of the waters of the Corutuba nesting system comprises two periods: the flood phase (the flooding and full flood phases), which coincides with the rainy season (from October to April), and the dry phase (the ebbing and dry phases), the months of drought and highest evaporation rates (Fig. 2a). The Corutuba nesting system is surrounded by a seasonally flooded forest whose trees are used as supports for the construction of the colonial birds' nests. This bay is linked to other waterbodies only during the flood period (from November to April) and is totally isolated during the dry season (from May to October). The Corixinho is connected to the Corixo Grande during the flood period. The Corixo Grande displays a low relief, draining its waters into the Cuiabá river, to which it is linked during the flood months, and disconnected only at the peak of the dry season (in September and October). At the peak of full flood, the waters of the Cuiabá river and the Jacurutubinha stream overflow the banks, flooding the forest and all the Corutuba nesting system. At the beginning of the dry season, the waters flow from the plains toward the rivers, especially to the Corixo Grande.

During the study period, a maximum depth of 1.05 meters was recorded in the Baía Ninhal Corutuba in the dry season and about 4.00 meters in the flood season. A mapping of the vegetal cover performed during the dry season revealed that the species Pistia stratiotes covered 3,339m^2, followed by Eichhornia crassipes (790m^2) and Hydrocotyle ranunculoides (168m^2).

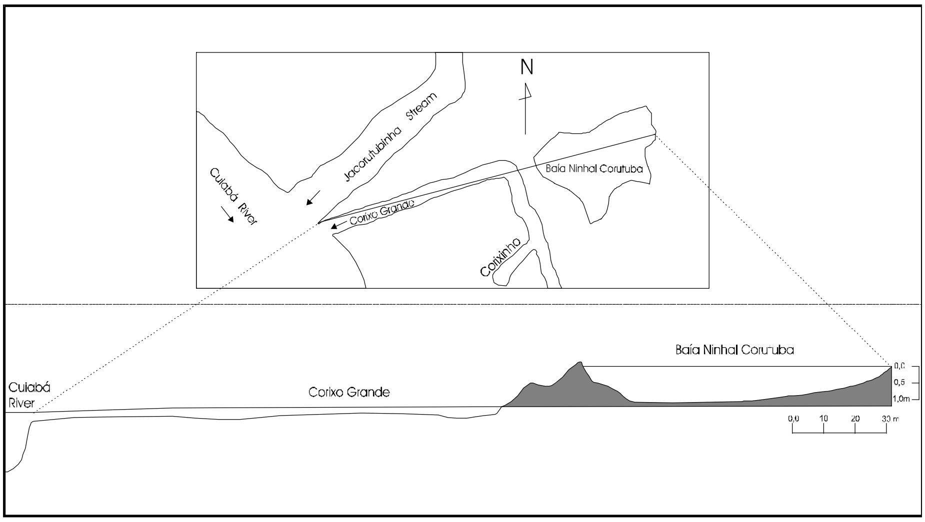

Figure 1: Sketch of the Corutuba nesting site. Corixo Grande and Corixinho (coordinates 16°28'187"S and 56°07'536"W) in relation to the Cuiabá River and topographic profile up to the junction with the Cuiabá river, during the dry period.

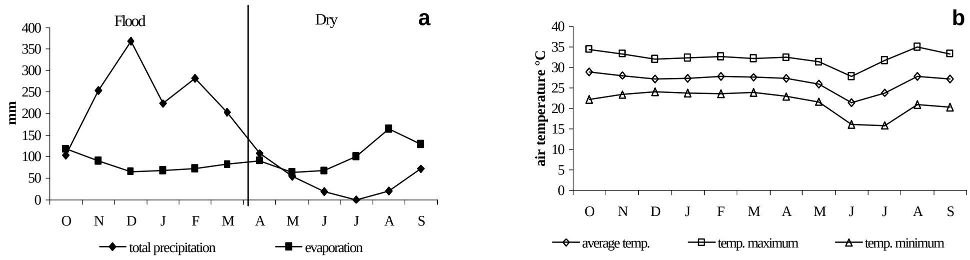

Figure 2: a) Total precipitation and evaporation. b) Monthly average of air temperature (average, maximum and minimum) at the Agrometeorological Station of Santo Antônio do Leverger from September 1995 to September 1996.

The water column of the Corixinho varied from 2.88 to 0.07 meters, while that of the Corixo Grande varied from 2.95 meters in full flood to completely dry during the drought. These water bodies were covered with the following species: Eichhornia crassipes, Pontederia rotundifolia, Eichhornia azurea, Pistia stratiotes, Ceratopteris pteridoides, Lemna sp., Hydrocotyle ranunculoides, Polygonum acuminatum, Oxycaryum cubense, Salvinia auriculata and Azolla sp. These aquatic macrophytes were concentrated during the dry season and spread out during full flood, leaving spaces of open water. The Cuiabá river near the Corutuba nesting site showed a water level varying from 1.22 meters in the dry season to 4.85 meters in full flood. Eichhornia azurea and Pontederia rotundifolia were recorded along the banks of the Cuiabá river.

The data on average monthly rainfall, air temperature and evaporation for 1995 and 1996 were supplied by the Agrometereological Post of the Federal University of Mato Grosso's Center for Agrarian Sciences, located in the municipality of Santo Antônio de Leverger (at 15°47' S and 56° 04' W; a.s.l. 140 meters) at 66 km from the municipality of Barão de Melgaço.

Monthly data were collected from October 1995 to September 1996 in the Corutuba nesting system. The following data were measured: depth of the water column (using a weighted and graduated cable), dissolved oxygen (Sat.%) (WTW 196 oximeter), pH (SET/WTW 320 pHmeter), electrical conductivity of the water (WTW 196 conductivimeter), water turbidity (HACH 2100 turbidimeter), water temperature (thermistor of the oximeter and the pHmeter) and air temperature (thermometer with a mercury bulb). These measurements were taken from 11 a.m. to 1 p.m. under the bank of Pistia stratiotes (Baía Ninhal Corutuba), Eichhornia azurea (Corixo Grande) and over open water (Corixinho and Cuiabá river).Water samples were also collected for the determination of ammonium, nitrate and orthophosphate (Goltermann et al., 1978; Mackereth et al., 1978); total nitrogen and phosphorus (damp oxidation digestion method by Anderson & Ingram, 1996, and determination by the colorimetric method by Goltermann et al., 1978; Mackereth et al., 1978; Allen, 1989), and calcium and magnesium (by Flame Atomic Absorption Spectrophotometry Perkin Elmer, according to Allen, 1989; Anderson & Ingram, 1996).

The relation between the water bodies and the physicochemical variables was based on a principal component analysis (PCA), using the PC-ORD, V 4.0 program (McCune & Mefford, 1999). Pearson's linear correlation was also calculated to identify the degree of relationships of the analyzed variables.

Results

The maximum air temperature varied from 34.9°C (August 1996) to 27°C (June 1996) while the minimum air temperature varied from 24.5°C (January 1996) to 15.8°C (June 1996) (Fig. 2b).

The behavior of the limnological variables of the Baía Ninhal Corutuba, Corixo Grande, Corixinho and Cuiabá river showed a pattern of variation inverse to that of the water during the annual cycle (Figs. 3 and 4). Turbidity in all the environments was highest in December, in the rainy season, diminishing over the subsequent months, when the water depth exceeds 2 meters. During the dry season, the Baía Ninhal Corutuba stands out for its highest values of electrical conductivity of the water (average of 272 mS/cm) and the greatest concentrations of nutrients (average of 7.50 mg/L of total nitrogen, 0.61mg/L of ammonium ions, 0.10 mg/L of orthophosphate, 0.85 mg/L of total phosphorus, 17.40 mg/L of calcium, and 8.51mg/L of magnesium). These contents are followed in a decreasing order by those of the Corixo Grande, the Corixinho and the Cuiabá river. During the full flood period, only the nitrate presented higher values (0.1 mg/L).

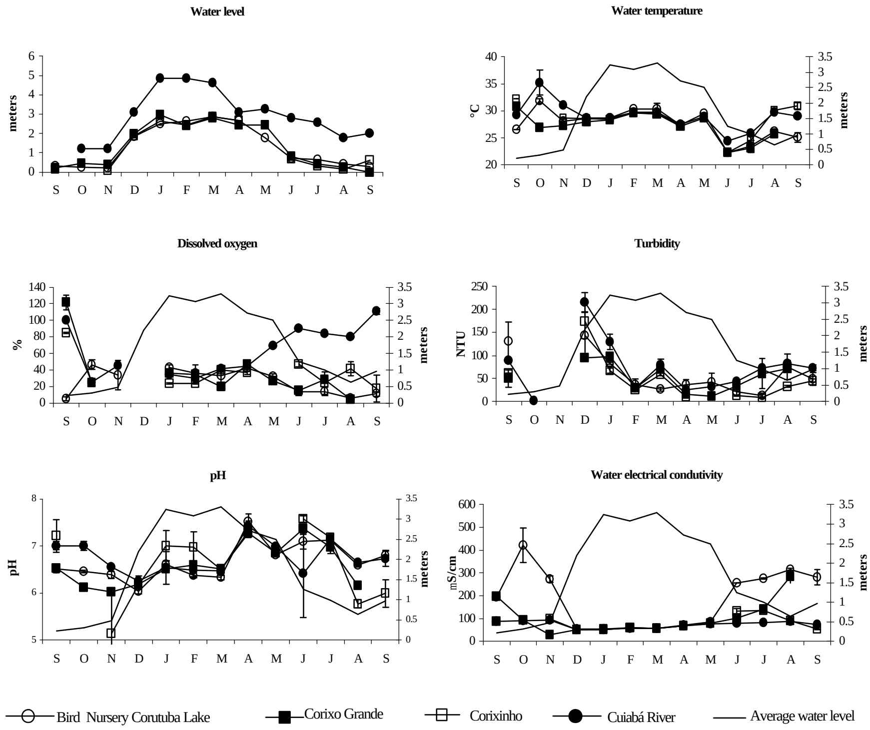

Figure 3: Water level on the four waterbodies and monthly average and standard deviation of water temperature, turbidity, dissolved oxygen (% sat.), water electrical conductivity and pH of the Baía Ninhal Corutuba, Corixinho, Corixo Grande and Cuiabá river, from October 1995 to September 1996.

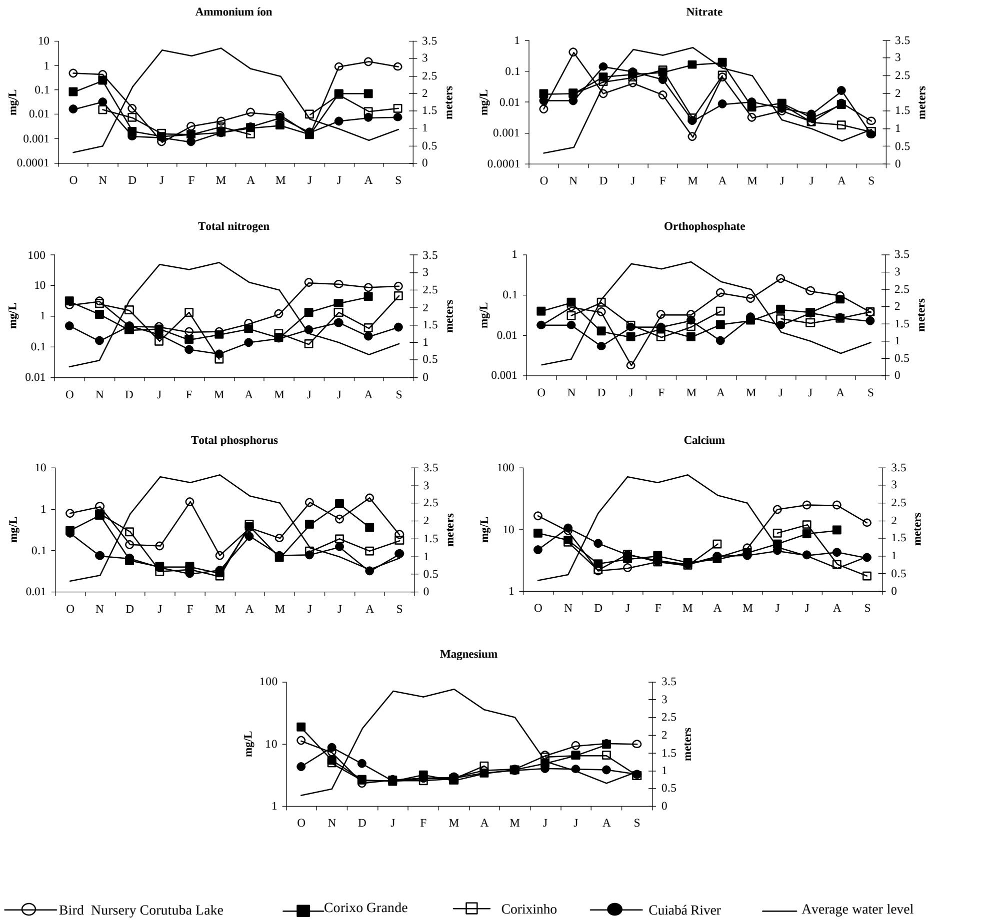

Figure 4: Monthly average of ammonium ion, nitrate, total nitrogen, orthophosphate, total phosphorus, calcium and magnesium from the water of Baía Ninhal Corutuba, Corixinho, Corixo Grande and Cuiabá River, from October 1995 to September de 1996.

The PCA of the four sampling sites, based on the physical and chemical variables, shows a similar behavior for all the sites during the full flood phase and a dispersion of these variables in the dry season. The first two axis of the PCA correspond to 82.84% of the variance, distributed as axis1 = 64.47%, axis2 =18.37%. Axis1 was interpreted as the flood gradient (flood pulse) related positively with the water level and negatively with nutrients. Axis 2 represents the nitrate and turbidity gradient (positive), and pH and dissolved oxygen (negative). The highest values for the eigenvectors were: total nitrogen (-0.3363), electrical conductivity (-0.3331) and calcium (-0.3214) for axis1. In axis 2, the highest eigenvectors were: pH (0.5466), nitrate (-0.4303) and turbidity (-0.3770) (Tab. I).

The PCA revealed that the difference between the Baía Ninhal Corutuba and the other water bodies during the dry season is due to the influence of high concentrations of nutrients, such as total nitrogen (axis 1; r = -0.97), calcium (axis 1; r = -0.93), magnesium (axis 1; r = -0.89), orthophosphate (axis 1; r = -0.91), ammonium ions (axis 1; r = -0.84) and total phosphorus (axis 1; r = -0.80) and conductivity (axis 1; r = -0.96) (Fig. 5).

The Corixo Grande and the Corixinho are similar. They are correlated with mean values of nutrient concentrations, differing only by the higher concentration of magnesium for the Corixo Grande and high pH (axis 1, r = -0.39; axis 2, r = -0.84) for the Corixinho. During the dry season (RCd), the Cuiabá river displayed the greatest similarity with other stations taken during the flood season. The PCA shows a positive correlation with axis 1 (temperature), but it differs for its high pH and oxygen concentration (axis 1, r = 0.54; axis 2, r = -0.46).

Table I: PCA eigenvectors values of limnological variables from Baía Ninhal Corutuba, Corixo Grande, Corixinho and Cuiabá River.

Variable	eigenvectors	
	1	2
Water electrical conductivity	-0.3331	-0.0794
Turbidity	0.2272	-0.3770
Dissolved oxygen (% sat.)	0.1877	0.3009
Water temperature	0.2994	-0.1177
pH	-0.1342	0.5466
Calcium (Ca)	-0.3214	-0.1007
Magnesium (Mg)	-0.3106	0.0632
Water level	0.2770	-0.2261
Ammonium ion (NH_4-N)	-0.2919	-0.2138
Nitrate (NO_3-N)	0.2096	-0.4303
Orthophosphate (PO_4-P)	-0.3138	-0.1982
Total nitrogen (Ntotal)	-0.3363	-0.1165
Total Phosphorus (Ptotal)	-0.2781	-0.3152

The temperature (axis 1, r = 0.86), water level (axis 1, r = 0.80), turbidity (axis 1, r = 0.65) and nitrate (axis 1, r = 0.60 and axis 2, r = 0.66) were correlatel to axis 1 of the PCA, which is in agreement with the grouping of the stations (Baía Ninhal Corutuba – BNCf; Corixo Grande – CGf; Corixinho – Cf; Cuiabá River – CRf), from the flood period (Fig. 5).

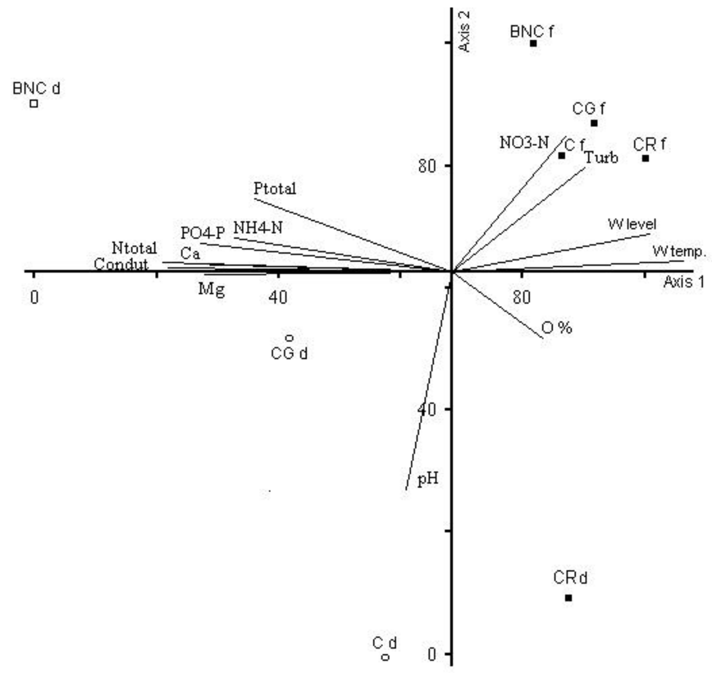

Figure 5: Principal Component Analysis (PCA) between Baía Ninhal Corutuba (BNC), Corixo Grande (CG), Corixinho (C) and Cuiabá River (CR), based on physical variable (W temp. - water temperature, W level - water level, Turb.- turbidity, O% - dissolved oxygen, pH, Condut. – water electrical conductivity) and chemical variables (NO_3-N – nitrate, NH_4-N – ammonium ion, PO_4-P – orthophosphate, Ntotal – total nitrogen, Ptotal – total phosphorus, Ca – calcium, Mg – magnesium) analysed during the flood (f) and dry periods (d).

Pearson's correlations revealed negative relationships of the nutrients in all the water bodies with the water level (Tab. II). The only positive correlation of the water level with nitrate was found for the Corixo Grande and the Corixinho. This behavior in nutrient concentrations with the water level was due to a dilution effect in the flood period.

Positive correlations of water conductivity with nutrients were found for Baía Ninhal Corutuba (Tab. III). In the Corixo Grande, a significant correlation between calcium and total nitrogen was obtained while in the Corixinho, a correlation of conductivity with magnesium, calcium and ammonium ions was found. No significant correlation was obtained for Cuiabá river.

Table II: Pearson Correlation between water level and the nutrients of the Baía Ninhal Corutuba, Corixinho, Corixo Grande and Cuiabá River. (* = p<0.05)

Variable	water level							
	Baía Ninhal Corutuba		Corixo Grande		Corixinho		Cuiabá River	
	r	p	r	p	r	p	r	p
Ammonium ion (NH_4-N)	-0.71*	0.0091	-0.67*	0.0241	-0.6	0.0682	-0.71*	0.0091
Nitrate (NO_3-N)	-0.26	0.4235	0.71*	0.0136	0.66*	0.0388	0.39	0.2162
Total nitrogen (Ntotal)	-0.79*	0.0024	-0.83*	0.0016	-0.4	0.1964	-0.45	0.1318
Orthophosphate (PO_4-P)	-0.25	0.4295	-0.88*	0.0004	-0.1	0.7733	-0.16	0.6350
Total Phosphorus (Ptotal)	-0.42	0.1780	-0.69*	0.0185	-0.34	0.3371	-0.48	0.0972
Calcium (Ca)	-0.79*	0.0023	-0.91*	0.0001	-0.39	0.2616	-0.55	0.0706
Magnesium (Mg)	-0.9*	0.0001	-0.67*	0.0235	-0.74*	0.0146	-0.64*	0.0291
Turbidity	0.06	0.8742	-0.14	0.6805	0.25	0.5120	0.21	0.2882
Water electrical conductivity	-0.93*	0.000	-0.54	0.0892	-0.81*	0.0088	-0.84*	0.0007
Dissolved oxygen (% sat.)	0.54	0.0897	0.55	0.0803	-0.04	0.9200	-0.34	0.3609
pH	-0.04	0.9062	0.23	0.5034	0.4	0.2896	-0.26	0.4067

Table III: Pearson Correlation between water electrical conductivity and the nutrients of the Baía Ninhal Corutuba, Corixinho, Corixo Grande and Cuiabá River. (* = p<0.05)

Variable	water electrical conductivity							
	Baía Ninhal Corutuba		Corixo Grande		Corixinho		Cuiabá River	
	r	p	r	p	r	p	r	p
Ammonium ion (NH_4-N)	0.71*	0.0091	0.02	0.9503	0.72*	0.0271	0.68*	0.0151
Nitrate (NO_3-N)	0.13	0.6829	-0.4	0.2194	-0.61	0.0839	-0.69*	0.0130
Total nitrogen (Ntotal)	0.72*	0.0085	0.84*	0.0013	0.09	0.7409	0.23	0.4770
Orthophosphate (PO_4-P)	0.21	0.5077	0.65	0.3020	-0.18	0.6473	0.49	0.1021
Total Phosphorus (Ptotal)	0.46	0.1306	0.27	0.4133	0.15	0.6951	0.38	0.2183
Calcium (Ca)	0.83*	0.0008	0.72*	0.0134	0.87*	0.0021	0.39	0.2128
Magnesium (Mg)	0.97*	0.0000	0.41	0.2134	0.9*	0.0010	0.52	0.0865

Discussion

The effects of the flood pulse as a homogenizing agent among the studied water body systems was evidenced through the limnological variables (dissolved oxygen, water electrical conductivity, pH, ammonium ion, total nitrogen, orthophosphate, total phosphorus, calcium and magnesium). The lowest values and the lowest variation amplitudes among water body were recorded in the period of high waters. This fact had already been observed in the floodplain system of the Paraná river (Thomaz et al., 1997).

Studies conducted in the Pantanal show that the limnological variables, particularly electrical conductivity, display different temporal and spatial variations (Tab. IV), that were related with the flood pulse (Da Silva & Esteves, 1995; Pinto da Silva, 1991; Da Silva & Figueiredo, 1999; Heckman, 1994; Pinto et al., 1999). The high values of electrical conductivity recorded in the Baía Ninhal Corutuba, Corixo Grande and Corixinho during the dry season are due to the presence of colonial birds, no found in other systems studied in the Pantanal.

Table IV: Water electrical conductivity values in different studies done in the Pantanal of Mato Grosso.

Basin	site	flood	dry	References
Cuiabá River	Baía Ninhal Corutuba	52	421	present study
	Corixo Grande	50.26	282	
	Corixinho	50.43	135	
	Cuiabá River	51	89	
	Porto de Fora Lake	58.0	17.8	Da Silva & Esteves (1995)
	Acurizal Lake	53.4	19.3	
	Buritizal Lake	54.0	47.0	Pinto da Silva (1991)
	Chacororé Lake	49.2	41.3	Da Silva & Figueiredo (1999)
	Sá Mariana Lake	46.2	33.44	
	Sá Mariana Lake	33	13.76	Pinto et al. (1999)
Bento Gomes River	Bento Gomes River	70.0	120.0	Heckman (1994)

In the dry season, the water bodies of the Corutuba nesting system disconnect at different times and presented differences in their limnological variables. The Baía Ninhal Corutuba remain disconnected for a longer period and is more strongly influenced by the bird colonies than the Corixo Grande and Corixinho. According to PCA, the four sites are one group in the flood period because of the dilution effect, a separation between the lakes in the dry period, after the morphology of the water bodies, the presence of colonial birds, and the lateral dimension of the connectivity.

Ward & Stanford (1989) define connectivity as the transfer of energy through the riverine landscape, whose interactive routes can be evaluated in three dimensions: the longitudinal (headwaters – mouth), the lateral (river – floodplain) and the vertical axis (river – groundwater). According to Pringle (2001), the lateral dimension of connectivity represents one of the most important attributes of the flood pulse to describe the dynamics of floodable ecosystems.

Thus, these systems are controlled, by the flood pulses that can differ from one geographic region to another: within the same region – as in the Pantanal, and locally – as in the Corutuba nesting system, as a function of biological controls, represented by the nesting site. Through the lateral connectivity, the flood pulse maintains the dynamics and the ecological continuity of the Corutuba nesting site system, renewing the water each year and thereby preventing the eutrophication.

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