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Effects of Natural Banks of Free-Floating Plants on Zooplankton Community in a Shallow Subtropical Lake in Southern Brazil

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ABSTRACT

The aim of this study was to test the effects of natural free-floating plants on zooplankton distribution in a shallow subtropical lake. First, the hypothesis that free-floating plants have an effect on physico-chemicals, leading to a decrease on nutrient availability and influencing the phytoplankton biomass and zooplankton community was tested. Second, the hypothesis that free-floating plants act as a refuge for zooplankton was tested. Three microhabitats were selected: free-floating plants, littoral area and open water. Results demonstrated that the effects of different microhabitats on phytoplankton biomass and physico-chemicals were not significant, indicating a weak influence of the plants. Zooplankton densities were higher in free-floating plants and littoral area, although the effect of microhabitats was weak for most of the predominant genera. The absence of free-floating plant effects on phytoplankton and physico-chemicals showed that it was not a factor influencing the microcrustacean distribution in the microhabitats. Low differences in densities of zooplankton among microhabitats and low abundance of large-bodied cladocerans led to reject the hypothesis that free-floating plants act as a refuge for zooplankton.

Key words: macrophytes, refuge, spatial distribution, tropical zooplankton

INTRODUCTION

In aquatic environments, aquatic macrophytes have been pointed as a factor causing variation on the trophic cascades (indirect effects of carnivores on the plants or algae mediated by herbivores) (Timms and Moss, 1984). In shallow temperate lakes, these plants can influence the spatial distribution of fish (Tatrái and Herzig, 1995; Jacobsen and Perrow, 1998; Schindler, 1999),

zooplankton (Timms and Moss, 1984; Lauridsen and Buenk, 1996), and phytoplankton (van Donk and van de Bund, 2001).

The clear water state and the turbid water state are the two distinct trophic conditions known in shallow temperate lakes based on the alternative stable states hypothesis (Scheffer et al., 1993). In the clear water state, shallow lakes can be transparent with the dominance of submerged vegetation. In the turbid water state, shallow lakes

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can be unclear and phytoplankton-dominated. Submerged vegetation can support the clear water state by decreasing nutrient availability and/or releasing allelopathic substances (bottom-up control) (van Donk and van de Bund, 2001), and providing refuges for zooplankton grazers (top-down control) (Scheffer et al., 1993). It can also provide a daytime refuge for large-bodied zooplankton, such as *Daphnia* (Timms and Moss, 1984; Lauridsen and Buenk, 1996; Lauridsen and Lodge, 1996; Burks et al., 2002) and has an effect on the spatial distribution of fishes (Tatrái and Herzig, 1995; Jacobsen and Perrow, 1998; Schindler, 1999) causing cascade effects in littoral area or open water.

Tropical and subtropical lakes are different from temperate lakes in general characteristics of the food webs. Tropical and subtropical lakes comprise few large specialist piscivorous fishes and more numerous sit-and-wait predators, whereas omnivores with continuous reproduction and small fishes are abundant, and apparently, there is a lower abundance of large-bodied zooplankton with a dominance of smaller and less efficient filtering species (Lazzaro, 1997). Free-floating plants, such as water hyacinth *Echhornia crassipes* (Mat.) and water cabbage *Pistia stratiotes* L., both native from South America are

quite frequent in the tropical and subtropical lakes (Meerhoff et al., 2003).

The aim of this study was to test the effects of natural free-floating plant banks on zooplankton distribution in a shallow subtropical lake**.** Two hypothesis were tested: first that free-floating plants have an effect on the physico-chemical variables, leading to a decrease on nutrient availability and influencing directly the phytoplankton biomass and indirectly the structure of zooplankton community; second, that the free-floating plants act as a refuge for zooplankton, especially to pelagic large-bodied size species.

MATERIAL AND METHODS

This study was carried out in Lake Jacaré, an oligotrophic, shallow (mean depth: 3 m), subtropical lake with an area of 1.45 km², located in the Conservation Unit Ecological Station of Taim, state of Rio Grande do Sul, southern Brazil (Fig. 1). Lake Jacaré is encircled by massive banks of macrophytes where free-floating plants are dominant (e.g. water hyacinth *E. crassipes*, water cabbage *P. stratiotes* and salvinia *Salvinia herzogii*). Farms and rice fields surround the Ecological Station of Taim.
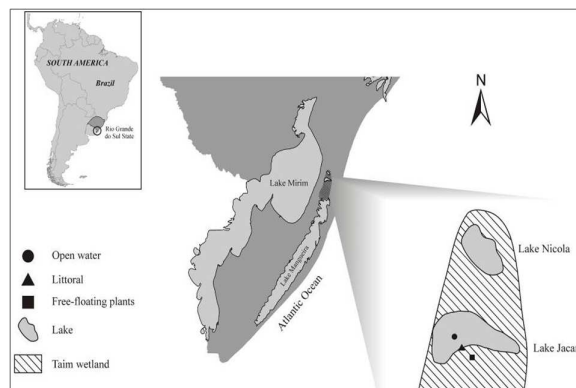

Figure 1 - Study area and sampling sites (free-floating plants, littoral area and open water).

Three microhabitats were selected as follows: a littoral vegetated natural bank of free-floating plants (multispecific bank dominated by *E. crassipes* and *Salvinia herzogii*), and a site without the plants both in littoral area, and an open water area (Fig. 1). Sites were sampled in August 2002 (winter), November 2002 (spring), February 2003 (summer) and June 2003 (autumn). Samples were taken at day-time (12 p.m.) and night-time (12 a.m.) to avoid the possible differences in the

results influenced by the diel horizontal migration (DHM) of the zooplankton. The free-floating plant site was not sampled in the dry season (February). Zooplankton samples were obtained by filtering 3 m³ of water in 90 µm plankton net with electric pumps. Samples were composed of the three strata (subsurface, middle and bottom in the water column) to avoid the possible differences related to vertical migration. In laboratory, samples were concentrated in 300 mL flasks and fixed with a

buffered 4% formaldehyde solution. Zooplankton counting was performed in 10% aliquots of the total sample using Bogorov (for cladocerans and copepods) and Sedgewick-Rafter chamber (for rotifers). Cladoceran species were identified according to El-Moor-Loureiro (1997), Montú and Goeden (1986), Olivier (1962), Smirnov (1974, 1996); copepod species: Rocha and Matsumura-Tundisi (1976), Reid (1985), Montú and Goeden (1986), Dussart and Defaye (1995); rotifer species: Olivier (1965), Koste (1978), De Smet (1995), Segers (1995), Nogrady and Segers (2002). In order to analyze if the aquatic macrophytes act as a refuge for pelagic species, the cladoceran genera *Bosmina, Bosminopsis, Ceriodaphnia, Diaphanosoma,* and *Simocephalus* were classified as free-swimming/pelagic and the remaining genera were classified as benthic/plant-associated.

Water samples were collected with a 5 L Van Dorn sampler at the same sites of the zooplankton sampling for the analysis of total phosphorus (TP), total nitrogen (TN), suspended solids (SS), organic matter (OM), and estimation of phytoplankton biomass as chlorophyll-a (Chl-a) (APHA, 1998). Conductivity (K), dissolved oxygen (DO), pH and temperature (T) were measured *in situ* with a portable instrument (YSI 6920® probe). Transparency was estimated as Secchi disc depth (SD).

The analyses of variance (One-way ANOVA) with Tukey's test for multiple comparison were carried out to detect the significant differences among the microhabitats and sampling dates (α= 0.05).

Tukey's test was applied after confirming the normality of data using Kolmogorov-Smirnov test (α= 0.05).

Data were submitted to multivariate exploratory analysis using the ordination method (Legendre and Legendre, 1998; Podani, 2000). The ordination of sample units was performed using the Principal Component Analysis (PCA). The similarity measure used was Euclidian distance between sample units. These analyses were performed with data on species density transformed to square root scale, and data on the physico-chemical normalized. The statistical program used was PCORD 4.0.

RESULTS

Physico-chemical variables in Lake Jacaré were characterized by low phytoplankton biomass (Chl-a= from 3.1 to 26.8 µg L^{-1}), low concentrations of TP (from 0.008 to 0.045 µg L^{-1}) and TN (from 0.52 to 1.95 µg L^{-1}), neutral to slightly alkaline pH (from 7.2 to 7.6) and low conductivity (from 215 to 302 µS cm^{-1}) (Table 1). Dissolved oxygen was relatively high with lowest value of 4.28 mg L^{-1} and highest of 7.58 mg L^{-1}. Suspend solids and organic matter showed lowest values in the open water and highest in littoral area. The effect of microhabitats on the environmental conditions was weak (p>0.05). There was a slight difference in the transparency results, with lower values registered in the littoral area (vegetated and no-vegetated) than in the open water (p<0.05).

Table 1- Limnological variables and chlorophyll-a in different microhabitats of Lake Jacaré (free-floating plants, littoral area and open water). Mean ± SE; ANOVA results (*statistically significant).

	Free-floating plants	Littoral	Open water	Microhabitat
Chl-a (µg L^{-1})	8.3 ± 2.4	11.1 ± 3.3	10.34 ± 1.8	p>0.05
TP (µg L^{-1})	0.018 ± 0.005	0.013 ± 0.002	0.014 ± 0.001	p>0.05
TN (µg L^{-1})	1.15 ± 0.16	1.25 ± 0.16	1.08 ± 0.12	p>0.05
SS (mg L^{-1})	188.25 ± 7.8	191.46 ± 9.3	175.42 ± 8.8	p>0.05
OM (mg L^{-1})	52.25 ± 13.2	53.46 ± 6.9	50.55 ± 9.4	p>0.05
DO (mg L^{-1})	6.59 ± 0.47	6.19 ± 0.63	7.04 ± 0.25	p>0.05
pH	7.30 ± 0.06	7.35 ± 0.05	7.43 ± 0.04	p>0.05
K (µS cm^{-1})	237 ± 0.010	256 ± 0.012	249 ± 0.010	p>0.05
T (°C)	17.7 ± 2.02	20 ± 2.14	19.7 ± 2.12	p>0.05
SD (m)	1.05 ± 0.21	1.21 ± 0.18	1.92 ± 0.29	p<0.05*

A significant temporal variation of the environmental conditions was not observed in the ANOVA analysis, although the Principal Component Analysis showed that the samples from the same sampling dates were more similar

than those from the same microhabitats (Fig. 2). Ordination axis concentrated 68 % of physico-chemical data variation, where Axis 1 (horizontal) explained 36% and Axis 2 (vertical) explained 32% of this variation.
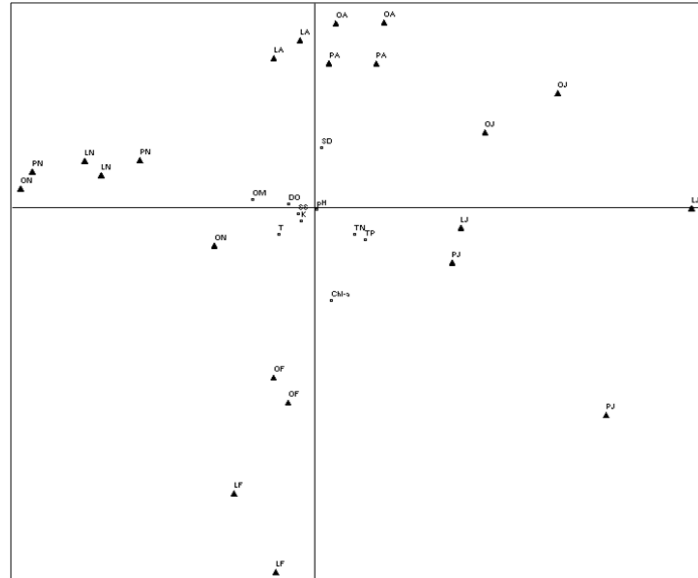
Figure 2 - Principal Component Analysis with physico-chemical variables in Lake Jacaré. Sampling sites are represented by P (free-floating plants), L (littoral), O (open water) and sampling dates by A (August), N (November), F (February), J (June).

Zooplankton community was represented by 76 species, 36 of which were cladocerans, 12 were copepods and 28 were rotifers (Table 2). Among the 76 species, 13 were new records for the state of Rio Grande do Sul: *Pseudochydorus globosus, Alona cambouei, A. guttata, Leydigia ipojucae, L. propinqua, Leydigiopsis curvirostris, L. ornata, Notoalona sculpta* (cladocerans), *Mytilina ventralis, Proales reinhardti, Testudinella mucronata, Trichocerca bicristata* and *Macrochaetus collinsi* (rotifers). Rotifers were represented by 15 families. Lecanidae and Brachionidae were the families with the highest richness. Lecanidae was represented by five species from *Lecane* genera, making it the most representative among the rotifers. Cladocerans were represented by six families. Chydoridae was the family with the highest richness. Copepods were represented by three families: Diaptomidae (Order Calanoida) was represented by *Notodiaptomus incompositus*, Canthocamptidae (Order Harpacticoida) was represented by *Atheyella fuhrmani*, and Cyclopidae (Order Cyclopoida) that showed the highest richness and was represented by ten species distributed in six genera.

Rotifers presented mean density of 23.27 ind m^{-3}. Mean densities in the microhabitats varied from 35.94 ind m^{-3} in the free-floating plants to 6.3 ind m^{-3} in the open water (Fig. 3). There were no significant differences of rotifer densities in the

three microhabitats (p= 0.841, ANOVA). *Lecane, Platyias, Testudinella,* and *Brachionus* were the most abundant genera of rotifers.

Mean density of pelagic/free-swimming cladocerans was 38.8 ind m^{-3}. Mean densities in the microhabitats varied from 76.4 ind m^{-3} in the free-floating plants to 13.04 ind m^{-3} in the open water area (Fig. 4). There were no significant differences of free-swimming cladoceran densities in the microhabitats (p= 0.264, ANOVA).

Free-swimming cladocerans were represented by small-bodied *Bosmina, Ceriodaphnia, Diaphanosoma*, and *Bosminopsis*, and by large-bodied *Simocephalus*. Small-bodied cladocerans occurred in higher densities than large-bodied (Fig. 5). Pelagic large-bodied *Daphnia* was not registered in Lake Jacaré. Mean density of benthic/plant-associated cladocerans was 7.95 ind m^{-3}. Mean densities in the microhabitats varied from 18.08 ind m^{-3} in the free-floating plants to 0.95 ind m^{-3} in the open water (Fig. 4). These differences were significant (p=0.004, ANOVA) and the density of the cladocerans in the free-floating plants was higher than in the other habitats (littoral and open water). Most of benthic cladocerans occurred in high densities in plants and littoral area and occasionally in the open water. Small-bodied chydorids *Chydorus, Picripleuroxus, Euryalona, Alonella, Macrothrix* and large-bodied *Pseudosida* dominated the benthic cladocerans (Fig. 5).

Table 2 - Zooplankton species registered in different microhabitats of Lake Jacaré (free-floating plants, littoral area and open water).

ROTIFERA	*Testudinella patina*	*Leydigia propinqua*
Asplanchnidae	**Trichocercidae**	*Leydigiopsis curvirostris*
Asplanchna sp.	*Trichocerca bicristata*	*Leydigiopsis ornata*
Bdelloidea	*Trichocerca capuccina*	*Notoalona sculpta*
Bdelloidea sp.	*Trichocerca* sp.	**Daphniidae**
Brachionidae	**Trichotriidae**	*Ceriodaphnia cornuta*
Brachionus caudatus	*Macrochaetus collinsi*	*Ceriodaphnia richardi*
Plationus patulus	*Trichotria tetractis*	*Simocephalus serrulatus*
Keratella tropica	**CLADOCERA**	**Ilyocryptidae**
Platyias quadricornis	**Bosminidae**	*Ilyocryptus spinifer*
Lepadellidae	*Bosmina longirostris*	**Macrothricidae**
Lepadella ovalis	*Bosminopsis deitersi*	*Macrothrix laticornis*
Euchlanidae	**Chydoridae**	*Macrothrix trisserialis*
Dipleuchlanis propatula	Subfamily Chydorinae	**Sididae**
Euchlanis dilatata	*Chydorus eurynotus*	*Diaphanosoma* cf. *brachyurum*
Euchlanis sp.	*Chydorus sphaericus*	*Diaphanosoma spinulosum*
Filiniidae	*Alonella dadayi*	*Pseudosida bidentata*
Filinia longiseta	*Alonella* cf. *lineolata*	**COPEPODA**
Lecanidae	*Dunhevedia odontoplax*	ORDER CYCLOPOIDA
Lecane bulla	*Ephemeroporus hibridus*	**Cyclopidae**
Lecane leontina	*Picripleuroxus (P.) denticulatus*	*Acanthocyclops robustus*
Lecane luna	*Pseudochydorus globosus*	*Eucyclops ensifer*
Lecane lunaris	Subfamily Aloninae	*Eucyclops serrulatus*
Lecane unguitata	*Acroperus harpae*	*Mesocyclops longisetus*
Mytilinidae	*Alona cambouei*	*Mesocyclops meridianus*
Mytilina ventralis	*Alona guttata*	*Mesocyclops* sp.
Notommatidae	*Alona* cf. *costata*	cf. *Metacyclops laticornis*
Cephalodella gibba	*Alona* cf. *quadrangularis*	cf. *Metacyclops mendocinus*
Proalidae	*Alona* cf. *rectangula*	*Microcyclops anceps*
Proales reinhardti	*Biapertura affinis*	*Paracyclops fimbriatus*
Scaridiidae	*Biapertura karua*	ORDER CALANOIDA
Scaridium longicaudum	*Biapertura verrucosa*	**Diaptomidae**
Synchaetidae	*Camptocercus dadayi*	*Notodiaptomus incompositus*
Polyarthra sp.	*Euryalona orientalis*	ORDER HARPACTICOIDA
Testudinellidae	*Kurzia latissima*	**Canthocamptidae**
Testudinella mucronata	*Leydigia ipojucae*	*Atheyella fuhrmani*
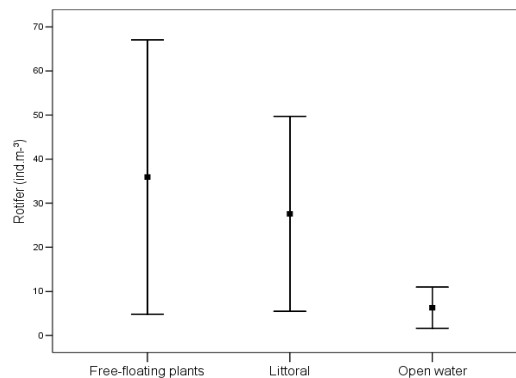
Figure 3 - Abundance of rotifers in different microhabitats of Lake Jacaré (free-floating plants, littoral area and open water). Symbol= mean density (ind m-3); bar= SE.
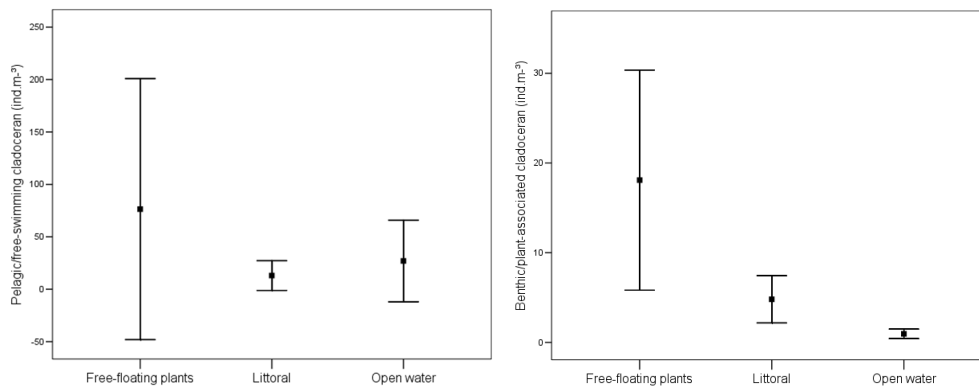
Figure 4 - Abundance of pelagic/free-swimming and benthic/plant-associated cladocerans in different microhabitats of Lake Jacaré (free-floating plants, littoral area and open water). Symbol= mean density (ind m-3); bar= SE.
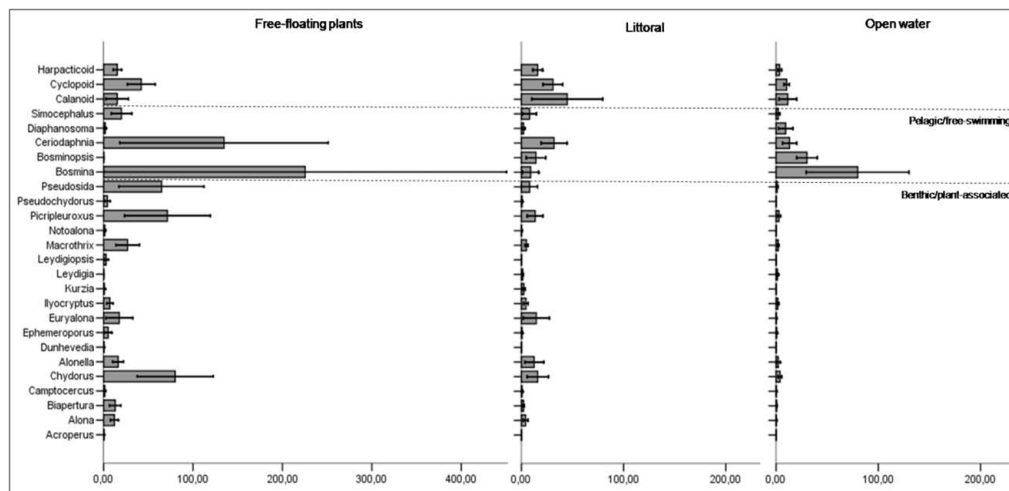

Figure 5 - Abundance of microcrustaceans (Cladocera and Copepoda) in the different microhabitats of the Lake Jacaré (free-floating plants, littoral area and open water). Symbol= mean density (ind m-3); bar= SE.

Adult cyclopoids presented mean density of 26.52 ind m^{-3}. Mean densities in the microhabitats varied from 42.11 ind m^{-3} in the free-floating plants to 10.42 ind m^{-3} in the open water area (Fig. 6). There were no significant differences of adult cyclopoid densities in the microhabitats (p= 0.084, ANOVA). Adult calanoids presented mean density of 24.62 ind m^{-3}. *N. incompositus* was the unique species of calanoid registered in Lake Jacaré. Mean densities in the microhabitats varied from 44.78 ind m^{-3} in the littoral site to 11.46 ind m^{-3} in the open water (Fig. 6). There were no significant differences of *N. incompositus* densities in the three microhabitats (p= 0.554, ANOVA). Nauplii presented mean density of 3204.04 ind m^{-3}. Mean densities in the microhabitats varied from 4372.92 ind m^{-3} in the open water to 2172.7 ind m^{-3} in the free-floating plants (Fig. 6). Copepodit mean density was 522.84 ind m^{-3} and mean densities varied from 696.75 ind m^{-3} in the free-floating plants to 385.76 ind m^{-3} in the littoral site (Fig. 6). There were no significant differences of nauplii (p= 0.548, ANOVA) and copepodit (p= 0.854, ANOVA) densities in the three microhabitats.

Atheyella fuhrmani was the unique species of harpacticoid registered in the samples. Harpacticoid mean densities varied from 15.97 ind m^{-3} in the littoral site to 3.47 ind m^{-3} in the open water (Fig. 5). There were no significant differences of *A. fuhrmani* densities in the three microhabitats (p= 0.070, ANOVA).

Densities were higher in the littoral area (vegetated and no-vegetated) for most of the zooplankton, such as benthic and pelagic cladocerans, harpacticoids, cyclopoids and rotifers. Despite that, the effect of microhabitats was weak for most of the predominant genera, even though it was strong to benthic small-bodied *Chydorus* (Table 3).
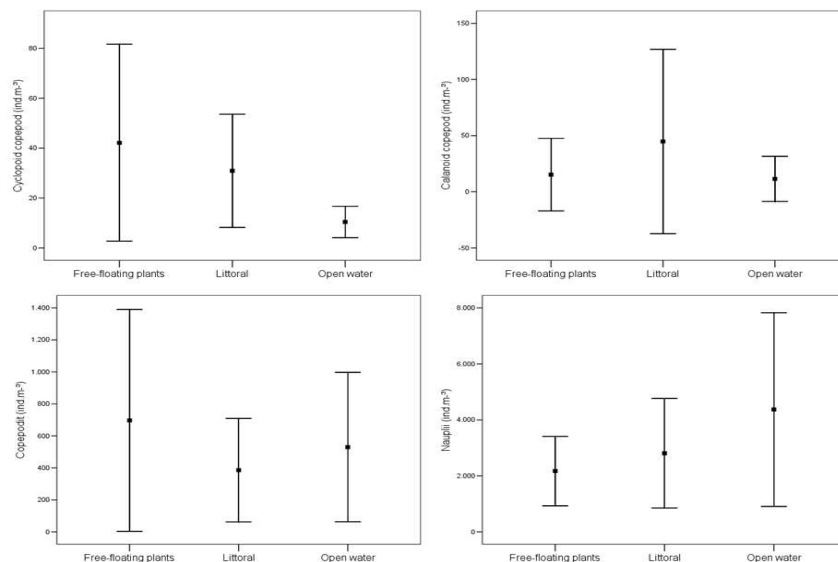

Figure 6 - Abundance of copepods in the different microhabitats of the Lake Jacaré (free-floating plants, littoral area and open water). Symbol= mean density (ind m-3); bar= SE.

Table 3 - Abundance (mean density (ind m^{-3}) and SE) of the dominant zooplankton genera in the three microhabitats of Lake Jacaré and ANOVA results (*statistically significant).

Genera	Size (mm)	Free-floating plants	Littoral	Open water	Microhabitat
Cladocerans					
Free-swimming					
Bosmina	0.33	225.4 ± 4.9	9 ± 7.8	79.8 ±50.2	p>0.05
Ceriodaphnia	0.45	134.7 ± 116.6	31.95 ± 12.6	13.21 ± 7	p>0.05
Simocephalus	1.2	19.9 ± 11.5	8 ± 6.8	2 ± 1.7	p>0.05
Plant-associated					
Chydorus	0.45	80.1 ± 42.5	15.9 ± 10.3	3.8 ± 1.6	p<0.05*
Picripleuroxus	0.32	71.2 ± 47.9	13.5 ± 7.7	2.7 ± 1.4	p>0.05
Pseudosida	1.7	64.8 ± 47.5	7.9 ± 7.9	1.3 ± 1.3	p>0.05
Copepods					
Notodiaptomus	1.5	15.3 ± 12.5	44.7 ± 34.7	11.4 ± 8.5	p>0.05

The Principal Component Analysis using the zooplankton abundance showed that the samples from the same microhabitats were less similar than those from the same sampling dates (Fig. 7). This variation pattern was similar to that observed for the physico-chemical variables (Fig. 2), indicating a weak effect of free-floating plants over time. Ordination axis concentrated 58.3 % of zooplankton data variation, where Axis 1 (horizontal) explained 44 % and Axis 2 (vertical) explained 15 % of this variation. In August, the pelagic small-bodied *Ceriodaphnia* was the most dominant species, and large-bodied *Pseudosida* was the most dominant benthic cladoceran, occurring at a higher density at the macrophyte banks. In November, the pelagic small-bodied *Bosmina* became dominant along with rotifers *L. leontina*, *P. quadricornis*, and *T. patina*. In February and June, rotifers dominated the zooplankton community being represented by *T. patina*, *C. gibba, P. quadricornis*, *L. bulla*, and *Testudinella* sp. Copepodites and nauplii were the commonly dominant zooplankton in three microhabitats during all the sampling dates.
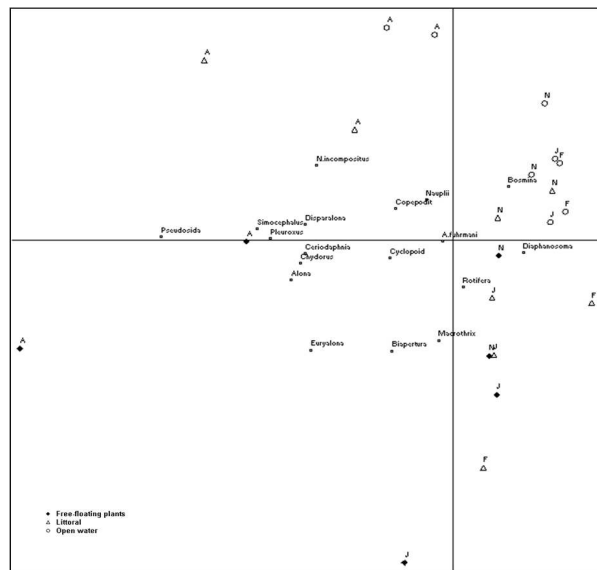
Figure 7 - Principal Component Analysis (PCA) of zooplankton community in Lake Jacaré.
Sampling dates are represented by A (August), N (November), F (February), J (June).

DISCUSSION

The effect of vegetation on water clarity can be a result of different mechanisms: resuspension of bottom material is reduced by vegetation; aquatic plants provide a refuge to zooplankton against planktivorous fish; vegetation suppresses algal growth due to a reduction of nutrient availability; plants release allelopathic substances that are toxic to algae and invertebrates (Scheffer et al., 1993; Scheffer et al., 1998). Several studies in shallow temperate lakes found the impact of submerged plants on water clarity by these mechanisms (Scheffer et al., 1994; Moss et al., 1996; Jeppesen et al., 1999; Scheffer, 1998; van Donk and van de Bund, 2001). Nevertheless, there are very few studies about the effects of aquatic macrophyte on the physico-chemicals in shallow tropical and subtropical lakes (Meerhoff et al., 2003; Meerhoff et al., 2007; Iglesias et al., 2007). Meerhoff et al. (2003), comparing the effects of submerged (*Potamogeton pectinatus*) and free-floating (*E. crassipes*) plants on water chemistry in a shallow hypertrophic lake (Uruguay) did not find any significant bottom-up process related to the plants. Similarly, Bachmann et al. (2002) have shown that the presence of aquatic plants (emergent, floating-leaved, and submerged) have no effect on the nutrient availability in the subtropical shallow lakes from Florida.

In the present study, except for the lower transparency in macrophyte banks, no effects of free-floating plants was found on the physico-chemical variables (Table 1). Nutrient availability and chlorophyll-a did not change significantly in the vegetated and no-vegetated littoral area. Accordingly, the hypothesis that free-floating plants had an effect on the physico-chemical variables was rejected.

Few studies have been shown the impact of aquatic plants on zooplankton in subtropics. These studies were conducted in submerged plants of eutrophic lakes (Meerhoff et al., 2003; Iglesias et al., 2007), and in laboratory (Meerhoff et al., 2006). The present study was the first to investigate the effect of vegetation on zooplankton in natural free-floating plants in an oligotrophic subtropical lake.

Zooplankton community in Lake Jacaré was dominated by the small-bodied cladocerans, such as *Bosmina, Ceriodaphnia,* and *Diaphanosoma*. No large-bodied *Daphnia* was registered in the lake. A study comparing the effect of the plant beds on zooplankton in the temperate and subtropical lakes have shown that the communities with higher species richness of large-bodied taxa (including *Daphnia* spp.) occurred in the temperate lakes, whereas small-bodied taxa characterized the subtropical lakes (Meerhoff et al., 2007). Other studies have observed that large-bodied pelagic cladocerans, particularly *Daphnia* spp., were uncommon in the (sub) tropics (Pinto-Coelho et al., 2005; Meerhoff et al., 2003; Iglesias et al., 2007).

Iglesias et al. (2007) have found a community dominated by small-sized zooplankton, such as nauplii, copepodits, rotifers, and *Bosmina*, as well as *Diaphanosoma*, and *N. incompositus* in a shallow eutrophic lake in Uruguay, which was very similar to the community observed in the present work. Meerhoff et al. (2007) have also observed the dominance of small-bodied zooplankton, such as *Bosmina*, and *Ceriodaphnia*, as well as copepodits, and nauplii in shallow lakes in Uruguay. Several studies have shown the occurrence of copepodits and nauplii in very high densities in the tropical freshwater zooplankton (Robertson and Hardy, 1984; Vásquez, 1984; Lima, 1994; Nunes et al., 1996; Branco et al., 2002).

All of the dominant cladocerans had the highest densities in the free-floating plants. Small-bodied *Chydorus* occurred in higher densities in the plants and littoral area during all the sampling dates, whereas the other predominant species changed with the seasons. Iglesias et al. (2007) have also found that most zooplankton were homogeneously distributed in different microhabitats (open water and plants), and *Chydorus* was significantly predominant in the plants (submerged), corroborating with the present results. Meerhoff et al. (2003) have also observed that cladoceran abundance did not differ among the open water and plants.

Some macrophytes can have an effect on the planktonic food web by allelopathy (Scheffer et al, 1993, van Donk and van de Bund, 2001). Studies have revealed macrophyte allelopathic effects on cyanobacteria (Nakai et al., 1999), phytoplankton (Wium-Andersen et al., 1982, Mulderij et al., 2005), macroinvertebrates and zooplankton (Gopal and Goel, 1993). Microcrustacean densities in the present study were frequently higher in the plants which could indicate there was no chemical effect (allelopathy) of macrophytes on their spatial distribution. The absence of free-floating plant effects on the physico-chemical variables observed in this study have shown that it was not a factor influencing the microcrustacean distribution in the microhabitats. Physico-chemical differences among the microhabitats most likely play a minor role in shaping spatial patterns of zooplankton in (sub) tropics.

The classical spatial heterogeneity of large-bodied zooplankton in the temperate lakes was not observed in Lake Jacaré. Low differences in the densities among the microhabitats and low abundance of large-bodied cladocerans observed in the present study led to reject the hypothesis that free-floating plants act as a refuge for zooplankton.

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