Copepod (Crustacea) distribution in the freshwater and hyposaline lakes of the Pantanal of Nhecolandia (Mato Grosso do Sul, Brazil)

Distribuição de Copepoda (Crustacea) nos lagos de água doce e hiposalinos do Pantanal de Nhecolândia (Mato Grosso do Sul, Brasil)

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Abstract: Aim: Eighteen freshwater and hyposaline lakes of the Nhecolândia floodplain were sampled in two periods, April/03 (beginning of dry period) and March/04 (end of wet period). **Methods:** Ten limnological parameters were measured and the copepod communities analyzed. **Results:** The limnological results identified five hyposaline lakes with salinities greater than 0.5‰. Three calanoid and five cyclopoid species were identified. Their distributions are discussed in relation to limnological factors. **Conclusions:** Only the cyclopoid *Metacyclops mendocinus* was found in the most saline (2.8‰) system.

Keywords: Copepoda, floodplain, Pantanal, limnology.

Resumo: Objetivo: Dezoito lagoas de água doce e de água hiposalina do Pantanal da Nhecolândia foram amostrados em dois períodos, abril/03 (inicio da seca) e março/04 (fim da cheia). **Métodos:** Dez parâmetros limnológicos foram medidos e a comunidade de Copepoda (Crustacea) foi analisada. **Resultados:** Os resultados mostraram cinco ambientes salinos com salinidade acima de 0,5‰. Foram identificados três espécies de Copepoda Calanoida e cinco de Copopepoda Cyclopoida. As distribuições destes organismos são discutidas relacionando com os fatores limnologicos dos corpos de água. **Conclusões:** A espécie de Cyclopoida *Metacyclops mendocinus* foi a única registrada em ambientes altamente salinos (2.8‰).

Palavras-Chave: Copepoda, planície de inundação, Pantanal, limnologia.

1. Introduction

Despite the great socio-economic and scientific value of the Pantanal wetland (declared a Reserve of the Biosphere. and Patrimony of Mankind by UNESCO in the year 2000) and evidence of growing anthropogenic impacts (Ferreira et al., 1994; Swarts, 2000), relatively few limnological studies have been carried out, with most in the north (Junk and Silva, 1995).

The Pantanal is a large area of approximately 210,000 km^2, periodically flooded by rivers and rainfall. Some areas are more affected by rivers while others are more influenced by rainfall. The flood-pulse is the main forcing-function of these environments, driving the ecological and biological dynamics (Junk et al., 1989).

The Nhecolândia sub-region is about 42,000 km^2 in area, with flooding arising principally from rainfall. Geological, topographical and water balance (rain and evaporation) characteristics have created thousands of lakes with different degrees of coalescence and degrees of salinity (Silva and Abdon, 1998; Sakamoto et al., 1999). In this region, there are two kinds of lakes, visually distinguishable, the co-called "Baías" characterized by the presence of macrophytes and freshwater, and the "Salinas" characterized by a lack of macrophytes, the formation of beaches and elevated salt concentration of the water. The latter type of environment usually does not coalesce with other water bodies.

The few works on limnology and aquatic biodiversity of this area include Mourão et al. (1988) on the fish fauna, Reid (1997) and Reid and Moreno (1990) on the Copepoda, and Medina Júnior and Rietzler (2005) on the zooplankton. For the entire Pantanal, studies including copepods have been made by Espíndola et al. (1996), Ishii et al. (1997) and Rocha and Por (1998).

The present study aimed at carrying out an inventory of the copepod fauna of 18 water-bodies of the Nhêcolandia sub-region in two periods, with an examination of species richness, and correlation of species distributions with physical and chemical characteristics of the waters.

1.1. Study area

The Pantanal is a large sedimentary plain situated in the depression of the Paraguay River basin. The Nhecolândia sub-region occupies about 18% of the Pantanal, being limited by the Rivers Paraguay, Taquarí and Negro (Figure 1). This sub-region is characterized by a large number of small water-bodies, with a great variety of morphologies, degree of permanency and inter-connectedness, and water chemistry (from fresh to hyposaline). The freshwater lakes generally possess more or less dense populations of macrophytes, while the hyposaline lakes are alkaline, with high concentrations of sodium bicarbonate, and are devoid of macrophytes (Mourão et al., 1988).

2. Material and Methods

Table 1 shows the geographic coordinates of the eighteen water-bodies sampled, all located on the Nhecolândia floodplain (Figure 1). Qualitative samples were collected, in April/03 and March/04, using a plankton net of 40 µm mesh size, and preserved in neutralized formaldehyde at a concentration of approximately 4%. Water temperature, pH and conductivity were measured in situ using a YSI probe. Chemical characteristics of the waters were analyzed in the laboratory using standard methodology.

For taxonomic analysis, entire samples were examined. For quantitative analysis, copepod adults were identified and counted in sub-samples using a dissecting microscope. Identification was carried out using the general keys of Reid (1985) and Matsumura-Tundisi (1986), and specialized keys.

Pearson correlation was carried out between conductivity and selected physical and chemical characteristics.

3. Results

The values of the physical and chemical characteristics for each lake in the 2003 and 2004 campaigns are shown in Tables 2 and 3. In 2004, one less lake was analyzed as number fourteen was dry. Two categories may be identified: “baías”, with salinity lower than or equal to 0.50‰, and “salinas” (hyposaline), with salinity over 0.50‰. In the “salinas”, there were no macrophytes, while in the “baias”, macrophyte growth was often extensive.

The results of the correlation between conductivity and physical and chemical characteristics (Table 4) show that in 2003, conductivity was strongly positively correlated with salinity and alkalinity. In 2004, strong positive correlations were found with salinity, alkalinity, pH, and sodium. The waters generally had higher ionic concentrations in 2003.

Three Calanoida species, two *Notodiaptomus* and one *Argyrodiaptomus*, and five species of Cyclopoida, in four genera: *Metacyclops, Microcyclops, Mesocyclops* and *Thermocyclops*, were found (Tables 5 and 6).

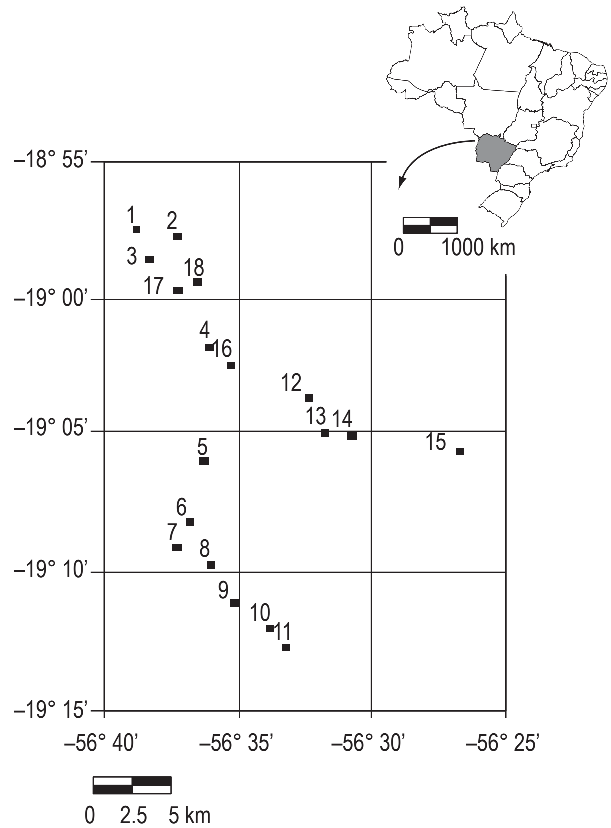

Figure 1. Localization of Mato Grosso do Sul State in Brazil, and distribution of the lakes sampled within the Pantanal of Nhecolândia.

Table 1. Geographic coordinates of the eighteen water bodies studied.

Water body number	Geographic coordinates
1	18° 57’ 56.8” S and 56° 38’ 01.8” W
2	18° 57’ 88.5” S and 56° 37’ 19.6” W
3	18° 58’ 33.3” S and 56° 38’ 50.1” W
4	19° 02 57.6” S and 56° 36’ 23.8” W
5	19° 06’ 13.0” S and 56° 36’ 28.0” W
6	19° 08’ 14.6” S and 56° 37’ 05.6” W
7	19° 08’ 29.7” S and 56° 37’ 13.2” W
8	19° 09’ 25.4” S and 56° 36’ 20.1” W
9	19° 11’ 33.4” S and 56° 35’ 40.2” W
10	19° 12’ 22.7” S and 56° 34’ 45.4” W
11	19° 12’ 31.7” S and 56° 34’ 28.4” W
12	19° 04’ 02.8” S and 56° 32’ 14.3” W
13	19° 05’ 03.0” S and 56° 31’ 50.8” W
14	19° 05’ 16.4” S and 56° 30’ 52.9” W
15	19° 05’ 30.9” S and 56° 27’ 18.7” W
16	19° 03’ 47.1” S and 56° 35’ 23.1” W
17	18° 59’ 44.0” S and 56° 37’ 27.2” W
18	18° 59’ 14.8” S and 56° 37’ 12.9” W

Table 2. Values of the physical, chemical and biological characteristics of the water-bodies analyzed in 2003.

Locality	Temp.	pH	Oxygen (mg.L^{-1})	Conductivity (µS.cm^{-1})	Salinity (‰)	Alkalinity (meq.L^{-1})	Total Nitrogen (µg.L^{-1})	Total Phosphorus (µg.L^{-1})	K (µg.L^{-1})	Na (µg.L^{-1})
1	29.3	7.9	1.3	1203	0.5	8116	2009	137	198	211
2	35.2	9.9	10.7	3253	1.7	28477	99	561	178	208
3	32.5	9.8	7.9	6060	2.8	30294	56	435	130	169
4	28.5	6.7	0.3	291	0.1	2656	1360	22	58	45
5	28.0	6.8	2.9	104	0.1	686	1094	228	10	10
6	28.5	6.8	3.3	276	0.1	1082	2966	46	49	42
7	40.0	9.1	6.6	1293	0.5	9391	1264	1088	136	168
8	30.9	7.3	1.5	410	0.2	3302	1235	204	101	238
9	32.1	9.7	5.0	3428	1.6	30282	89	1193	383	549
10	30.1	8.9	2.3	2230	1.0	20209	3270	65	22	14
11	31.4	6.1	0.8	120	0.1	454	7305	140	13	10
12	27.6	6.7	2.1	165	0.1	1068	4974	396	19	5
13	30.0	8.5	6.3	113	0.1	658	992	105	19	11
14	31.0	6.4	4.1	39	0.0	208	725	36	10	5
15	32.0	6.3	6.0	27	0.0	33	-	-	7	8
16	29.3	6.8	2.5	335	0.1	1889	2225	98	89	43
17	26.7	6.6	0.8	179	0.1	1471	1217	161	20	16
18	29.0	8.2	3.8	1245	0.6	6207	60	652	274	149

Table 3. Values of the physical, chemical and biological characteristics of the water-bodies analyzed in 2004. Lake 14 was dry on the date of sampling.

Local	Temp.	pH	Oxygen (mg.L^{-1})	Conductivity (µS.cm^{-1})	Salinity (‰)	Alkalinity (meq.L^{-1})	Total Nitrogen (µg.L^{-1})	Total Phosphorus (µg.L^{-1})	K (µg.L^{-1})	Na (µg.L^{-1})
1	30.0	7.30	0.40	684	0.3	5309	3872	313	51	51
2	34.0	10.30	19.80	1140	0.5	8145	54	263	240	164
3	36.9	10.10	24.70	2116	1.1	12208	946	169	155	358
4	30.3	6.80	1.50	186	0.1	1747	1446	66	33	14
5	33.0	6.70	13.00	114	0.1	622	3447	337	13	6
6	29.1	6.50	2.70	220	0.1	1235	877	163	23	23
7	32.5	8.70	4.80	1173	0.5	12363	1652	3105	166	243
8	33.5	7.50	6.80	365	0.2	3118	1525	38	18	66
9	36.0	9.60	21.20	2099	0.9	18648	113	463	187	282
10	36.3	9.00	6.40	1569	0.6	13737	1248	3184	157	247
11	34.5	6.20	4.80	68	0.0	317	458	25	20	17
12	28.8	6.20	2.10	114	0.1	862	3192	101	8	9
13	29.1	6.30	4.40	128	0.1	1022	1494	410	17	8
15	29.5	6.20	0.60	142	0.1	817	1770	61	2	3
16	33,9	7.05	11.98	220	0.1	1476	2475	125	49	14
17	34.4	6.50	10.50	151	0.1	1331	1026	152	15	5
18	33.8	6.80	3.00	438	0.2	3200	2644	1032	88	62

Table 4. Values of the Pearson Correlation Coefficient for conductivity versus physical and chemical characteristics (n = 18) Values with p < 0.005 are indicated in bold.

Characteristics	Year	
	2003	2004
pH	**0.84**	**0.92**
DO	0.60	**0.71**
Salinity	**0.99**	**0.99**
Alkalinity	**0.94**	**0.96**
Total Nitrogen	–0.41	–0.39
Total Phosphorus	0.48	0.41
K	0.57	**0.86**
Na	0.58	**0.98**

In 2003, only nine of the eighteen lakes presented copepod species, while in 2004, all lakes presented some species. Richness in 2003 was high in Lake 1, with 5 species (two Calanoida and three Cyclopoida). Although classified as a freshwater lake (a Baía), the conductivity was high. In 2004, 2 lakes had 4 species, one with three Calanoida and one Cyclopoida, and the other with two Calanoida and two Cyclopoida.

The endemic calanoid species *Argyrodiaptomus nhumirim* was present in four freshwater lakes in 2003, and in three in 2004, but only water-body number 16 presented this species in both periods. The other two calanoid species,

Table 5. Percentage occurrence of the copepod species in the water-bodies sampled in 2003. Hyposaline environments are indicated in grey.

Species(%)/localites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Argyrodiaptomus nhumirim	33		**	**		28				**	15	**		**		17		
Notodiaptomus henseni	22		**	30		**				**	27	**		70		43		
Notodiaptomus coniferoides	**		**	45		**				80	34	35		4		**		
Metacyclops mendocinus	**		56	**		**				**	**	**		**		**		
Microcyclops anceps anceps	3		**	**		12				**	4	**		**		22		
Mesocyclops longisetus curvatus	8		**	**		**				**	**	**		**		**		
Mesocyclops meridianus	8		**	**		**				**	**	**		**		**		
Thermocyclops decipiens	**		**	**		**				**	**	**		**		17		
Copepodite Calanoida	19		**	**		**				20	17	65		26		**		
Copepodite Cyclopoida	6		44	25		60				**	4	**		**		**		

Table 6. Percentage occurrence of the copepod species in the water-bodies sampled in 2004. Hyposaline environments are indicated in grey.

Species(%)/localites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Argyrodiaptomus nhumirim	**	**	**	20	**	**	**	**	**	**	**	23	**		**	7	**	**
Notodiaptomus henseni	17	**	**	25	**	**	**	11	**	**	**	31	69		**	25	32	**
Notodiaptomus coniferoides	**	9	**	**	81	**	**	11	**	**	43	38	8		**	**	36	**
Metacyclops mendocinus	67	75	31	**	**	**	76	**	42	**	2	**	**		**	**	**	20
Microcyclops anceps anceps	**	**	**	**	10	**	24	78		100	**	**	**		**	**	11	60
Mesocyclops longisetus curvatus	**	**	**	**	**	**	**	**	**	**	**	**	**		100	**	**	**
Mesocyclops meridianus	**	**	**	**	**	**	**	**	**	**	**	**	**		**	**	4	20
Thermocyclops decipiens	**	**	**	25	**	100	**	**	**	**	10	8	**		**	18	**	**
Copepodite Calanoida	**	**	**	10	**	**	**	**	**	**	**	**	15		**	**	11	**
Copepodite Cyclopoida	17	16	69	20	10	**	**	**	58	**	45	**	**		**	50	7	**

Notodiaptomus henseni and *N. coniferoides*, were present in more water-bodies in 2004 than in 2003. The same was generally true for the cyclopoid species. *Metacyclops mendocinus* was present in seven water-bodies in 2004, while in 2003, it was present in only one, a hyposaline lake.

4. Discussion

In the sub-region of Nhecolândia, the inundated areas are rarely influenced by river waters. Mámora et al. (2004) related the higher degree of conductivity in March/03, as compared to April/04, of the lakes of the present study, to a greater degree of precipitation in the months preceding the samplings of 2004. This shows that the physical and chemical characteristics of the water in the "salinas" is not constant, capable of varying from fresh to hyposaline along the course of the hydrological period. This pattern is analogous to the dynamics of estuaries, where spatial change is the main forcing function (Tundisi and Matsumura-Tundisi, 1968; Tundisi and Matsumura-Tundisi, 2008), while in the hyposaline systems, the main forcing function is seasonal.

Elevated levels of salinity were a barrier for most of the copepods, with the hyposaline lakes tending to contain more copepod species in 2004, when salinity levels were lower. *Mesocyclops mendocinus* was the only species found in the most hyposaline water, as also recorded by Reid and Moreno (1990) and Medina Junior and Rietzler (2005).

The Calanoida species showed a lower range of tolerance to salinity than the Cyclopoida species. Tundisi (unpubl. data), in experiments on the salinity tolerance of copepods from Barra Bonita Reservoir, observed a similar tendency, with Cyclopoida being more tolerant than Calanoida. Matsumura-Tundisi and Silva (1968) pointed out that Cyclopoida species distribution, with low endemism, and Calanoida species distribution, with high endemism, might be promoted by the different degrees of environmental tolerances presented by these two groups.

Of the three species of Calanoida found, two were registered by Reid (1997), while the other is a new record, *Notodiaptomus henseni*. However, in the latter work, an unidentified *Notodiaptomus* species was recorded. The *Argyrodiaptomus nhumirim* registered is an endemic species of the Nhecolândia system (Reid, 1997). In contrast to the others, this species was more widely distributed in 2003 than in 2004.

Other environmental features at present under study may elucidate further the factors governing the distribution of the copepod species in this lakes district. For example, Reid and Moreno (1990) found the large-bodied species

Argyrodiaptomus nhumirim and *Mesocyclops longisetus* only in freshwater lakes lacking fish.

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