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Copepods (Crustacea, Maxillopoda) from shallow reservoirs

Copépodes (Crustacea, Maxillopoda) em reservatórios rasos

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Abstract: Aim: Among the planktonic microcrustaceans, copepods Cyclopoida and Calanoida are the most representative groups, being the largest biomass of the plankton community. The aim of this work is to catalogue and analyze the distribution of copepod species (Crustacea, Maxillopoda) in pelagic and littoral zones from small reservoirs in the northwest of the São Paulo State, in dry and rainy seasons (2007 and 2009). **Methods:** Zooplankton samplings were carried out in littoral and pelagic zones of 13 small shallow reservoirs (mean depth: 2.6 m) using vertical hauls and plankton net (45 µm). Water physical and chemical parameters were also monitored with a multiparameter Horiba® U10. **Results:** Eighteen species of copepods were identified, 13 Cyclopoida and 5 Calanoida. There was no statistical difference between the distributions of species from the littoral and pelagic zones and neither between dry and rainy seasons. Three species occurred exclusively in the littoral zone - *Eucyclops elegans, Paracyclops chiltoni* and *Mesocyclops ogunnus*. *Tropocyclops prasinus* and *Thermocyclops decipiens* were the most frequent species in the studied environments. **Conclusion:** Our data suggest that in shallow reservoirs copepods present a homogeneous distribution between the littoral and pelagic zones and Cyclopoida are more diverse than Calanoida. Shallow depths and eutrophic state may be regarded as limiting conditions for the development of Calanoida in these reservoirs.

Keywords: copepods, cyclopoida, calanoida, littoral zone, shallow lakes.

Resumo: Objetivo: Dentre os microcrustáceos planctônicos, os copépodes Cyclopoida e Calanoida são um dos grupos mais representativos, contribuindo com a maior biomassa para a comunidade planctônica. O presente trabalho tem o objetivo de caracterizar as comunidades de copépodes (Crustacea, Maxillopoda) pelágicos e litorâneos presentes em pequenos reservatórios na região noroeste do Estado de São Paulo, nas estações seca e chuvosa de 2007 a 2009. **Material e métodos:** As amostragens foram realizadas tanto na zona litorânea quanto pelágica de 13 pequenos reservatórios rasos (média de 2,6 m), através de arrastos verticais com rede de plâncton (45 µm). Parâmetros físicos e químicos da água também foram avaliados utilizando-se o aparelho Horiba® U10. **Resultados:** Foram identificadas 18 espécies de copépodes, sendo 13 Cyclopoida e 5 Calanoida. Não houve diferença estatística entre as distribuições das espécies nas zonas litorâneas e pelágicas bem como entre as estações. Três espécies ocorreram exclusivamente na zona litorânea - *Eucyclops elegans, Paracyclops chiltoni* e *Mesocyclops ogunnus*. As espécies *Tropocyclops prasinus* e *Thermocyclops decipiens* foram as mais frequentes nos ambientes estudados. **Conclusão:** Nossos dados sugerem que, em reservatórios rasos, Copepoda não apresenta diferenças significativas na ocupação das regiões litorânea e pelágica e que a diversidade de Cyclopoida é maior do que Calanoida. Características tais como baixa profundidade e estado eutrófico podem ser consideradas como condições limitantes para o desenvolvimento de espécies de Calanoida nesses reservatórios estudados.

Palavras-chave: copépodes, cyclopoida, calanoida, zona litorânea, lagos rasos.

1. Introduction

Among microcrustacean planktonic, the copepods Cyclopoida and Calanoida are one of the most representatives, being the largest biomass of the plankton community (Rocha and Matsumura-Tundisi, 1984; González et al., 2008). These microcrustaceans can be found in a wide variety of lentic environments, in littoral and pelagic zones (Williamson and Reid, 2001). In the zooplankton community, copepods are commonly dominated by one or both species of the Calanoida and Cyclopoida.

Calanoida and Cyclopoida species have been recorded in São Paulo State since the late nineteenth and early twentieth century. However, it was from the 1970's that the knowledge about these microcrustaceans increased, when limnology studies from several reservoirs in the state were intensified (Matsumura-Tundisi and Silva, 1999).

Shallow reservoirs are found in almost all farms in country areas of Brazil. These lentic environments provide the establishment of zooplankton communities, which are important links in the trophic webs. The shallow characteristics of these aquatic ecosystems present, especially in its littoral areas, a high species richness of macrophytes which, while fostering diversity of habitats and micro-habitats, also increase the number of aquatic species. High zooplankton diversity has been linked with high macrophytes diversity in other studies (Matsumura-Tundisi et al., 1990; Nunes et al., 1996; Nogueira et al., 2003; Maia-Barbosa et al., 2008). Besides the diversity, high abundance of zooplankton has also been found in littoral areas (Walseng et al., 2006). These studies show the importance of zooplankton sampling in the littoral zones.

Few studies report the distribution of copepods species in littoral and pelagic zones in lentic aquatic environments. In shallow lakes, almost all species can be found in both zones, but specific information about the habitats preferences of adults and larval stages are scarce. As part of a wider project on the list of species of several groups of animals and plants (Program BIOTA/FAPESP- Virtual Institute of Biodiversity, www.biotasp.org.br), this project aims to survey Calanoida and Cyclopoida copepods species in small and shallow reservoirs in the northwestern region of São Paulo, characterizing its distribution in littoral and pelagic zones.

2. Material and Methods

2.1. Study Area

Samples were obtained from 13 small and shallow reservoirs located in rural areas in the northwest of the São Paulo State (Figure 1). The climate of the region is considered tropical, hot and rainy (Aw Köppen classification) with a dry season from April to September and a rainy season from October to March. The vegetation consists of semideciduous forest and savanna, which currently consists of only 9% of the original vegetation, as the

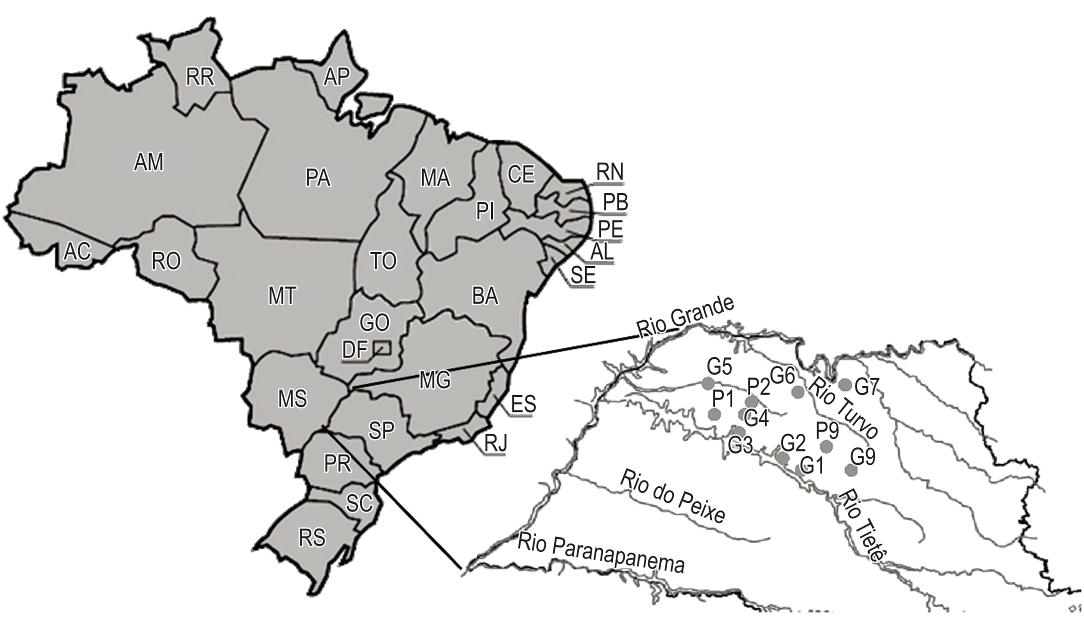

Figure 1. Map of the reservoirs in the northwestern State of São Paulo.

rest has been transformed into pastures, plantations and urban areas. Table 1 shows the sampling points and some characteristics of the reservoirs.

2.2. Sampling, qualitative and quantitative assessments of copepods

Samples were taken by vertical hauls with a 45 µm plankton mesh net in the littoral and pelagic zones of all reservoirs. In the littoral zone, sampling always took place in a macrophyte bed when it was available. Samples were taken in the dry season of 2007, wet and dry 2008 and wet 2009. Species identification was carried out under optical microscope, using specific identification keys (Sendacz and Kubo, 1982; Reid, 1985; Matsumura-Tundisi, 1986; Silva et al., 1989; Silva and Matsumura-Tundisi, 2005). Nauplii, copepodites and adults of Cyclopoida and Calanoida were counted in 1 mL-subsamples taken with the Stempel pipette, placed in the counting chamber and counted using a stereoscopic microscope. At least sixty individuals were numbered in each subsample; the coefficient of variation did not exceed 0.20, as recommended (McCauley, 1984). Low-density samples were fully counted.

The constancy of occurrence index of each species was calculated based on Dajoz (1972): $C = P/Q \times 100$, where: C = constancy of occurrence of the species (%), P = number of samples where the species occurred and Q = total number of samples. According to the result, the species can be classified as: Constant ($C > 50\%$); Acessorie ($25\% \leq C \leq 50\%$) or Accidental ($C < 25\%$). Richness, diversity of Shannon-Wiener, evenness and Simpson's dominance indices were calculated following the recommendations of Magurran (2011). T-test was used to compare data of diversity and abundance of Cyclopoida and Calanoida between the littoral and pelagic zones.

In the pelagic zone, some environmental variables such as depth (m) and water transparency (m) were measured with a Secchi disk, while other physical and chemical variables such as temperature (°C), dissolved oxygen ($mg.L^{-1}$), pH and conductivity ($\mu S.cm^{-1}$) were obtained with a multiparameter Horiba® U-10.

To verify the correlation between copepods' abundances and environmental variables, we performed a canonical correspondence analysis (CCA) with the CANOCO 4.5 (Ter Braak and Smilauer, 2002). Stability and significance of the CCA were evaluated by means of the Monte Carlo. Figure 2 lists the names of copepods with their respective codes used in the analysis.

Table 1. Location, depth, and characteristics of the reservoirs and land use in the northwest of São Paulo State.

Reservoirs	City	Coordinates	Depth	Land use
P1	Vicentinópolis	50 W 2051" and 20 S 560"	Littoral 0.5 m Pelagic 1.8 m	Forest and culture
P2	Macaubal	49 W 5613" and 20 S 4440"	Littoral 0.3 m Pelagic 2.4 m	Culture
P9	Pindorama	48 W 5541" and 21 S 1331"	Littoral 0.5 m Pelagic 3.6 m	Forest
G1	Novo Horizonte	49 W 1829" and 21 S 3010"	Littoral 0.8 m Pelagic 2.1 m	Culture
G2	Sales	49 W 2959" and 21 S 2533"	Littoral 0.3 m Pelagic 2.4 m	Forest
G3	Planalto	49 W 5841" and 21 S 0054"	Littoral 0.7 m Pelagic 3.8 m	Forest and culture
G4	União Paulista	49 W 5517" and 20 S 5428"	Littoral 2.1 m Pelagic 4.9 m	Culture
G5	Magda	50 W 1143" and 20 S 320"	Littoral 0.2 m Pelagic 1.3 m	Forest and culture
G6	Onda Verde	49 W 1615" and 20 S 3352"	Littoral 0.9 m Pelagic 3.7 m	Forest
G7	Barretos	48 W 5031" and 20 S 293,9"	Littoral 0.8 m Pelagic 1.8 m	Forest
G91	Matão	48 W 3312" and 21 S 3618"	Littoral 1.3 m Pelagic 2.4 m	Forest
G92	Matão	48 W 3247" and 21 S 3100"	Littoral 0.6 m Pelagic 1.9 m	Forest
G93	Matão	48 W 3033" and 21 S 3625"	Littoral 0.2 m Pelagic 2.5 m	Culture

3. Results

3.1. Limnological variables

Reservoirs showed a low average depth (2.6 m), and, as expected, a slight increase occurred during the rainy season, when the average was 3.0 m (Table 2). Transparency was low in some reservoirs, P2 in the dry season, but high in others, G3 and G4. The water temperature ranged from 18.1 to 24.9 °C in the dry season and increased to 24.5 to 28.4 °C in the rainy season. During both seasons, pH ranged from 5 to 8.4, with the highest values in P9, G2, G6, G7 and G93. Almost all reservoirs showed low conductivity values - ca. 20 $\mu S.cm^{-1}$ - but in the rainy season, G5 and G93 showed conductivity above 100 and 140 $\mu S.cm^{-1}$, respectively. Dissolved oxygen concentrations were lower in the rainy season than in the dry season in all reservoirs, ranging from 2.6 to 8.0 $mg.L^{-1}$ in the dry season and 1.2 to 5.7 $mg.L^{-1}$ in the rainy season.

3.2. Copepoda

Eighteen species of Copepoda were identified in the studied reservoirs, 13 Cyclopoida and 5 Calanoida (Table 3). Most species occurred both in the littoral and pelagic zone, except *Eucyclops elegans* (Herrick, 1884), *Paracyclops chiltoni* (Thomson, 1882) and *Mesocyclops ogunnus* Onabamiro, 1957, that occurred exclusively in the littoral zone. Some species were found in only one of the seasons, as *Euclyclops elegans*, *Macrocyclops albidus* (Jurine, 1820), *Mesocyclops ogunnus* and *Microcyclops anceps anceps* (Richard, 1897) in rainy season and *Argyrodiaptomus azevedoi* (Wright, 1935) in the dry season.

The average species richness per reservoirs showed no differences between points located in the littoral and pelagic zone (Table 4) but was statistically higher in the rainy than in dry season ($t = -2.5$, $p = 0.01$, $n = 15$). The Shannon-Wiener diversity index average ranged from 0.3 to 0.6 and no statistical difference between points or season was found. The Simpson dominance index and evenness were around 0.5 and also showed no statistical difference between points or season.

Thermocyclops decipiens (Kiefer, 1920) and *Tropocyclops prasinus* (Kiefer, 1931) showed the highest occurrence frequencies in the reservoirs (Figure 2), and were classified as constant species for both the dry and rainy seasons. All other species were classified as accidental species because they presented low frequency of occurrence in the collected samples.

T. decipiens was also the most abundant species of Cyclopoida, followed by *T. prasinus*, especially in the dry season (Figure 3). Calanoida were more abundant in the dry season, especially of *Notodiaptomus conifer* Sars, 1901 (Figure 4).

Nauplius was the most abundant copepod stage in the pelagic and littoral zones (Figure 5). In the dry season, they reached the highest density values, above 50,000 ind/m^3, especially in the pelagic zone, and in the rainy season the highest abundance of nauplii was observed in the littoral zone. In the dry season, copepodites were more abundant in the pelagic zone (Figure 5) and in the rainy season, high densities of this stage were observed in littoral. Adult Cyclopoida were more abundant than calanoids, occurring in higher density in the pelagic than in the littoral zone (Figure 5). Calanoida were more abundant in the littoral than in the pelagic zone, with a significant decrease in the rainy season.

The principal environmental variables, according to the CCA analysis, were depth ($p = 0.020$), conductivity ($p = 0.060$) and transparency ($p = 0.048$) (Figure 6). Depth correlated positively with the species *Notodiaptomus iheringi* Wright, 1935, and *Paracyclops chiltoni* at G4 and G3 points. Dissolved oxygen explained the occurrence of *Microcyclops alius* Kiefer, 1935 in P2. Higher temperature explained the distribution of *Mesocyclops meridianus* (Kiefer,1926) and *Argyrodiaptomus azevedoi* in G2, G5 and G9. Transparency was positively related to *Mesocyclops* cf. *brasilianus*. A group of species, among them Dipatomidae sp., *Macrocyclops albidus*, *Argyrodiaptomus furcatus* Sars, 1901, *Thermocyclops minutus* (Lowndes, 1934) and *Notodiaptomus conifer*, showed no correlation with the variables measured in this study. These species were found in P1 and G1.

4. Discussion

The reservoirs were shallow and small, and the physical and chemical variables varied between the dry and rainy seasons. The lowest depths observed during the rainy season in three reservoirs could be related to the management activity of the reservoir to prevent flooding and emptying. The transparency and oxygen concentrations appeared to influence the species occurrence. The low oxygen concentration, even with the increase of temperature in summer, can be explained by the increase in decomposition rates, typical of shallow waters, whose lower pH values also indicate high decomposition rates in these environments (Wetzel,

Table 2. Physical and chemical variables analyzed in the reservoirs during the dry and rainy seasons.

		P1	P2	P9	G1	G2	G3	G4	G5	G6	G7	G91	G92	G93
Depth (m)	Dry	1.8	2.4	3.4	2.1	2.4	3.8	4.9	1.3	3.7	1.6	2.4	1.9	2.5
	Rainy	2.2	2.3	2.2	1.8	-	4.5	4.9	1.9	2.5	3.9	-	3.2	3.5
Transparency (m)	Dry	1.8	0.2	1.3	2.0	1.0	1.9	2.6	0.9	2.2	1.4	1.2	0.8	1.1
	Rainy	2.2	0.6	0.7	0.8	-	3.0	2.6	1.4	0.8	1.1	-	0.8	1.2
Temperature (°C)	Dry	23.5	18.8	22.9	22.4	23.0	18.1	19.0	25.1	22.3	24.9	22.9	23.2	23.3
	Rainy	24.8	24.5	25.9	25.1	-	25.7	26.1	25.6	25.5	28.4	-	25.2	24.5
pH	Dry	6.3	6.4	7.6	5.8	7.8	5.9	6.2	6.8	6.7	6.5	5.7	6.3	7.9
	Rainy	5.0	5.6	7.3	5.5	-	5.7	6.2	6.3	8.4	7.8	-	5.4	6.6
Conductivity (µS/cm)	Dry	12.0	10.0	80.3	2.0	54.0	20.0	10.0	43.0	49.1	14.3	16.0	42.0	55.0
	Rainy	17.3	27.0	52.7	4.0	-	13.3	25.5	100.7	12.8	3.6	-	48.0	141.7
DO (mg/L)	Dry	5.8	5.8	7.8	6.1	6.6	5.6	6.8	3.8	6.3	6.7	2.6	3.7	8.0
	Rainy	4.8	5.5	4.0	5.7	-	3.0	3.6	1.6	3.4	3.3	-	1.2	3.8

Table 3. Cyclopoida and Calanoida species with respective densities in littoral and pelagic zones of reservoirs in the northwestern region of São Paulo, in the dry and rainy seasons.

		Dry		Rainy	
		Littoral	Pelagic	Littoral	Pelagic
Cyclopoida					
Eucyclopinae	*Eucyclops elegans* (Herrick, 1884)*			101 - 1000	
	Macrocyclops albidus (Jurine, 1820)			<100	<100
	Paracyclops chiltoni (Thomson, 1882)*	101 - 1000		101 - 1000	
	Tropocyclops prasinus (Kiefer, 1931)	>1000	>1000	>1000	>1000
	Tropocyclops prasinus meridionalis (Kiefer, 1931)	101 - 1000	>1000	>1000	101 - 1000
	Tropocyclops prasinus prasinus (Fischer, 1860)	>1000	>1000	101 - 1000	>1000
Cyclopinae	*Mesocyclops* cf. *brasilianus*	>1000	>1000	>1000	>1000
	Mesocyclops meridianus (Kiefer,1926)	101 - 1000	101 - 1000	>1000	>1000
	Mesocyclops ogunnus Onabamiro, 1957 *			101 - 1000	
	Microcyclops alius Kiefer, 1935	101 - 1000	>1000	>1000	101 - 1000
	Microcyclops anceps anceps (Richard, 1897)			>1000	>1000
	Thermocyclops decipiens (Kiefer, 1920)	>1000	>1000	>1000	>1000
	Thermocyclops minutus (Lowndes, 1934)		<100	>1000	>1000
Cyclopoida density (ind/m³)		63474.4	95348.5	83441.2	68984.8
Calanoida					
Diaptominae	*Argyrodiaptomus furcatus* Sars, 1901	101 - 1000	<100	101 - 1000	
	Argyrodiaptomus azevedoi (Wright, 1935)	>1000	>1000		
	Notodiaptomus conifer (Sars, 1901)	>1000	>1000		<100
	Notodiaptomus iheringi (Wright, 1935)	>1000	>1000	>1000	101 - 1000
	Diaptominae sp.		<100		
Calanoida density (ind/m³)		30325.5	14165.5	3394.7	259.5

<100 ind./m³; 101 - 1000 ind./m³; >1000 ind./m³. *Species that have occurred exclusively in the littoral zone.

Table 4. Species richness (S) variation, mean and standard deviation of Shannon-Wiener diversity (H'), Simpson dominance (D) and evenness (e) indices of Copepoda found in the littoral and pelagic zones of reservoirs during the dry and rainy seasons from 2007 to 2009.

	Dry		Rainy	
	Littoral	Pelagic	Littoral	Pelagic
Richness (S)	1.0-3.0	1.0-3.0	1.0-4.0	1.0-3.0
Shannon-Wiener diversity (H')	0.4 ± 0.3	0.5 ± 0.2	0.6 ± 0.3	0.3 ± 0.4
Simpson dominance (D)	0.7 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.8 ± 0.3
Evenness (e)	0.5 ± 0.3	0.7 ± 0.3	0.6 ± 0.3	0.4 ± 0.4

2001). Although not a factor assessed in this study, data from eutrophication, obtained in other studies in the same locations (M. S. M. Castilho-Noll and C. F. Câmara, unpublished data) showed that 11 of the 13 reservoirs were eutrophic or hypereutrophic. This classification suggests that these reservoirs are subject to nutrient input from adjacent crops, since they are located in agricultural environments.

Greater diversity of zooplankton species can be found in the littoral of reservoirs, especially those colonized by macrophytes. In these zones, the environmental heterogeneity, with great diversity of niches, allows the colonization of a large number of species, resulting in a high diversity. According to Rocha et al. (1995), comparisons between the littoral and pelagic zones of reservoirs are important aspects to be considered in studies of zooplankton for a better understanding of the diversity of this community. For the Cladocera community, Castilho-Noll et al. (2010) found a significant increase of species richness (approximately 40%) in samples collected in the littoral zone in the small reservoirs studied here.

Studying both zones, it was not found significant differences between the copepods distribution, as was reported to Cladocera in the same reservoirs (Castilho-Noll et al., 2010). This reflects the habits of most copepods species, mainly Cyclopoida, which are usually associated to a substrate in the littoral zone of aquatic environments (Williamson and Reid, 2001). Thus, although some species have been observed only in littoral areas, it is possible that, unlike what is suggested for Cladocera (Castilho-Noll et al., 2010), especially in shallow lentic ecosystems, most copepods species are not segregated in one of the zones and can occupy most of the microhabitats. Even to the larval stages – nauplii and copepodites - no significant differences were found between the densities in zones in both seasons. This can reinforces the hypothesis that a greater percentage of the copepods species may occupy and develop in two zones, being less demanding with respect to habitat.

The canonical correspondence analysis results suggest that some reservoirs, as P1 and G1, showed specific features that are not explained by the evaluated variables. These features possibly favoured the development of some species that occurred exclusively in those reservoirs. In this way, three of the five calanoids species were found only in these reservoirs.

The composition and abundance of zooplankton species are influenced by changes in the trophic status of aquatic ecosystems (Pinto-Coelho, 1998). Changes in community structure of calanoids, including the disappearance of several species of the lentic ecosystems in São Paulo, are indicated as the result of rapid and intense processes of eutrophication (Arcifa, 1984; Pinto-Coelho, 1998; Tundisi and Matsumura-Tundisi, 2003).

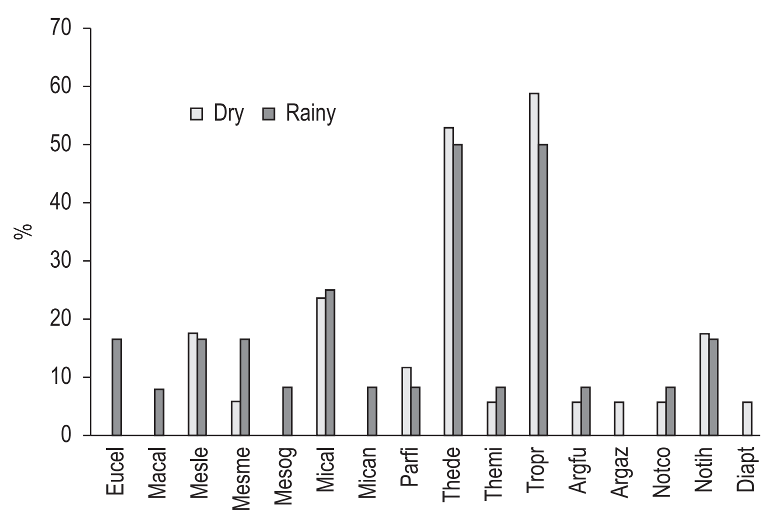

Figure 2. Frequency of occurrence (%) of copepods species recorded in the reservoirs in the northwest of São Paulo State. (Eucel = *Eucyclops elegans*, Macal = *Macrocyclops albidus*, Mesle = *Mesocyclops* cf. *brasilianus*, Mesme = *Mesocyclops meridianus*, Mesog = *Mesocyclops ogunnus*, Mical = *Microcyclops alius*, Mican = *Microcyclops anceps*, Parfi = *Paracyclops chiltoni*, Thede = *Thermocyclops decipiens*, Themi = *Thermocyclops minutus*, Tropr = *Tropocyclops prasinus*, Argfu = *Argyrodiaptomus furcatus*, Argaz = *Argyrodiaptomus azevedoi*, Notco = *Notodiaptomus conifer*, Notih = *Notodiaptomus iheringi*, Diapt = Diaptomidae sp.).

The high endemism of Calanoida is restricted to narrow longitudinal bands, mainly due to its high sensitivity to chemical and physical changes of the water (Matsumura-Tundisi, 1986). Temperature is one of this factor that restricts the distribution of some species to certain regions (Matsumura-Tundisi and Silva, 1999). Other factors such as conductivity, pH and dissolved oxygen in water can also affect community composition of Calanoida. In all 13 studied reservoirs, the four calanoids species were found in only five, reinforcing the idea that the group has restrictions for their establishment. At the moment it is not possible to suggest what conditions they need to survival, or set of them, but it is evident that Calanoida is more sensitive than Cyclopoida which occurred in greater numbers and distribution in all reservoirs.

Calanoids are primarily planktonic (Williamson and Reid, 2001) and besides the trophic state, the shallowness of the reservoirs can be a limiting factor for Calanoida populations development, since they are more adapted to deeper environments, which favour the planktonic communities establishment and development. Feeding habits of these groups may also explain the low frequency of occurrence of them, whose species feed on suspended particles, creating a flow of water with the second antennae. The high levels of suspended material very common in shallow reservoirs can difficult these animals to feed. Some of the studied reservoirs presented decrease in the transparency in rainy season, indicating increasing in the suspended material

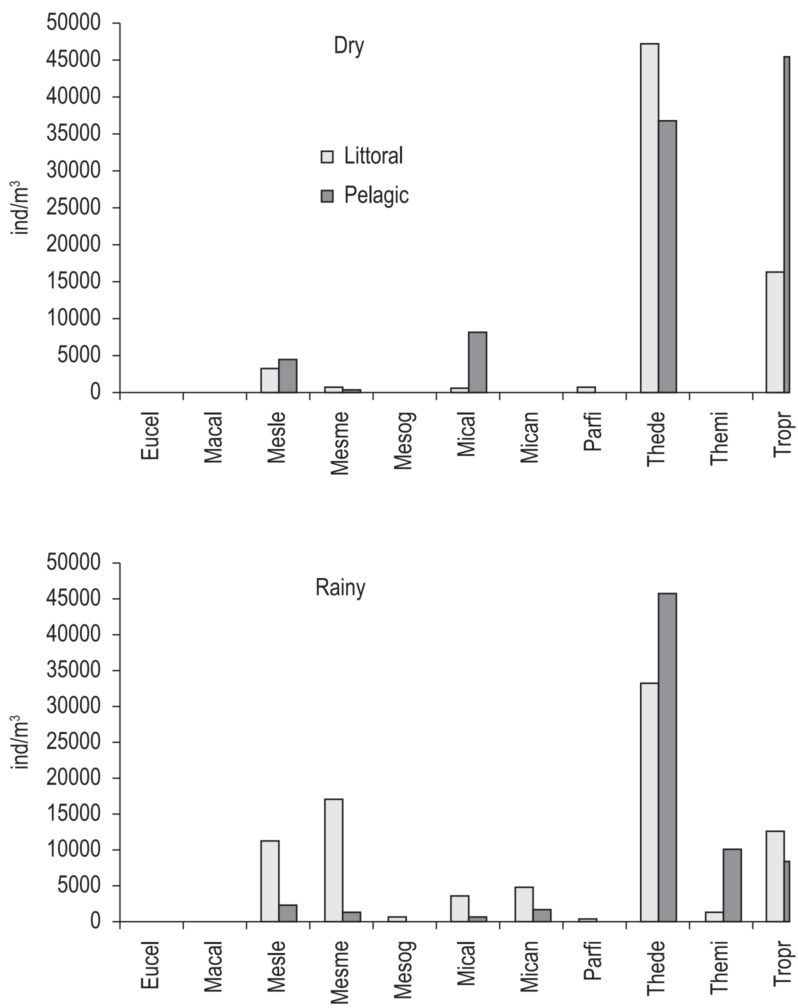

Figure 3. Densities of Cyclopida species registered in the littoral and pelagic zones of the reservoirs during the dry and rainy seasons. (Eucel = *Eucyclops elegans*, Macal = *Macrocyclops albidus*, Mesle = *Mesocyclops* cf. *brasilianus*, Mesme = *Mesocyclops meridianus*, Mesog = *Mesocyclops ogunnus*, Mical = *Microcyclops alius*, Mican = *Microcyclops anceps*, Parfi = *Paracyclops chiltoni*, Thede = *Thermocyclops decipiens*, Themi = *Thermocyclops minutus*, Tropr = *Tropocyclops prasinus*).

in water, which could be the reason for the lower densities of the Calanoida in the rainy than dry season. On the other hand, Cyclopoida detects the prey by mechanoreceptors and catch them with their first jaw (Williamson and Reid, 2001), the suspended material should not be a problem to it as to Calanoida.

Notodiaptomus iheringi, for example, occurred only in the two reservoirs that had the greatest depths, as shown by canonical correspondence analysis that correlated positively this species and the depth of the reservoirs, mainly the reservoirs G3 and G4, where it occurred which must have been determinant to the occurrence of this species of Calanoida.

According to Tundisi and Matsumura-Tundisi (2003), over the years the anthropogenic impacts in the reservoirs have caused changes in the composition of calanoids in the whole State of São Paulo. In some reservoirs, as in Broa, the replacement of species formerly dominant has been observed, such as *Argyrodiaptomus furcatus* by *N. iheringi*, which is more tolerant (Rietzler et al. 2002, Tundisi and Matsumura-Tundisi, 2003). The highest frequency and densities of *N. iheringi* in the studied reservoirs can reinforce its higher capacity to tolerate the eutrophic state environments than the other Calanoida species. The association of the occurrence of *N. iheringi* with eutrophic lake have been also sugested by another author (Sendacz, 2001).

Cyclopoida species are more widely distributed than Calanoida, and some species are considered cosmopolitan. Cyclopoida is also considered

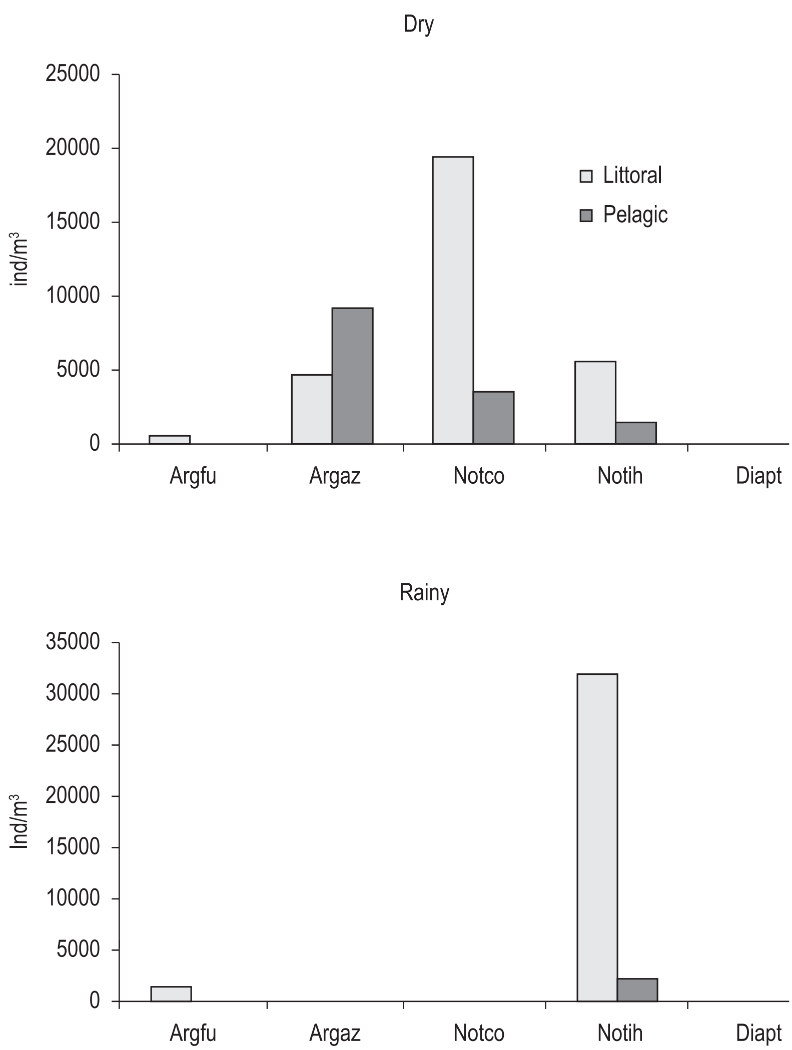

Figure 4. Densities of Calanoida species registered in the littoral and pelagic zones of the reservoirs during the dry and rainy seasons. (Argfu = *Argyrodiaptomus furcatus*, Argaz = *Argyrodiaptomus azevedoi*, Notco = *Notodiaptomus conifer*, Notih = *Notodiaptomus iheringi*, Diapt = Diaptomidae sp.).

more tolerant to higher trophic levels than Calanoida (Matsumura-Tundisi and Silva, 1999), which favours its dominance in many eutrophic aquatic environments (Tundisi et al., 1988 apud Matsumura-Tundisi and Silva, 1999).

The Cyclopoida species registered in the reservoirs are part of the fauna of São Paulo State, according to Silva (2008). Silva and Matsumura-Tundisi (2005) also found the species *Thermocyclops decipiens* as being the most frequent in other reservoirs in São Paulo State. For the authors, this species has a wide distribution, occurring in different environments in all hydrographical basins in the State. It can be considered one of the most abundant species, followed by *T. minutus* (Singh, 2008). The characteristic of eutrophic reservoirs can also favour *T. decipiens*, since it is dominant in these environments (Silva and Matsumura-Tundisi, 2005). Sendacz (2001) also reported *T. decipiens* in only one of the lakes in the floodplain of the upper Paraná River (MS), which was considered eutrophic. According to Landa et al. (2007), this species may be used as indicator species of eutrophic environments with low water quality in the state of Minas Gerais.

In conclusion, our data show that communities of copepods, in all stages of development, can occupy and survive as in the pelagic as in the littoral zones of shallow aquatic environments. Cyclopoida has more species than Calanoida, whose frequencies and abundances are also lower. It is possible that the shallow and eutrophic state represent limiting

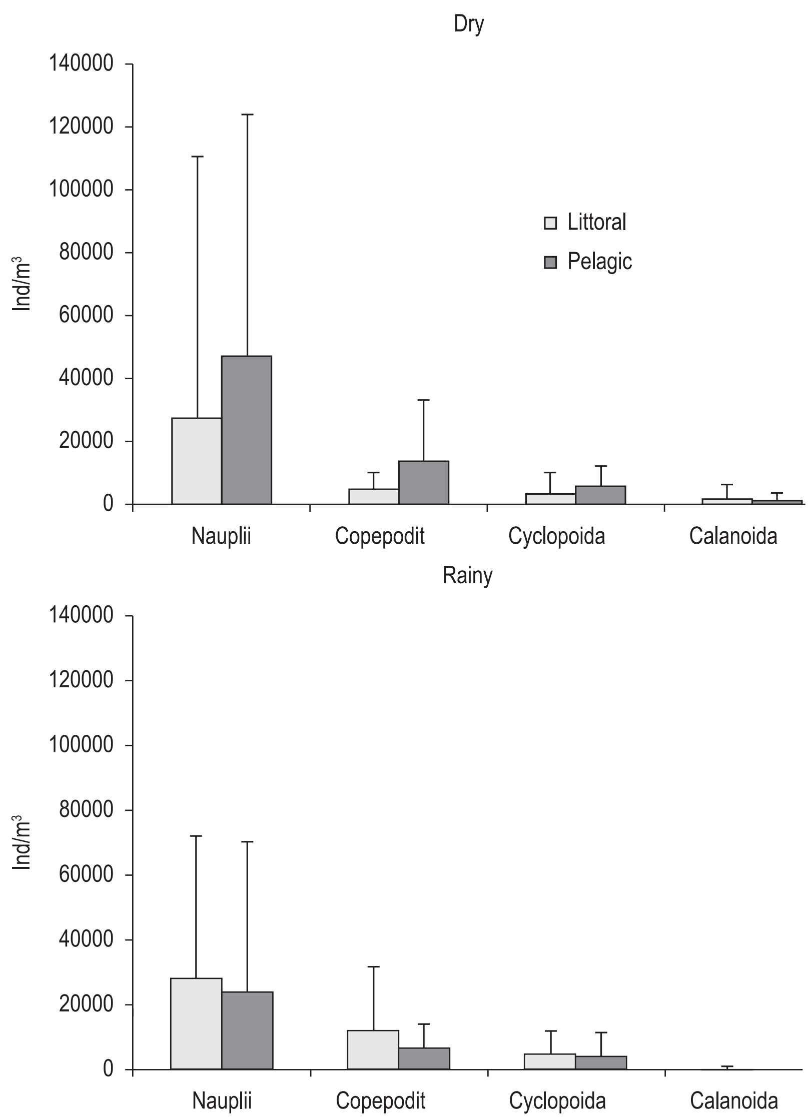

Figure 5. Densities of nauplii, copepodites and adults of Cyclopoida and Calanoida, recorded in the littoral and pelagic zones of the reservoirs during the dry and rainy seasons.

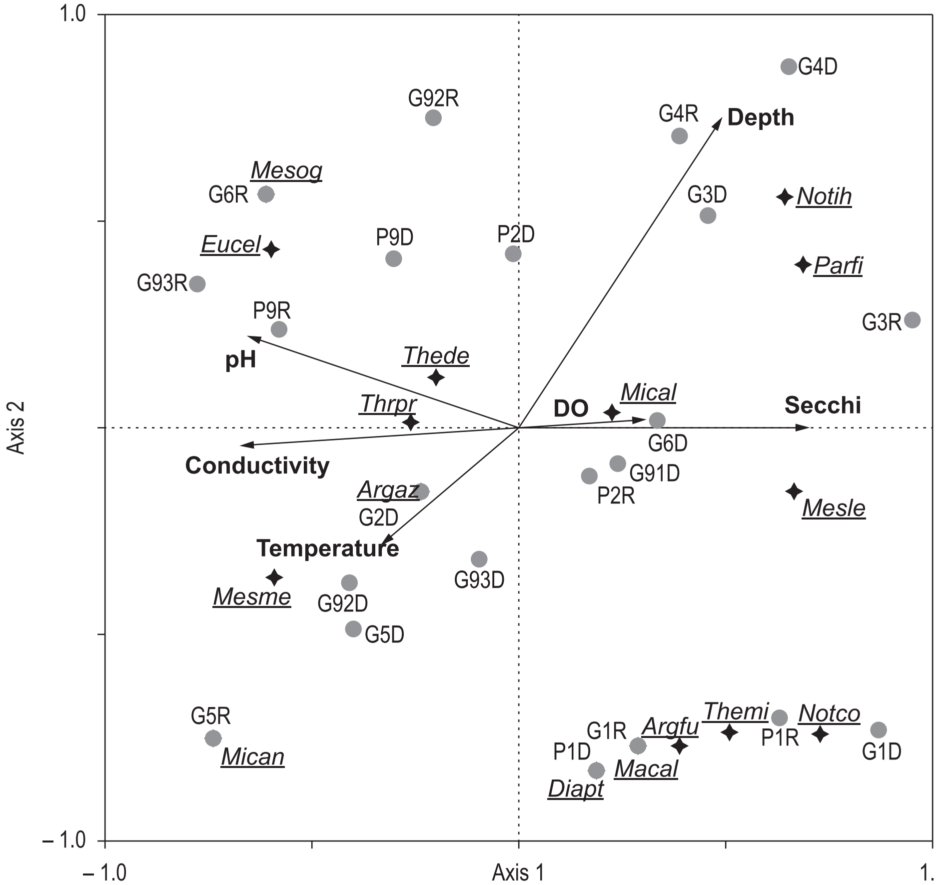

Figure 6. Ordination diagram representing the first two axes of canonical correlation analysis, showing all aquatic environments sampled (circles, with D = dry, R = rainy), species (stars) and environmental descriptors (arrows). The significance test of Monte Carlo (4999 permutations) on the option of full model indicates that the canonical axes are significant (F-ratio = 3.013, P-value = 0.03). For species codes, see Figure 2.

conditions for the establishment and development of Calanoida in the aquatic environments.

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